A MANUAL FOR MONITORING CORAL REEFS WITH INDICATOR SPECIES:

Butterflyfishes as Indicators of Change on Indo-Pacific Reefs

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Sponsored by
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PREFACE

The importance of coral reef ecosystems may be seen in their numerous ecological, aesthetic, economic and cultural functions. Atoll and barrier reef islanders recognize that healthy reefs are essential for the support, creation, and repair of the coral islands upon which they live. Coral reefs also protect coastlines from shoreline erosion, and serve as a living pantry for the subsistence harvest and consumption of many reef organisms. The cycle of reef accretion and erosion maintains beaches, and provides habitat for seagrasses and mangroves. Coral reefs are important recreational resources for most of the world's people having the privilege of living near them. An outgrowth of the International Coral Reef Initiative (CRI) is the early development of national coral reef initiatives. The United States is developing an inter-agency CRI to create the base for a combined domestic and international effort aimed at the conservation and effective management of coral reef ecosystems (Crosby *et al*., 1995, Crosby and Maragos, 1995).

The ability of coral reef ecosystems to exist in balanced harmony with other naturally occurring competing/limiting physico-chemical and biological agents has been severely challenged in the last several decades by the dramatically increased negative and synergistic impacts from poorly managed anthropogenic activities (Maragos *et al*., 1996). Globally, scientists are now working together and with other groups to promote assessment, monitoring, other research, protection, and restoration of coral reefs. Many non-governmental groups have been at the forefront in local implementation of various coral reef monitoring efforts. These grassroots efforts should be applauded and encouraged. However, long-term nationally and globally coordinated coral reef monitoring programs are essential to manage, archive, translate and transfer data to scientists, managers and other interest groups. Within the U.S., the National Oceanic and Atmospheric Administration (NOAA) is developing a nationally coordinated coral reef monitoring program to be implemented in 1996, and is actively pursuing partnerships with other agencies (such as the National Park Service and the Environmental Protection Agency) and volunteer interest groups (such as American Oceans, The Nature Conservancy, REEF and Reefkeeper) in this effort.

Numerous coral habitats (particularly in the American Flag Pacific Islands - AFPI) are under Department of Defense (DOD) management and are sites of military training exercises. It is, therefore, appropriate that an additional partner in the Coral Reef Initiative is the U.S.

Department of Defense, and this manual is a direct product of that partnership. This manual describes a non-invasive and "low-tech" approach to assessing and monitoring coral reef habitats. It will serve as a reference for individuals with limited technical science background and expertise. Contents include step by step instructions for determining coral-feeding fish behavior and how to relate these traits to changes in coral habitat condition, as well as basic techniques for assessing coral and fish biodiversity and percent cover.

It has become evident that new and innovative techniques are needed that can provide an "early warning" of stress within coral habitats so that investigations to determine causes of the stress and implementation of counteractive management strategies to protect these critical habitats can be initiated. A critical need also exists for relatively low cost, simple (low technology) methods for assessing the overall stress levels ("health") of coral reef habitats throughout the world. This need is especially high in regions that do not have readily available "high" technology equipment and expertise for conducting comprehensive "high-tech" ecological studies. Even within the more "developed" regions of the world, the availability of low cost methods for coral reef assessments that could be conducted by persons without extensive technological training and education would be of immense value to monitoring the stress in these ecosystems.

To date, no DOD studies have been initiated to determine the nature or extent of possible coral reef damage resulting from amphibious exercises. Past actions have excluded amphibious exercises from training because of a lack of scientific data to prove/disprove damaging effects on coral reefs. If the U.S. DOD is to maintain its "readiness" capabilities, training exercises in the direct and/or indirect vicinity of coral reef habitats are critical. If these exercises are to be conducted with no (or at least minimal) significant negative impacts to these fragile ecosystems, coral reef habitat assessment and long-term monitoring protocols must be developed and implemented. It is also desirable that the local indigenous peoples of the islands where the exercises occur should be significantly involved with DOD in any assessment and monitoring activities.

In a broad sense, the development of the coral reef monitoring approach described in this manual will provide the basis for a future, more comprehensive effort to provide scientific evidence of the compatibility of amphibious exercises or highlight potential damages, and recommendations for mitigating alternatives to minimize effects of these exercises. The protocols encompassed in this approach will have applicability throughout the Indo-Pacific region and will serve to not only assist DOD in being able to conduct military exercises while also protecting coral habitats, but will also serve to empower local populations in managing their coral ecosystems in partnership with DOD.

As part of the development of this manual and associated video, Drs. Crosby and Reese conducted pilot classroom and in situ coral reef assessment and monitoring training exercises with selected individuals from the Commonwealth of the Northern Mariana Islands, American Samoa and Hawaii. Participants in this training exercise were nominated by the Governors' Principal Points of Contact for the U.S. Coral Reef Initiative in Hawaii, American Samoa and the Commonwealth of the Northern Mariana Islands, as well as the Kaho'olawe Island Reserve Commission. Trainees participated in approximately three days of training at the study sites that Drs. Crosby and Reese are examining as part of a larger Marine and Coastal Ecosystem Directorate Core Project of the U.S. Man and the Biosphere Program. Field testing of the approach described in this manual included 640 man-hours of on-site, in water, data collection from November, 1992 to June, 1996.

The pilot training exercise was accomplished by demonstrating the use of indicator species of coral feeding chaetodontid fishes to detect low level, sub-lethal changes in the coral reef habitat. These techniques serve as an early warning of stress within a coral reef prior to reaching a "point-of-no-return" (hence remedial actions may be taken). Specifically, correlations of fish feeding preference, abundance, and behavior with coral abundance and health are determined. Demonstrations of line transect methods for determining coral diversity and abundance, and fish counting methods were also made. Proper methods for data entry and analyses were also presented.

Support of this study and the collaborative interplay between DOD, NOAA scientists, University scientists, as well as the Local Level Coral Reef Initiatives, Coastal Zone and Natural Resource agencies has produced a monitoring approach important to the future planning and management of sensitive coral reef habitats, and will facilitate transfer of developed techniques and information to local indigenous peoples in the AFPI and other sites around the world. Of special utility will be the ability to utilize a low cost, low technology method in areas of the world that critically need assistance in determining the level and degree of environmental perturbations to coral and hard bottom marine habitats. Such local level monitoring programs will form the basis of efforts to not only produce the scientific data required to objectively ascertain impacts of training exercises and recommend mitigation actions, but will also serve to demonstrate DOD and NOAA commitment to forming partnerships in training and information transfer that will support the empowerment of local populations in the ability to better assess and manage their coral reef ecosystems.

The authors wish to thank the Legacy Resource Management Program and Department of the Navy - Department of Defense, the National Oceanographic and Atmospheric Administration, the U.S. Man and the Biosphere Program, and the University of Hawaii for their support in this effort. In addition, they are grateful for the active participation by the Governors' Principal Points of Contact for the U.S. Coral Reef Initiative (Lelei Peau, American Samoa; Douglas S.Y. Tom, Hawaii; and Manuel Sablan and Eric L. Gilman, Commonwealth of the Northern Mariana Islands), the Local Level Coral Reef Initiative Programs in Hawaii, American Samoa and the Commonwealth of the Northern Mariana Islands, as well as the Kaho'olawe Island Reserve Commission. Special thanks to Katie Geenen and Kai Wang for their assistance in preparing this manual and associated video; to Javier Mendez and Randy Kosaki for their assistance with the field work and in situ training aspects of this project; and to the trainees of our pilot training sessions.

Cover Photograph: A pair of butterflyfish, <u>Chaetodon multicinctus</u>, the indicator species being used in Hawaii. Photo by Randall Kosaki using a Nikonos V camera with a 35 mm lens, Nikon SB-103 flash, Kodachrome 200 film at f16.

I. INTRODUCTION

There are many methods to monitor coral reefs and the associated biota. Each method has its strengths and weaknesses, benefits and costs, all of which must be considered carefully. Each method also varies in how much scientific training is necessary to successfully use it.

The choice of a method depends on the question being asked, the resources available, and the training of the persons who will do the work. The approach described in this manual is aimed at answering the question: *Is the condition of the coral reef changing?*

The *Butterflyfish Fish Indicator* method is relatively simple and inexpensive. It does not require highly trained personnel with extensive knowledge of reef organisms. More importantly, however, it is sensitive to changing conditions on the reef and, we believe, should provide an "early warning" that change is occurring. This may provide enough time for remedial actions to be taken before entire coral reef habitats are irreversably lost.

The approach described in this manual has at least four important features:

- It does not require that the scientific names of all the coral and fishes are known by the data collectors. It does require that one or two key coral feeding indicator species be recognized for each geographical location. Suggested species are listed in Appendix 1.

- It can be used stepwise with each step providing more information. The first step, which is counting the coral feeding butterflyfishes along the transect, or even just the designated indicator species, provides useful information. The next step, which is counting the corals species occurring at 0.5 m points along the transect line, provides further information and so forth. This means that the method can be used to match the time, resources and personnel available.

- It is best applied where gradual, slow (even sub-lethal) environmental disturbance is suspected, which would be difficult and expensive to measure by other methods, such as collecting water samples or tissue samples for analysis. Clearly, the method is not appropriate for catastrophic disturbance such as oil spills, storms, etc.

- It is an "environmentally friendly" non-destructive or non-consumptive method that can be used by volunteers, local communities, and individuals with no previous former technical scientific training.

A. The Indicator Species Concept

Butterflyfishes of the family Chaetodontidae are conspicuous inhabitants of coral reefs throughout the world (Burgess, 1978; Motta, 1989). Many species are obligate corallivores, and thus depend on the live tissue of corals for their food. Because their metabolic or energetic demand is so intimately linked to the existence and overall condition or "health" of the coral substrate, we believe that these species of butterflyfishes are excellent candidates for indicators of changes in conditions on the coral reef.

