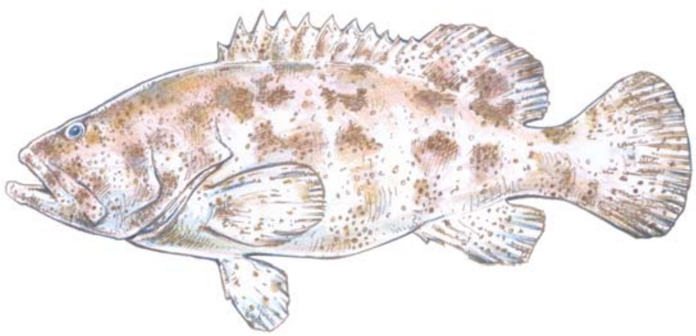
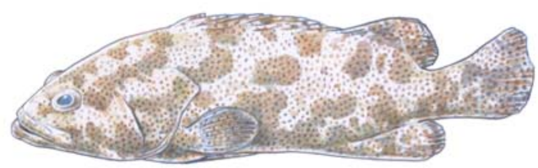
Introduction to Monitoring and Management of Spawning Aggregations and Aggregation Sites for Three Indo-Pacific Grouper Species

Epinephelus fuscoguttatus,
Epinephelus polyphekadion, and
Plectropomus areolatus

A Manual for Field Practitioners



Epinephelus fuscoguttatus



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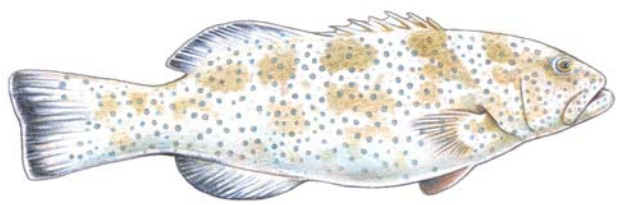

Plectropomus areolatus

THE NATURE CONSERVANCY
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1. Preface

The general goal of this manual is to provide an introduction to the identification, monitoring and conservation of grouper spawning aggregations and aggregation sites as they occur on coral reefs in the Asia-Pacific region. This manual focuses on three species of groupers, *Epinephelus fuscoguttatus*, *E. polyphekadion* and *Plectropomus areolatus*. These species often form large seasonal spawning aggregations at specific sites where they can be effectively monitored, providing an important opportunity to track trends in local populations. A number of spawning aggregations of these three species have been studied and described in the region, although much remains unknown. Scientific information on spawning aggregation dynamics and life histories of these fishes is still incomplete.

The three species listed are among the most heavily targeted groupers in the coral reef fisheries of the Asia-Pacific region, and they are often specifically destined for the live reef food fish trade. Following trends in populations of these species at their spawning aggregation sites is an efficient way to assess changes in the populations for purposes of fisheries management and conservation.

The initiation of monitoring programs often results from certain developments in the local reef fisheries warranting attention from fisheries management or conservationists, and/or with the development of some form of locally managed marine / protected area. In these situations there is often a need to design and implement monitoring programs that will provide information on management or conservation success and indicate which management programs are effective and efficient.

The target audience for this manual consists mainly of field practitioners in marine conservation and fisheries and marine protected area (MPA) management, usually in tropical developing countries. The intention of this manual is to be accessible for field staff with little scientific training, who are tasked with the development and implementation of a monitoring program for grouper spawning aggregations. The manual is to be introduced to practitioners during short training workshops (~2 weeks) that include practical training on aggregation sites as well as some basic background and other land-based, or ‘dry’, training. Information has been combined here to allow this document to function as both a training and extension guide, and as a manual for monitoring. Much of the material included below is available elsewhere in more detailed scientific format.

2. Introduction to Spawning Aggregations, Species, Threats and Management

Spawning aggregations are critically important in the reproductive life history of many reef fish species. Many of the larger and economically important reef fishes (e.g. groupers and snappers) are known to concentrate in large numbers at specific times and places to reproduce. These concentrations of reproducing reef fish are known as reef fish spawning aggregations (FSA). The sites where these spawning aggregations occur are referred to as reef fish spawning aggregation sites. These sites may be used by single species or by several species, either simultaneously or at different times of the day, month or year. This manual focuses on grouper spawning aggregations (GSA), which we define as concentrations of groupers coming together at a certain place and time specifically to spawn.

A spawning aggregation is defined as an increase in fish densities to at least three times the 'normal' density on the site (Colin et al., 2003) and two types of aggregations are known: 'resident' and 'transient'. Resident spawning aggregations consist of individuals from a relatively small area (a few hectares) usually situated within or in proximity to the home range of the aggregating fish. Resident spawning aggregations usually (1) occur at a specific time of day over numerous days, (2) last only a few hours or less, (3) occur daily, and/or (4) can occur year round (Domeier et al. 2002). The spawning output from a resident spawning individual in this type of aggregation usually represents only a small part of the total annual spawning output.

In contrast to resident aggregations, transient spawning aggregations may consist of fish from a relatively large area (e.g. tens to hundreds of square km) that may travel considerable distances to reach the sites. Transient aggregations typically (1) occur during very specific portions of one or more months of the year, (2) persist for a period of days or, at most, approximately two weeks and (3) do not generally occur monthly year-round (Domeier et al. 2002). The spawning output from a single 'transient' aggregation may represents a substantial portion of the total spawning output of the individual, while the combined aggregations within the year likely represent the complete reproductive output for the population. Reef fishes forming 'transient' spawning aggregations are considered highly vulnerable to over-fishing since spawning activity is concentrated in time and space.

The three species of groupers for which this manual describes monitoring and management issues (*Epinephelus fuscoguttatus, E. polyphekadion, and Plectropomus areolatus*) all form 'transient' spawning aggregations, often at reef promontories and channel corners, with two or all of these species often forming spawning aggregations simultaneously at the same site. Where the term grouper spawning aggregation (GSA) is used in this manual, this always and only refers to the spawning aggregations of the species discussed here. Since much or all of the adult population may be present during aggregation periods, monitoring aggregations provides an opportunity to assess population trends in ways that are not possible for species that are more dispersed throughout their life cycle, i.e. do not form spawning aggregations.

Most commercially important species forming 'transient' spawning aggregations are locally threatened by fishing. At many sites additional threats exist such as habitat destruction, pollution, disturbance by tourism, subsistence fishing, etc. According to Domeier et al. (2002), species particularly at risk include those characterized by: "large maximum size, long life, late sexual maturation (i.e., sexual maturation occurring after several to many years) and forming transient spawning aggregations". These three species of grouper all fall in the 'particularly at risk' category and their spawning aggregations are probably capable of withstanding only very low levels of fishing pressure. All three species are heavily targeted throughout most of their area of distribution by unsustainable fishing practices that have already resulted in many aggregation losses.

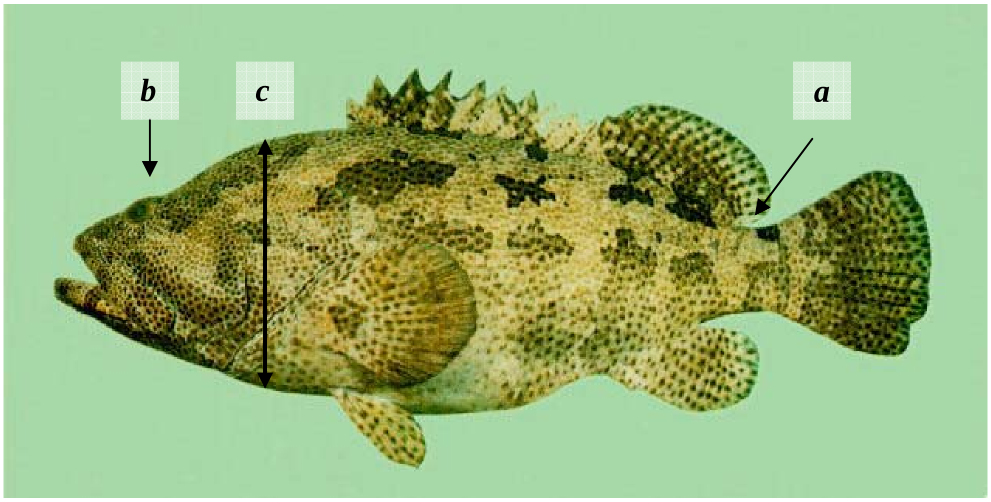

Figure 2.1 Epinephelus fuscoguttatus

Latin name: *Epinephelus fuscoguttatus*
Common name (FAO): brown-marbled grouper
Distribution: Indo-Pacific, Red Sea, coast of Africa to Mozambique, east to Samoa and the Phoenix Islands, north to Japan (Ryukyu I) and south to Australia.
Key characteristics: Maximum size 120 cm total length (TL). Normally orange-brown or olive-colored and blotched body. A black saddle patch (*a)* is located on the top of the caudal peduncle (just before tail). Head robust and wide in profile with a distinct notch above the eye (*b*) that is obvious in profile on adults. Body thick from the front of the dorsal (top) fin to the bottom of the fish below the pectoral (side) fins (*c*). Often confused with camouflage grouper, but can be easily differentiates by the thickened body, maximum size, spawning color (*see below*) and head notch.
Coral reef fisheries form an important sector of the economy of coastal communities in many Asia-Pacific countries and the conservation of reef fish spawning aggregations is essential for sustaining the fisheries that depend on them. Under low levels of subsistence fishing, aggregations may persist. However, following heavy exploitation of GSA by commercial fishing, fishing at even subsistence levels may be unsustainable.

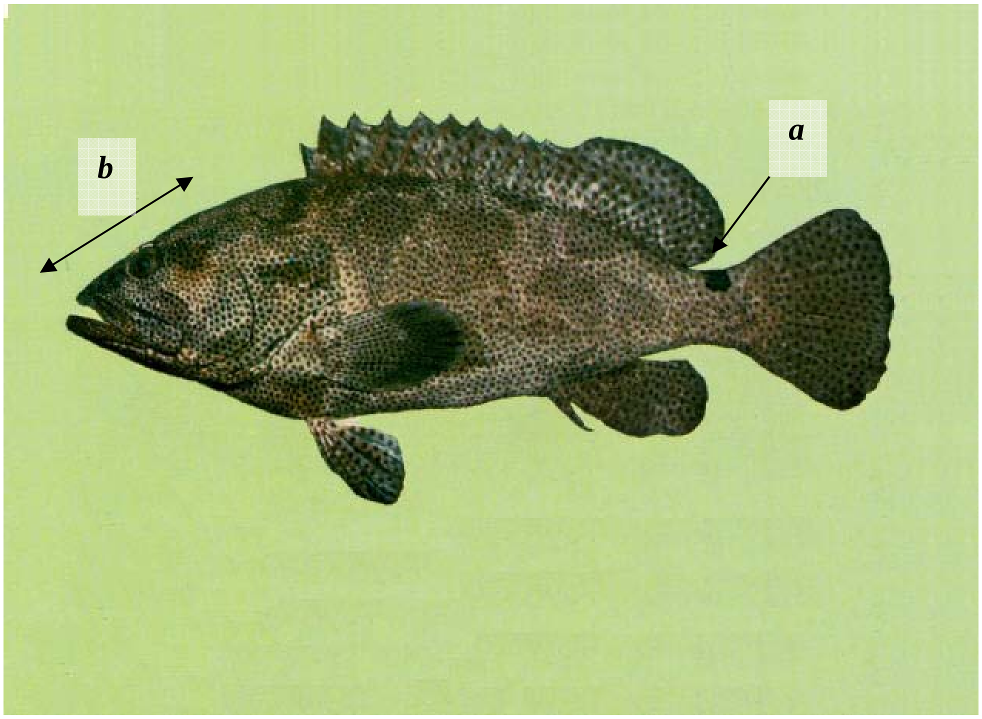

Figure 2.2 Epinephelus polyphekadion

Latin name: *Epinephelus polyphekadion*
Common name (FAO): camouflage grouper
Distribution: Indo-Pacific- Red Sea, east to the coast of Africa, west to French Polynesia, north to Japan and south to southern Queensland, Australia.
Key characteristics: Maximum size 70 cm total length (TL). Normally chocolate-colored and blotched body with a black saddle patch on the top of the caudal peduncle (*a*) (narrow region of the body before tail). Head smooth in profile (*b*) and narrow. Body torpedo-shaped.

Over-fishing by the live reef food fish trade may already have depleted many of the known spawning aggregations of groupers in Southeast Asia and is now threatening those in the western Pacific. Currently, there is little management of reef fish spawning aggregations in place in the region. The depletion of spawning aggregations results in substantial local economic impacts. The protection, management and conservation of reef fish spawning aggregations therefore urgently need to be included in the wider context of fisheries management and marine conservation efforts.

If protective management is implemented before collapse, GSA have the potential to recover, but depletion of populations of aggregating species can only be prevented if over-fishing and habitat destruction are also addressed elsewhere and during other phases of the life cycle. That is, protection of GSA alone will not prevent grouper fisheries declines or fisheries collapse. Proper management must include all life cycle stages for sustainable fisheries.

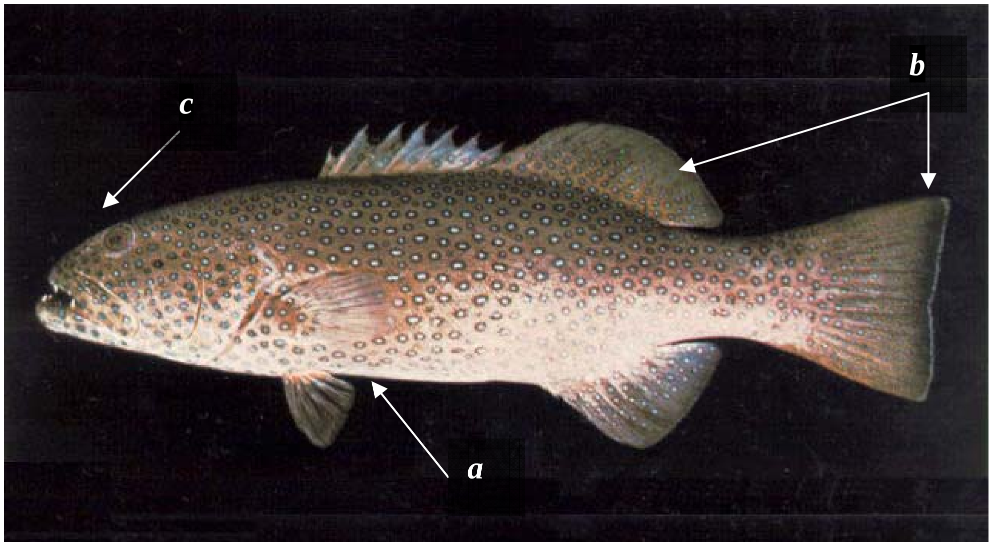

Figure 2.3 Plectropomus areolatus

Latin name: *Plectropomus areolatus*
Common name (FAO): squaretail coralgrouper
Distribution: Indo-Pacific, Red Sea, east to the Phoenix Islands and Samoa, north to Japan and south to Australia.
Key characteristics: Maximum size 75 cm total length (TL). Reddish body with large blue-ringed spots over the entire body, including the belly area (*a*). A white margin is usually observed at the dorsal (top) and tail fin margins (*b*). The squaretail coralgrouper is similar in appearance to other coralgroupers and is most easily confused with the leopard coralgrouper (*P. leopardus*) that has a *complete* blue ring surrounding the eye [the ring is incomplete in *P. areolatus* (*c*)]. These two species can be easily differentiated by the absence of spots on the belly of the leopard coralgrouper.
Incorporation of GSA in no-take zones of large multi-purpose marine protected areas (MPAs) is one management option contributing to the conservation of aggregating fish populations. MPAs are particularly effective when regular and effective enforcement and monitoring are possible. Other options, such as temporal catch, area or sales closures may be equally effective, but will depend on local circumstances. A combined approach, using multiple options, may be necessary in many locales. Decisions on how to prevent fisheries collapse should be tailored to local management conditions Identification and monitoring of the GSA sites are essential components of effective coral reef fisheries. Stakeholder support for GSA management depends on the understanding of the importance of healthy reef fish spawning aggregations for local fisheries.

3. Objectives of Monitoring Grouper Spawning Aggregations

The design of any monitoring program is dependent on the objectives of management. Monitoring is essential to determine how fish populations respond to management, or the lack thereof. Results can be used to initiate or adjust management actions and to set performance indicators for adaptive management. Whenever possible, fishers and other stakeholders should be involved in the design and implementation of monitoring and in the processing and dissemination of the generated information. Monitoring of GSA should foremost provide information to managers and stakeholders on the trends in the aggregating populations that are being managed, protected and/or exploited. The following objectives are used in this manual as the starting points for design of GSA monitoring programs:

- to measure impacts of management actions and provide feedback for adaptive management,
- to assess trends (declines/recovery) in aggregation populations,
- to provide predictive power for other sites/species,
- to provide some insight into reproductive biology,
- to maintain field presence to deter poaching, and
- to encourage feeling of ownership and control by resource users and managers.

Providing basic information on trends in the aggregating populations can be done (to some extent) by monitoring the temporal changes in spawning aggregation abundance and size structure. The aim of this manual is to provide an introduction to quantitative monitoring of GSA, enabling documentation of location and timing of the aggregations and trends in the numbers and sizes of the fish. This manual will focus mainly on the use of under water visual census (UVC) techniques for monitoring abundance and length frequencies on fishes forming GSA.

