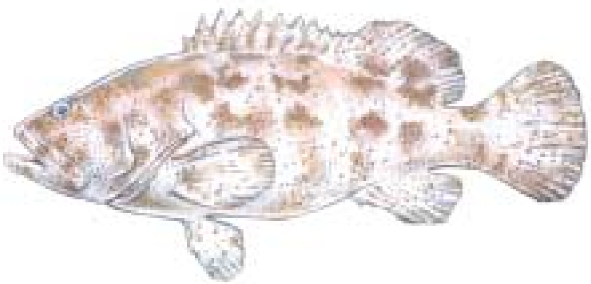
Introduction to Monitoring of Spawning Aggregations of three Grouper Species from the Indo-Pacific

A Manual for Field Practitioners

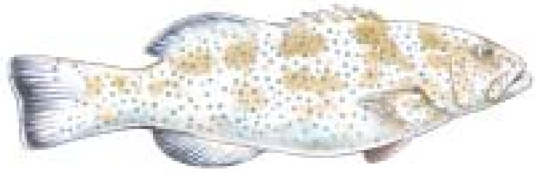
Version 1.2

April 2005



Epinephelus fuscoguttatus

Epinephelus polyphekadion



Plectropomus areolatus

Jos S. Pet, Peter J. Mous, Kevin Rhodes, and Alison Green

The Nature Conservancy
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Preface

The 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 Indo-Pacific region. This manual focuses on three species of groupers, *Epinephelus fuscoguttatus*, *E. polyphekadion* and *Plectropomus areolatus*. These species form large seasonal spawning aggregations at specific sites where they can be effectively monitored, providing an important opportunity to track trends in local populations.

E. fuscoguttatus, *E. polyphekadion* and *P. areolatus* are heavily fished groupers targeted by coral reef fisheries of the Indo-Pacific, 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 inform fisheries management and conservation. Spawning aggregations of these three species have already been described in the region, providing a sound basis for the design of monitoring protocols. For many other aggregation-forming species, this information is still scarce.

The target audience for this manual consists mainly of field practitioners in marine conservation, fisheries and marine protected area management in developing countries who are tasked with the design and implementation of a monitoring program for grouper spawning aggregations.

Field practitioners in developing countries may have extensive knowledge on spawning aggregations, but may have little or no scientific training. This manual is intended to help practitioners collect, analyze and present data in a scientific manner. The manual is best introduced to practitioners during a short training workshop (~2 weeks) that includes practical training on methods as well as some background on monitoring and management of spawning aggregation sites. Such workshops are best facilitated by acknowledged experts on spawning aggregation monitoring. Technical advisors will find this manual a useful tool for developing a training curriculum on monitoring of spawning aggregation sites. Practitioners may find the step-by-step protocols that are included in this manual particularly helpful for use in the field.

This manual complements, and is partly inspired on, the Society for the Conservation of Reef Fish Aggregations's "Manual for the Study and Conservation of Reef Fish Spawning Aggregations", which provides more detailed technical advice for scientists wishing to provide scientific research for conservation (Colin et al., 2003).

1 Introduction

1.1 What are spawning aggregations and why is it important to protect them?

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 are known as fish spawning aggregations, and the sites where they occur are referred to as spawning aggregation sites. These sites may be used by a 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 (GSAs), which we define as concentrations of groupers coming together at a certain place and time to spawn.

An aggregation is defined as an increase in fish densities to at least three times the 'normal' density on the site (Colin et al., 2003). Two types of aggregations are distinguished: '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 ranges 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 (4) can occur year round (Domeier et al. 2002). Therefore, the output from a single spawning event of a group of fish forming a resident spawning aggregation usually represents only a small part of the total annual spawning output of these fish.

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 times of the month, (2) persist for a period of days or, at most, approximately two weeks and (3) do not generally occur year-round (Domeier et al. 2002). The spawning output from a single 'transient' aggregation usually represents a substantial portion of the total spawning output of the fish in the aggregation, while the combined aggregations probably represent the complete reproductive output for the population. Reef fishes forming 'transient' spawning aggregations are highly vulnerable to over-fishing since a large portion of the harvestable stock concentrates at predictable sites during predictable periods, facilitating catch rates that are much higher than when the fish are dispersed in their day-to-day habitat.

The mechanism that makes transient fish aggregations vulnerable to fishing also helps resource managers efficiently monitor the status of the populations. Since much or all of the adult population may be present during aggregation periods, monitoring transient aggregations using underwater survey techniques provides an opportunity to assess local population trends in ways that may not be feasible for species that are more dispersed throughout their life cycle.

1.2 What are the major threats to spawning aggregations?

Most commercially important species forming 'transient' spawning aggregations are locally threatened by over-fishing. At some sites, additional threats exist such as habitat destruction, pollution, disturbance by tourism, 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". The three species of grouper that are the focus of this manual all fall in this 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 distribution area by unsustainable fishing practices. 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.