The conceptual ideas are simple. Corallivorous butterflyfishes have coevolved with, and are intimately related to the corals on which they fed (Reese, 1977, 1981, 1991; Harmelin-Vivien and Bouchon-Navaro, 1983; and Roberts *et al*., 1988). The distribution and abundance of these fishes should be directly correlated with the distribution and abundance of the corals. If the corals are adversely affected by stressful environmental conditions, such as chronic low levels of pollution, their health will deteriorate. This deterioration should be detected by the fishes which feed on them. In many species of organisisms sub-lethal levels of stress cause re-allocation of available energy. A shifting of energy from production of storage products such as glycogen or lipids to an increase in respiration would make an organism less "nutritious" for those consuming that organism. The corals are sessile and cannot avoid the stress, whereas the fishes are mobile, and can emigrate to healthier regions of the reef. Chronic low levels of pollutants on the reef and the slowly deteriorating condition of the corals are difficult to detect by conventional methods (Dahl, 1981; Brown and Howard, 1985; IUCN, 1993; UNEP/AIMS, 1993; Rogers *et al*., 1994; Jones and Kaly, 1996). In contrast, simply counting the abundance of the brightly colored, diurnal butterflyfishes using conventional census techniques is a relatively simple task. However, as will be discussed in a following section, it is important to focus on coral feeding fishes since plankton-feeding fishes would be less dependent on the coral. A diver can be taught in a few hours to recognize and census key indicator species along a transect. The indicator hypothesis can be stated as follows: *Coral-feeding butterflyfishes respond to declines in coral quality or abundance by behavioral and spatial adjustments that can be easily and rapidly observed.*

Reese (1977, 1981) first proposed that obligate corallivores, such as many species of butterflyfishes, could serve as indicator organisms. Subsequent experimental studies have increased our knowledge of the relationships between butterflyfishes and corals, and support their potential as indicators to monitor changes in conditions of coral reefs.

B. Behavioral Ecology of Butterflyfishes

Fishes of the family Chaetodontidae, the butterflyfishes, are found in all tropical seas of the world. There are 114 species in 10 genera with 90 of the species in the genus *Chaetodon*. The systematics of the family is well studied using classical systematic methods (Burgess, 1978). Butterflyfishes are characterized as diurnally active, brightly colored inhabitants of coral reefs. They belong to three feeding guilds: corallivores, benthic omnivores, and planktivores. The coral feeders are especially interesting because they are closely associated with the living coral reef for both food (as described in the previous section) and shelter. Coral feeding species tend to live in monogamous pairs and are broadly home ranging or territorial.

Pair bonds are established based on size reflecting a division of labor between mates. Males actively defend the territory allowing the female more time to feed. Larger males are able to defend larger territories, while larger females produce more eggs. Thus, there is assortative mating and pair bond formation based on size. Butterflyfishes are dusk spawners on evenings around new and full moon. They are broadcast spawners so there is no parental care. Coral-feeding pairs of chaetodontids show a very high degree of site fidelity with the same individual pairs being found on the same territories for seven to eight years (Reese, 1991). Their life span is 10 to 12 years depending on the species. Predation is minimal on adults but may play a significant role in limiting population sizes during the planktonic larval dispersal stage in their life history. Their striking color patterns make them ideal for behavioral observation in the field, while their typical life history allow individual paris to be observed for many years. Not only can species be readily identified from a distance and interactions recorded, but variation within each species permits individual recognition in the field. All of these characteristics make butterflyfishes ideal candidates for indicator species of ecological conditions on coral reefs.

C. Butterflyfishes as Indicator Species

The concept of using certain key species as indicators of ecological conditions is now well established (Soule and Kleppel, 1988; Jones and Kaly, 1996). The situation with respect to butterflyfishes is reviewed by Hourigan *et al.* (1988).

A number of points must be emphasized. First, sensitive biotic indicators are most useful when one wishes to detect low levels of chronic perturbations such as low levels of chemical pollutants or small changes in temperature or nutrient levels. Over time such low levels of chronic perturbations can have marked detrimental effects on the ecosystem they are impacting. Yet it is extremely difficult and expensive to devise a sampling regime to detect such low levels. It is under such conditions that sensitive biological indicators are most useful. Clearly, one doesn’t need a sensitive indicator for episodic, catastrophic events like oil spills or storms. The second point of importance is that not all chaetodontids are candidates for indicator species. The planktivores, in particular, hovering above the reef facing into the current to intercept plankton are not sensitive to the corals on the reef beneath them. Likewise, the more omnivorous species, feeding on benthic invertebrates other than corals and on algae, tend to be opportunistic and they feed on prey in proportion to their abundance. Therefore, as the prey changes, they change their diets and so do not indicate that a change is occurring in the ecosystem.

In contrast, the coral feeding chaetodontids make ideal indicators because they are directly dependent on the corals as their principal source of energy. Many species are obligate corallivores and do not feed on anything else. Furthermore, they show strong preferences for certain species of corals which provides a further dimension of sensitivity to the system. Since they are territorial, strongly site attached, and live for many years, they provide a longitudinal component to the system which has great value. Even if changes occur very slowly over a number of years in the ecosystem which will eventually make the corals moribund, the same individual pairs of butterflyfishes will be present to experience the change.

Current efforts to use butterflyfishes as indicators of coral reef diversity in Indonesia and the Philippines (Nash, 1989; White, 1989) have overlooked this important point. Forty species are listed on their survey form and many of these are not corallivores. To recognize all these species is a difficult task for non-specialists charged with making the surveys. In addition, less time and attention can be given to the distribution, abundance and social behavior of the truly important indicator species, the corallivores. Nevertheless, these efforts are an important start and make it even more important that the utility of the concept be demonstrated in the correct way.

A reef which is dead from siltation or from crown-of-thorns or from some other causal factor no longer has its characteristic assemblage of coral feeding chaetodontids (Reese, 1981; Bouchon-Navaro *et al*., 1985; Hourigan *et al.,* 1988). The time course of this change in population structure is unknown at present and currently is being investigated. There appears to be a threshold level of reef deterioration at which the fishes begin to leave, perhaps related to the decrease in both abundance and diversity of the corals upon which they are feeding. However, once a coral reef has died, preventive medicine in the form of monitoring with indicator species is useless. Although this approach should still be useful in assessing coral reef recovery.

The size of corallivorous butterflyfishes territories are determined by the amount of coral food contained therein. Experimental removal of coral from territories results in pairs of fish attempting to enlarge their territories at the expense of their neighbors which results in increased agonistic levels of behavior (Hourigan, 1987; Tricas, 1986, 1989). These changes in social behavior, in what otherwise is a stable situation, provide a sensitive early indication that changes are occurring. Furthermore, these events which precede the actual exodus of the fish from the reef appear to occur at a time when the corals are becoming stressed ("unhealthy") but before they have become moribund beyond recovery. Since we are interested in detecting slow changes in the ecosystem, this early warning should provide time for remedial actions to be taken by persons or agencies charged with management of the reef resources, providing the changes are due to perturbations caused by human activities which are impacting the area and could otherwise be controled.

II. APPLICATION OF THE METHOD

A. Assessment of the Problem

The first steps in the application of the indicator species method are to:

- *accurately assess the problem*
- *clearly identify the questions to be asked*
- *state the goals of the monitoring program*

For example, in an ongoing study of the condition of the coral reefs in Hawaii (Crosby, 1994), we assess reefs in near pristine condition, as well as those impacted only by non-point source runoff high in sediments and those impacted only by recreational diving. In the reef impacted by sediments, the sediment came from erosion of the soil due to grazing of the vegetation by feral goats and the effects of using the island as a military target causing fires and further destruction of the vegetation.

Since the military stopped bombing the island and removed the goats, and Hawaiian groups began an extensive replanting program, we asked the question: *Will the coral reefs recover as the amount of sediment impacting them decreases?* In order to answer this question, we looked for two coral reefs areas, one which was severely impacted by the sediment and another which was relatively pristine and less impacted by sediment. Using information gathered by the Division of Aquatic Resources, Department of Land and Natural Resources, State of Hawaii (Kanenaka *et al.*, 1993), we identified two coral reef areas: one near Hakioawa is pristine with little evidence of sediment damage, while the second reef area near Kuheia Bay is heavily impacted by sediment. We also include as a third study site, the island of Molokini which has as its only clear human perturbation, excessive recreational diving and boat anchoring. In recent years, mooring buoys have been installed in Molokini and commercial boat permits are required.

The goal of our monitoring program is to establish long-term monitoring stations to detect evidence of the coral reefs recovering or declining at Kuheia Bay and Molokini Island, that is a change in the direction of replenishment of the coral biota gradually over time. In contract, we postulated that we would see less change in the relatively pristine reefs at Hakioawa.

Thus we assessed the problem, asked the relevant question, and clearly stated our goals.

B. Field Observations

All of the data collection described in this manual involves direct observation of butterflyfishes and corals. Therefore, it is necessary to use scuba. Since butterflyfishes are diurnal, all work is done during daylight hours. In addition, reef fishes don't demonstrate "normal" behavior patterns under conditions of high turbulence and surge and poor visibility. Hence most observations should be collected under normal weather conditions for the particular study site. Because many flourishing coral reefs in the Indo-Pacific region are at depths of about 5 - 20 m, surface weather conditions directly affect the underwater conditions.

C. Getting Started: Establishing the Transect Lines

Transect lines are simple to make. Brightly colored polypropylene line about 1/4 to not more than 1/2 inch in diameter (approximately 1 cm in diameter) works best. We recommend sections slightly longer than 30 m. The line floats so it does not get tangled in the coral. At one meter intervals colored cloth or colored surveyor's tape can be knotted through the weave of the line. Use different colored cloth for different lines. It is convenient to tie a lead weight at both ends of the line which helps secure the line at either end.

Transect lines are <u>not</u> placed haphazardly (Fig. 1). They are placed in areas where coral is abundant since the question that is the focus of this *Indicator Species Approach* is whether or not the condition of the coral on the reef is changing. If one was interested in assessing the relative amount of different kinds of bottom substrata such as sand, coral, algae turf, rubble etc., over the broader area of the study site, then, one would place the lines randomly in the area to be sampled. There is much confusion on this point, but what is important is to always consider the essential question being asked. Again the approach described in this manual focuses on the condition of the coral, not its abundance relative to other kinds of bottom in a broad area.

We recommend that at each study site from one to four 30 m transects be established. The configuration depends on the reef's contour. For example, on an expansive reef of fairly uniform coral cover, a star-burst pattern is used. If the reef is a system of raised coral ridges ("spur and groove") or a narrow reef front, the transects are placed roughly in a parallel pattern. Since we are interested in change of the living corals and behavior of coral feeding butterflyfishes, the transects are purposely placed in areas of high coral cover.