Monitoring results can be used in outreach materials to enhance awareness and promote sustainable management and conservation both locally and regionally. Monitoring can also provide a better understanding of the ecology and biology of the aggregating species that can be used to improve monitoring effectiveness. Monitoring may be used to compare protected sites to unprotected sites to gauge conservation effectiveness, such as when marine protected areas or no-take zones are instituted. Finally, monitoring can provide a protective measure against poachers, since the presence of monitoring teams at aggregation sites often deters illegal fishing.

4. Monitoring GSA: Data, Parameters and Methods

4.1 Fishery Dependent and Fishery Independent Data and Monitoring

Either or a combination of fishery dependent and/or fishery independent data can be used to monitor grouper spawning aggregations. Simply put, fishery–dependent monitoring depends on information obtained from the fishery, whereas fishery-independent (e.g. under water visual census or UVC) does not. For this reason, fishery-dependent monitoring takes place at the point of catch, point of sale, or point of export where fish can be inspected. Examples of fishery-dependent data are (1) catch-per-unit-effort (CPUE) (e.g. fish taken per hour, fisher, or trip), (2) number of boats or fishers affecting the site, or (3) fish length, sex, weight and reproductive state of fish captured.

Fishery-dependent data can also include gear type, vessel type and target area(s) to determine how and where GSA are being affected. It is also important to know who or what activity is affecting the GSA to focus management actions. Examples may include subsistence fishing, local or foreign commercial fishing, fishing for export, or recreational use of aggregations (e.g. diving or sport fishing). Any of these activities or changes therein may affect GSA in ways that require management attention.

Market and site-based monitoring provides information that may be used to assess the effects of the fishery on the GSA or provide information about the GSA itself, such as spawning season. Long-term changes in fish size, catch volumes, CPUE or spawning season can all provide indications of changes to the GSA. The use of fishery dependent data for determining spawning seasons is relatively easy and cost-efficient and is useful for developing site-based monitoring programs (*see below*).

Monitoring programs are always most complete and effective when fishery-dependent and fishery-independent data collection are combined. For example, trends in CPUE may remain constant even while the total fish abundance in the aggregation is declining. This will happen when fishers target the core of a GSA, containing a relatively constant density of fishes while the size of the total aggregation is decreasing. The combined use of this type of data with UVC eliminates the problem and can provide additional insight into population trends. For this and other reasons, fishery-dependent data should always be interpreted with caution and be combined with direct observation of the GSA.

4.2 Assessment of Grouper Spawning Aggregation Sites and Migration Pathways

Locating Grouper Spawning Aggregation Sites

Many GSA sites in Southeast Asia are already known to local fishing communities and are either being fished or have previously been fished and depleted (in which case they may even have been forgotten). In situations where management plans call for the identification of the local GSA sites, practitioners should always enlist local fishers familiar with the grouper fisheries and the local reef systems. In fact, most GSA sites known to scientists and conservationists have been located through fishers who often not only knew the locations, but also the temporal (daily, monthly, seasonal) reproductive patterns and migration pathways.

In many areas of the western Pacific, aggregation sites are unknown. When management plans call for the identification of new sites, some common reef features can be used to locate GSA. While no two GSA sites are the same, many may have been located on the seaward edge of channel corners, or at points along the reef (Figure 4.1). While features such as channel corners are obvious, others may not be. Topographic maps, nautical charts and/or aerial photographs of the reef may assist in identifying potential sites. **To prevent aggregation loss newly discovered sites should not be revealed until protective measures for GSA are already in place or likely to be implemented**.

Aggregation Site Mapping for Fish Abundance Estimates

Changing trends in GSA abundance likely reflects changing trends in the entire population. Monitoring GSA, therefore, provides a unique opportunity to conduct studies on the adult population. For smaller aggregations, the total number of fish within a GSA can be counted directly. In contrast, monitoring large GSA depends on (1) taking counts within sub-sample(s) of the total area, (2) counting the number of fish within each sub-sample, and (3) accurately estimating the total area and shape of the GSA.

Since GSA are closely associated with the reef substrate within clearly defined areas and concentrations are often high, mapping can be a relatively simple task. Mapping for the purpose of monitoring abundance involves locating the GSA perimeters based on fish presence and density and calculating the area within those boundaries. This is typically best performed close to spawning time when abundance is highest (and monitoring typically conducted) and the aggregation is clearly defined.

To locate boundaries for mapping, divers swim a series of parallel, side-to-side straight lines (transects) through the aggregation and mark the 'edges' of the GSA. By definition, GSA boundaries are areas where fish density drops less than three times 'normal' density. At each boundary line, markers are placed that can be relocated and used to measure the area. The area can be measured using a vinyl measuring tape and a rough map of the area can be sketched to help in placing transects (sub-samples). Alternatively, a float line can be set to the surface to mark positions with the GPS. Once the dimensions are known, the area can be calculated.

Once the area is mapped, densities throughout the aggregation should be estimated before designing the final monitoring scheme. Areas within the aggregation that show consistently different densities from other areas need to be identified and included in at least one separate transect (sub-sample) to represent the aggregation as best possible. Total aggregation abundance can be estimated from sub-sample counts by the total area-to-sub-sample area ratio (*see below*).

In some situations, changes in total abundance are only reflected in changes in the size of the aggregation area. For GSA, densities within the center, or core, of the aggregation may remain stable while the total number of fish may be changing considerably. To gauge such changes, mapping of the sites must be occasionally repeated (annually, at a minimum) to gauge changes. In case of smaller aggregations the size and shape of the aggregation is less critical than ensuring all fish are counted.

Migration Pathways to and from the GSA Sites

In order to arrive at GSA sites, groupers may swim considerable distances along specific paths. Fishing along these pathways can have substantial impacts if large numbers of fish are removed. Locating these fish during their migration to the GSA is possible by viewing fish from the surface on snorkel or on SCUBA. GPS readings can be taken along the path and later recorded. Management that involves closed areas should include migration pathways for aggregating fish.

4.3 Temporal Patterns in Aggregation Abundance and Reproductive Activity

Determining Seasonal Trends

For the three target grouper species, aggregation formation and spawning usually occurs over periods of two to several months each year (e.g. Johannes et al., 1999; Rhodes and Sadovy, 2002). Determining spawning season is critical for the design of monitoring plans when monitoring is to be conducted around periods of peak abundance or when management is considering seasonal closures. There are several recommended ways to obtain information on GSA season, including (1) fisher interviews

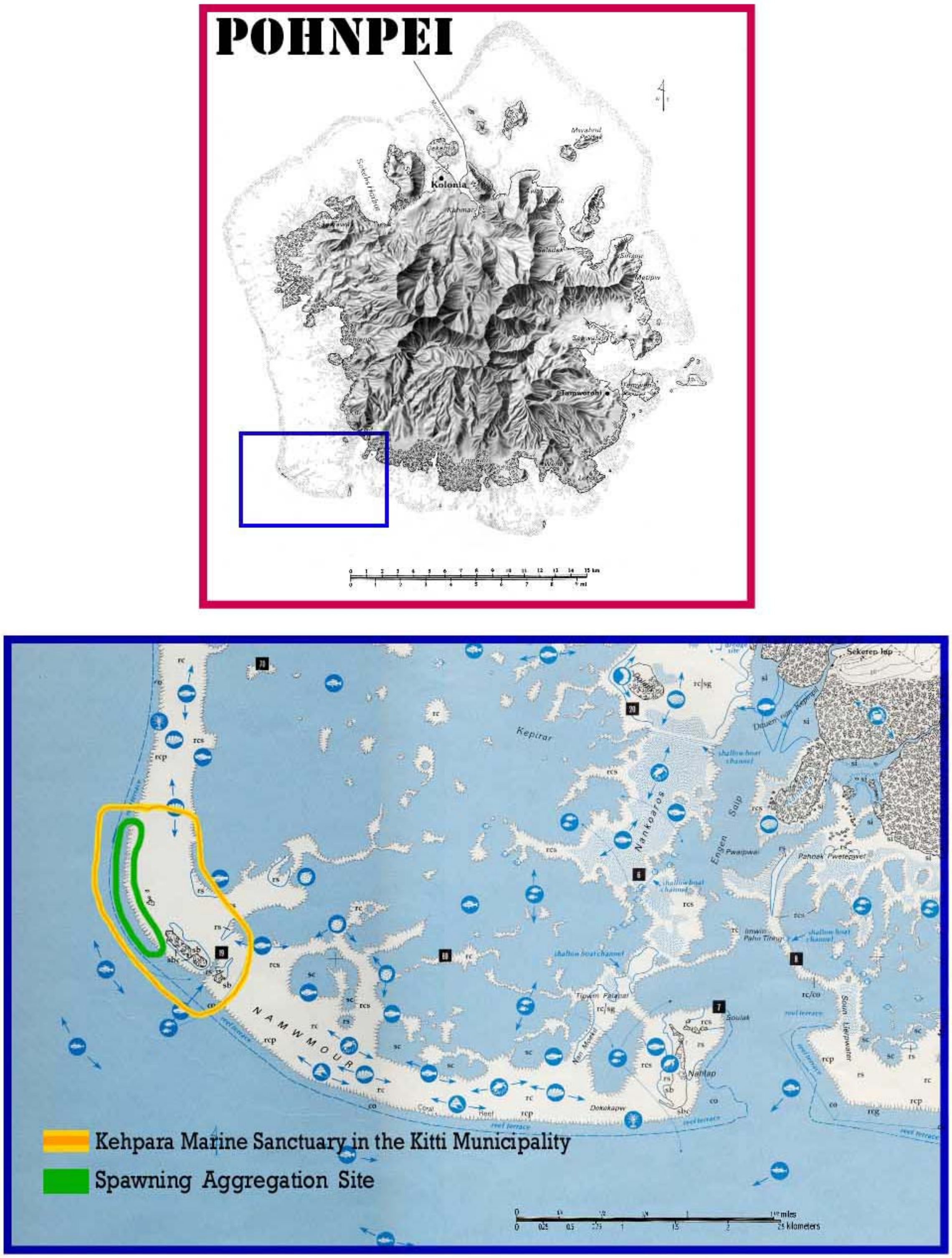

Figure 4.1. An example of a well-known, monitored and protected GSA site located at a large, prominent reef promontory at the barrier reef of Pohnpei in the Federated States of Micronesia.

combined with direct observations of increased numbers of fish in fisheries and markets, (2) examination of fish and gonads (reproductive organs) in market samples or catch of target species, and (3) direct observation of GSA using UVC (underwater visual census).

Table 4.1. Criteria used in (macroscopic) determination of maturity stage in grouper gonads

Maturity Stage	Appearance
OVARIES (females)	
Immature	Ovary small, strand-like, compact, pink or cream; oocytes (eggs) not clearly distinct; not obviously different from immature or inactive males
Maturing	Ovary relatively small but rounded, less strand-like in appearance, grayish with thickened gonad wall; eggs not clearly distinct and small ; Not clearly different from mature males prior to the development of yolk within the eggs
Mature, active	Ovary large and grayish with transparent gonad wall; large yolky eggs becoming clearly visible and tightly packed
Mature, ripe	Ovary relatively large, clear, watery (hydrated) eggs visible through wall; typical of individuals just prior to spawning; egg release possible with application of light abdominal pressure
Post-spawn	Ovary flaccid with obvious capillaries (small blood vessels); few eggs visible
TESTES (males)	
Immature/inactive	Testes not obviously different from immature females (see the description of immature females)
Maturing	Testes expanding and becoming rounded and large; grayish in appearance; early maturing individuals are not clearly different from maturing females until milt (sperm) becomes evident in the sperm sinus along the gonad wall
Mature, active	Testes large and white with sperm visible in sinuses along the gonad wall; milt release with light abdominal pressure
Post-spawn	Testes flaccid and bloody; sperm release still possible on application of abdominal pressure

Seasonal patterns in aggregations and spawning can often be determined through fisher interviews, by posing such simple questions as “When is the best time to catch this fish (e.g. squaretail coralgrouper)”, or “Have you ever noticed eggs in these fish and, if so, do you remember the time of year?” A second option for determining spawning seasons is by monitoring fisheries and markets to look for peaks in catch during the year, which usually coincides with reproductive periods. Where there is a live reef food fish operation, sudden increases in the number of fish within the holding pens could signify increased catches from fishing on an active spawning aggregation.

If it is possible to handle the fish, spawning seasons can be detected by looking for ripe eggs and milt (sperm), by applying continuous pressure to each side of the abdomen and sliding your fingers along the fish from front-to-back (Figure 4.2). When the fish is very ripe and ready to spawn, eggs or milt are usually easy to expel. Egg data sheets can be used by monitors or through the assistance of market owners to record the number or relative frequency of occurrence of ‘ripe’ animals in catch that can, in turn, can be used to determine reproductive season (Table 4.1). Males often produce sperm outside the spawning season and are less reliable indicators than females.

The maturity stages of the gonads (see Table 4.1 and Figures 4.2 and 4.3) are the best indicators for determining spawning season. If the fish are being gutted at the market or at the catch site where gonads can be examined, gonad maturity stages and reproductive activity can often be easily determined by squeezing the belly or checking egg development state. For groupers, yolky or watery eggs are good indicators that spawning is approaching. In cases of abundant GSA, some animals could be sampled to check gonad maturity and/or to determine whether concentrations of fish represent spawning aggregations.

Gonadosomatic Index (GSI): Determining Reproductive Seasons from Catch

The gonadosomatic index (GSI) is a relatively straightforward and simple method for determining reproductive seasons in fishes. The determination of GSI involves taking two measurements, the total fish weight and the gonad weight. As gonads grow in size during the spawning season, the gonad weight increases relative to fish weight to create an increase in GSI values. These increases show up graphically as peaks (e.g. Figure 4.4). Following spawning, GSI values dip as gonad weights decrease. The use of this simple index can provide monitors with valuable information on spawning times to optimize monitoring.

Equation: GSI = (gonad weight / total fish weight) x 100.

Table 4.2 An example of a monitoring sheet for recording the presence of ripe and/or mature eggs during the year. Spaces are provided for the number of fish examined, number with ripe or mature eggs and nearest lunar phase. Data are used to determine spawning or best monitoring periods.

Latin name	**Month**											
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Plectropomus areolatus												
total number observed												
total with eggs mature or ripe												
moon phase (full, new)												
Epinephelus fuscoguttatus												
total number observed												
total with eggs mature or ripe												
moon phase (full, new)												
Epinephelus polyphekadion												
total number observed												
total with eggs mature or ripe												
moon phase (full, new)												

Indicate the total number of fish examined, the number of those that had eggs in late stages of development (see Table 4.1), and the nearest moon phase (as new or full moon). Data entered will be used to develop monitoring programs and reproductive seasons for the target species.

Figure 4.2. Mature active female Plectropomus oligocanthus. Large, yellow eggs can be observed through the gonad wall. For the three target species, this stage of egg development is typically found only within the reproductive season indicating spawning is approaching. (S Seeto)

Figure 4.3. A ripe male Plectropomus areolatus. Milt is expelled by applying pressure to the abdomen and sliding your fingers along the fish front-to-back. Males produce milt before and after spawning periods; females with ripe eggs are better indicators of spawning seasons. (S Seeto)

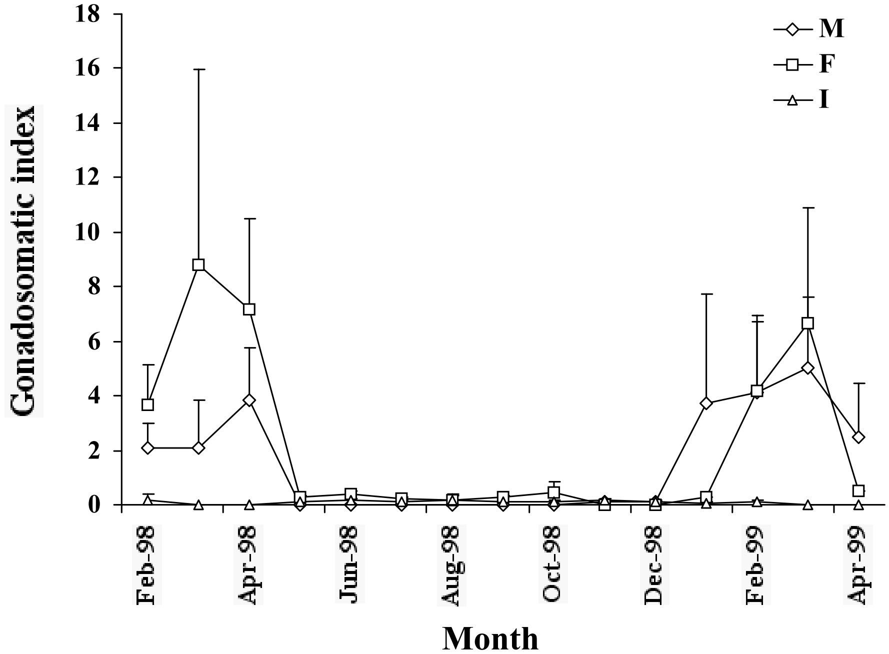

Figure 4.4. The reproductive season for E. polyphekadion as indicated by peak GSI values between February and April. Values were used to initiate site monitoring. M=male; F=female; I=immature.