Coral reef fisheries form an important sector of the economies of coastal communities in many countries of the Asia-Pacific region and the conservation of reef fish spawning aggregations is essential for sustaining the fisheries that depend on them. 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 needs to be included in the wider context of fisheries management and marine conservation efforts. Stakeholder support for GSA management depends on their understanding of the importance of healthy reef fish spawning aggregations for fisheries in areas surrounding the aggregation sites. Hence, monitoring and dissemination of monitoring results among local stakeholders is essential for effective management of GSAs.

If protective management is implemented before complete collapse, GSAs have the potential to recover (Nemeth 2005).

1.3 Management of groupers that form aggregations

All grouper spawning aggregations (GSA) formed by the species in this manual should be protected in permanent (year-round) no-take zones wherever possible. Nevertheless, depletion of populations of aggregating species can only be prevented if over-fishing and habitat destruction are also addressed elsewhere, and if take of aggregating populations during other phases of their life cycle is constrained to a sustainable level. Therefore, no-take zones should be embedded in larger multi-purpose Marine Protected Areas (MPAs). Alternative or additional management approaches may be considered as well. The essential criterion for adopting a management approach is that it must guarantee full protection of reproductively active fish at GSA sites. Such approaches may include limits on catch volume (quota), effort restrictions, minimum size and gear restrictions, but also closure of part of the areas that comprise the home range of these fish species outside the spawning season.

To protect GSAs of which the locations are unknown, resource managers may prohibit all take of aggregating species during the spawning season as an additional management measure. No-take seasons for specific species should be designed and implemented on a region-by-region basis (districts, provinces or small island countries), because of variations in seasonality of spawning between locations. This recommendation is best implemented at the local level, preferably within the framework of large multi-purpose MPAs. No-take seasons may not be effective to manage the fishery for live reef food fish, where fish can be stored in holding pens in remote and difficult to patrol areas during no-take seasons. Furthermore, no-take seasons are also less effective if aggregating species change the timing of the reproductive season, as has been observed for *P. areolatus* in Komodo National Park, Indonesia.

Additional measures may be necessary to aid compliance of no-take areas and no-take seasons for the protection of GSAs. These measures may include a ban on keeping live fish in pens, export controls, hookah or SCUBA dive prohibitions near spawning aggregations, or fishing bans in or near migration routes to and from GSAs.

The Call for Action to protect reef fish spawning aggregations from the Second International Tropical Marine Ecosystems Management Symposium (ITMEMS2) provides additional recommendations for the management of reef fish spawning aggregations (Text Box 1). ITMEMS2 was held in Manila, Philippines in March 2003, and bought together 200 delegates from 36 countries comprising a broad range of experience from managers, scientists, private sector, non-governmental organizations, development and funding agencies. The Call for Action comprises part of the Action Statement resulting from this conference (www.icriforum.org/itmems.html).

Text Box 1.

ITMEMS 2 CALL FOR ACTION –
REEF FISH SPAWNING AGGREGATIONS NEED PROTECTION

A threat to sustainable reef fish fisheries

Many commercially valuable reef fishes are particularly vulnerable to overexploitation because they form spawning aggregations that are highly predictable in time and location. These aggregations, and in some cases the migration routes to and spawning aggregation sites, are easy to find and target by fishers. The evidence is unequivocal that spawning aggregations can be decimated rapidly by heavy fishing, resulting in serious declines in the fish populations they serve. Moreover, they are increasingly being targeted globally, particularly in the Pacific Ocean for commercial salted and chilled fish and for lucrative live fish export markets. Best known is the example of the Nassau grouper, *Epinephelus striatus*: a significant number of Nassau grouper aggregations are depleted in the western Atlantic, and some have possibly disappeared completely. The species is listed as endangered on the IUCN Red List of Threatened Species. Evidence is growing of aggregation depletions in SE Asia and the western Pacific.

Spawning aggregations are critically important for maintaining fish stocks and may thus underpin fisheries that contribute significantly to livelihoods in coastal communities, as well as to food supply. However, little management has been implemented to protect reef fishes when they spawn, despite the widely recognized need to protect spawning areas in marine protected areas. Unmanaged aggregation fishing is clearly non-precautionary. Management options include combinations of spatial and/r temporal controls, such as short-term, seasonal closures during the aggregation period, closures of aggregation sites, incorporation of aggregation sites into marine reserves, and various controls on catch and effort.