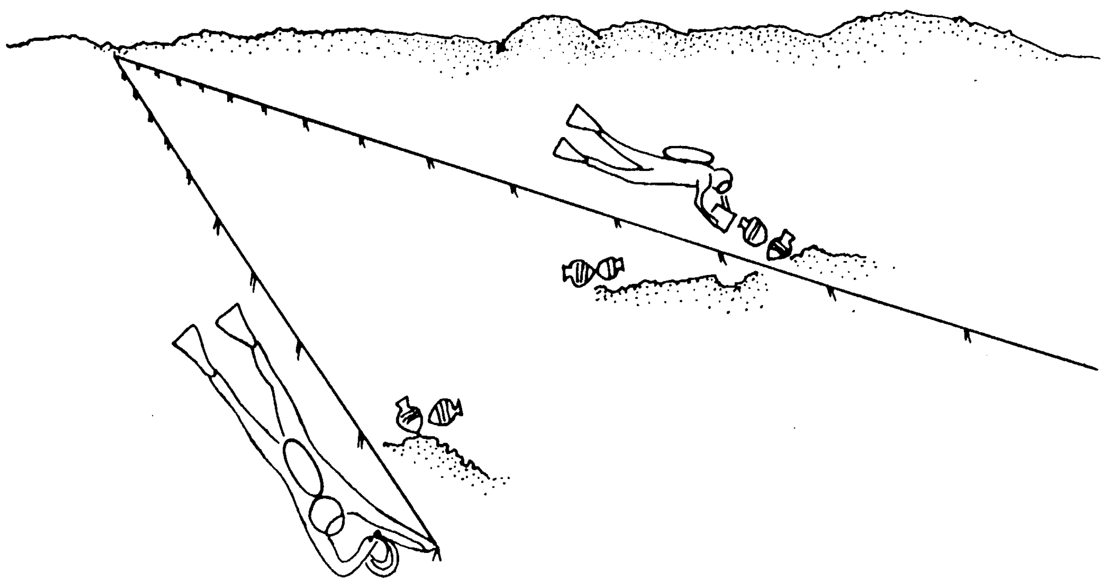


Figure 1. The transect lines are set at 90 degrees to each other in a star-burst pattern. Here only two lines are visible. The diver on the left is in the process of laying out the 30 meter transect line, while the diver at the right is counting pairs of butterflyfishes along the transect line.

Data are recorded on underwater paper attached to a regular, inexpensive clipboard using a soft lead No. 1 pencil. Plastic underwater paper is available under the brand name of "Nalgene Polypaper".[1] Since plastic paper and woodless pencils are relatively expensive, an inexpensive alternative is to cut pieces of matte acetate to the correct size, place the acetate sheet on top of the appropriate data sheet, securing it under the clip on the board and with a rubber band at the bottom of the board. A regular No. 1 or 2 lead pencil writes easily on the acetate sheet. Upon completion of the dive, the data from the acetate sheet can be copied onto

[1] Nalgene Polypaper is available from Technical Service, Nalge Company, Sybron Corp., Box 20365, Rochester, N.Y. 14602-0365 U.S.A., Telephone (716) 586-8800, Fax (716) 586-8431. Although regular No. 1 or 2 lead pencils work, we have found that woodless pencils which are available in most art supply stores or from a manufacturer such as "Pentalic Woodless Pencils", M. Grumbacher, Inc., Cranbury, N.J. 08512 U.S.A., work even better. The softer grade of woodless pencils work best.

regular paper or duplicated with a copier if one is available. The acetate sheet can then be scrubbed clean using a kitchen scouring pad and reused many times. Matte acetate comes in sheets and is available in art supply and most stationary stores.

D. Counting the Numbers of Coral Feeding Butterflyfish

Once the transect lines are established, the numbers of each species of butterflyfish within five meters of either side of the transect line are counted. This is known as the *Belt Transect Census* method (Brock, 1954, 1982; Rogers *et al.*, 1994), and is widely used. Where one is interested in the numbers of fishes of all kinds, including smaller cryptic species and larger transitory species, the *Stationary Fish Census* method (Bohnsack and Bannerot, 1986) may be preferred.

Since coral feeding butterflyfishes are home ranging and often territorial and are not preyed on by large transient predators, they usually do not hide or flee when a diver swims along the transect line (Fig. 1). An exception to this may be in areas where spear fishing has occurred. Furthermore, since they usually occur in female and male pairs, the observer places a "2" on the data sheet (Fig. 2) when a pair is counted, a "1" for a solitary individual, and a "3, 4, 5, etc." if a larger group is observed. An experienced observer may wish to place the letters "J, S, M, L" above the numbers to indicate relative size such as juvenile, small, medium, and large. Please note: This additional size designation method should only be used by a thoroughly experienced individual who is familiar with the size categories of the species in question.

Note that on the Fish Transect Data sheet (Fig. 2) the designated indicator species, C. multicinctus, is shown both as an adult and as a juvenile. C. ornatissimus and C. trifasciatus are obligate coral feeders and they could be used as indicator species as well. Because C. multicinctus is more abundant and has smaller territories, it is a more convenient indicator species in Hawaii. C. unimaculatus is a facultative coral feeder. It is, therefore, not as good a choice for an indicator species. C. fremblii is an omnivore and feeds on a variety of small invertebrates. It is, therefore, not as closely dependent on coral as the other species, and may serve as a sort of control. If a pair is seen, the number "2" is placed to the right of the fish, if a single fish is seen, the number "1", if a group, the number designating the numbers of fish in the group is noted, for example "3". Monitoring trainees often ask the following two important questions: *How much time should I take counting the fish along the 30 m transect?* and *Should I count all the butterflyfishes along the 30 m transect line?*

Slowly swimming a 30 m transect line, visually scanning the reef 5 m to either side of the line should take about 5 minutes. Every effort must be made not to count any individuals twice and swimming at this rate decreases the chance that pairs of fish swim back into the observers' view.

The second question is more difficult to answer, because it depends on the experience of the observer and the amount of circumstantial data she or he wishes to collect. Usually only one or two, at the most three, species of butterflyfishes are designated as the indicator species for a given study site. In Hawaii, we are using only one species, the brown-barred butterflyfish Chaetodon multicinctus. It is abundant and easily observed. In most tropical locations where diversity is greater, the decision may be made to use two or more species as the local indicator species. Candidate species are listed in Appendix 1.

The following is a step-wise progression of observations that data collectors should employ as they become more experienced over time and more comfortable with their knowledge of the local fish assemblages.

Below are listed the species which observers may wish to count along the transect:

1. At the minimum, the numbers of pairs and single individuals of the designated focal indicator species must be counted.

2. Next, all the known coral feeding species of butterflyfishes should be counted.

3. If the observer knows the fish fauna well, she or he may wish to count other species of butterflyfishes as well. For example, species which feed on plankton or are benthic omnivores feeding on algae and small invertebrates like crabs, shrimps, tube worms, etc. may be counted. These may serve as a "control" since their abundance and distribution should be less immediately or directly affected by the changing condition of the coral than those species which depend on the coral directly for their food.

DATE:________________ TIME:________________ DEPTH:________

SITE:________________________ OBSERVER:________________________

Fish Transect Data: Record the number of ea. spp. seen within 5m on either side of 30m line

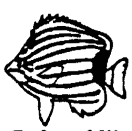
species	number of individuals
 *C. multicinctus*	2 2 2
 *C. multicinctus* Juveniles (<4 cm.)	1 1
 *C. ornatissimus*	2
 *C. trifasciatus*	2
 *C. unimaculatus*	3 2
 *C. fremblii*	1
other species:	

Figure 2. *This is an example of the Fish Transect Data sheet being used in Hawaii. Sample data entries are shown on the data sheet.*

E. Estimating the Percent Coral Cover under the Transect Line

Prior to beginning the estimation of coral cover along the 30 m transect line, the observer should make note of the most abundant or apparent species under the transect line. This familiarization period usually focuses on six to perhaps 12 species of corals. The six species of coral shown on the <u>Coral Transect Data</u> sheet (Fig. 3) are those which are most abundant at the Kaho'olawe and Molokini study sites in Hawaii.

If the scientific names of the coral species are known, these can be entered on the data sheet. If the scientific names are not known, common local names, such as "finger coral" or "brain coral", can be used. Even a simple description is useful, such as "brown lumpy coral" or "reddish brown plate coral with white polyp tips." The latter description for example would be adequate to recognize <u>Montipora verrucosa</u> in Hawaii.

After the data collector feels comfortable with his or her coral identification skills, he or she swims along the same 30 m transect line used for the fish counts and records the coral directly beneath the line at 0.5 or 1.0 m intervals. If a 30 m transect line is in use, then this results in either 60 or 30 data points, each data point being a type of coral. This is known as the *Line and Point Intercept Transect* method (Ohlhorst *et al.*, 1988; Rogers *et al.*, 1994). These authors also discuss other widely used methods for estimating coral cover such as the *Quadrat Grid Transect* method. However, the *Line and Point Intercept Transect* method is quicker, somewhat easier for novices, provides reliable data and is the preferred when applying our *Indicator Species Monitoring* method.

A shortfall of both the *Line and Point Intercept Transect* and the *Quadrat Grid Transect* methods is that they do not take into account the rugosity or uneven surface contours of many coral reefs. A more accurate estimation of the surface coral cover, taking into account the rugosity of the reef, can be obtained using the *Chain Transect* method. This method also has its limitations, is time consuming, and can be destructive to fragile corals. Simulation studies of the different methods indicate that the best estimates of percent coral cover and diversity are obtained by doing more *Line and Point Intercept Transects* rather than fewer and more time consuming samples taken with the other methods (Kinzie and Snyder, 1978).

The percent coral cover is calculated by dividing the number of observations of a certain species of coral by the number of data points along the transect line. For example, if an observation was made at each 0.5 m interval along the 30 m transect, and the coral <u>Porites compressa</u> was recorded at 12 of the 60 data points along the transect, then <u>P. compressa</u> accounts for 20% of the coral cover along the transect line.