Determination of Imminent Spawning in Grouper Aggregations

Spawning for the target species has not been observed, although studies suggest that spawning is at night. Therefore, the chances of observing spawning are small and other indicators must be used to determine whether a concentration of groupers has formed for spawning. As mentioned, gonad analysis can be used when catch is available or when samples can be taken from the GSA. Where the grouper spawning aggregation is small (20-200 animals), protected, and/or where fish are otherwise unavailable, sampling may not be possible or desirable. For large GSA, monitors may decide to take small numbers of samples (preferably as catch and release). Otherwise, monitors must rely on fish appearance or behavior to assess aggregation function (i.e. feeding or schooling versus spawning).

Figure 4.5. Fish behavior and body characteristics used in determining aggregation function (from left to right): grouping; territorial disputes, and; gravid female camouflage grouper (A Smith)

Groupers that form GSA are typically solitary during non-spawning times and rarely encountered. Therefore, when divers encounter several individuals (up to several thousand!) in a single area, it may be safe to conclude a spawning aggregation is forming or has formed. To confirm this, other evidence, such as the frequency of certain behaviors associated with GSA can be used. The types of behavior used to determine GSA activity include (1) aggression between individuals; (2) courtship between sexes; (3) gravid females; and (4) spawning. We do not include color change (Figure 4.5 and *below*).

In GSA the behaviors listed are frequently observed, easily recorded and may be used to verify aggregation function. ***We suggest that when the relative frequency of occurrence (RFO) of the aforementioned behavior increases to at least three times the RFO commonly observed in the population, 'potential spawning' may be indicated.*** The RFO is calculated as the frequency of occurrence (FO) of 'spawning' behavior divided by the total number of fish observed.

In a hypothetical *example*, we normally record two or fewer occurrences of each of the above behaviors in a specific population of 50 individuals of one target grouper (RFO • .04) in a designated area. Later, we see 50 fish concentrated within the area and note 6 occurrences (RFO = 0.12) that later increases to 20 combined occurrences (RFO = 0.40). For grouper, the increase in these behaviors provides strong support that a spawning aggregation has formed. The case is strongest when these behaviors co-occur. Although arbitrary, the index can be useful, particularly when aggregations are small, cannot be sampled, and are in need of immediate identification (as GSA) and protection.

Aggressive behavior is frequently observed when groupers converge to form spawning aggregations. Aggression, typically associated with territorial disputes among males, often results in bite-marks on the fish (patchy scrape marks in *Epinephelus sp*. and puncture marks in *Plectropomus* sp.). Chasing, biting, fighting and color change is also common within GSA. During color changes, the body may lighten/change (often rapidly) from normal color to pale that highlights certain areas. For *E.*

fuscoguttatus, the pale color is most apparent on the lips, chin, cheeks, belly and tail (caudal) fin (Figure 4.6) while for *E. polyphekadion* only the saddle patch and a black eye slit are apparent (Figure 4.7). *Plectropomus areolatus* has six distinct color phases; some are shown in Figure 4.8.

Figure 4.6. Color change in E. fuscoguttatus. The pale color pattern on the bottom half of the male (left) is common to spawning aggregations during territorial disputes or courtship. (J Pet)

Color change in males during courtship is similar to that displayed during fighting. When courting, males swim on their side while wobbling and quivering. On the days just prior to spawning, females show swollen bellies that are particularly evident. Generally speaking, males of the three grouper target species are usually larger than females although there is size overlap between the sexes.

Figure 47. Color change in presumed E. polyphekadion males during establishment of territory. The fish on the right has shifted to the pale color often associated with spawning periods. (KL Rhodes)

Figure 4.8. Three of six color changes in P. areolatus (from left to right): bicolor (males and females); camouflage (males and females); yellow/green phase (females) (A Smith)

Figure 4.9. Seasonal variation in fish abundance on spawning sites, with variation in the initial month of aggregation formation and peak aggregation month. The peak aggregation month is August in Year 1 and July in Year 2, detected by monthly short-term monitoring.

Natural Variation in GSA Abundance, Preliminary Surveys and Consistency in Monitoring

Natural fluctuations in GSA abundance occur between years, months, days and hours (Johannes et al., 1999; Rhodes and Sadovy 2002). Months of highest abundance are referred to as ‘peak’ months (Figure 4.9). ‘Peak’ months may differ slightly between years and can affect monitoring effectiveness.

Within a reproductive month, abundance changes daily (Figure 4.10). The highest abundance is usually associated with the day of spawning. Prior to this, there is a period of gradual ‘build-up’ in abundance leading up to spawning. ‘Declines’ in abundance follow spawning and are often quite rapid. The periods of ‘build-up’ and ‘decline’ vary both among locations and species.

Spawning in these species most likely takes place at night and has not been described. The ‘spawning day(s) for our target species usually fall on, or one to three days before either the full moon or new moon of each spawning month. Before fixing a monitoring schedule it is recommended to monitor at least one full week before both new and full moon for several months of the presumed aggregation season in order to identify and pick the most reliable day to record aggregation abundance peaks.

Finally, abundance levels change within individual days during the spawning period in relation to activity patterns. In general, highest abundance is associated with afternoon or evening periods whe fish come ‘out of hiding’ to court or establish territory. Therefore, mornings and evenings are best for monitoring, when conditions (e.g. currents in channels) allow.

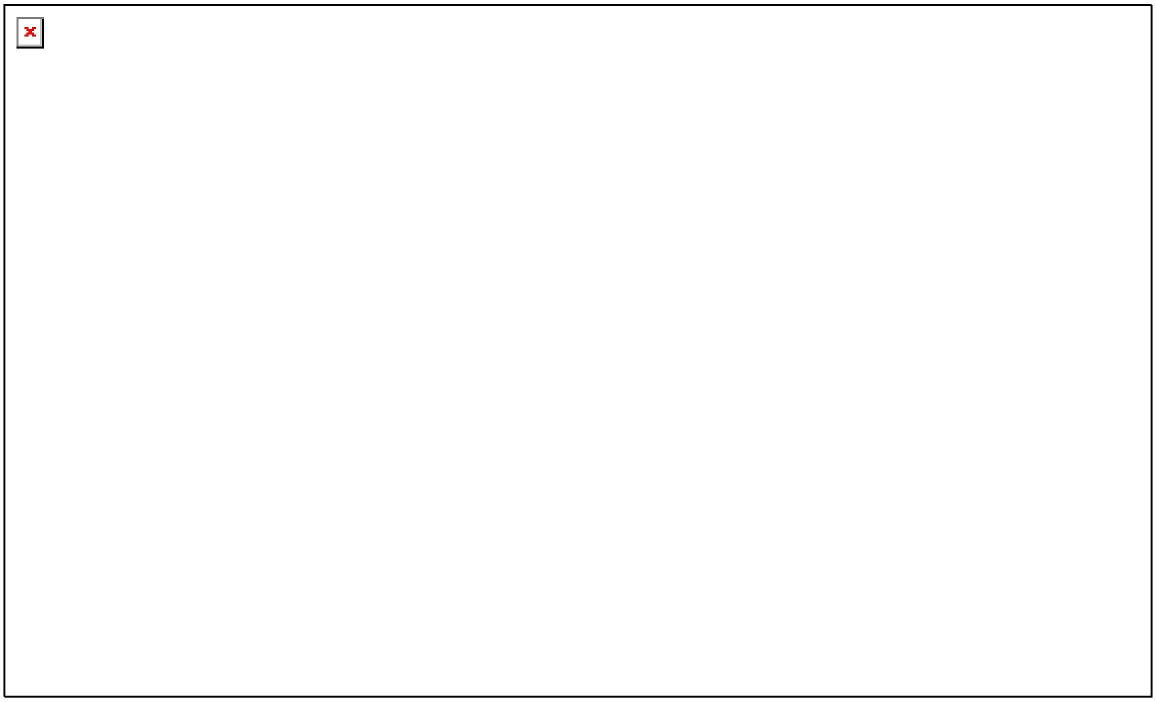

Figure 4.10. Consistency in the overall pattern in aggregation build-up and day of peak abundance is demonstrated in this hypothetical example.

Developing a Sampling Strategy

The total number of fish at the site determines how abundance should be estimated:

1. *The number of fish is so small that all fish in the aggregation can be counted. Counting all fish may be possible for aggregations of up to 500 or even 1000 fish, depending on the size of the site and the conditions during UVC. For numbers below 200, we can normally count fish individually, whereas for more than 200 it is recommended to count fish in groups of 5 or more.*

Method: After mapping of the aggregation site, design a single transect (which does not need to be a straight line!) that leads you through the entire site in the most comfortable way without disturbing the fish (usually following the prevailing current as much as possible, often meandering). Count all the fish you see in the aggregation.

2. The number of fish is too large to be able to count all the fish. In this case a sub-sample of fish will have to be counted, and the total number in the population must be calculated from the sub-sample, the area covered by the sub-sample and the total area of the aggregation site. For large, highly concentrated GSA, it is recommended to count in groups of 5, 10, 20 and even 50 individuals.

Method: Estimate the total area of the aggregation site for the target fish species (*described above*). Lay one or more transects in order to cover all areas of the aggregation and in a representative way. In other words, if it appears there may be areas of higher and lower densities of fish, try to place the transect(s) across all such areas to get a representative sub-sample of fish from the GSA.

Make sure that transect start and end points and boundaries are clearly marked underwater to ensure that counts are conducted within the same transect location and area every time. The total number of fish in the aggregation is later calculated by using a raising factor (*see below*) of the known sub-sample area/counts to the total abundance/ total area of the aggregation. Each transect needs to be numbered and recorded on each data sheet.

Sub-sampling

In large aggregations it is necessary to sub-sample the population. The sub-sample areas in the spawning aggregations are the areas covered by transects. We recommend a maximum transect size of 100 m X 10 m. [***NOTE:*** It is more important to count the precise number of fish in smaller transect s than trying to maximize transect width and get imprecise counts.] Total counts for the entire aggregation are estimated by raising the number of fish from sub-sample count(s). For example, if the sub-sample area represents 20% of the total area, the sub-sample counts should be raised by 5 times to get the total count (5 X 20% = 100%).

To improve precision in estimating total aggregation abundance when using sub-samples, an (arbitrary) minimum of 10% of the total aggregation area should be sampled. This requires a relatively even distribution of fish within the aggregation and is insufficient for GSA with widely varying fish densities. Sub-sampling a higher percent of the total area using more transects that are clearly marked will increase the accuracy of estimates in any GSA.

The Line Transect Method

The line transect method is used to count fish within strips of reef of known length and width placed within the GSA. Line transects can be straight or curved as long as the area covered remains consistent over time and space and end-points and boundaries are clearly marked and visible (Figure 4.11). Complete descriptions of transect design and use is found in English et al.1987, Samoilys 1997 and Labrosse et al. 2002.

When using transects to estimate GSA abundance, consistency is the key. Transects should always be of consistent length and width, with the dimensions ultimately dependent on the site and conditions (depth, current, visibility, structural reef complexity). Regardless of conditions, trained monitors should be able to swim transects and record consistently during each dive. Short (50 m) and narrow (10 m) transects are often preferred to long (100 m) and wide (20 or 30 m) transects in cases where conditions may degenerate within the monitoring period (e.g. season). To minimize disturbance to the fish, monitors should always maximize the distance they swim above the transect line while still being able to accurately count fish.

For line transects, divers locate the initial transect starting point and swim the transect length while counting and measuring all fish within the boundaries. For a transect 20 m wide, each diver counts or measures fish 10 m on either side of the 'center' (i.e., usually a meter tape) of the line transect. Transects should always be laid/marked prior to counts so as not to disturb the fish. Following the initial site mapping and once densities of fish within the aggregation are estimated, permanent transects can even be placed within the area between spawning periods. Rebar stakes marked with survey tape or fitted with a 1/4" PVC pipe sleeve make good transect markers, remaining present and visible for long periods. Overgrown tape can be replaced and PVC sleeves can be removed between monitoring periods.

The Size Structure of the Population on the Aggregation Site and Length Estimation

Since buddy-pairs are commonly used for monitoring on SCUBA, one observer should estimate abundance (count fish) while the other estimates fish length and spawning signs from a sub-sample of fishes (records length-frequency). The estimation of abundance is the most important and difficult task and should not be mixed with recording of other parameters. When three divers are available, length frequency and behavior monitoring and recording can be split between Divers 2 and 3.

Recording lengths for all fishes in an aggregation is possible during a single dive only for aggregations containing a few hundred fish. For aggregations or sub-sample transects containing more than this, we recommend concentrating on getting good estimates of lengths from a sub-sample of some 200 to 250 individuals, haphazardly picked from the transect. This can usually be achieved by trained observers and will result in sufficient data to obtain a good indication of the length frequency distribution of all the fish in the transect. Since length frequencies taken within sub-samples (transects) are assumed to be representative of the total population, a raising factor is not necessary to present the data (although the methods for raising data to represent the total population are presented below).

The Merits of Video Recording

The results of under water visual census (UVC) methods are greatly improved and the value of data can be better established when UVC is combined with the use of digital video. Digital video allows practitioners to review their assessments and provides a visual record of the GSA. This video record allows monitors to 're-visit' the aggregation as often as necessary to look for nuances in behavior and verify counts.

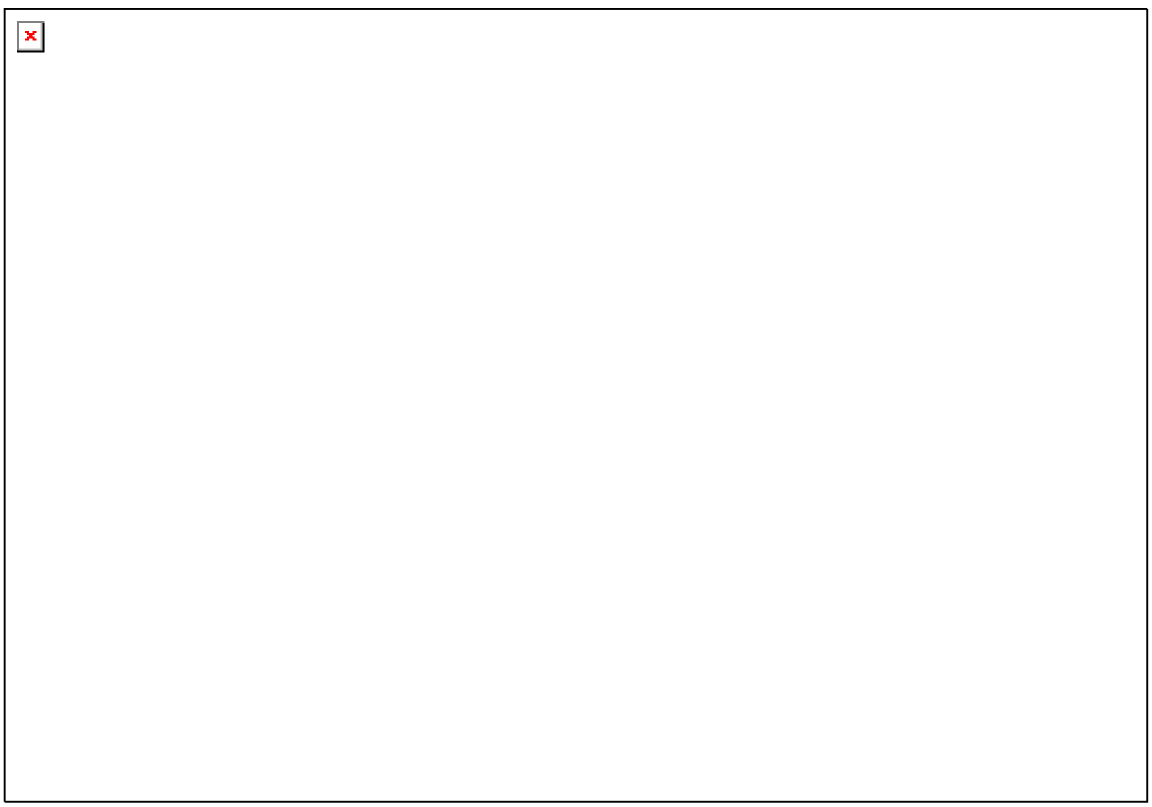

Figure 4.11. Fixed transects in (a) a homogeneous reef environment and (b) a reef environment dominated by high coral heads. Note the total distance and width of both transects is equal.

5. Example of Monitoring a Hypothetical Large Grouper Spawning Aggregation (GSA)

A hypothetical GSA is located along the seaward-facing side of the barrier reef surrounding the island of "Isla Pacifica". The site contains all three species in aggregations adjacent to each other, with only minor overlap at the common borders. After a preliminary site survey and subsequent site mapping, site dimensions and area are determined. Each aggregation forms along the wall and extends onto the slope at the bottom of the wall (Figure 5.1). Only the *P. areolatus* aggregation extends onto the reef flat.