Specific recommendations

- Ideally, fishing of aggregations should be avoided unless part of important local traditional or subsistence fisheries;
- If spawning aggregations are fished for subsistence, they should be closely monitored and carefully managed;
- Fishing of spawning aggregations should not be permitted for export/commercial markets;
- Spawning aggregations should be included routinely in fishery management plans and marine protected areas design;
- The potential impacts and benefits of tourism on fish aggregations should be evaluated, especially to determine the possible disturbance caused by tourism activities;
- Education is needed to increase understanding of the biological and fishery importance of spawning aggregations and their vulnerability to fishing; and
- Extreme caution should be exercised not to make public information on the specific locations of aggregation sites that cannot be adequately protected from exploitation.

Key recommendation: fish spawning aggregations should be conserved, through robust management strategies. Whenever possible, this should include complete or managed protection, to ensure persistence of the populations that form aggregations, the integrity of reef ecosystems and the livelihoods and food supply of communities that depend on aggregating species.

1.4 Monitoring objectives

The design of any management-supporting monitoring program is dependent on the needs of the resource manager, but generally speaking the major objectives are:

- to measure success of management actions by assessing how fish populations respond to management intervention (or the lack thereof)
- to provide feedback for adaptive management.

To satisfy these objectives, monitoring programs generally assess:

- trends (decline or recovery) in aggregation populations (this is usually the most important information required for management),
- spawning locations and periods.

Additional benefits of monitoring are:

- maintaining a field presence to deter poaching, and
- enhancing public awareness and a feeling of ownership and control by resource users and managers - whenever possible, fishers and other stakeholders should be involved in the design and implementation of monitoring and in the processing and dissemination of the findings.

2 Types of monitoring discussed in this manual

2.1 Baseline surveys and long-term monitoring

Baseline surveys provide the information required to design a long-term monitoring program. Hence, baseline surveys are conducted at the beginning of a monitoring program. Typically, baseline surveys aim to locate spawning aggregation sites, and to establish timing and species composition of aggregations. Locating spawning aggregation sites is often done by interviewing reef fishers. If this is not possible, spawning aggregation sites may be located by searching for certain physical characteristics using a detailed nautical chart (see Section 4.1 below). Establishing timing of GSA formation includes identification of the time of day (diurnal pattern), day of the month (lunar pattern), as well as the month of the year (seasonal pattern) of the peak aggregation period. This information provides guidance on how long-term monitoring can be designed for maximal effect. Often, the baseline survey relies on information that can be obtained by interviewing local fishers on the location of spawning aggregation sites and timing of spawning. In addition, the baseline survey may include up to a year of underwater surveying (see Sections 6-9 below) using a protocol that would later form the basis for a long-term monitoring protocol. Long-term monitoring programs comprise repeated observations over time to monitor trends in abundance and length-frequency distributions of fish in spawning aggregations necessary to inform management for protection of spawning aggregation sites.

2.2 Fishery-dependent and fishery-independent monitoring

Grouper spawning aggregations can be monitored using fishery-dependent methods, fishery-independent methods or, preferably, a combination of the two. Fishery–dependent monitoring relies on data gathered from the fishery, whereas fishery-independent monitoring (e.g. underwater visual census) does not. Underwater visual census (UVC) comprises non-destructive methods for estimating abundance, distribution and population structure of fish populations. Although their objectives may differ, most UVC methods involve a systematic enumeration of animals within a search (census) area, often accompanied by the collection of information on environmental variables (e.g. visibility).

Fishery-dependent monitoring takes place at the point of catch, point of sale, or point of export where catches can be inspected. Examples of fishery-dependent data are (1) total catch from an area or a spawning aggregation site, (2) number of boats or fishers using the site, (3) catch-per-unit-effort (CPUE) (e.g. fish taken per hour, fisher, or trip), (4) length, sex, weight and reproductive state of fish captured.

Fishery-dependent monitoring typically collects information on type of fishing gear, vessel type, target areas, and total numbers of fishers. To determine what, if any, actions need to be taken to reduce potential threats, it is also important to describe socio-economic attributes of the fisheries affecting the grouper spawning aggregations. Examples of important socio-economic attributes are commercialization (local subsistence vs. local or foreign commercial fishing), and destination of the produce (local vs. export market).

Fishery-dependent 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. Fishery-dependent monitoring for determining spawning seasons is relatively cost-efficient and is helpful for developing fishery-independent monitoring programs.

Whether fishery-dependent monitoring can be used depends on both the access to the fisheries and whether the catch can be inspected or handled. Where fishing is secretive, where there is no direct local sale of fish or where markets are distributed over broad, hard-to-reach areas, this type of monitoring may not be feasible. If catch can be inspected and data on CPUE, fish length, weight and sex of individuals can be taken, analysis can provide useful information on trends in the fishery and the population.