DATE:________________ TIME:________________ DEPTH:________

SITE:____________________ OBSERVER:____________________

Coral Transect Data: Record the type of substratum lying directly under the transect line at 0.5m intervals

number of points

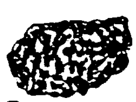
Porites compressa
Finger Coral — ////////////

Porites lobata
Lobe Coral — /////

Montipora verrucosa
Brown plate coral — ///////////////

Montipora patula
Crown calyx coral — //////////////////

Pocillopora meandrina
Cauliflower coral — /////



Pavona varians
Meandering polyp coral — //

OTHER CORAL SPP. //

NON-CORAL (dead coral, sand, algae, etc.) /

Figure 3. *This is an example of the Coral Transect Data sheet being used in Hawaii. Sample data entries are shown.*

F. Marking the Territory Boundary and Measuring Chasing Behavior

Marking of obligate coral feeding Butterflyfish territory boundaries and observations of chasing behavior are usually done together in a single dive using the data sheet shown in Figure 4. First the diver locates along the transect line the focal pair of fish whose territory will be marked. Once this pair is recognized and the first color tagged nail is placed where the pair of fish is first seen, the diver begins the first 10 minute period of observation and marking territory. It is hightly recommended that a diver watch with a timer and audio alarm feature be used for all timed observations. It is advised to look at your watch and enter the time you start above the "0-10 min." designation, for example 0930-0940, the next "10-20 min." designation, 0940-0950 etc. This helps the diver remember in which 10 minute observation period she/he should be noting the chasing observations.

If you are observing Chaetodon multicinctus, the indicator we are using in Hawaii, and one fish in your focal pair chases a fish in an adjacent pair of C. multicinctus, you would record "Agg Cm" in the appropriate 10 min. block on the data sheet. This indicates that one fish of the pair you are watching was the aggressor and chased a fish of the neighboring pair of C. multicinctus. If *both* fish of the pair you are observing chase *both* fish of the neighboring pair, then you should note "Agg Cm 2x." This indicates that two chases occurred and it is entered as two aggressive chases initiated by the pair you are watching in the computer entry.

If the neighboring pair of C. multicinctus is the aggressor and the pair you are observing is submissive, that is, they flee, then you would record "Sub Cm" in the appropriate time interval on the data sheet. If all four fish of the two pairs are involved, you would enter "Sub Cm2x". Please note: Any shorthand that one wishes to use, such as "+" and "-" instead of "agg" and "sub" respectively is perfectly acceptable as long as the shorthand is clearly defined.

These behavioral encounters often occur in bouts where one pair chases another pair out of the territory, but then when the pair being chased enters its own territory, it turns and becomes the aggressor. Thus your entry might look like, "Sub Cm, Agg Cm" or if all four fish are involved, "Sub Cm 2x, Agg Cm2x." It is well known that animals tend to be more aggressive when they are in their home territory but they become submissive when they are outside of their territory. Thus, you may observe sort of a "see-saw battle" as they chase each other back and forth between their territories.

Note that another species, Plectroglyphidodon johnstonianus, a damselfish, is included on the Chase Data sheet. This is because this little fish often lives within the territory of pairs of C. multicinctus where it feeds on coral. It also lays its eggs on the coral. It is aggressive and often chases C. multicinctus. In contrast, C. fremblii which is not a coral feeder is rarely chased.

The diver observes the pair of fish for 50 minutes as shown on the data sheet (Fig. 4). This is not an arbitrary time period. Please note: While it is advisable to complete all 50 minutes of observations in a single dive, it is not essential. However, if a second dive is required, it should be done as quickly as safety requirements allow. Previous studies have shown that for coral feeding butterflyfishes with relatively small territories, 50 minutes of observation and placing nails on the perimeter of the territory provides an accurate measure of the boundary of the territory.

The process of marking the territory proceeds throughout this 50 minute period after the first nail is placed on the reef where the pair of fish is noted. In all probability this first nail is inside the territory and subsequently will be relocated as the boundary of the territory becomes more clearly defined (see Fig. 5 in which the color tagged nails on the boundaries of the territories are connected by a dotted line).

As the diver observes the pair of fish, she/he places a color tagged nail where the fishes hesitate and turn back into their territory. This hesitating and turning behavior is repeated when the fishes reach the boundary of their territory. Most agonistic chasing behavior occurs at the boundaries as well. With experience the diver learns to recognize these movements and becomes very good at placing the nails along the territory boundary. The diver places most of the nails during the first two or three ten minutes observation periods as the pair of fish forage through their territory. By the fourth and fifth ten minutes periods very few nails are placed because the boundary of the territory has already been fairly accurately marked. Throughout this process nails placed during the first few observations periods may be moved to more accurately delineate the boundary of the territory.

It is often useful to know the sizes of the focal pair of obligate coral feeding Butterflyfish one is observing. Since the method is unobtrusive, we do not catch the fish to measure them. Rather when the fish stops to feed, you note the spot behind its snout and the tip of its tail on the substratum. Then when the fish swims away you measure this distance with the ruler glued to the side of your clipboard and note it on the data sheet. This can be done while you are marking the territory and observing chasing behavior and also when you are recording feeding behavior. With a little practice this method of estimating fish length is quite accurate. Nevertheless, for the sake of accuracy it is good to take at least five to six measurements and average them. It is useful to try to measure the lengths of both members of the pairs even though we know that the sizes of the two fish of a pair are about the same.

Another method of estimating fish sizes underwater without catching them is to practice observing fish shapes of known size at different distances underwater (Bell *et al.*, 1985). This method is useful where the diver does not have time to observe a fish for a long period of time, for example when counting fish along a belt transect census or when counting fish using the stationary census method.

The first method described above is recommended when using the indicator species monitoring method.

At the completion of this dive, the boundaries of the territory have been marked by the color tagged nails and agonistic chasing behavior recorded on the data sheet. The rate of chasing behavior should be higher where the reef is undergoing change. The next step is to measure feeding behavior.

DATE:________________ TIME:________________ DEPTH:________

SITE:______________________ OBSERVER:______________________

Chase Data: Record each event when the focal pair:
- chases another fish -- **Agg** __(sp. name)__
- is chased by another fish -- **Sub** __(sp. name)__

time period	chases
0-10 min.	Agg Cm, Sub Cm, Sub Co, Agg Cm
10-20 min.	
20-30 min.	
30-40 min.	
40-50 min.	

C. multicinctus *C. ornatissimus* *C. trifasciatus* *C. unimaculatus* *C. fremblii* *P. johnstonianus*

Figure 4. *This is an example of the Chase Data sheet being used in Hawaii.*

G. Measuring Feeding Behavior and Measuring the Size of Territory

These two activities can usually done in a single dive using the data sheets shown in Figures 6 and 7. The two activities are depicted in Figure 5. Unlike marking the territory boundary and observing chasing behavior which are done simultanously over the entire dive, measuring feeding behavior and measuring the territory size are done sequentially. First feeding behavior is observed for three 10-minute observation periods, then the territory size is measured during the remainder of the dive or on a subsequent dive. Please note: Observations of feeding behavior will require very focused attention by the data collector.

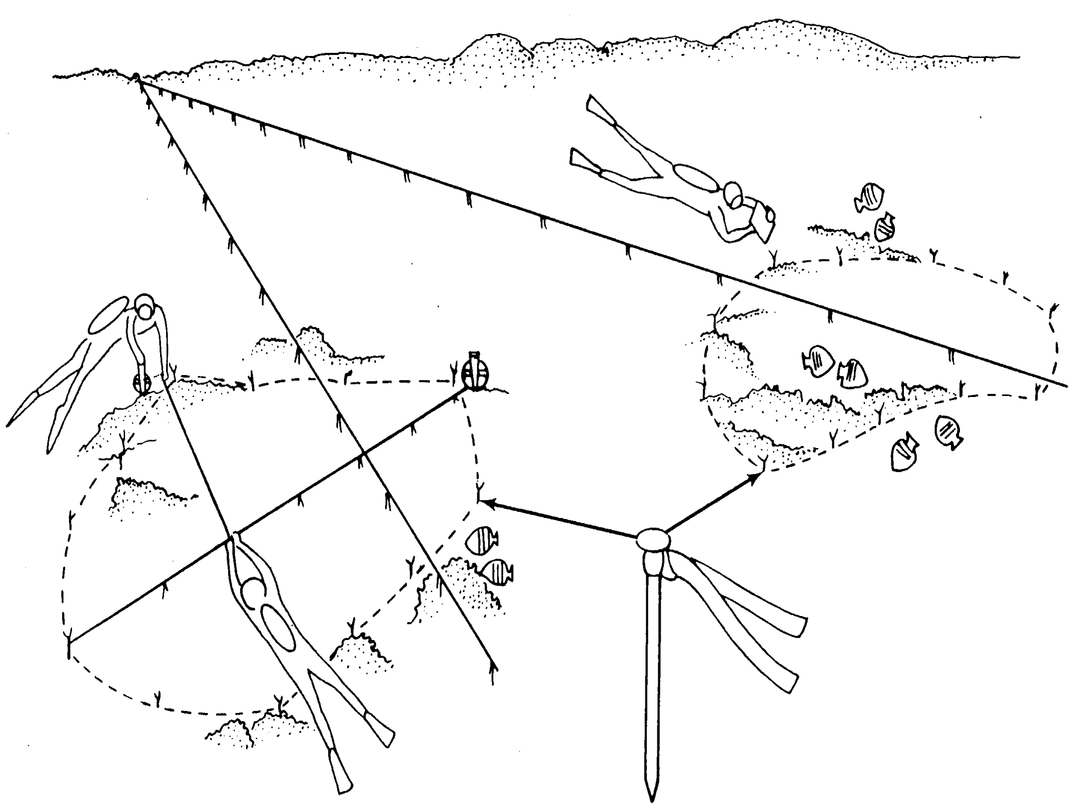


Figure 5. *Observations are made on territory size, chasing and feeding behavior. The two divers on the left are measuring a territory. The diver at the right is observing the focal pair of butterflyfish in the territory.*

1. Measuring Feeding Behavior

The data collector should look for any individual identifying marks on one fish of the focal pair. Variations in the marking pattern of the fish enable an experienced diver to recognize individual fish in the pairs, and this fish is then used to measure feeding behavior. The Feeding Data sheet (Fig. 6) shows three 10-minute time periods in which the number of bites on a particular species of coral is recorded. At the conclusion of the dive the numbers of bites per 10 minutes for each species of coral can be calculated. This gives an indication of which coral is preferred as food, but one must take into consideration the relative abundance of the corals (Fig. 3). A species of coral which is preferred as food may be rare in the area of reef and so the rate at which it is fed on may be relatively low. Feeding bites may occur as a single bite and be designated in the proper space as “1”, or they may occur in bouts of two or more bites and be designated as “2”, “5”, etc. Since feeding bites usually occur in bouts of two or three bites with often a brief pause in between each bite, a typical data entry may look like “| | |” indicating three bites on the species of coral. Sometimes bites may be grouped more closely in rapid sequence. The observer counts five bites and then records “5” in the appropriate square on the data sheet.