Estimating Total and Sub-sample GSA Areas

The three GSA vary considerably in area. Initial mapping surveys show the *camouflage grouper* aggregation to extend horizontally 100 m along the wall and from 20 to 50 m deep. (Although the vertical depth is 30 m, actual linear distance is 35 m (20 to 30 m depth = 10 m linear distance and 30 to 50 m depth = 25 m linear distance). The total aggregation area (S_T) (*blue lines*) is, therefore, 3,500 m^2 (100 m X 35 m). The *brown-marbled grouper* aggregation extends horizontally for 300 m and vertically from 20 m (top of aggregation) to 50 m deep. The total surface area of the aggregation site (S_T) is 10,500 m^2 (300 m X 35 m). The *squaretail coralgrouper* aggregation extends 500 m horizontally

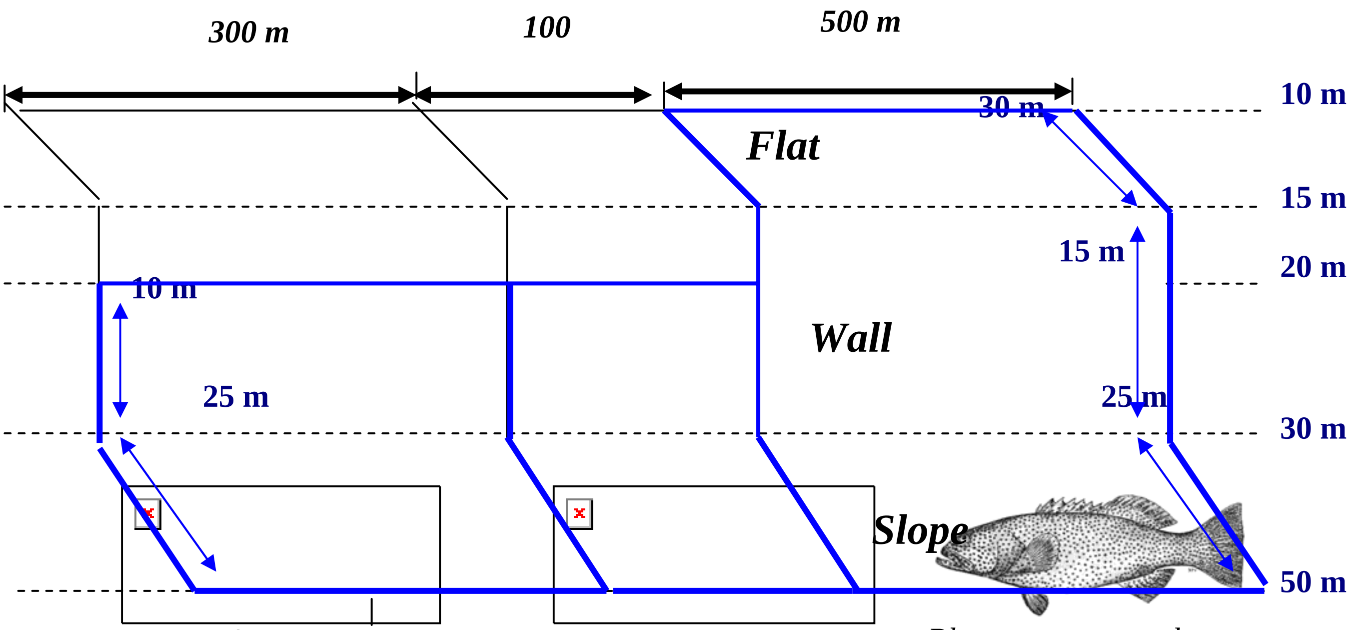

Figure 5.1 Composite drawing of the total aggregation (blue lines) of the three target species.

and 10 m to 50 m deep (30 m+15 m+ 25 m=70 m linear distance) for a total area (S_T) of 35,000 m^2 (500 m X 70 m).

In the example, all transects are 100 m long and 10 m wide (1000 m^2 sub-sample area for each transect) regardless of consistent 30-50 m visibility at this site. The number of transects is set to provide a minimum of10% sub-sample coverage within the total GSA area. For the *E. fuscoguttatus* aggregation, a minimum of two transects (10% X 10,500 m^2 = 1,050 m^2) are needed and are set at 25 m depth. For *E. polyphekadion*, one transect is set at 25 m. Four transects are set for *P. areolatus*, in accordance with its larger area. Depth-time limits on SCUBA do not allow regular monitoring on the slope. The three GSA are sampled over three days using two and three dives per day.

Each GSA is monitored by two divers who cover each transect (1 transect per dive) starting 3 days before spawning (previously determined to be full moon). Diver 1 records sub-sample abundance (N_S) in the sub-sample area S_S (*shaded areas*). Fish are often counted in groups of 5, 10 or 20 because of the high numbers and density of fish. Diver 2 records length frequencies of a smaller sub-sample of fish (about 200 to 250 individuals), as well as frequencies of behavior. We now provide three examples for estimating total abundance of each of the three above spawning aggregations. Following the calculations, examples for the length-frequencies and relative frequencies for spawning behaviors are detailed.

Example 1: E. polyphekadion — A Case with a Single Transect

A simplified version of the *E. polyphekadion* GSA and sample area is shown in Figure 5.2. The single transect has a total area of 1,000 m^2 (100 m X 10 m). This transect area equals the total sub-sample area, S_S since there is only one transect (*not* the case if there is more than one transect). The transect is sampled at 25 m with divers swimming approximately 5 m from the wall to minimize fish disturbance and counting and measuring fish 5 m along each side of the transect centerline. Boundaries are clearly marked with flagging tape at each 10-m interval to increase count accuracy. Diver 1 counts all the *E. polyphekadion* in the transect. This number represents the sub-sample abundance (N_S) within the sub-sample area, S_S. For this example, 500 fish are counted by diver 1, so that

$$N_S = 500 \text{ and } S_S = 1000 \text{ m}^2.$$

To find the total number of fish in the aggregation, the number of fish counted in the transect must be multiplied by the raising factor (*R*). As defined, (*R*) is the total aggregation area, S_T, divided by the sub-sample area, S_S. In this example,

$$R = S_T/S_S = 3{,}500 \text{ m}^2/1{,}000 \text{ m}^2 = 3.5.$$

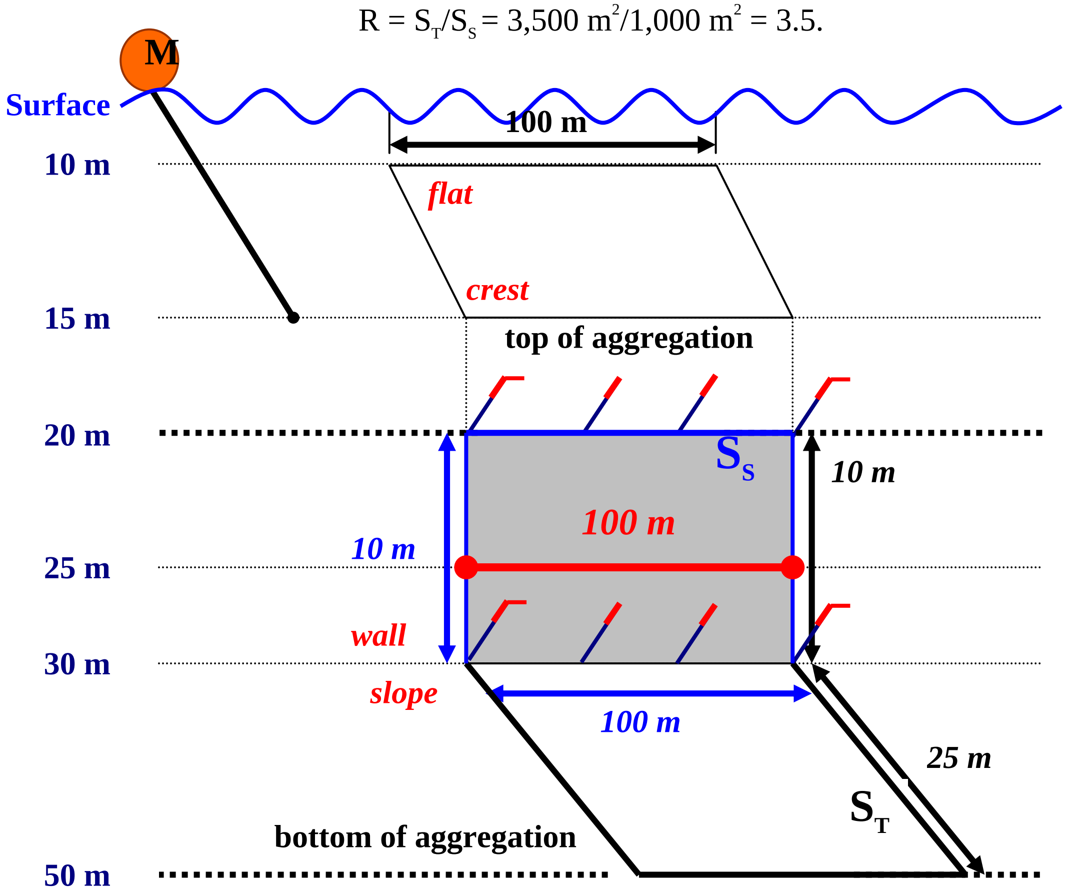

Figure 5.2 Hypothetical aggregation of E. polyphekadion. The sub-sample area is outlined in blue, the total aggregation in bold black (+blue sub-sample area). The transect is designated by the red line.

The percentage of the total aggregation area that has been sampled with the single transect is 1/R X 100 = (1/3.5) X 100, or 29%. The total abundance of fish in the aggregation (N_T) is the sub-sample abundance (N_S) multiplied by the raising factor. For this example, then, 500 fish were counted in the transect, so the total abundance (N_T) is estimated as

$$N_T = 500 \text{ fish X } 3.5 = 1{,}750 \text{ fish.}$$

In summary, there are thus 1,750 fish in the total *E. polyphekadion* spawning aggregation using the 1000 m^2 transect that covers 29% of the total aggregation area of 3,500m^2.

Example 2: E. fuscoguttatus— A Case with 2 Transects

For this aggregation (Figure 5.3), two transects are used to cover at least 10% of the total aggregation area. Again, the transects are sampled at 25 m, divers swim approximately 5 m from the wall to minimize fish disturbance and count and measure fish 5 m along each side of the transect centerline. Boundaries are marked each 10 m to increase count accuracy. Diver 1 counts all *E.*

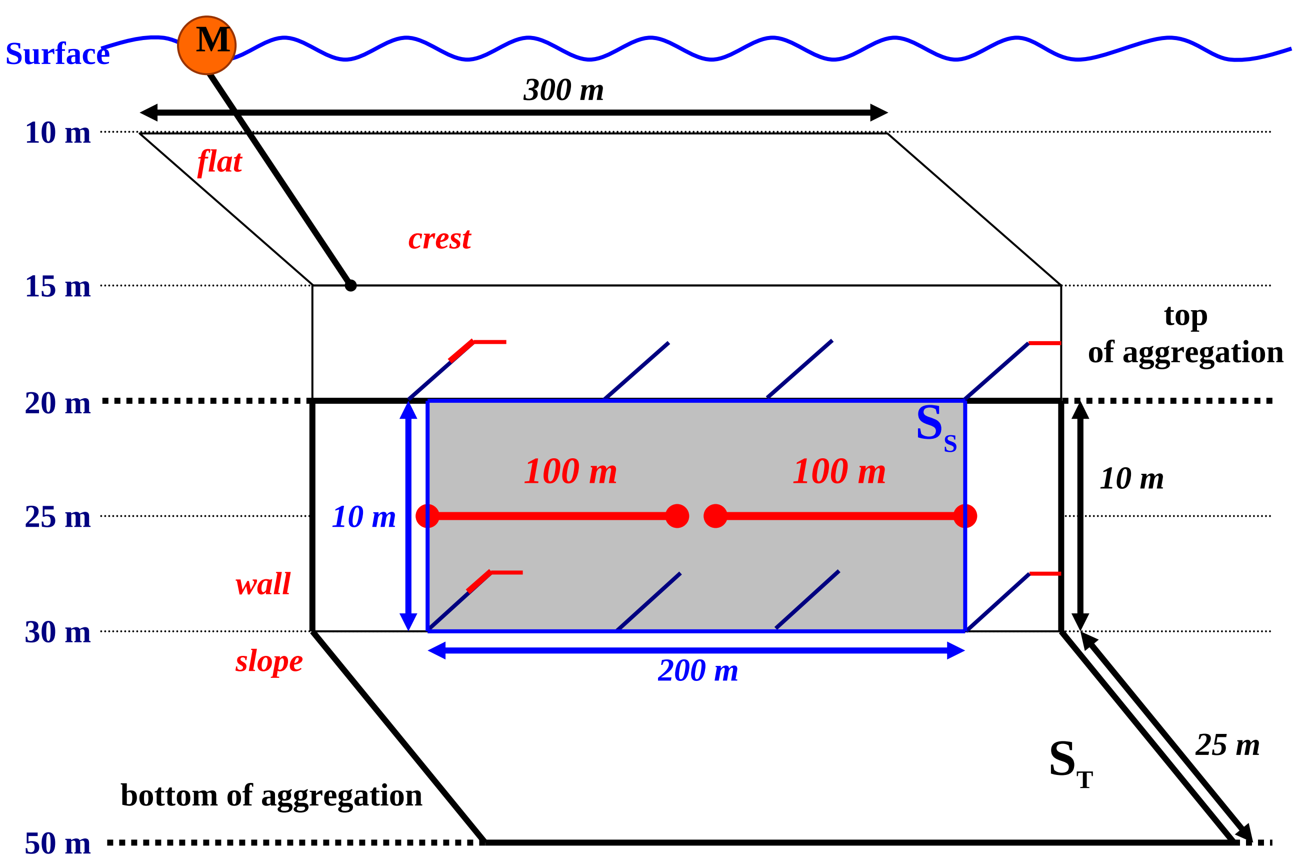

Figure 5.3. Hypothetical spawning aggregation of E. fuscoguttatus. Areas bordered in black represent total areas (S_T), blue for sub-sample areas (S_S), with corresponding colored text for distance measures. Transects are designated by red lines.

fuscoguttatus in each transect. The two combined transects represent the sub-sample total count (N_S) taken within the sub-sample area (S_S). In this case, diver 1 counts 400 fish in the first transect and 600 fish in the second transect, so

$$N_S = 400 \text{ fish} + 600 \text{ fish} = 1{,}000 \text{ fish}.$$

The sub-sample surface area (S_S) in the *E. fuscoguttatus* aggregation is

$$S_S = 1{,}000 \text{ m}^2 \text{ X } 2 \text{ transects} = 2{,}000 \text{ m}^2.$$

The total aggregation area (S_T) is 10,500 m^2 (from previous calculations). To find the total abundance in the aggregation, N_T, we again multiply the raising factor R by N_S. Thus, in this example, the raising factor is

$$R = S_T/S_S = 10{,}500 \text{ m}^2/2000 \text{ m}^2 = 5.25,$$

So the sub-sample represents ~ 1/R X 100 = 19% of the total aggregation area.

The total abundance in the aggregation is

$$N_T = R \text{ X } N_S = 5.25 \text{ X } 1000 \text{ fish} = 5{,}250 \text{ fish}.$$

In summary, by sampling with two, 1000m^2 transects a total abundance of 5,250 fish was estimated for the total *E. fuscoguttatus* aggregation area (10,500 m^2).

Example 3: P. areolatus aggregation —A Case with 4 Transects

As calculated above, four transects are needed to cover ~10% of the total aggregation area of 35,000 m^2. As shown in Fig 5.4, of the four transects, two are located along the edge of the reef at 15 m looking 5 m in and 5 m down along the wall, and two are set at 25 m, looking 5 m up and 5 m down the wall.

Since each of the four transects is 1,000 m^2 (100 m X 10 m) in area, the sub-sample area is

$$S_S = \text{the combined transect area} = 4 \text{ X } 1{,}000\text{m}^2 = 4{,}000 \text{ m}^2.$$

In this example, Diver 1 counts 400 *P. areolatus* in the first transect, 425 in the second transect, 350 in the third transect, and 325 in the fourth transect. The sample abundance is thus

$$N_S = 400 \text{ fish} + 425 \text{ fish} + 350 \text{ fish} + 325 \text{ fish} = 1{,}500 \text{ fish}.$$

The total area (S_T) (calculated previously) is 35,000 m^2, so

$$R \text{ is } S_T/ S_S = 35{,}000 \text{ m}^2/4{,}000 \text{ m}^2 = 8.75.$$

The total abundance in the *P. areolatus* in the aggregation is

$$N_T = R \text{ X } N_S = 8.75 \text{ X } 1{,}500 \text{ fish} = 13{,}125 \text{ fish}.$$

In summary, by sampling with four 1000m^2 transects, a total abundance of 13,125 fish was estimated for the total aggregation area (35,000 m^2). A summary of all calculations is shown in Figure 5.5.