Fishery-dependent data should always be interpreted with caution and should, whenever possible, be combined with fishery-independent data. For example, trends in CPUE may remain constant even while the total fish abundance in the aggregation is declining (‘hyperstability’, Sadovy & Domeier (2005)). This happens when fishers target the core of a GSA that contains a relatively high and constant density of fish. The decline in numbers at the GSA is reflected not by a decline in density and CPUE, but rather by a decrease in the size of the total aggregation while the CPUE remains constant until the GSA is fished out. The combined use of CPUE data with UVC addresses this problem.

Besides fishers, other users such as recreational divers, dive guides and dive operators may provide useful information on spawning aggregations, provided that basic training on simple observation protocols can be provided.

3 Identifying species

This manual focuses on three grouper species, *Epinephelus fuscoguttatus* (Figure 1), *E. polyphekadion* (Figure 2) and *Plectropomus areolatus* (Figure 3). A guide to their identification is provided below.

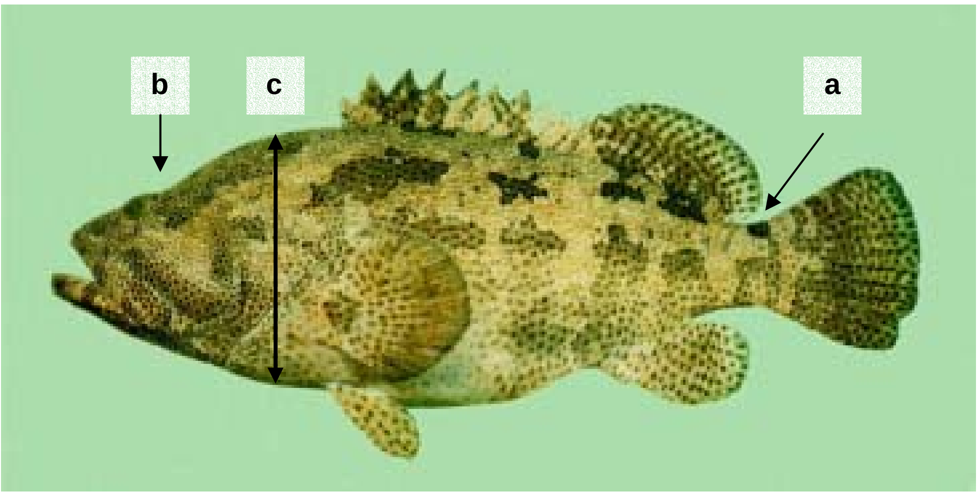


Figure 1. *Epinephelus fuscoguttatus*
Common name (FAO): brown-marbled grouper. *Distribution:* Indo-Pacific, Red Sea, coast of Africa to Mozambique, east to Samoa and the Phoenix Islands, north to Japan (Ryukyu I) and south to Australia. *Key characteristics:* Maximum size 120 cm total length (TL). 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 differentiated by the thickened body, larger size, spawning color (see below) and head notch. *Picture from FishBase, Froese & Pauly 2000.*

Figure 2. *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. *Picture from FishBase, Froese & Pauly 2000.*

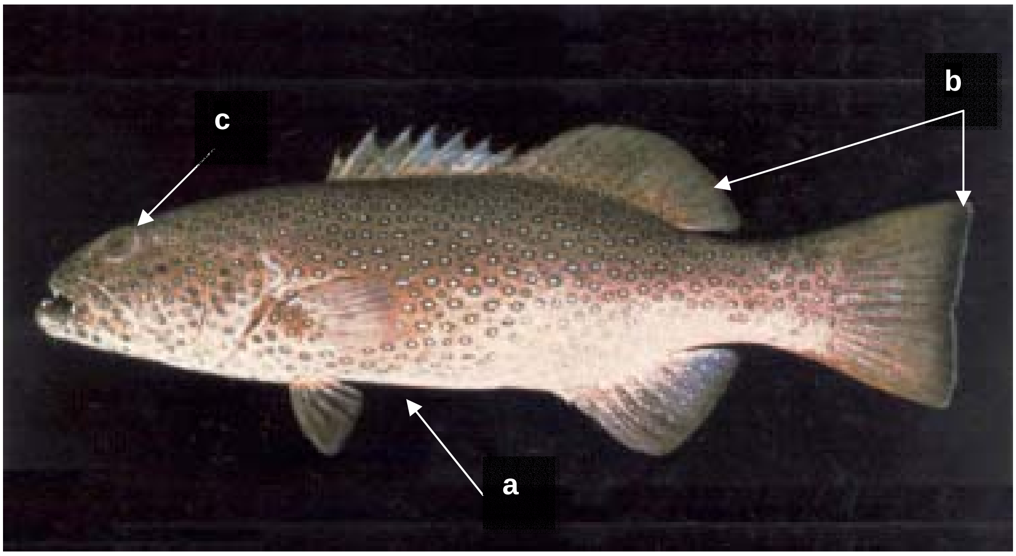


Figure 3. *Plectropomus areolatus*
Common name (FAO): squaretail coralgrouper. *Distribution:* Indo-Pacific, Red Sea, east to the Phoenix Islands and Samoa, north to Japan and south to Australia. *Key characteristics*: Maximum size 75 cm total length (TL). Reddish body with large blue-ringed spots over 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. *Picture from FishBase, Froese & Pauly 2000.*