On the left side of the data sheet are shown the six most common species of corals in our study sites at Kaho’olawe and Molokini Islands in Hawaii. Note that a sketch of the coral to help an inexperienced diver identify it is shown together with its common and scientific name. Please note that at the bottom there is space for bites taken on “other coral” and on “Non-coral” substrata.

It must be emphasized that the scientific names of the corals are not necessary to be known for the successful application of the indicator species method described in this manual. It is extremely important, however, that descriptive names are given to the most common species of corals in the study area and those which are fed on by the species of butterflyfishes being used as indicators. These names and perhaps sketches should be used on the data sheet. They must be used consistently by all data collectors. Consistency is the key to the data quality control required for successful application of the method. The reason that scientific names of the corals are not important is that we are looking for *changes in feeding rates as an indication of changing conditions on the reef*. Therefore, it is important to know that the indicator species of fish is feeding more or less on the “brown lumpy” coral. It is not necessary to know the scientific name of the coral. Please note: With an accurate and thorough description of the physical appearance of the coral, scientific names to at least the genus level can usually be determined at a later date.

DATE:____________ TIME:____________ DEPTH:______

SITE:____________ OBSERVER:____________

Feeding Data: Record no. of bites taken (per 10 min. period) on each spp. of coral by one focal fish

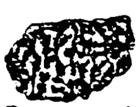
	0-10 min.	10-20 min.	20-30 min.
 *Porites compressa* Finger Coral	11312		
 *Porites lobata* Lobe Coral	1511		
 *Montipora verrucosa* Brown plate coral	1122113		
 *Montipora patula* Crown calyx coral	111231		
 *Pocillopora meandrina* Cauliflower coral	112516		
 *Pavona varians* Meandering polyp coral	11		
OTHER CORAL	11		
NON-CORAL	1		

__Figure 6__. This is an example of the Feeding Data sheet being used in Hawaii. Sample data entries are shown for the first 0-10 min. time period.

2. Measuring the Territory Size

The boundary of the territory is marked with color-tagged nails. The shape of territories is usually more or less circular or oval, and the longest axis across the territory is evident to the diver (Fig. 5). It is possible for one diver to measure a territory, but it is much easier and faster if the diver's buddy or assistant helps to measure the territory. First, a fiberglass measuring tape[2] is stretched across the longest axis of the territory and anchored at both ends with a small weight. Then, while one diver holds one end of the second tape at each meter interval along the first tape, the second diver measures the distance to the boundary of the territory and enters the distance on the data sheet (Fig. 7). Note that in Figure 7 the line down the center represents the tape measured line down the longest dimension of the territory (Fig. 5). The length of the line is indicated at the appropriate meter mark, in this example it is 15 meters. Then the distance to the boundary of the territory is measured at each meter to the right and left sides of the line, and the distances are recorded to the right and left sides of the line on the data sheet. The territory size (in square meters) is estimated by simply adding up all the values on the data sheet. Sample entries in Figure 7 are shown for the first five meters on the right side. The last data entry on the right side would be at 15 meters. The process is then repeated for the left side of the territory.

As with all aspects of this and other activities described in this manual, every effort should be made to avoid contact with the coral during the measurement. This is best done if the divers are slightly positively buoyant.

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[2] Fiberglass Measuring Tapes are available from companies such as Ben Meadows Co., P.O.Box 80549, Chamblee, GA 30366, U.S.A., Fax: U.S. and Canada 1-800-628-2068, International 1-770-457-1841, or Forestry Supplies, Inc., P.O.Box 8397, Jackson, MS 39284, U.S.A., Fax: U.S. and Canada 1-800-543-4203, International 1-601-355-5126. They are available in both English and Metric units of measure, in varying lengths. Two excellent brand names are Keson and Lufkin. For our research we prefer the 30m open reel model. Current 1996 prices are about U.S. $ 25-30.

DATE:________________ TIME:________________ DEPTH:________

SITE:______________________ OBSERVER:____________________

Territory Measurement: Measure and record the distance from the center line to the territorial boundary at 1 m intervals

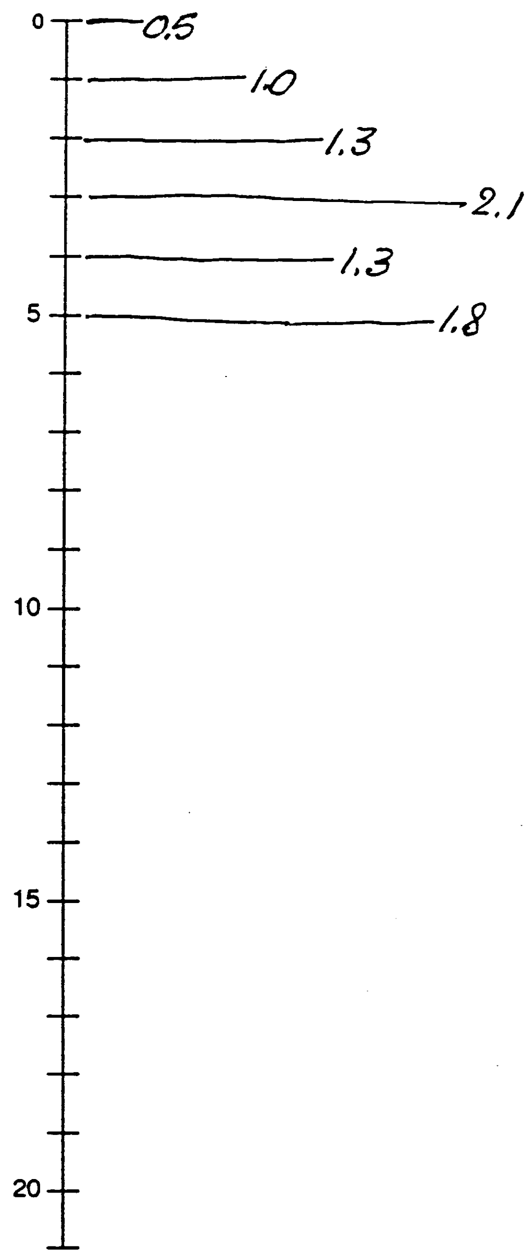


Figure 7. *This is an example of the Measuring Territory Data sheet being used in Hawaii.*

H. Picking-up the Color-tagged Nails, the Fiberglass Measuring Tapes, and the Polypropylene Transect Lines

After the final territory measurements have been collected, the color-tagged nails and the fiberglass measuring tapes are removed from the reef. The polypropylene transect lines can be left in place for several days until the work is completed in the study area. Then they too are removed from the reef. At the conclusion of the study, nothing should be left on the reef in order to leave the area as undisturbed as when the study began. Providing that the fish are not collected by spear or hand nets, they habituate to the presence of a diver by the end of the first dive. By the third or fourth dive the focal pairs have become so tame that a diver may approach within a meter before their normal feeding/foraging behavior is affected. In order to ensure that monitoring can continue at the same site for many months and years, it is advisable to record accurate site coordinates, note any shoreside landmarks, and/or leave a buoy marker (sub-surface or surface) as the particular situation allows. Please note: Ensure that any buoy markers deployed meet all federal, state and local regulations, and are as environmentally "friendly" as possible.

III. ANALYSIS OF DATA

A. The Design of the Monitoring Program

The correct analysis and interpretation of data depends on an understanding of the design of the monitoring program, and the design is based on the question being asked. For this monitoring approach we are relying on the behavioral ecology of the coral feeding butterflyfish to provide the answer to the question: *Is the condition of the coral reef changing?*

The design of the monitoring program must include at least two study sites. One site should have no (or limited and known) environmental perturbations or chronic anthropogenic disturbances. Little or no change in the behavioral ecology of the indicator species of butterflyfishes is postulated for this site which can then serve as a control or reference reef. Additional sites are selected due to concern that disturbance is either occurring or anticipated. Here the hypothesis is that changes in the behavioral ecology of the indicator species will provide an “early warning” that sub-lethal and/or potentially lethal change is occurring on the reef, providing time for remedial action to be taken before the corals on the reef become moribund and die. Although comparisons between the two sites for any sampling period may be interesting, *it is the comparison of the data at the same site over time which is essential.*

B. Step-wise Use of the Monitoring Program

The *Indicator Species Monitoring* approach has the advantage of providing useful information in a step-wise or incremental fashion. For example, in its simplest form or first step, the numbers of coral feeding butterflyfishes and especially the species selected as the indicator species are counted along the 30 meter Belt Transect (see Section II. D. above). Since two important criteria for the indicator species are (1) being long-lived and (2) being strongly site attached, home ranging or territorial, then within-site changes in their abundance and distribution suggest that changes are occurring on the reef where disturbance is anticipated. This evidence of change is strengthened if similar within-site changes do not occur on the control or reference reef.

The next incremental step is the estimation of coral cover along the transect (see Section II. E. above). Again the within-site comparisons are important and the reasoning is the same as for the abundance and distribution of fishes with one very important difference: the fish are mobile and are able to leave the area as conditions deteriorate whereas the corals are attached and therefore are unable to avoid the changing conditions of the water around the reef. They must tolerate and adapt to the conditions or become moribund and die. Needless to say, when dead corals begin to appear and the estimation of coral cover decreases, evidence that the reef is being impacted by detrimental environmental factors is strong. Unfortunately it may be too late to enact remedial management policies at this stage of manifestation to lethal perturbations.

It is important to note that the overall abundance of corals, as estimated by the percent coral cover, may not change, but the distribution of the different species, the composition of the coral community may change. This is because the different species of corals compete with one another for space on the reef. Alterations in environmental conditions may alter competitive advantages between corals. For example, in Hawaii corals of the genus Montipora are able to kill and grow over corals of the genus Porites, but the presence of coral feeding butterflyfishes, especially Chaetodon unimaculatus, which selectively feeds on Montipora corals prevents this from happening (Cox, 1986). Nevertheless, if adverse conditions affect the reef, and the numbers of coral feeding butterflyfishes decline, then changes in the species composition of the corals on the reef may occur. These changes occur slowly, yet are within the time-frame of a long-term monitoring program of a few years duration.