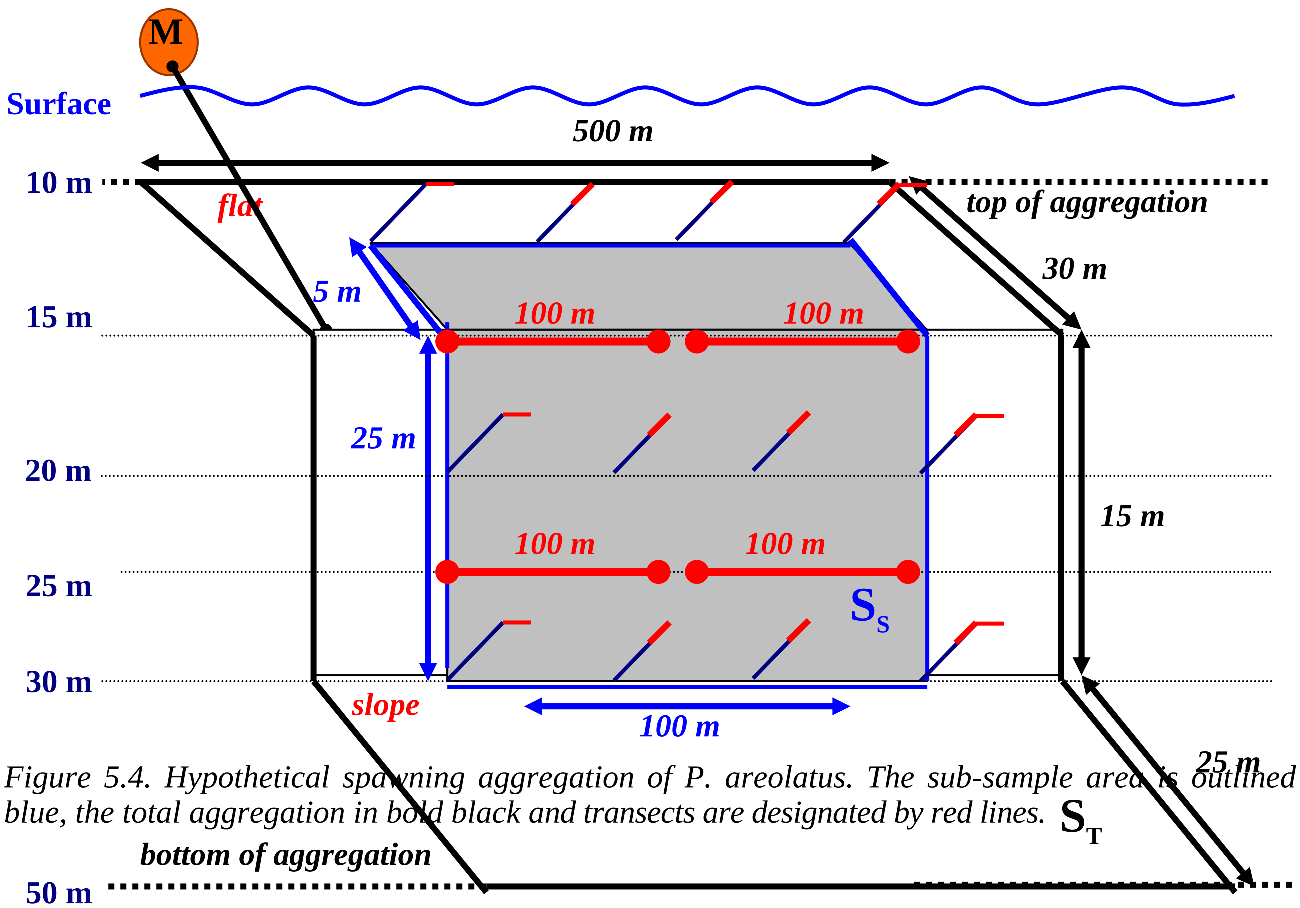

Figure 5.4. Hypothetical spawning aggregation of P. areolatus. The sub-sample area is outlined in blue, the total aggregation in bold black and transects are designated by red lines.

CASE 1: 1 TRANSECT	CASE 2: 2 TRANSECTS	CASE 3: 4 TRANSECTS
$\mathbf{A_T}$ = 3,500 m^2 (calculated previously) $\mathbf{S_S}$ = (10 m X 1,000m) X 1 transect = 1,000 m^2 X 1 = 1,000 m^2 Area covered by transect = = (1,000 m^2/3,500m^2) X 100 = 29%	$\mathbf{A_T}$ = 10,500 m^2 (calculated previously) $\mathbf{S_S}$ = (10 m X 1,000m) X 2 transects = 1,000 m^2 X 2 = 2,000 m^2 Area covered by transect = = (2,000 m^2/10,500m^2) X 100 =19%	$\mathbf{A_T}$ = 35,000 m^2 (calculated previously) $\mathbf{S_S}$ = (10 m X 1,000m) X 4 transects = 1,000 m^2 X 4 = 4,000 m^2 Area covered by transect = = (4,000 m^2/35,000m^2) X 100 =11%
$\mathbf{N_S}$**:** Diver 1 counts 500 fish in transect 1, so $\mathbf{N_S}$ = 500 fish and the density of fish is $\mathbf{D}$ = $\mathbf{N_s/S_s}$ = 500 fish/1000m^2 = 0.5 fish/m^2 = 0.5 fish/m^2 $\mathbf{N_T}$ = 0. 5 fish/m^2 X 3,500 m^2 = 1,500 fish	$\mathbf{N_S}$**:** Diver 1 counts 500 fish in transect 1 and 700 fish in transect 2, so the density of fish is the average of the two: $\mathbf{D}$ = (500 + 700 fish)/2,000m^2 = 0.5 fish/m^2 $\mathbf{N_T}$ = 0. 5 fish/m^2 X 10,500 m^2 = 6,000 fish	$\mathbf{N_S}$**:** Diver 1 counts 400 fish in transect 1, 600 in transect 2, 300 in transect 3, 200 in transect 4. The density of fish is: $\mathbf{D}$ = (400 + 600 + 300 + 200 fish)/4,000m^2 = 0.375 fish/m^2 $\mathbf{N_T}$ = 0.375 fish/m^2 X 35,000 m^2 = 13,125 fish

$\mathbf{A_T}$ =total GSA area; $\mathbf{S_S}$ =sub-sample GSA area; $\mathbf{N_T}$ =total abundance (i.e., number) of fish in the total GSA area; $\mathbf{N_s}$ =abundance of fish in the (combined) sub-sample GSA area; $\mathbf{D_s}$ =fish density in the transects = # fish counted/ unit area (# fish/m^2)

$$\mathbf{N_T} = \mathbf{D_S} \times \mathbf{A_T}$$

Figure 5.5. Summary table of the calculation used to determine fish abundance in the example GSA.

Estimating Length Frequencies and Relative Frequencies of Occurrence

As discussed above, Diver 2 records length frequencies and frequencies of occurrence for typical spawning aggregation behaviors within the transects. Diver 2 records lengths of a sub-sample (N_{LFD}) of about 200-250 fish, focusing on fish clearly distinguished. These data result in a length frequency distribution (LFD) for that sub-sample. The LFD_S in the sample area can be calculated by multiplying by a sub-sample factor $R_{LFD} = N_S/N_{LFD}$. The number per length class in the LFD of the total aggregation (N_T) is calculated during data processing by multiplying n_{LFD} with the sub-sample factor $R_{LFD} = N_S/N_{LFD}$ and with the raising factor $R_S = S_T/S_S$. $N_L = n_{LFD} * R_{LFD} X R_S$. The total number on the aggregation on any date is calculated during data processing as the sum over all length classes for that date $\mathbf{N_T = SUM\ (N_L)_{DATE}}$.

Diver 2 also records spawning signs in the sub-sample as frequency of occurrence (FO_S*)* To calculate the FO per spawning sign for each species the FO is multiplied by the raising factor from previous abundance calculations, R_S, wher*e* $R_S = S_T/S_S$ for each species. The FO is accumulated within species to result in a figure representing the activity on the site for that specific month. RFO is calculated as FO/N_T.

5.1 Data Recording

An example of data recording for a hypothetical GSA in Isla Pacifica is shown below. Simple coding is used to input data for species, site, transect number and lunar date. The Isla Pacifica site is #1 in our example, but can be any unique number to identify each individual site. Once designated, no other site can be #1. Species are similarly coded with unique numbers. In our example, *E. fuscoguttatus* is Species #*1* and *E. polyphekadion* is #*2*. The two transects for *E. fuscoguttatus* are numbered #*1* and #*2*, with the single transect in the *E. polyphekadion* GSA coded as #*1*.

Lunar dates correspond to days 1 through 28 on the lunar calendar, with new moon = Day 1 and full moon = 14. The lunar day increases by 1 for each day until Day 28, which corresponds to the day before new moon, which again begins at Day 1. Calendar dates, species, visibility and observer are non-coded, or written normally. Time should be in military time (e.g. 0000 to 2400 hrs) for clarity.

For abundance, counts are recorded as groups (Column 1) with a single tick mark. For example, 85 single and 9 groups of 5, 17 groups of 10 and 5 groups of 20 *E. fuscoguttatus* were recorded at Site 1, transect 1 at 1430 hr on 8 May 2003, Lunar Date 13, one day prior to the full moon (Figure 5.6). Figure 5.8 shows the data for *E. polyphekadion* on the same day (Lunar Day 13) on its single transect (*1*).

For length frequency recording, individual lengths are ticked as a single mark in each size category (5-cm increments) (Figure 5.7). An example of data taken for Species 1, Site 1, Transect 1 at 1600 hr, Lunar Date13 shows 24 fish observed that measured 41-45 cm total length (Figure 5.9). **Note**: Lengths should be in centimeters ***total length*** (TL), which is the length from the tip of the snout to the tip (end) of the tail. Finally, observations on spawning or spawning behavior, recorded by the length frequency recorder are tallied as number of individual observations (Figure 5.7 and Figure 5.9).

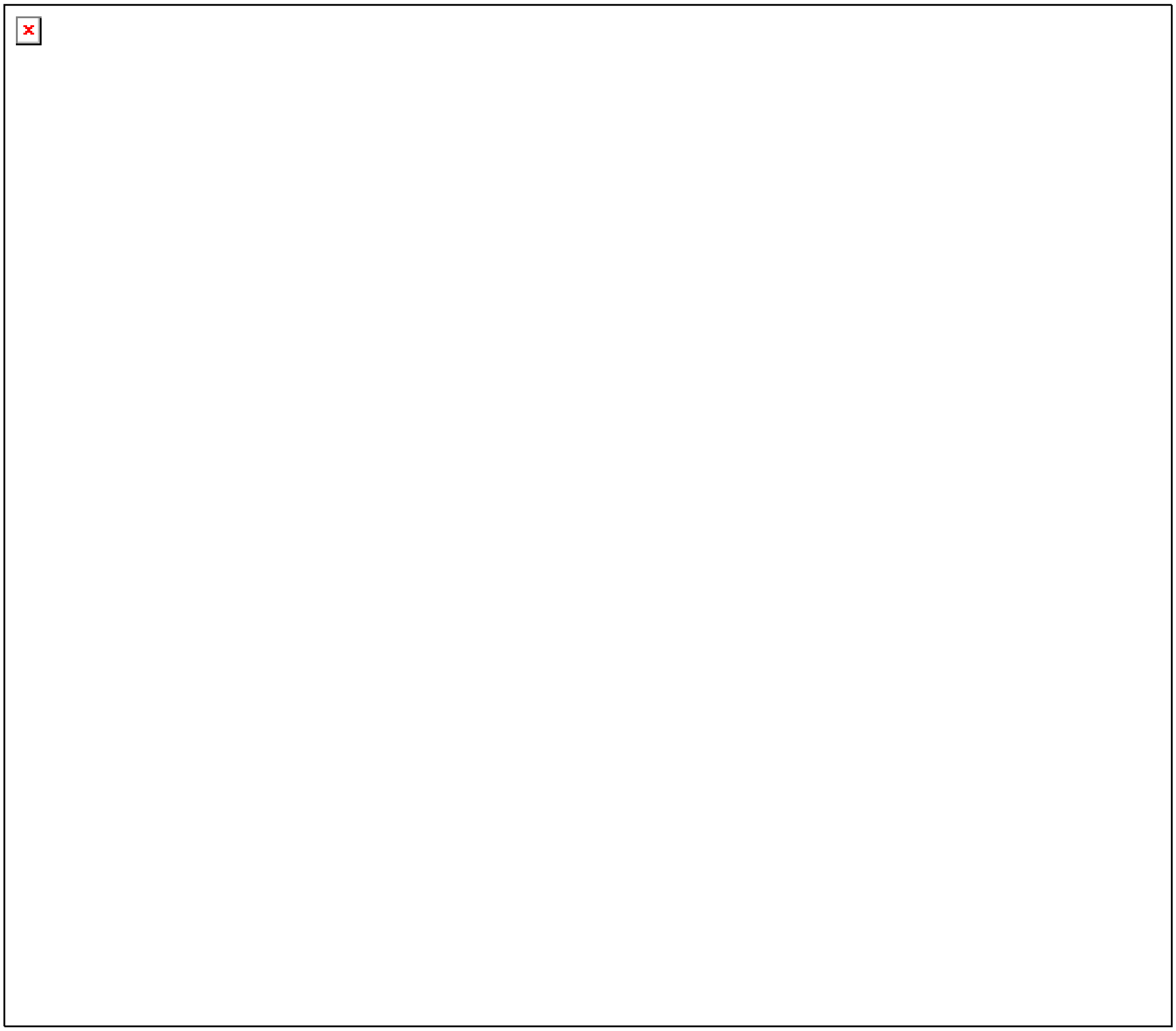

Figure 5.6. Abundance data recorded on the GSA for Epinephelus fuscoguttatus.

Site No: _#1 _Isla Pacifica_____ Time: 14:30 p.m. Date:_08/ 05/ 04____		
Species:_Epinehelus fuscoguttatus_ Lunar Date:_13__ Transect No.:_# 1_______________		
Observer name:_Charles Toonah_____________________ Visibility:_80 ft.____		
Size	**Frequency**	**Total**
21-25		0
26-30		0
31-35		0
36-40	I	1
41-45	IIIII III	8
46-50	IIIII IIIII I	11
51-55	IIIII IIIII IIIII	15
56-60	IIIII IIIII IIIII IIIII III	23
61-65	IIIII IIIII IIIII IIIII II	22
66-70	IIIII IIIII IIIII IIIII I	21
71-75	IIIII III	8
76-80	II	2
81-85		0
86-90	I	1
91-95		0
96-100		0
101-105		0
106-110		0
Total in LFD		112
Spawning: 0	Courtship: IIIII IIIII IIIII II = 17	
Aggression: IIIII III = 8	Gravid: IIIII IIIII IIIII IIIII IIIII IIIII III = 33	

Figure 5.7. Length frequency and behavior data recorded at the GSA for Epinephelus fuscoguttatus.

Figure 5.8. Abundance data recorded on the GSA for Epinephelus polyphekadion.

Figure 5.9. Length frequency and behavior data on the GSA for Epinephelus polyphekadion.

5.2 Data-processing and Analysis

Data worksheets can be designed in spreadsheet programs such as Microsoft Excel for purposes of electronic data storage and processing. Data entry for abundance and length frequency distributions (LFD) is done in the file LFD-GSA.xls. In the LFD-GSA file the data from the individual transects are raised to estimates for the complete aggregations, as was illustrated in the three aggregation examples above. The person responsible for data processing enters all information from the data-recording sheet into the data file and adds information on raising factors (Table 5.1).

Data entry for the total number of fish in the GSA and calculation of relative frequency of occurrence of various behavior are done in the file BEHAVIOR.xls. The data from transects are raised to estimates for the complete aggregations (Table 5.2). The example below does not include the timing of the dive which is fixed for each transect and dive in accordance with slack tide at the aggregation and therefore always has the same value of 1430 for *E. fuscoguttatus* and 1600 for *E. polyphekadion*.

5.3 Outputs from Short-term and Long-term Monitoring

The information gathered from monitoring is generally only reliable when it has been systematically and carefully recorded and analyzed and after it has been clearly documented and presented. This can be an expensive undertaking and should therefore be carefully planned in terms of cost-efficiency. However, with consistency in monitoring protocols and good record-keeping, informed, proper management decisions can be made that may make the difference between the loss of an aggregation and fishery versus the provision of resource benefits to users for years to come.

Short-term Monitoring
Short-term results from monitoring will provide practitioners with baseline information on spatial and temporal patterns within GSA to design effective and cost-efficient long-term monitoring programs. The minimum information required from short-term monitoring for development of a long-term program is a detailed GSA spatial description of the site and location, particularly site dimensions and aggregation area. Short-term monitoring must also provide information on temporal patterns to determine the best time of day, day of the month (lunar pattern), and month(s) of the year (seasonal pattern) to monitor. Prior to developing a long-term GSA monitoring program from short-term data, practitioners should bear in mind the natural variations in spatial and temporal patterns that commonly occur. Therefore, any long-term seasonal monitoring program should include ‘extra months’ at the beginning and end of the spawning season to allow for variations.