4 Locating spawning aggregation sites, migration pathways and spawning periods

4.1 Locating spawning aggregation sites and migration pathways

Many GSA sites 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 assistance from local fishers familiar with the grouper fisheries and the local reef systems. 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. Practical advice on how to interview fishers can be found in Bunce et al. (2000) and Bunce & Pomeroy (2003).

Where the fishery cannot be used as a source of information on GSA sites, it may be possible to locate them by searching for certain physical characteristics that many spawning aggregation sites share. For instance, experts find that GSA sites are often located on the seaward edge of channel corners, or at points or promontories along the reef (Figure 4). While features such as channel corners can be easily located on a nautical chart, promontories along the outer reef are more difficult to find. Nautical charts (scale at least 1:200,000) or aerial photographs of the reef may assist in identifying potential GSA sites. Any potential site selected from maps or photographs should be checked for the actual occurrence of a GSA before being referred to as a GSA site. A search for GSAs should include various seasons and moon phases before final conclusions can be drawn about GSA occurrence. To prevent depletion of newly discovered GSA sites, their location should not be made public until protective measures are in place.

Groupers may swim considerable distances along specific migration pathways to reach GSA sites. Migrating females of squaretail coral grouper often form large schools. Locating these migration pathways can be conducted by snorkeling above migrating fish, with another observer following in a boat to take GPS readings along the way. From this information and from observations on fishing activity, practitioners can decide whether the migration pathways warrant some type of protective management measure. For at least two of the three species discussed here, migration to the site is sex-specific: males tend to arrive as the aggregation site several days prior to females (Johannes et al. 1999; Rhodes & Sadovy 2002; Rhodes, unpublished data).

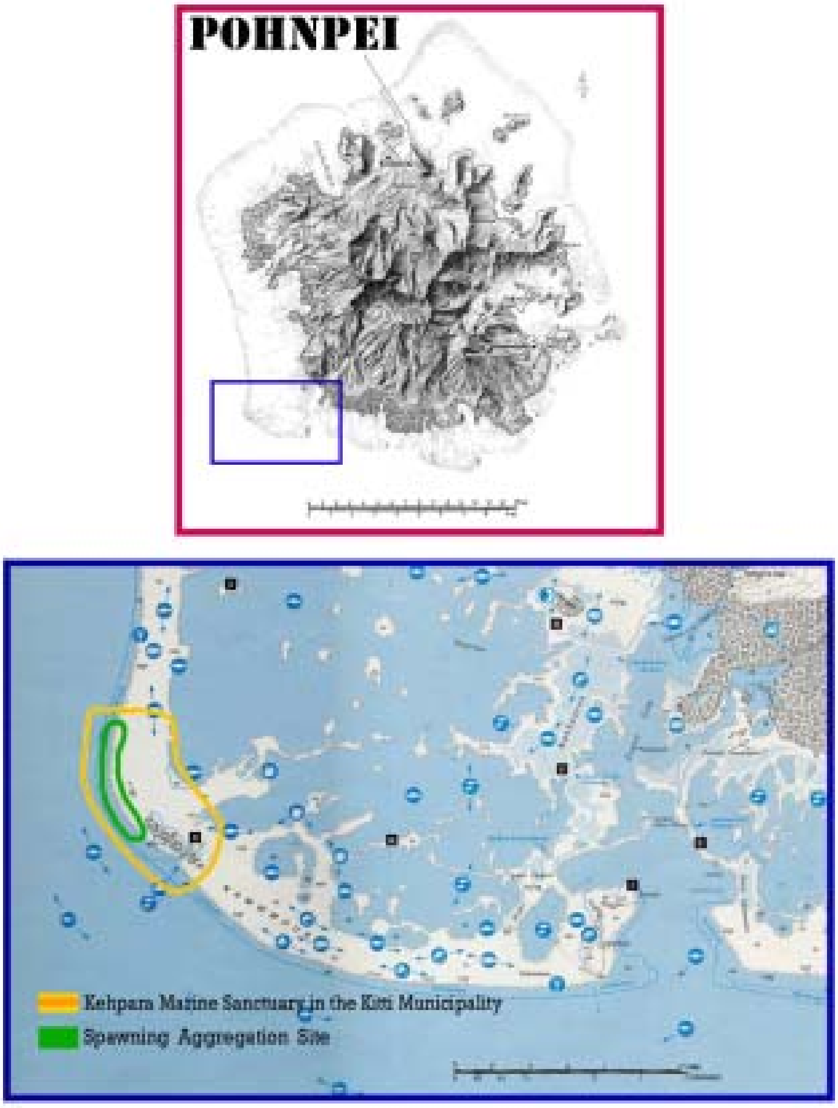


Figure 4. Example of a well known, monitored and protected GSA site in Pohnpei, Federated States of Micronesia (top). The GSA site is located at a large reef promontory at the barrier reef (bottom).