The next steps in the monitoring program involve the behavioral observations of agonistic behavior, as indicated by aggressive behavior, and territory size (see II. F. above) and feeding behavior (II. G. above). Within-site changes in any of these measure provide evidence that change is occurring on the reef. For example if low level chronic inputs of pollutants are gradually causing the healthy conditions of the coral on the reef to deteriorate, the food "value" of the coral to the fishes may decrease as discussed earlier.

Under these conditions, we expect the following changes in behavior to occur:

1. The amount of agonistic encounters (chases), will increase as fish try to find more food in their neighbor's territories.

2. Territory sizes will change. Fish try to enlarge their territories to gain access to more food. This may be possible for larger, dominant pairs at the expense of smaller, more submissive pairs whose territories may become reduced in size. Subordinate fish with small, marginal territories may be forced to leave. (These possibilities still need to be verified experimentally.) Thus, as the reef changes, territory sizes are expected to change as well.

3. Feeding rates will change. At first, as the nutrient food value of the corals decreases, feeding rates will increase as the fish must feed on more coral polyps to gain the same amount of nutrients and energy for metabolism, growth and reproduction. Later, as chasing behavior increases, there may be less time for undisturbed feeding and feeding rates may decline. Thus there is a dynamic relationship between the food value of the corals and the chasing, territorial and feeding behavior of the fish.

Clearly, the more that is known about each of these behavioral steps, the greater the sensitivity and predictive use of the monitoring method will be. Nevertheless, each suceeding step of the method provides additional useful information.

C. Data Management

All too often environmental monitoring (especially volunteer efforts at local levels) ends with the collection of the raw data. This is unfortunate because without careful data entry and statistical analysis the significance of the results cannot be determined. Without a careful analysis of results, it would not be prudent to advocate remedial action. The United Nations Conference on Environment and Development (UNCED) in Rio De Janeiro in 1992 and Agenda 21 brought worldwide attention to the need for monitoring and protection of coral reef ecosystems. Globally, scientists are now working together and with other groups to promote monitoring of coral reefs. For example, a Global Task Team on Climate Change and the International Oceanographic Commission (IOC) have also published recommendations on coral reef monitoring procedures and are organizing a global network for monitoring coral reefs. A major activity in support of the International Coral Reef Initiative is the Global Coral Reef Monitoring Network. This activity will involve coral reef researchers around the world in coordinated monitoring of selected coral reefs.

A clear need exists for biological surveys of benthic, coral, and fish communities to collect the raw data that can be converted into some form of condition indices. Ideally these indices would be indicative of levels of stress or change before the "point of no return" so that appropriate research can be initiated to provide information to the management community responsible for mitigation strategies. There have been numerous calls (see Crosby *et al.*, 1996; Eichbaum *et al.*, 1996) for a network of "index" sites for long-term monitoring and assessment at the national, regional, and global levels. The current dearth of individuals with high level technical expertise, not to mention funding resources, precludes the implementation of such a comprehensive network of coral reef monitoring sites (especially in remote regions) without the significant involvement of adequately trained, local-level participants. Many non-governmental groups have been at the forefront of various local coral reef monitoring efforts. These grassroots efforts should be applauded and encouraged. However, long-term national and globally coordinated coral reef monitoring programs are essential to manage, archive, translate, and transfer data to scientists, managers, and other interest groups. NOAA is developing a nationally coordinated coral reef monitoring program to be implemented in 1996 and actively pursuing partnership efforts with other agencies (such as the National Park Service and the Environmental Protection Agency) and volunteer interest groups (such as American Oceans, The Nature Conservancy, REEF, and Reefkeeper). The key to successful monitoring programs, whether professions or volunteer based, is good data management.

From Data Collection to Long-term Data Management

It is very important that the data observations collected in the field on the underwater data sheets be transferred as soon as possible to long-term data storage. The preferred method is for all data observations to be entered onto computerized data spread sheets. At the very least the field observations should be transferred to hard copy paper data spread sheets. The advantage to storing your data on a computer format is that data manipulations, transfers of data to central data bases such as those discussed above, and statistical analyses are much easier than with hard copy paper storage. Whether one uses IBM based or Macintosh based computers, there are numerous spreadsheet and statistical analyses packages available. The pros and cons of these computer software packages are numerous and often subjective based on individual preferences.

The following procedures should be followed to maintain quality control of your data files:

- Ensure that column headings in your data spread sheets are clearly and consistently labeled.
- Keep accurate descriptions of any abbreviations used in the actual data set and what units (feet, meters, minutes, hours, etc.) the data are expressed as.
- Keep accurate and full descriptions of the how, who, when, and where each datum was collected.
- Routinely check and double check (it is best if you have someone else double check your data for you) to ensure that the data you have entered in the long-term data file accurately reflects the data observations in the field.
- Maintain at least one complete set of "backup" data files on floppy disks and/or other hard drives, and update these backups periodically.

Please Note: While it is often not practical to maintain the full and complete descriptions as part of the actual data files, always make sure to reference where the complete "meta-data" files exist.

Examples of data spread sheets that can be used with the *Indicator Species Monitoring* approach described in this manual are in Figures 8-11. These data sheets were created using the Microsoft Excel program. Figure 8 may be used as a format to record the observations from the fish transect method. ["Trip" refers to the sequential number of field trips in this study. "Site" refers to one of three sites being examined as part of this study. "PI" refers to the individual who collected this data. "Station" refers to one of a number of different specific transects conducted by a particular PI at a given site during a specific trip. "Date" is the specific calendar point in time that the data was collected. "C. multi" refers to the number of C. multicinctus observed by the PI on this particular transect line. "C. multi juv" refers to juvenile C. multicinctus. The next five column headings are abbreviations for other species of butterfly fishes observed on the transect line. The final column is a summation of all butterfly fishes observed.]

Figure 9 may be used as a format to record the observations from the coral transect method. [The first five column headings are the same as in Figure 8. The next seven column headings are abbreviations for different coral species found in this study. "Unknown" refers to any coral species that can not be identified to species or genus. "Noncoral" refers to an observation point on the transect line that has neither living nor dead coral. "Deadcoral" is self explanatory. "∑ counts" refers to the total number of observation points along the transect line. "∑ live coral" refers to the total number of live coral occurring at observation points along the transect line. "% coverage" refers to the percent of observation points along the transect line that had living coral.]

Figure 10 may be used as a format to record the observations from the butterfly fish chasing method. The first five column headings are the same as in Figure 8. "Time" data are presented sequentially in each of the 10 minute time periods in which they occurred (i.e., 2 refers to the second 10 minute time period), and for the total 50 minute period of observation. The next 12 columns represent different fish species that the focal pair of fished had agonistic encounters with, broken down as whether the focal pair was the aggressor (agg) or submissive (sub) to the species noted in the column heading. The sum of both aggressive and submissive encounters with the species noted in the column heading are given under the "∑" headings. The "agg?", "sub?' and "∑?" headings refer to encounters the focal pair had with a species that the data collector could not identify. The "∑agg" represents the sum of all encounters that the focal pair had with other fished in which the focal pair was the aggressor. "∑sub" is likewise for all encounters in which the focal pair was submissive, and "∑∑" represents the sum of all encounters that the focal pair had with all other fishes. "Terr sqM" refers to the territory size in square meters, of the focal pair, "hour" refers to the time of day (rounded to the nearest 15 minutes) that the observations began, and "fish cm" refers to the size estimate for one individual of the focal pair. (As an example - during the sixth trip of this study, Javier Mendez made an observation at station 1 of site 2 on June 3, 1995 that during the first 10 minute period of observing his focal pair of fish, an individual in his focal pair made two aggressive chases against a C. multicinctus. In the fifth 10 minute period of this total 50 minute observation period, Javier noted that an individual in his focal pair again made an aggressive chase against a C. multicinctus. No other encounters occurred with his focal pair during this 50 minute observation period. The territory size of the focal pair that he observed during this period was 53.6 m^2, and the size of one individual in his focal pair was 8.0 cm.)

Figure 11 may be used as a format to record the observations from the butterflyfish feeding method. The first five column headings are the same as in Figure 8. “Min” refers to each of the 10 minute time periods (i.e., 2 refers to the second 10 minute time period) during the total 30 minute period of observation. The next seven columns represent the number of bites made on different species of coral that an individual of the focal pair of fish fed upon. “Unknown” refers to bites that were made on an unknown species of coral, and “noncoral” refers to bites made upon a substrate other than living coral. “∑coral” refers to the sum of all bites on coral during the given time period, and “∑bites” refers to all bites regardless of substrate. “Hour” refers to the time of day (to the nearest 15 minutes) that the observation period began.

If one desires, conventional statistical methods may be used to analyze changes over time and differences between sites (see Sokal and Rohlf, 1981 and Mendenhall, 1971 for complete overview of statistical analyses of data sets). In the ecological sciences, a probability level >0.05 is generally used for rejection of null hypotheses. In laymen’s terms this means that in order to make the conclusion that observations between two or more times or sites are “significantly” different, analyses must indicate that there is a 95% probability that there is a difference. Just as there are numerous data spread sheet software packages available commercially for both IBM and Macintosh computers, there are also a number of easy to use statistical software packages that one can employ to do a range of elementary descriptive and more sophisticated statistical analyses of your data sets. Any of a number of paired-comparison tests can be used to detect trends of directional changes in measurements, an Electivity Index (Gore, 1984) is used to compare feeding preferences to coral abundance, and a number of different parametric and non-parametric approaches can be used to determine differences between two or more sites or events in time and over time. Please note: It is highly advisable to consult with an individual who is experienced with statistical analyses and discuss the questions that you are trying to answer in order to design the appropriate data formats and conduct the appropriate statistical analyses.