Long-term Monitoring
Long-term monitoring provides information on trends in aggregation abundance and size distribution for decision-making in management. However, long-term trends need to be studied taking into account the various possible causes. Fish populations experience short- to medium-term

Table 5.1. Abundance and LFD data for 8 May 2004, Isla Pacifica, for brown-marbled and camouflage grouper.

file: LFD-GSA	lunar date	1=fusco 2=poly 3=areo	site no.	transect number	length class upper	number per length	total number of fish	number of fish in	raising factor LFD	raising factor sample	total N fish per length

NOTE$_1$: $N_T = SUM(N_L)_{date}$
NOTE$_2$: $N_L = n_{LFD} X R_{LFD} X R_S$

					limit	class in LFD	in LFD	sample area	N_S/N_{LFD}	area S_T/S_S	class
date	***moon***	***species***	***site***	***transect***	***length***	n_{LFD}	N_{LFD}	N_S	R_{LFD}	R_S	N_L
08/05/04	13	1	1	1	40	1	112	112	3.57	5.25	19
08/05/04	13	1	1	1	45	8	112	112	3.57	5.25	150
08/05/04	13	1	1	1	50	11	112	112	3.57	5.25	206
08/05/04	13	1	1	1	55	15	112	112	3.57	5.25	281
08/05/04	13	1	1	1	60	23	112	112	3.57	5.25	431
08/05/04	13	1	1	1	65	22	112	112	3.57	5.25	412
08/05/04	13	1	1	1	70	21	112	112	3.57	5.25	394
08/05/04	13	1	1	1	75	8	112	112	3.57	5.25	150
08/05/04	13	1	1	1	80	2	112	112	3.57	5.25	838
08/05/04	13	1	1	1	90	1	112	112	3.57	5.25	19
08/05/04	13	2	1	1	25	3	185	500	2.70	3.5	28
08/05/04	13	2	1	1	30	25	185	500	2.70	3.5	236
08/05/04	13	2	1	1	35	37	185	500	2.70	3.5	350
08/05/04	13	2	1	1	40	34	185	500	2.70	3.5	321
08/05/04	13	2	1	1	45	24	185	500	2.70	3.5	227
08/05/04	13	2	1	1	50	33	185	500	2.70	3.5	312
08/05/04	13	2	1	1	55	27	185	500	2.70	3.5	255
08/05/04	13	2	1	1	60	2	185	500	2.70	3.5	19

Table 5.2. Behavior data for 8 May 2004 at Isla Pacifica, for brown-marbled and camouflage grouper. Data for brown-marbled grouper is only for one of two transects.

file: BEHAVIOR	lunar date	1=fusco 2=poly 3=areo	site no.	transect number	1=spawning 2=aggression 3=courtship 4=gravid	FO in sample	raising factor sample S_T/S_S	FO in GSA	total number of fish in GSA	relative FO in GSA FO/N_T
date	***noon***	***species***	***site***	***transect***	***behavior***	FO_S	R_S	***FO***	N_T	***RFO***
08/05/04	13	1	1	1	2	8	5.25	42	400	0.10
08/05/04	13	1	1	1	3	17	5.25	89	400	0.22
08/05/04	13	1	1	1	4	33	5.25	173	400	0.43
08/05/04	13	2	1	1	2	32	3.5	112	1760	0.06
08/05/04	13	2	1	1	3	12	3.5	42	1760	0.02
08/05/04	13	2	1	1	4	77	3.5	270	1760	0.15

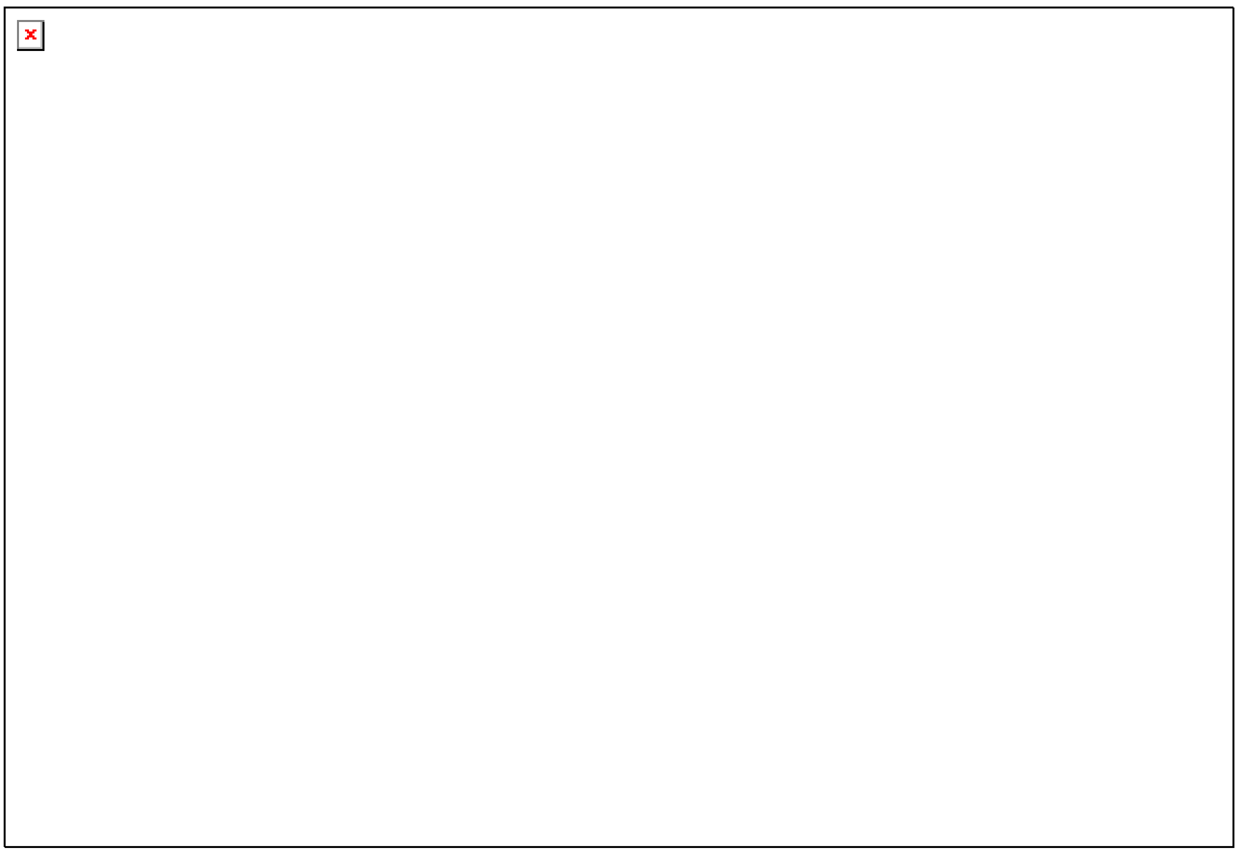

Figure 5.10. Hypothetical outputs from short-term monitoring for abundance. There is a consistent pattern in the lunar days (Day 29) exhibiting peak abundance.

natural fluctuations and only long-term monitoring results can 'tease out' consistent trends. Variations in abundance between years can be related to any number of events, such as recruitment variations, fishing, natural mortality or other reasons. Interpretation of trends in numbers requires first of all that data collected each year have been collected in a standardized way every year and can be compared.

Moreover, a minimum of 5-10 years of data is needed to identify patterns that might be meaningful. Below several hypothetical examples of analyzed data from short- and long-term monitoring are

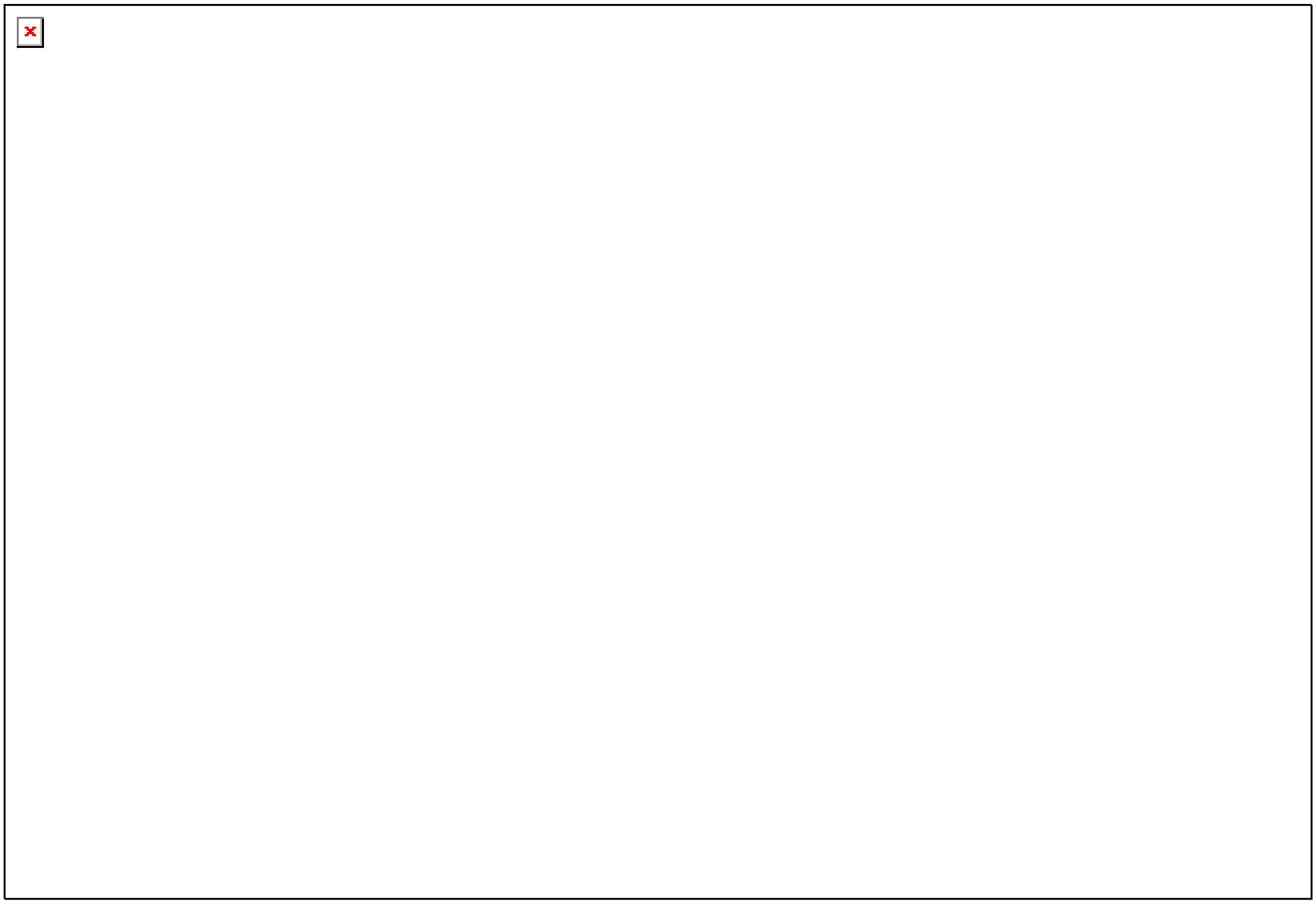

Figure 5.11. Hypothetical output of short-term monitoring for spawning season in more than one species. Variation is exhibited in both the timing and duration of the reproductive season.

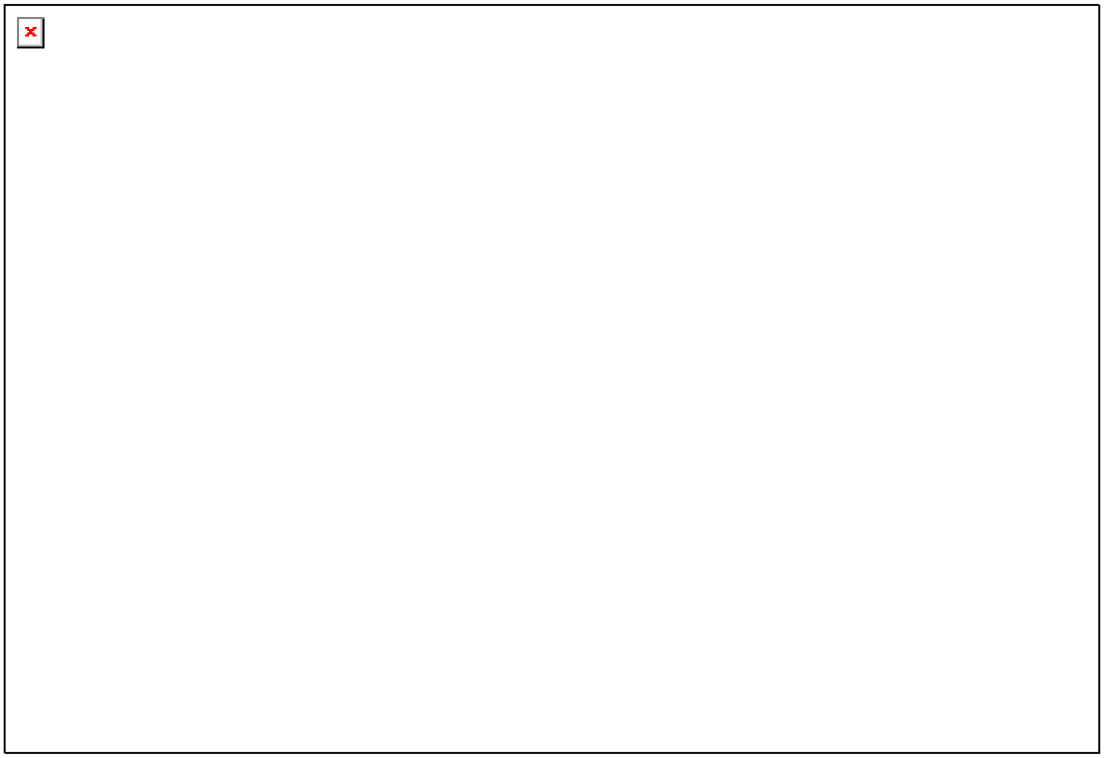

Figure 5.12. Hypothetical output from monitoring of length frequencies during a single aggregation month. Changes to the length frequency distributions should be monitored long-term for changes

Figure 5.13. Hypothetical output from short-term monitoring of RFO for key behaviors.

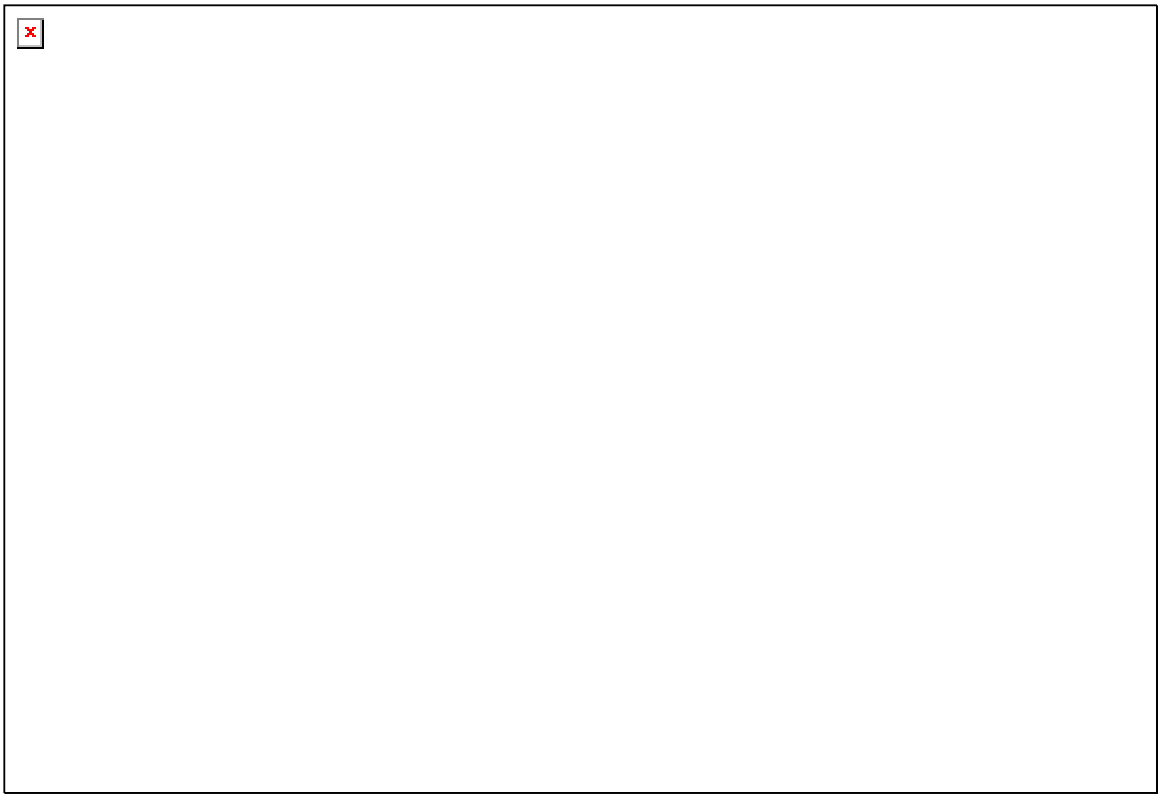

Figure 5.14. Hypothetical output from long-term monitoring, showing initial consistency in the number of months within the spawning season, but inter-annual variation in the months of GSA formation.

5.4 Monitoring Costs

The costs of monitoring must be evaluated to assess the cost efficiency of monitoring in relation to the monitoring program objectives. Monitoring costs depend on several factors: (1) fuel price, (2) local wages, (3) distance of the monitoring site, (4) number of monitoring days, (5) maintenance costs, (6) administrative support, and (7) associated data analysis costs. Daily cost analysis for GSA monitoring has been reproduced from a recommended monitoring program for Palau GSAs (Johannes et al. 1999). The total daily cost of monitoring in this situation was USD$265 consisting of the following line items:

Personnel (2 divers and 1 driver @ USD$50/person/day)	$150
Fuel (12 gal @ USD$2/gal)	$25
Boat and equipment (capital and maintenance)	$50
Supplies	$10
Administration	$10
Recording and data analysis	$20

Eight days of monitoring per year would be required for one GSA site at a total annual cost of USD$2,100. In Pohnpei, the annual cost of a three-person monitoring team with a driver monitoring a single GSA site for three days monthly and around a single lunar phase (full moon) was estimated in 2001 to be approximately US$6,000. Two years were necessary to determine seasonality and resulting optimization would lead to a long-term monitoring program with 6 months of active monitoring per year, costing US$3,000 per year.