4.2 Determining spawning periods through gonad analysis and fisher interviews

For our three grouper species, aggregation formation and spawning usually occurs over periods of two to several months each year (e.g. Johannes et al. 1999; Rhodes & Sadovy 2002; Conservation Society of Pohnpei, unpublished data). Determining the spawning season is critical for management if seasonal closures are considered as a management tool. Also, knowledge on the spawning season is important for the design of monitoring programs, since monitoring is most efficiently conducted around periods of peak abundance. There are three ways to obtain information on the spawning season: (1) assessing seasonal variation in numbers of fish in catches of local fishers and in numbers of fish traded at markets through fisher interviews and fish market surveys combined with direct observations, (2) examination of fish from market samples or from catches of local fishers, and (3) direct observation of GSAs using UVC (see Sections 6 and 8).

Seasonal patterns in aggregations and spawning can often be determined by interviewing fishers (cf. Section 4.1), asking questions such as "When is the best time to catch this fish species?", or "Have you ever noticed eggs in these fish and, if so, do you remember the time of year?"

Spawning seasons can also be determined 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 an active spawning aggregation.

If the fish are being gutted at the market or at the catch site where gonads can be examined, assessment of gonad maturity stages (Table 1, Figure 5 and Figure 6) provides additional clues on the reproductive period. If a high proportion of the sampled fish are 'mature, active' or 'mature, ripe' this suggests that the population is close to spawning. For very large aggregations (> 1000 fish), a small number of animals from the aggregation could be sampled to check gonad maturity and/or to determine whether concentrations of fish represent spawning aggregations.

If it is possible to handle live or freshly dead fish, but not to cut fish for inspection of the gonads, spawning seasons can still be detected by determining the percentage of fish that are 'mature, ripe' (females) or 'mature, active' (males) (cf.. Table 1). By applying continuous pressure to each side of the abdomen and sliding your fingers along the fish from front-to-back (Figure 5) eggs or sperm can usually be expelled if fish are 'ripe' or ready to spawn. Also a technique known as 'canulation' can be used. Canulation is the removal of a small sample of eggs or sperm from a live fish using suction applied to a ca. 1 mm diameter plastic tube (a ball point pin ink tube may suffice) that is inserted in the gamete duct. An increase in the proportion of 'ripe' animals of all fish examined is indicative of the start of the reproductive season. Males often produce sperm outside the spawning season and are less reliable indicators than females. See Table 2 for an example of a format to present observations on the relative frequency of occurrence of ripe or mature fish.

Changes in the size of the gonads relative to the body of the fish provide additional information on the reproductive season. If larger numbers of fish can be sampled for inspection of gonads, the weight of the gonads and the total weight of the fish can be measured to calculate the gonadosomatic index (GSI). GSI increases as gonads grow in size during the spawning season and GSI decreases as fish release sperm and eggs. Hence, seasonal trends in GSI (e.g. Figure 7) provide accurate information on the reproductive period.

$$\text{GSI} = \frac{\text{gonad weight}}{\text{total fish weight}} \times 100 .$$ [Formula 1]

Table 1. Criteria used in visual 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 yellow, orange or pinkish with transparent gonad wall; large yolky eggs becoming clearly visible and tightly packed (see Figure 6).
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 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; sperm release with light abdominal pressure
Post-spawn	Testes flaccid and bloody; sperm release still possible on application of abdominal pressure

Figure 5. A ripe male *Plectropomus areolatus*. Sperm is expelled by applying pressure to the abdomen, fingers sliding front-to-back along the fish. Males produce sperm before and after spawning periods; females with ripe eggs are better indicators of spawning seasons. (photo by S Seeto).