Figure 8. Fish Transect Data

TRIP	SITE	P I	STATION	DATE	C. multi	C. multi juv.	C orn.	C. unimac	C. kleinii	C. trifas	C. miliaris	total fish
5	1	JM	1	3/15/95	16	0	0	10	6	1	0	33
5	2	JM	1	3/15/95	14	6	0	0	0	0	0	20
5	3	JM	1	3/18/95	8	0	0	7	5	4	0	24
5	3	JM	2	3/18/95	6	0	2	7	2	2	0	19
5	1	ESR	1	3/15/95	8	0	0	4	4	6	0	22
5	2	ESR	1	3/15/95	20	0	0	0	0	0	0	20
5	3	ESR	1	3/18/95	12	0	0	8	3	2	1	26
5	3	ESR	2	3/18/95	8	0	1	17	12	8	0	46
5	1	MPC	1	3/15/95	16	0	4	6	0	2	0	28
5	2	MPC	1	3/15/95	18	0	0	0	3	0	0	21
5	3	MPC	1	3/18/95	2	0	0	4	1	4	0	11
5	3	MPC	2	3/18/95	4	0	0	6	2	1	1	14
6	1	JM	1	6/3/95	10	1	1	3	1	2	0	18
6	2	JM	1	6/3/95	16	7	0	0	0	0	0	23
6	1	JM	2	6/4/95	8	1	1	9	0	2	0	21
6	3	JM	1	6/6/95	10	0	0	25	14	0	0	49
7	2	JM	1	11/17/95	10	24	3	1	0	0	0	38
7	1	JM	1	11/18/95	13	8	2	9	0	2	0	34

Figure 9. Coral Transect Data

TRIP	SITE	P I	STATION	DATE	P.compressa	P.lobata	M.patula	M.verrucosa	Poc.meand	Pav.varians	P.deur	unknown	noncoral	deadcoral	∑counts	∑livecoral	%coverage
5	1	ESR	1	3/15/95	39	1	3	5	3	1	0	0	8	0	60	52	86.67
5	2	ESR	1	3/15/95	32	2	2	1	2	0	0	0	21	0	60	39	65.00
5	3	ESR	1	3/18/95	2	1	28	27	1	1	0	0	0	0	60	60	100.00
5	3	ESR	2	3/18/95	1	5	31	21	1	1	0	0	0	0	60	60	100.00
5	1	JM	1	3/15/95	21	9	16	6	2	2	0	0	0	0	56	56	100.00
5	2	JM	1	3/15/95	21	10	12	5	6	0	0	0	0	6	60	54	90.00
5	3	JM	1	3/18/95	3	5	20	23	4	3	0	0	0	2	60	58	96.67
5	3	JM	2	3/18/95	7	11	26	11	1	0	0	0	1	3	60	56	93.33
5	1	MPC	1	3/15/95	29	2	5	4	0	1	0	0	2	11	54	41	75.93
5	2	MPC	1	3/15/95	25	6	4	2	1	1	0	0	3	17	59	39	66.10
5	3	MPC	1	3/18/95	4	12	20	11	2	0	1	0	3	2	55	50	90.91
5	3	MPC	2	3/18/95	10	10	24	6	2	0	0	0	2	4	58	52	89.66
6	1	JM	1	6/3/95	24	2	7	7	7	0	0	0	0	13	60	47	78.33
6	1	JM	2	6/4/95	14	7	25	5	1	2	0	0	0	6	60	54	90.00
6	2	JM	1	6/3/95	28	15	9	2	3	0	0	0	0	3	60	57	95.00
6	3	JM	1	6/6/95	2	6	26	23	2	1	0	0	0	0	60	60	100.00
6	1	MPC	1	6/3/95	26	2	19	5	0	2	0	0	0	6	60	54	90.00
6	1	MPC	2	6/4/95	26	3	19	7	1	1	0	0	0	3	60	57	95.00
6	2	MPC	1	6/3/95	23	4	10	4	3	2	0	1	0	13	60	46	76.67
6	3	MPC	1	6/6/95	9	12	17	10	4	1	0	0	3	3	59	53	89.83
7	1	JM	1	11/18/95	19	8	23	3	4	0	0	1	0	2	60	57	95.00
7	2	JM	1	11/17/95	20	7	11	5	6	5	0	0	0	6	60	54	90.00
7	1	MPC	1	11/18/95	27	0	18	6	1	0	0	0	0	8	60	52	86.67
7	2	MPC	1	11/17/95	22	8	8	2	3	1	0	0	0	15	59	44	74.58

Figure 10. Fish Chase Data

TRIP	SITE	P I	STATION	DATE	TIME	aggCm	subCm	ΣCm	aggCo	subCo	ΣCo	aggCmil	subCmil	ΣCmil	aggPj	subPj	ΣPj	aggCs	subCs	ΣCs	aggCt	subCt	ΣCt	aggCh	subCh	ΣCh	aggAn	subAn	ΣAn	agg?	sub?	Σ?	Σagg	Σsub	ΣΣ	terr sqM	hour	fish cm
6	1	JM	1	6/3/95	1	0	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	82.5	1000	9.0
6	1	JM	1	6/3/95	2	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	82.5	1000	9.0
6	1	JM	1	6/3/95	3	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	82.5	1000	9.0
6	1	JM	1	6/3/95	4	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	82.5	1000	9.0
6	1	JM	1	6/3/95	5	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	82.5	1000	9.0
6	1	JM	1	6/3/95	50	0	0	0	0	0	0	0	0	0	0	14	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	14	82.5	1000	9.0
6	1	JM	2	6/4/95	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	142.8	1000	10.0
6	1	JM	2	6/4/95	2	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	142.8	1000	10.0
6	1	JM	2	6/4/95	3	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	142.8	1000	10.0
6	1	JM	2	6/4/95	4	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	2	1	3	142.8	1000	10.0
6	1	JM	2	6/4/95	5	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	142.8	1000	10.0
6	1	JM	2	6/4/95	50	0	0	0	0	0	0	0	0	0	0	7	7	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	2	7	9	142.8	1000	10.0
6	2	JM	1	6/3/95	1	2	0	2	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	3	53.6	1300	8.0
6	2	JM	1	6/3/95	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53.6	1300	8.0
6	2	JM	1	6/3/95	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53.6	1300	8.0
6	2	JM	1	6/3/95	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53.6	1300	8.0
6	2	JM	1	6/3/95	5	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	53.6	1300	8.0
6	2	JM	1	6/3/95	50	3	0	3	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	4	53.6	1300	8.0
6	2	JM	2	6/5/95	1	1	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	48.9	1030	6.5
6	2	JM	2	6/5/95	2	1	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	48.9	1030	6.5
6	2	JM	2	6/5/95	3	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	48.9	1030	6.5
6	2	JM	2	6/5/95	4	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	48.9	1030	6.5
6	2	JM	2	6/5/95	5	1	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	48.9	1030	6.5
6	2	JM	2	6/5/95	50	4	0	4	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	8	48.9	1030	6.5
6	3	JM	1	6/6/95	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	133.0	930	10.0
6	3	JM	1	6/6/95	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	133.0	930	10.0
6	3	JM	1	6/6/95	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	133.0	930	10.0
6	3	JM	1	6/6/95	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	133.0	930	10.0
6	3	JM	1	6/6/95	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	133.0	930	10.0
6	3	JM	1	6/6/95	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	133.0	930	10.0
6	3	JM	2	6/7/95	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	122.3	930	10.0
6	3	JM	2	6/7/95	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	122.3	930	10.0
6	3	JM	2	6/7/95	3	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	122.3	930	10.0
6	3	JM	2	6/7/95	4	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	122.3	930	10.0
6	3	JM	2	6/7/95	5	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2	2	122.3	930	10.0
6	3	JM	2	6/7/95	50	0	0	0	0	0	0	0	0	0	0	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	7	7	122.3	930	10.0
6	1	MPC	1	6/3/95	1	5	0	5	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6	1	7	59.5	1000	10.0
6	1	MPC	1	6/3/95	2	5	0	5	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2	7	59.5	1000	10.0
6	1	MPC	1	6/3/95	3	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4	59.5	1000	10.0
6	1	MPC	1	6/3/95	4	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	59.5	1000	10.0
6	1	MPC	1	6/3/95	5	4	0	4	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	5	59.5	1000	10.0
6	1	MPC	1	6/3/95	50	20	0	20	0	0	0	0	0	0	0	4	4	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	21	4	25	59.5	1000	10.0
6	1	MPC	2	6/4/95	1	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	66.9	1000	8.0
6	1	MPC	2	6/4/95	2	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	3	66.9	1000	8.0
6	1	MPC	2	6/4/95	3	2	0	2	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	3	66.9	1000	8.0
6	1	MPC	2	6/4/95	4	2	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	4	66.9	1000	8.0
6	1	MPC	2	6/4/95	5	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	66.9	1000	8.0
6	1	MPC	2	6/4/95	50	5	3	8	0	0	0	0	0	0	0	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	5	9	14	66.9	1000	8.0
6	2	MPC	1	6/3/95	1	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	46.3	1300	7.0
6	2	MPC	1	6/3/95	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46.3	1300	7.0
6	2	MPC	1	6/3/95	3	2	0	2	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	4	46.3	1300	7.0
6	2	MPC	1	6/3/95	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46.3	1300	7.0
6	2	MPC	1	6/3/95	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46.3	1300	7.0
6	2	MPC	1	6/3/95	50	4	0	4	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	6	46.3	1300	7.0
6	2	MPC	2	6/5/95	1	5	0	5	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	1	7	40.7	1000	8.0
6	2	MPC	2	6/5/95	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40.7	1000	8.0
6	2	MPC	2	6/5/95	3	5	1	6	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	3	8	40.7	1000	8.0
6	2	MPC	2	6/5/95	4	3	0	3	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	4	40.7	1000	8.0
6	2	MPC	2	6/5/95	5	1	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	40.7	1000	8.0
6	2	MPC	2	6/5/95	50	14	1	15	0	0	0	0	0	0	1	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	6	21	40.7	1000	8.0
6	3	MPC	1	6/6/95	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117.4	930	10.0
6	3	MPC	1	6/6/95	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117.4	930	10.0
6	3	MPC	1	6/6/95	3	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	117.4	930	10.0
6	3	MPC	1	6/6/95	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117.4	930	10.0
6	3	MPC	1	6/6/95	5	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	117.4	930	10.0
6	3	MPC	1	6/6/95	50	0	0	0	0	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	117.4	930	10.0