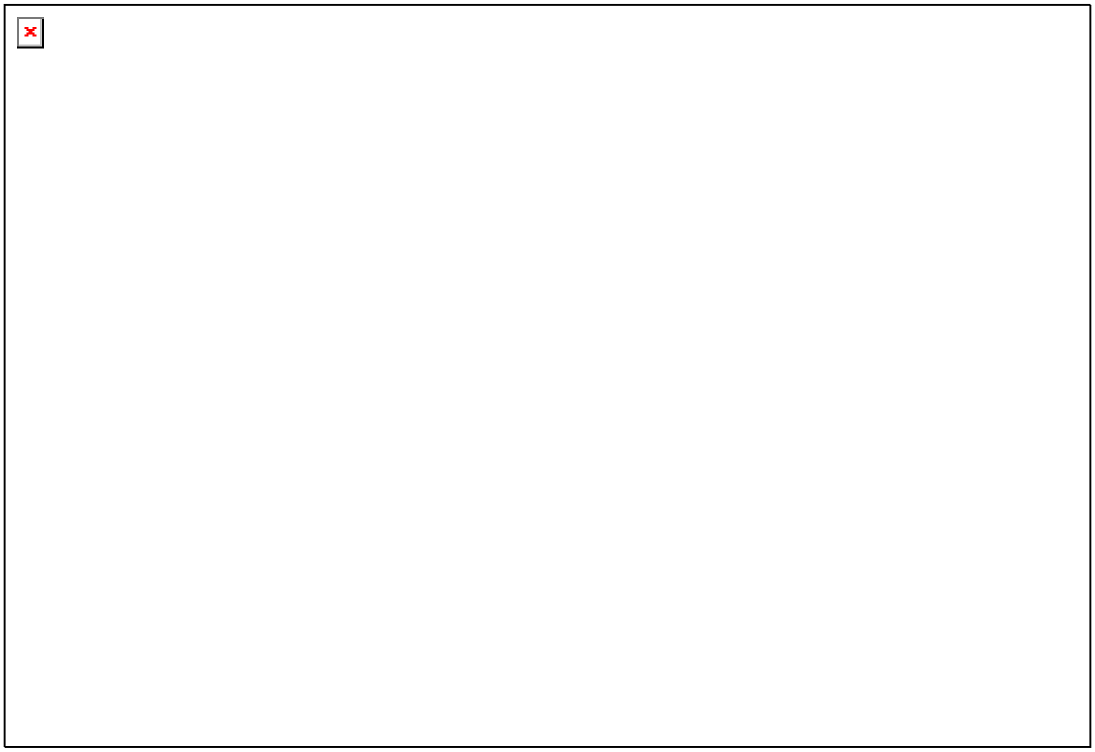

Figure 5.15. Hypothetical output from long-term monitoring to establish changes to aggregations after fishing. Following changes to management (Fishing, Yr 6), aggregation area decreased.

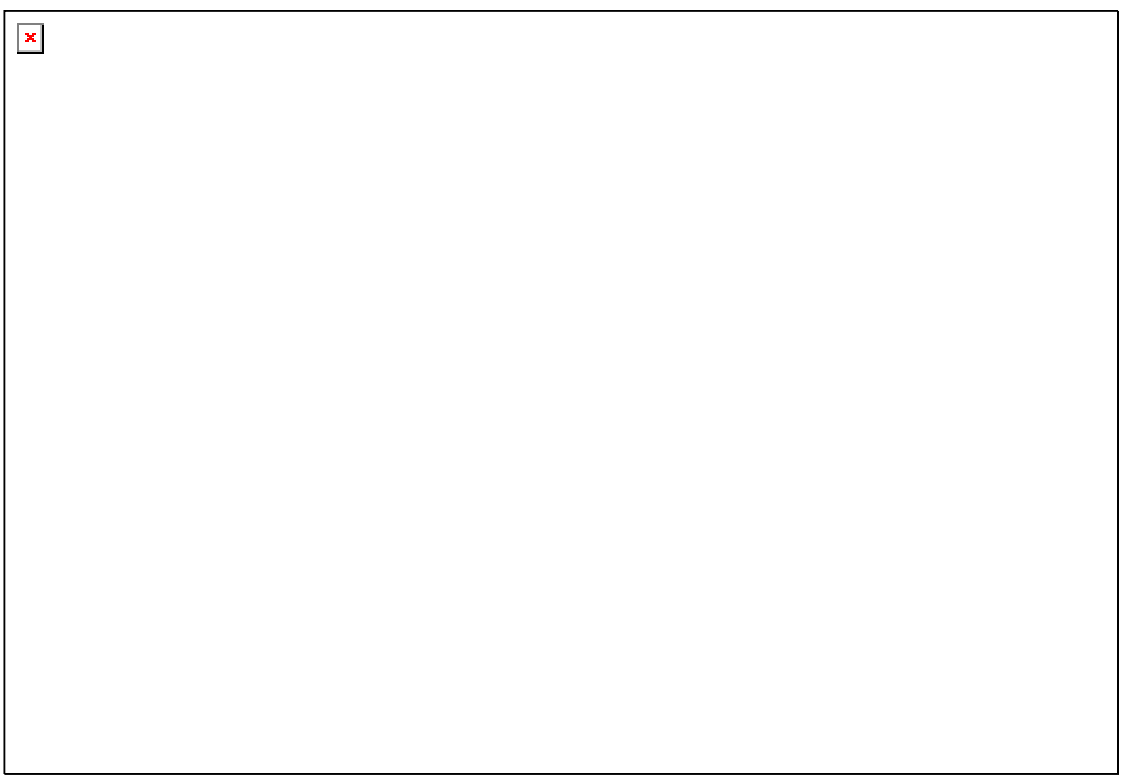

Figure 5.16. Hypothetical output from long-term monitoring to establish changes to aggregations after protective management. Following protection (Yr 6), total abundance increased.

6. Extension of Monitoring Results

After a report has been produced, an important task remains: communicating key findings to various audiences. It is the practitioners responsibility to ensure that key findings from monitoring are properly disseminated. Often, publication of monitoring results in scientific, peer-reviewed journals is regarded as the most appropriate vehicle to extend results from a monitoring program. For monitoring in support of management this is insufficient, because local policy makers, managers and users are rarely reached through scientific papers alone. It is highly recommended that the practitioners develop communication strategies outlining target audiences that need to be reached and in what way. In developing a communication strategy, the following should be considered:

- intended audiences
- content (which key messages should be disseminated)
- timing (when and how frequent must these messages be disseminated)
- tools (in what way should messages be disseminated)

In this section, we discuss which extension tools can be used, and how the choice of tools depends both on the targeted audience and the type of message to be disseminated. Here, we assume that monitoring is carried out in support of sustainable use of natural resources.

6.1 Audiences

Natural Resource Managers and Policy Makers
Managers require the highest level of detail from the monitoring program and guidance for the interpretation of results. The following information is of relevance to managers:

- Status of the spawning population (abundance, size composition, species composition), timing of spawning, and migration to and from the aggregation site. For example: 'Over the period 2000 – 2003, the number of fish at the spawning aggregation site decreased by 50%'.
- Human activities impacting the GSA (e.g. fishing operations at the aggregation site, tourism activities, etc). For example: 'Dive tourism has increased by more than 100% between 2002 and 2004 and this has resulted in disturbance to the spawning aggregations at sites X, Y and Z'
- Implications for conservation management. For example: 'The lower number of fish at the spawning aggregation site suggests that one or more of the following measures would be necessary to stop the downward trend and to help the populations recover: (1) Expand no-take zones around the aggregation site, (2) ban all fishery on the spawning aggregation site, etc.'.
- Operational information, such as logistical challenges, staffing of the monitoring team, and costs per monitoring trip.

Only if information reaches the manager in time can it be included in management considerations. A concise report produced in a timely manner is often more useful than a more complete report that took a long time to prepare! As managers often need quick access to information, and because they usually do not have time to glean reports for the major conclusions, it is important to always include an abstract or executive summary as well as a section with major conclusions as bullet points. Especially for higher-level managers and policy makers it is important to include a cover letter when sending the report, which should also include one or two major conclusions from the report, to get their immediate attention and increase their interest in reading further.

Peers
All too often, reports are forwarded only to the direct supervisor or manager of the monitoring team. Whereas the organizational communication policy dictates what process a report or any other publication need to go through before it is shared, the bottom line is that the monitoring team must share its findings with peers inside and outside the organization. Peers include other monitoring teams as well as planning, surveillance, community awareness, and community development teams. These teams must base their programmatic decisions on the best available information, and it is the responsibility of the monitoring team to make sure that information from the field is passed on to these teams. Information needs for peers are essentially the same as for managers, though operational information may only be of relevance for groups that share resources (boats, manpower etc.) with the monitoring team. At the very least, the monitoring team should regularly update peers on all new communication materials that were produced.

Scientists
Monitoring teams must frequently communicate with scientists who work in the same field, and the monitoring team must share technical reports with scientists with whom there was earlier correspondence. Direct communication with scientists who are not directly involved in the monitoring program can help tremendously to put monitoring results in a broader context, and it is also a great way to develop new ideas on monitoring and application of monitoring results. The scientific community as a whole can be reached through publication of monitoring results in scientific and technical journals. If the monitoring team has the ambition to publish monitoring results in a scientific journal, it is important to involve scientists at the earliest possible stage.

Users
It is essential that users (fishers, fishing cooperatives, middlemen, tourists, tourism operators, etc.) are involved in the management of the resources on which they depend. This means that resource managers and resource users must develop a common understanding of the state of the resources, and the monitoring team takes a pivotal role in this process. Users generally do not require as much detail as managers, especially for operational information, but as their knowledge of the resources can be considerable this group can absorb much more technical or local information than, for instance, donors and the general public. Monitoring results that have implications for management should be shared in a concise and clear manner with users.

Donors
Information requirements for donors vary widely, and quite often donors will provide some guidance on what type of information is required, and how this information should be formatted. Usually, donors require operational information that documents how the money was spent. Often, donors require details on how the information collected by the monitoring team was put to use rather than details on the information itself. Where possible, the monitoring team should maintain a good working relationship with donors or with the people that represent them through direct communication and by providing regular updates. Reports to donors cannot always be widely disseminated because they may contain confidential information. Therefore, only a few people are likely to read the donor report. For reasons of efficiency, information for reports to donors should be gleaned from other communications as much as possible. Extension to prospective donors usually involves putting together a compilation of already existing communication materials in combination with a proposal that is tailored to the needs of the donor.

General Public

The ‘general public’ is understood here as all groups in society that do not have a direct interest in the resources that are being monitored. As such, this audience requires much less detailed information than the audiences listed above. To gain broad understanding and support for the conservation program as a whole, it is important that the monitoring team helps to bring conservation messages to the general public. As interest in nature among the general public is high, the monitoring program may actually serve as a vehicle to also bring management issues to the attention of the general public. Often, a bit of ‘human interest’, i.e., some background on the people involved in monitoring and management of spawning aggregation sites can help to direct some attention to the conservation program. In many organizations, outreach to the general public is coordinated by a Public Relations or Communications Expert, and the members of the monitoring team are only required to provide inputs for press releases. Nevertheless, the monitoring team should take a pro-active role by informing Public Rations or Communications Experts about any findings or results that should be disseminated.

6.2 Extension Tools

Personal Contact (phone calls, meetings, seminars, training)
Direct personal contact not only includes meetings and phone calls, but also seminars and training sessions. The importance of personal contact, even in this information age, should not be underestimated. Personal contact is one the most efficient ways to get direct and informed feedback on the monitoring program, and personal contact is usually required to explain to managers and peers the results of the monitoring program. The monitoring team should maintain an e-mail contact list to quickly disseminate information to solicit feedback on the monitoring program.
Especially in rural areas, personal contact may be one of the few efficient ways to convey monitoring results to user groups and the general public. Where possible and appropriate, members of the monitoring team should sit in on community meetings. Another great way to reach out to local communities is by contributing to the biology curriculum of local schools.

Reports
Especially in remote areas, reports are the main means of communication. Roughly, the following types of report can be distinguished:

> Activity report – a monthly report that includes mostly operational information on the scheduling of activities implemented by the monitoring team. It may also include some financial information and important or remarkable observations.
>
> Data report - monthly or bi-monthly report that includes all data that were collected over the reporting period. Data reports are useful to address urgent information needs.
>
> Technical report – semi-annual or yearly report that includes analyzed data, as well as information on some of the major operational challenges. This report also compares results from the reporting period with earlier results, but it does not include a comprehensive literature review. The technical report usually follows the format of scientific publications (Abstract, Introduction, Materials and Methods, Results, Discussion, Conclusions)

Scientific Publication
Benefits of publishing monitoring results in peer-reviewed journals are significant. Respected scientific journals usually have wide distribution, meaning that the monitoring program can get global exposure. Even if the publication itself may only be read by a selected group of scientists, the publication is often referenced in more popular media resulting in an even wider distribution of key messages. Furthermore, managers tend to take conclusions more seriously if these conclusions were peer-reviewed by other experts.

Press Release
Press releases are required if it is expected that there will be considerable interest from mass media for a particular issue that involves a GSA. Especially for issues that are urgent and possibly controversial, it is important that all communications are clear and consistent. Examples of such issues are the devastating effect of a newly developing fishery on a spawning aggregation site, or the ramifications of a new fishery policy on a particular spawning aggregation site. Usually, a PR or Communications Expert will coordinate the compilation of a press release, but the monitoring team must make sure that all technical information in the press release is correct.

Information Sheet
Information sheets provide general information on the monitoring program and how it is carried out. Usually, they are intended to arouse interest for the monitoring program rather than to disseminate monitoring findings. As such, it is important that the info sheet clearly explains the objectives of the monitoring program, where results presented are more illustrative in nature. Of course, the information sheet must contain a clear reference to where more information on the monitoring program can be obtained. Info sheets are usually up-dated once every two years or even less frequent than that.

Fact Sheet and Leaflets
Fact sheets differ from information sheets in that they contain less narratives and more technical information. Fact sheets are often produced to inform users and field staff on characteristics of a vulnerable species, on regulations pertaining to a certain area. Especially where fact sheets have information on regulations, care must be taken that the contents are up-to-date. Whereas the monitoring team does usually not take the lead in the production of fact sheets or other informative leaflets, they must be involved in the editorial team to ensure that technical data are correct.

Newsletter (quarterly)
Some organizations issue newsletters (mostly quarterly) that provide information on the organization, on the people working in the organization, on upcoming events as well as updates on the projects carried out by the organization. If such a newsletter exists, the monitoring team should make it a matter of routine to always contribute with updates on their activities and, if possible, provide some preliminary results and conclusions. This is a great way to keep colleagues and others informed. If such a newsletter does not exist, there may be an opportunity to reserve some space in thematic newsletters that are produced by other organizations. A monitoring team should not maintain a newsletter themselves, as this usually requires too much effort.

Bulletin Board
Especially in rural areas, bulletin boards can be effective to disseminate newsletters, information sheets, fact sheets and leaflets. Bulletin boards have to be maintained carefully, and care must be taken to keep the publications that are put there up-to-date. Whereas monitoring teams are usually not directly responsible for bulletin boards, they do need to be aware where bulletin boards are placed and the monitoring team must consider whether these bulletin boards may be helpful to extend information on the monitoring program.

Television and Radio Broadcast
Television and radio provide important opportunities for practitioners to inform a wide variety of audiences about the benefits of protecting and monitoring GSA. Local radio stations can be effective in reaching out to local user groups, whereas national broadcasters are more efficient in targeting the general public. Practitioners can also use these media to announce and discuss monitoring and management decisions and changes affecting GSA in relation to these decisions. Whenever possible, visual media should include underwater images that help describe aggregation dynamics and monitoring methods.

Web Site
One of the most cost-effective ways to make information available to a wide range of audiences is through a website on the Internet. Of course, only those audiences that have access to the Internet can be reached, which excludes most resource users in rural areas. Constructing a basic website does

require some technical expertise, but most personal computer users would be able to acquire these technical skills by self study in a couple of days. Whereas for browsing the Internet a fast and reliable connection is a great advantage, construction of a simple website that is hosted by professional Internet Service Provider does not require fast Internet access. This means that even remote field offices with unreliable phone connection can establish a presence on the web. One of the most useful features of a website that focuses on protection and monitoring of spawning aggregation sites is the possibility to make extension materials and reports available for downloading. In this way, Internet users from all over the world can have immediate access to project documents without any interference from project staff. Considerable savings in photocopying, printing and e-mail can be realized.

6.3 Developing an Extension Strategy for Monitoring

Obviously, not all tools are suitable for all audiences, and practitioners should be able to combine the information above with common sense and experience to develop extension strategies for which target audiences to reach and how. This extension strategy should also consider costs. Given the importance of extension for monitoring, at least 10% of the total monitoring budget should be allocated to extension. Table 6.1 below presents general guidelines for extension strategies.

Table 6.1. Matrix that provides guidance on which audiences can be most effectively reach with which tools. Only primary audience – tool combinations are indicated.