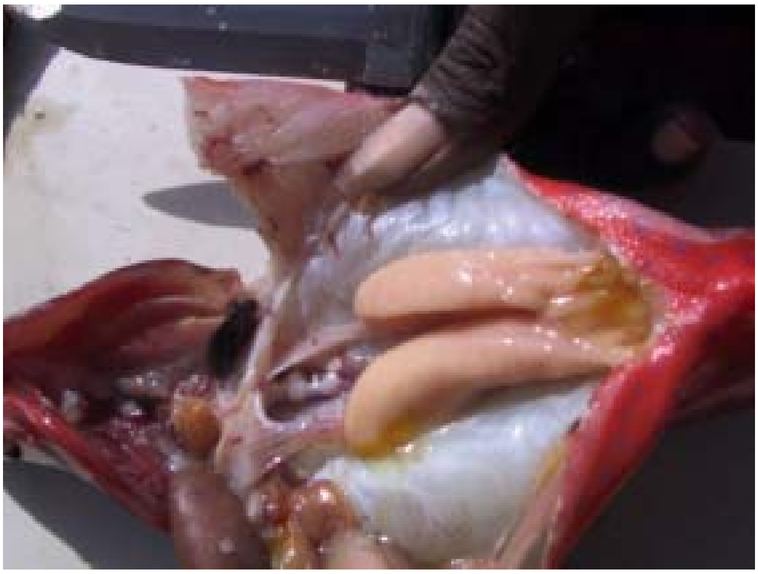


Figure 6. Mature, active female *Plectropomus oligocanthus*. Large, yellow eggs can be observed through the gonad wall. For the three target species, this stage of egg development is typically found only within the reproductive season, indicating that spawning is approaching (photo by S. Seeto).

Table 2. An example of a format to compile observations on the presence of ripe and/or mature fish during the year. Spaces are provided to fill in the total number of fish examined, the number of those that had eggs in late stages of development (see Table 1), and the nearest moon phase (as new or full moon).

	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)												

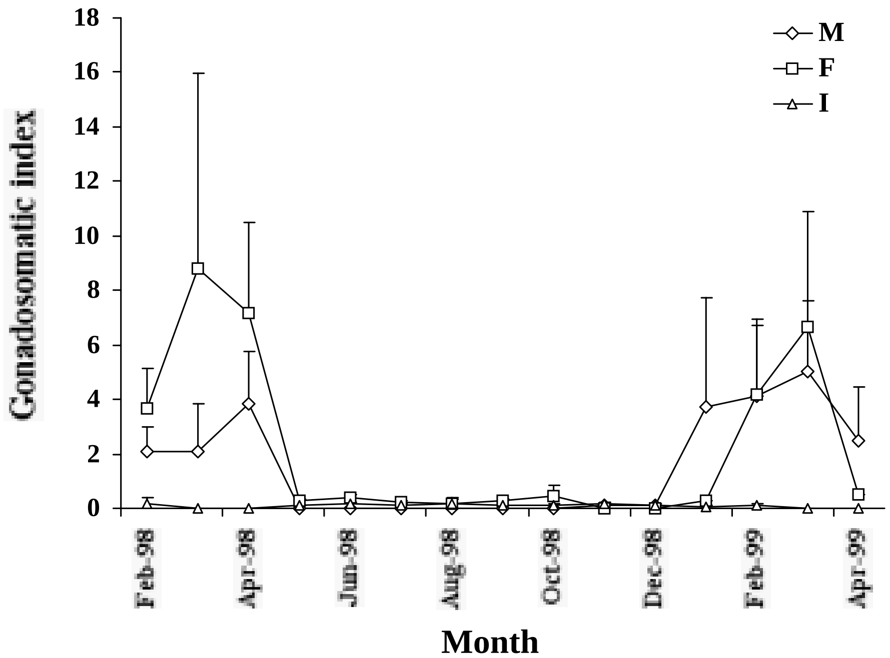


Figure 7. The reproductive season for *E. polyphekadion* as indicated by peaks in GSI values between February and April. Fish were samples from the Pohnpei fishmarket. M=male; F=female; I=immature. From: Rhodes & Sadovy (2002).

5 Mapping aggregation sites

Once a spawning aggregation site has been located, the next step is to map the site. Mapping is essential for estimating abundance.

Since GSAs are closely associated with the reef substrate within clearly defined areas and concentrations are often high, mapping is a relatively simple task. Mapping involves locating the GSA perimeters based on fish density, and calculating the area within those boundaries. To map the perimeter of the GSA site, divers swim a series of parallel, side-to-side straight lines through the aggregation and mark the boundaries of the GSA. The boundary is defined as the line around the GSA site where fish density drops to less than three times 'normal' density. At each boundary section, markers are placed so that the area can later be measured using a plastic measuring tape. Alternatively, a float line can be set to the surface to mark positions with the GPS (Rhodes & Sadovy 2002). Detailed bathymetric maps and aerial / satellite imagery (for instance with a scale between 1:100 to 1:1000) greatly facilitate mapping of the site (see Colin et al 2003 for examples). Once the site has been mapped to scale, the total surface area can be calculated.