Figure 11. Fish Feeding Data

TRIP	SITE	P I	STATION	DATE	MIN	P.compressa	P.lobata	M.patula	M.verrucosa	Poc.meand	Pav.varians	P.deur	unknown	noncoral	∑coral	∑bites	hour
5	3	JM	1	3/18/95	1	1	4	146	28	1	2	0	0	0	182	182	1215
5	3	JM	1	3/18/95	2	0	4	108	11	0	0	0	0	0	123	123	1215
5	3	JM	1	3/18/95	3	0	4	192	16	0	0	0	1	0	213	213	1215
5	3	JM	2	3/19/95	1	3	0	86	34	1	5	0	0	0	129	129	830
5	3	JM	2	3/19/95	2	6	4	46	36	5	0	0	0	0	97	97	830
5	3	JM	2	3/19/95	3	1	4	99	47	3	0	0	0	0	154	154	830
5	1	MPC	1	3/16/95	1	21	4	31	11	11	5	0	0	0	83	83	1030
5	1	MPC	1	3/16/95	2	19	3	45	18	5	3	0	0	0	93	93	1030
5	1	MPC	1	3/16/95	3	17	0	59	12	3	1	0	0	0	92	92	1030
5	1	MPC	2	3/16/95	1	8	0	46	13	28	0	0	0	0	95	95	1500
5	1	MPC	2	3/16/95	2	12	16	38	26	15	2	0	0	1	109	110	1500
5	1	MPC	2	3/16/95	3	12	0	31	9	19	0	0	0	1	71	72	1500
5	2	MPC	1	3/17/95	1	49	3	23	4	14	1	0	0	2	94	96	1030
5	2	MPC	1	3/17/95	2	23	10	29	5	17	2	0	0	1	86	87	1030
5	2	MPC	1	3/17/95	3	30	9	45	6	11	0	0	0	1	101	102	1030
5	2	MPC	2	3/17/95	1	37	14	52	10	14	7	0	0	4	134	138	1430
5	2	MPC	2	3/17/95	2	36	2	34	4	8	0	0	0	8	84	92	1430
5	2	MPC	2	3/17/95	3	40	2	25	5	18	0	0	0	5	90	95	1430
5	3	MPC	1	3/18/95	1	12	38	33	18	3	0	0	0	0	104	104	1200
5	3	MPC	1	3/18/95	2	14	41	5	16	0	0	0	0	0	76	76	1200
5	3	MPC	1	3/18/95	3	8	54	6	23	3	0	0	0	0	94	94	1200
5	3	MPC	2	3/19/95	1	13	40	25	39	0	2	0	0	0	119	119	930
5	3	MPC	2	3/19/95	2	15	61	1	38	2	0	0	0	0	117	117	930
5	3	MPC	2	3/19/95	3	1	41	27	29	8	8	0	0	0	114	114	930

APPENDIX 1

Possible Indicator Species of Butterflyfishes from Different Indo-Pacific Regions

The pictures on pages 40 and 41 are examples of possible indicator species of butterflyfishes from different Indo-Pacific regions. The sizes indicated below the pictures represent the *total length of mature fish* from a number of resources.

A convenient source for excellent pictures of all these species, excepting Chaetodon multicinctus, which only occurs in Hawaii, is Robert Myers' *Micronesian Reef Fishes*, or John Randall, Gerald Allen and Roger Steene's *Fishes of the Great Barrier Reef and Coral Sea*, Gerald Allen and Roger Swainston's *Reef Fishes of New Guinea.* For Hawaii, see Randall's *Guide to Hawaiian Reef Fishes* and John Hoover's *Hawaii's Fishes.* See the literature cited for complete references.

The species marked with an asterisk (*) are particularly promising indicator species.

* Chaetodon austriacus occurs only in the Red Sea. It is replaced by C. melapterus in the Arabian Gulf.

* Chaetodon baronessa occurs from Cocos-Keeling Island in the Indian Ocean, east to Fiji, north to Japan, and south to the Great Barrier Reef. It is replaced by C. triangulum in the rest of the Indian Ocean.

* Chaetodon larvatus occurs in the Red Sea. It appears to be ecologically equivalent to C. triangulum in the Indian Ocean and C. baronessa in the Pacific Ocean.

Chaetodon melannotus occurs from East Africa and the Red Sea, east to Samoa, north to Japan, and south to the Great Barrier Reef. This species specializes in feeding on soft corals as well as hard corals.

* Chaetodon melapterus occurs in the Arabian Gulf but is rare in the Red Sea. Ecologically it is similar to C. austriacus in the Red Sea, and C. trifasciatus in the rest of the Indo-Pacific.

* Chaetodon meyeri occurs from East Africa across the Indian Ocean extending eastward to

the Line Islands. It occurs widely in Micronesia and extends south to the Great Barrier Reef and north to Japan.

* Chaetodon multicinctus occurs throughout the Hawaiian Archipelago and Johnston Atoll.

* Chaetodon ornatissimus occurs from Sri Lanka in the Indian Ocean eastward to Hawaii, Tahiti and Polynesia, north to Japan, and south to the Great Barrier Reef.

Chaetodon plebeius occurs from the Andaman Sea in the eastern Indian Ocean, extending eastward to Fiji, north to Japan, and south to the Great Barrier Reef. Apparently it is rare or does not occur in Micronesia and Polynesia.

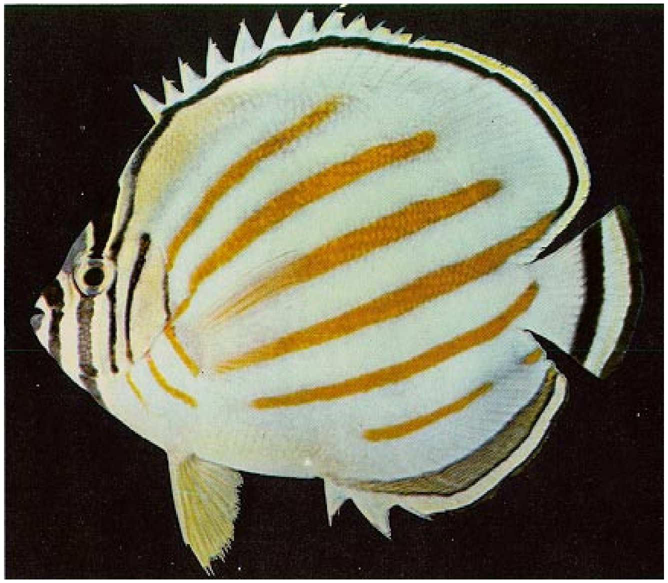
Chaetodon quadrimaculatus occurs throughout Micronesia and eastward to Polynesia, Tahiti and Hawaii, and north to Japan. This species specializes in feeding on corals of the genus Pocillopora.

Chaetodon reticulatus occurs form the Great Barrier Reef in the west, northward to Japan, and eastward through Micronesia to Polynesia, Tahiti, and northwest to Hawaii where it is relatively rare.

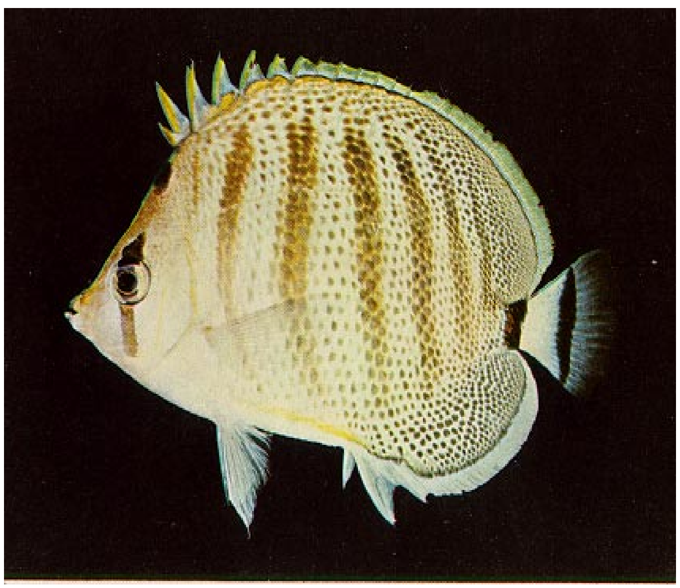
* Chaetodon triangulum occurs in the Indian Ocean. Ecologically it is similar to C. baronessa in the Pacific Ocean and C. larvatus in the Red Sea.

* Chaetodon trifascialis occurs from East Africa and the Red Sea, eastward to Tahiti and throughout Polynesia to Johnston Atoll and the Northwest Hawaiian Islands, but not the high islands of Hawaii.   It is widespread throughout Melanesia, and Micronesia, extends southward to the Great Barrier Reef and northward to Japan. It specializes in feeding on corals of the genus Acropora.

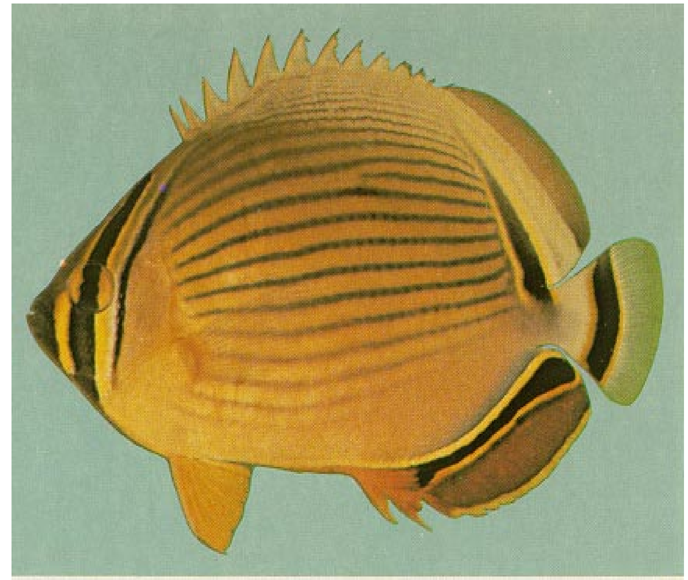
* Chaetodon trifasciatus occurs from East Africa eastward in Polynesia to Hawaii and Tahiti. It is widespread in Melanesia and Micronesia. It extends north to Japan and south to the Great Barrier Reef. It is replaced in the Red Sea by C. austriacus, and by C. melapterus in the Persian Gulf.



Ornate butterflyfish, *Chaetodon ornatissimus,* to 7.5 in. (190 mm)



Brown-barred/Multiband butterflyfish, *Chaetodon multicinctus*, to 3.7 in. (93 mm)



Oval butterflyfish, *Chaetodon trifasciatus,* to 6 in. (152 mm)

Reticulated butterflyfish, *Chaetodon reticulatus*, to 6.3 in. (160 mm)

Triangle butterflyfish, *Chaetodon baronessa,* to 6 in. (152 mm)

Chevron butterflyfish, *Chaetodon trifascialis,* to 7 in. (178 mm)

Meyer's butterflyfish, *Chaetodon meyeri,* to 7 in. (178 mm)

Photographs by John E. Randall, Bernice P. Bishop Museum, Honolulu, Hawaii. Following the common and scientific name of each fish, the approximate largest total length the species attains is given in inches and millimeters.

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