	Managers, policy makers	Peers	Scientists	Users	Donors	General public[1]
Personal contact	X	X	X	X	X	
Reports	X	X	X		X	
Scientific publication		X	X			
Press release						X
Information sheet				X	X	X
Fact sheet and leaflets				X	X	X
Newsletter		X	X	X	X	
Bulletin board				X		X
Television and radio broadcast				X		X
Web site		X	X	X[2]	X	X

1. The ‘general public’ here includes mass media that provide information to the general public
2. Only users that have access to the Internet

7. Options for Management of GSAs and Populations of Aggregating Groupers

We recommend that all the grouper spawning aggregations (GSA) formed by the species in this manual should be embedded in permanent (year-round) no-take zones which are part of larger multi-purpose marine managed areas or marine protected areas. In addition, we recommend that all take of each aggregating species be prohibited during the spawning season. The latter recommendation would best be designed and implemented at the local level due to variations in seasonality between locations and the difficulties related to implementation of such areas over larger countries or regions.

Implementation of seasonal closures on specific species should be designed on a region-by-region basis (districts, provinces or small island countries) or within the framework of large multi-purpose marine protected areas with extractive use zones. Seasonal closures will enhance the safety of GSAs that are not known to resource managers, if the closures can be implemented effectively. This may be hard in case of the fishery for live reef food fish, which can easily store live fish in holding pens in remote areas during times of seasonal closures. Remote locations will bring problems of surveillance and enforcement in situations outside marine protected areas.

A more comprehensive approach might be necessary to aid compliance of species-specific spawning aggregation protection measures, such as export controls, hookah or SCUBA dive prohibitions near spawning aggregations, or fishing bans in proximity to or on migration routes to and from GSAs. Although management of the stock during the non-reproductive period is beyond the scope of this document, there is an urgent need for general fisheries management plans to be developed and implemented for coral reef fisheries. In the absence of effective fishery management, the populations will remain at risk, despite measures to protect the aggregations.

It should never be forgotten that spawning aggregations are just one part of the life-history of many reef fish species and that, to ensure persistence of target species, protection of spawning aggregations is only one of several possible management tools available. Others can be applied to protect the species during times of the year in which it is not aggregating, such as limits on catches, minimum size and gear restrictions, etc.

8. Training Methods to Develop GSA Monitoring Skills

Any monitoring program should begin with training (both land-based and underwater) including estimating population abundance and fish length, species identification and site mapping. Training should also include macroscopic gonad analysis, as well as sessions on data entry, processing and results presentation. Most of the methods are simple concepts that can be easily learned, but that require proper training to master.

In the underwater environment all monitoring tasks are more difficult to perform, but over time and with practice, many—but not *all*— practitioners can gain the experience and confidence necessary to do underwater visual census of GSA. Those practitioners who manage to gain the skills to conduct UVC of GSA *must* also undergo occasional re-training to test and upgrade the skills learned in the initial training program. The best time to conduct re-training is prior to the beginning of the annual reproductive (and monitoring) period. Materials specifically used for training are listed below in the materials list in Chapter 9.

8.1 Estimating Abundance and Detecting Spawning Patterns

The estimation of fish abundance is the most important aspect of UVC monitoring and proper training is critical. Since actual conditions are hard to reproduce on land or underwater, the best way to learn to count fish in GSA is by conducting real or virtual counts on actual GSAs. Virtual abundance training is conducted using video recordings of GSAs , while real counts are performed in real time on GSA sites during training sessions and with skilled and experienced practitioners as trainers. During training dives, skilled monitors will make counts with monitor trainees along GSA-based transects. Simultaneously, video recording should be conducted and replayed to determine actual counts and analyze trainee performance. Dive videos can also be used to train in identification of spawning behaviors and color patterns.

8.2 Length Estimation and Species Identification

Wooden fish models (Figure 8.1; Item a) are used for length estimation training both on land (dry training) and underwater (wet training) using length estimation training sheets (Figure 8.2). Models are measured in cm total length (TL). Dry training begins using wooden models to introduce concepts (e.g. total length and measuring in cm) and begin practicing on length estimation.

During wet training, four rows of 16 wooden fish (strung together at 1-m intervals) are tethered just above the bottom of a clear, shallow (~10 m) water location close to the training site. Rows are placed parallel along the bottom at10-m intervals. Divers chose a row and begin estimating individual ‘fish’ lengths (1 through 16) from a minimum distance of 5 m. ‘Estimated’ lengths are recorded on underwater length estimation training sheets (Figure 8.2) until all fish lengths on an individual row have been estimated. The trainee then returns to the first fish to check his/her performance by comparing the ‘actual’ lengths written on the back of each fish with the estimated lengths on the data sheet. Divers then calculate the difference (underwater) between ‘actual’ and ‘estimated’ lengths to judge their performance and make corrections before proceeding to the second row of ‘fish’. The procedure is repeated twice daily until trainees can estimate lengths correctly to within ±3 cm TL for 75% of the batch of wooden models in each row.

Figure 8.2. Wooden fish models used in dry and underwater training for length estimation.

Plastic fish models (Figure 8.3) of varying lengths are used in length estimation training as well as species identification training. Species identification and length estimation testing is conducted by holding up plastic fish models in succession while trainees record the perceived identification and length. Training continues throughout the session, with the speed of testing increasing gradually until trainees can quickly and accurately identify species and estimate fish length at a glance.

Along with plastic fish models, fresh caught samples of target species from markets or sites (if the fishery is active) are used along with plastic models to test trainees on species identification and length estimation. Samples should whenever possible encompass the sizes normally observed on the GSA. Samples are placed on a flat surface with tags or numbers identifying the sample during testing (e.g. Sample 1,2,3). Trainees rotate around the table and stop at each fish for approximately 30 sec to record estimated lengths and IDs. Samples are kept on ice and used daily throughout the training session. Species identification training with fresh fish samples incorporates the use of available fish identification guides (*Chapter 9*). Fish identification guides remain available to participants throughout the training sessions to provide more detailed information on identification characteristics, life history attributes and distribution. Training on spawning behavior and color patterns is provided by projected still images or video recording.

8.3 Site Mapping

Site mapping to locate aggregation boundaries and estimate GSA area and transect placement will be conducted during the initial stages of training. Trainees will learn how to placing markers at key boundary locations (e.g. corners, top, bottom, sides), taking length measurements along site boundaries and learn to calculate GSA area. Once mapped, trainees will be involved in monitoring design that includes the number and placement of transects. Transect location and design are discussed and chosen in relation to monitoring objectives and resources availability.

Figure 8.3. Plastic fish models used in dry training of species identification and length estimation.

8.4 Underwater monitoring

Once the site is mapped and trainees have achieved an acceptable degree of accuracy in length estimation and species identification, trainees will start practicing actual monitoring of GSA. Underwater visual census (UVC) will use underwater armbands (Figure 8.4) with datasheets to record data on fish aggregations. Data recording sheets (*Chapter 9*) are made of plastic paper and preferably printed using laser printers to maintain the integrity of the print. Data is recorded using ***pencil only*** and datasheets can be re-used once data is recorded electronically or in a monitoring workbook. Data will include date, species, depth, site, time, visibility and lunar phase for each dive. A single species will be recorded during each dive.

8.5 Measuring training success and performance

At the end of the training session, and to be qualified to be on a monitoring team, trainees must be able to accurately count fish within transects (as determined by individual estimates and actual counts from video), identify all target species accurately, make consistently reliable (75%) length estimates to within ±3 cm TL for *all* species (training and actual recording sessions) and recognize spawning behavior. At least two persons on each monitoring team must meet these minimum requirements, also recognizing that re-training is necessary on occasion and before each monitoring season. Undoubtedly, not all trainees will meet these minimum requirements and cannot be allowed to monitor until their skill levels improve.

Grouper Size Estimation Sheet

To join the monitoring team, you will have to be very good at estimating fish lengths. Only those who consistently score •75% correct can qualify. The sheet has 2 rows (A & B) of 20 'fish' to test your ability. Each number represents one 'fish'. Swim down the row and record your estimated (Est) fish length (in cm) for Row A. Go back to the beginning, look on the back of the 'fish' and record the actual (Act) fish length. Estimate the difference (Diff.) between actual and estimated 'fish' lengths. If you guessed bigger than the actual, check the (+) column, if smaller, check (-). If you were within ±3 cm of the actual length, you are 'OK'. Repeat the exercise for Row B. When you consistently score 15 out of 20 'OK', you are OK to begin practicing on the aggregation.

A	**Est**	**Act**	**Diff**	**+**	**-**	**OK**
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

B	**Est**	**Act**	**Diff**	**+**	**-**	**OK**
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

Figure 8.2. Data sheet used in the fish length estimation training. Explanation on top of the sheet is included to remind trainees how to fill in and use the sheet for self-training. The trainee can judge performance (including trends to over- or under-estimate) directly during the dive.

9. Materials and references

Initial Survey Materials

A. Site mapping

1. Local map (bathymetric, topographic, aerial)
2. GPS (global positioning satellite receiver
3. 100- or 50-m vinyl tape measure
4. Float markers (to mark beginning, end and along transect or area)

5. Rope or twine to hold floats
6. Rebar (metal) stakes to mark corners and transects
7. Surveyor’s tape (colored fluorescent vinyl marker tape)
8. Underwater compass

B. Gonad analysis

1. Cannula or ball point pen ink tube or filling
2. Magnifying glass or 10 X eyepiece
3. Microscope and microscope slides (optional)

Monitoring Materials

1. Boat and engine (maintained and sufficiently fueled)
2. Dive gear for all monitors, with dive computer and back-up gear (mask, fin, snorkel, BCD, weights and belts, wetsuit, boots, regulator)
3. Dive safety equipment [dive whistle, flares, dive flag, underwater or waterproof flashlight or strobe, safety sausages, DAN oxygen kit, first aid kit, emergency procedures list for (evacuation plan, phone numbers)]
4. Global Positioning Satellite receiver (GPS)
5. Waterproof, laser-printed data sheets, (abundance, length frequency, *see below*)
6. Laser pointer or underwater length reference guide (weighted 1-m or other PVC pipe)
7. PVC armbands (1 hole drilled to attach line and pencil)
8. Pencils (20 each; composite, not natural wood), sharpeners, erasers (rubber type)
9. Duct tape or electrical tape to affix sheets to the PVC armbands
10. Sun protection (hat, sunscreen lotion)
11. Drinking water

Monitoring personnel

1. boat driver
2. practitioners (minimum 2, optimum 3)
3. 1 alternate or back-up practitioner (required)

Training Materials

A. Abundance counts

1. Video camera with underwater housing
2. LCD projector or TV monitor
3. Projector screen or white sheet

B. Length estimation

1. Wooden fish models (100 pieces, 25-120 cm TL, varying lengths)
2. 100 m nylon string or rope (1/4” or 3 cm)
3. dive weights or other material to hold fish to the bottom
4. Plastic fish models (30-40 pieces, 25-120 cm TL, varying lengths)

C. Species Identification

1. Plastic fish models (see above)
2. Market and/or catch samples (20-30 specimens of varying sizes)
3. Field or scientific fish identification guides
4. Micronesian Reef Fishes, RL Myers (1 copy)
5. Groupers of the World Family Serranidae, Subfamily Epinephelinae. An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper and lyretail species known to date, PL Heemstra, and JE Randall (1 copy)

D. Spawning behavior, aggregation ecology and aggregation dynamics

1. National Geographic “The Perils of Plectropomus” (1 copy)
2. The Nature Conservancy “At the Confluence of Currents” (1 copy)
3. National Geographic “Feast of the Giants” (1 copy)
4. “ The Boom or Bust Syndrome” (1 copy)

E. General electronics and presentation materials

1. VCR (NTSC/PAL compatible, if available)
2. Color printer (or black and white, if color unavailable)
3. Laminator (if available)
4. Extension cords (with plug adapters, if needed)
5. Multi-outlet power strips
6. Whiteboard and markers or chalkboard and chalk (colored)
7. General office supplies (stapler, hole punch, scotch tape, paper clips, bulldog clips)

F. Monitoring manuals (scientific guides)

1. Colin PL, Sadovy YJ, Domeier ML. 2003. Manual for the study and conservation of reef fish spawning aggregations. Society for the Conservation of Reef Fish Aggregations (SCRFA) Special Publication No. 1 (version 1.0), 98 + iii p (http://www.scrfa.org•)
2. Labrosse P, Kulbicki M, Ferraris J. 2002. Underwater visual fish census surveys: proper use and implementation. SPC Reef Resources Assessment Tools (REAT). ISBN 982-203-878-X (• HYPERLINK http://www/spc.org.nc ••http://www/spc.org.nc•)
3. English S, Wilkinson C, Baker V (eds). 1997. Survey Manual for Tropical Marine Resources. Australian Institute for Marine Science, Townsville, Queensland. ISBN 0-642-25953-4.
4. Samoilys M (ed). 1997. Manual for Assessing Fish Populations on Pacific Coral Reefs. Dept. of Primary Industries, GPO Box 46, Brisbane, Queensland 4001. ISBN 0812-000, ISBN 0-7242-6774-3.

Site No: ________________	Time:___________________	Date:_____________
Species:________________________		Transect No.:______________
Observer name:__________________________		Visibility:_________
Lunar date: _____		

Group	Frequency	Total
1		
5		
10		
20		
50		
Total		

Figure 9.1. Blank data recording sheet for recording abundance of groupers on a GSA.•

Site No: ________________ Time:___________________ Date:_____________

Species:_____________________ Lunar date:_________ Transect No.:______________

Observer name:_________________________ Visibility:________

Size	Frequency	Total
21-25		
26-30		
31-35		
36-40		
41-45		
46-50		
51-55		
56-60		
61-65		
66-70		
71-75		
76-80		
81-85		
86-90		
91-95		
96-100		
101-105		
106-110		
Total in LFD		

Spawning:	Courtship:
Aggression:	Gravid:

•*Figure 9.2. Blank data recording sheet for recording length frequencies and behavior on GSA.*

Dive monitoring checklist **checked by:______________**

Dive equipment[1]

(•Mask (•Fins (•Snorkel (•Booties
(•Regulator (•BCD (•Weights (•Computer

Safety Equipment (required)

(•Safety sausage (•Dive whistle ❒ Flashlight/strobe ❒ Oxygen kit
❒ Emergency plan ❒ Flares ❒ First aid kit ❒ Water

Monitoring equipment

❒ Abundance sheets ❒ Length estimation sheets ❒ PVC armbands
❒ GPS ❒ Pencils ❒ Erasers ❒ Duct tape

Boat supplies[2]

❒ Fuel (____ gal) ❒ Spark plugs ❒ Toolkit ❒ Paddles
❒ Spare propeller ❒ Rain gear ❒

Mapping supplies[3]

❒ Vinyl tape measure ❒ Floats and lines ❒ Rebar ❒ 5-lb sledge
❒ GPS ❒

General supplies

❒ Hat ❒ Sunscreen ❒ Water ❒ Bug repellent
❒ Rain gear ❒ Duct tape ❒ Survey/flagging tape

Other

❒ ❒ ❒
❒ ❒ ❒

[1]Monitoring teams should be equipped with one back-up set of dive gear.
[2]Spare plugs and props can save a monitoring trip.
[3]Mapping supplies should be on-hand for replacement of lost or missing transect markers.

Dive monitoring training checklist *checked by:_______________*

Dive equipment[1]
❒ Mask ❒ Fins ❒ Snorkel ❒ Booties
❒ Regulator ❒ BCD ❒ Weights ❒ Computer

Safety Equipment (required)
❒ Safety sausage ❒ Dive whistle ❒ Flashlight/strobe ❒ Oxygen kit
❒ Emergency plan ❒ Flares ❒ First aid kit ❒ Water ❒ DAN card

Abundance estimation and presentation equipment
❒ Abundance sheets ❒ Video camera UW housing ❒ Digital tapes
❒ TV monitor ❒ LCD projector ❒ Electronics cables ❒ Extension cords ❒ Multi-plug outlets ❒ VCR
❒ Projection screen ❒ Power generator and fuel ❒ Laptop computer
❒ Whiteboard and markers ❒ ❒

Length estimation training and monitoring equipment
❒ Wooden fish ❒ Length estimation sheets ❒ PVC armbands ❒ Pencils
❒ Rope or string ❒ Dive weights ❒ Erasers ❒ Duct tape

Boat supplies[2]
❒ Fuel (_____ gal) ❒ Spark plugs ❒ Toolkit ❒ Paddles
❒ Spare propeller ❒ Rain gear ❒ ___________________________

Mapping supplies[3]
❒ Vinyl tape measure ❒ Floats and lines ❒ Rebar ❒ 5-lb sledge
❒ GPS ❒

Species identification
❒ Plastic fish ❒ Market specimens ❒ Cooler with ice
❒ Fish ID guidebooks ❒ Drawing paper or notebooks

General office supplies
❒ Stapler ❒ Tape and tape dispenser ❒ Paper clips ❒ Ruler ❒ Scissors
❒ Office paper (2-3 reams) ❒ Printer ❒ Print cartridges ❒ Laminator and supplies
❒ Thumbtacks

General personal supplies
❒ Hat ❒ Sunscreen ❒ Bug repellent ❒ Sunglasses ❒ Rain gear

[1]All participants; monitoring teams should be equipped with one back-up set of dive gear.
[2]Spare plugs, props and fuel can save an otherwise failed monitoring trip.

[3]Mapping supplies should be on-hand for replacement of lost or missing transect markers.