After the site has been mapped, a decision must be made whether the complete site can be surveyed effectively. For smaller aggregations, the total number of fish within a GSA can be counted directly. For larger aggregations, fish abundance can be estimated by sub-sampling. Sub-sampling is done by counting fish in transects located within the GSA site. The total number of fish in the GSA can then be calculated as:

$$\text{number of fish in the transects} \times \frac{\text{total area of the GSA site}}{\text{surface area of the transects}} \quad \text{[Formula 2]}$$

Mapping must be repeated at least once a year to ensure that any changes in the size and shape of the aggregation site are recorded. This is especially important if changes in abundance cause the size of the aggregation to vary, while density of fish at the GSA site remains constant. In such situations, fish transect counts within the GSA may show little change while the total number of fish may be changing significantly. For smaller aggregations where the entire site is searched and all fish are counted, the exact shape of the aggregation is not as critical, as long as the complete aggregation is covered each time the number of fish is being counted.

For large aggregation sites that require sub-sampling, estimates of densities of various areas within the aggregation (core, periphery) will need to be compared before designing the final monitoring scheme. Areas within the aggregation that show consistently different densities from other areas need to be identified as 'strata' within the aggregation. Each area or stratum within the aggregation site should have at least one separate transect to estimate densities and the total surface area of the stratum need to be calculated to estimate sub-total of abundance within the stratum. Total abundance within the aggregation is estimated as the sum of the estimated abundances in each stratum. More detailed discussion of this can be found in Colin et al., 2003.

6 Estimating abundance

The total number of fish at the site determines how abundance should be estimated. Estimating abundance at small aggregations is a fairly straightforward process, whereas estimating abundance at large aggregations is more complicated.

6.1 Small aggregations

In small aggregations, all fish in the aggregation can be counted accurately. If fish are counted in groups of 5 or more, counting all fish may be possible for mid-sized aggregations of up to 500 fish, depending on the size of the site and the conditions during UVC.

Method: After mapping of the aggregation site, design a single transect that passes through the entire site in the most comfortable way without disturbing the fish. The transect does not need to be a straight line, and may meander through the site following the prevailing current as much as possible. Count all the fish seen in the aggregation. At regular intervals (e.g., annually), check the mapping of the aggregation site and adjust the transect to cover the entire aggregation. If the number of fish in a transect is lower than ca. 200, individual fish can be counted whereas for numbers exceeding 200 it is recommended that fish be counted in groups of 5 or more.

6.2 Large aggregations

In large aggregations (> ca. 500 fish), the number of fish is too large to accurately count all individuals. In this case, a sub-sampling approach must be adopted which involves counting fish in a known part (sub-sample) of the aggregation. To ensure sufficient precision in the estimated total number of fish in the GSA, we recommend sub-sampling a minimum of 10% of the total aggregation area (but preferably higher as resources allow). If a single transect covers less then 10% of the total aggregation, additional transects need to be positioned until the total area covered by transects is larger than 10% of the total aggregation site.

Method: Estimate the total area of the aggregation site for the target fish species (described above). Position one or more transects so that all areas or strata within the aggregation are represented. In other words, if it appears there are areas with higher and lower densities of fish, try to place transect(s) across all such areas to get a representative sub-sample of fish from the GSA. For large, highly concentrated GSA that may number over 1000 fish, record in groups of 5, 10, 20 and even 50 individuals. Use Formula 1 to calculate total abundance.

6.3 Transect methods

In the transect method, fish are counted within strips of reef of known length and width placed within the GSA. Transects can be fixed (stationary and used repeatedly over time) or random (positioned randomly during each monitoring occasion). Fixed transects are recommended for monitoring GSAs. Transects can be straight or curved as long as the area covered remains consistent over time, and end-points and transect boundaries are clearly marked (Figure 8). Details on transect methods, including statistical considerations, can be found in English et al.(1987), Samoilys (1997) and Labrosse et al. (2002). Forms for recording observations are provided in Appendix 3.

Transects should always be of constant length and width throughout the monitoring period. They should be positioned such that they represent the complete GSA site accurately. A typical transect for UVC on a GSA may be 100 meters long and 20 meters wide, depending on depth and associated light conditions, water clarity (visibility), site dimensions, current, and structural complexity of the reef. Trained observers are usually able to slowly swim a 100 m transect and do all recordings well within 25 minutes. During UVC the diver will try to swim roughly in the middle and slightly above the transect counting all this within the transect boundaries. To minimize disturbance to the fish, observers should always maximize the distance they swim above the transect line while still being able to accurately count fish. Swimming depths and survey time must never exceed safe diving limits.

Make sure that transects are clearly marked underwater to ensure that counts are conducted within the same transect every time. Re-bar 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. Enough time should be allowed between marking transects and counting, so that fish that were disturbed by marking of transects have time to revert back to their normal behavior. Each transect must be numbered and the transect number must be recorded on each data sheet.

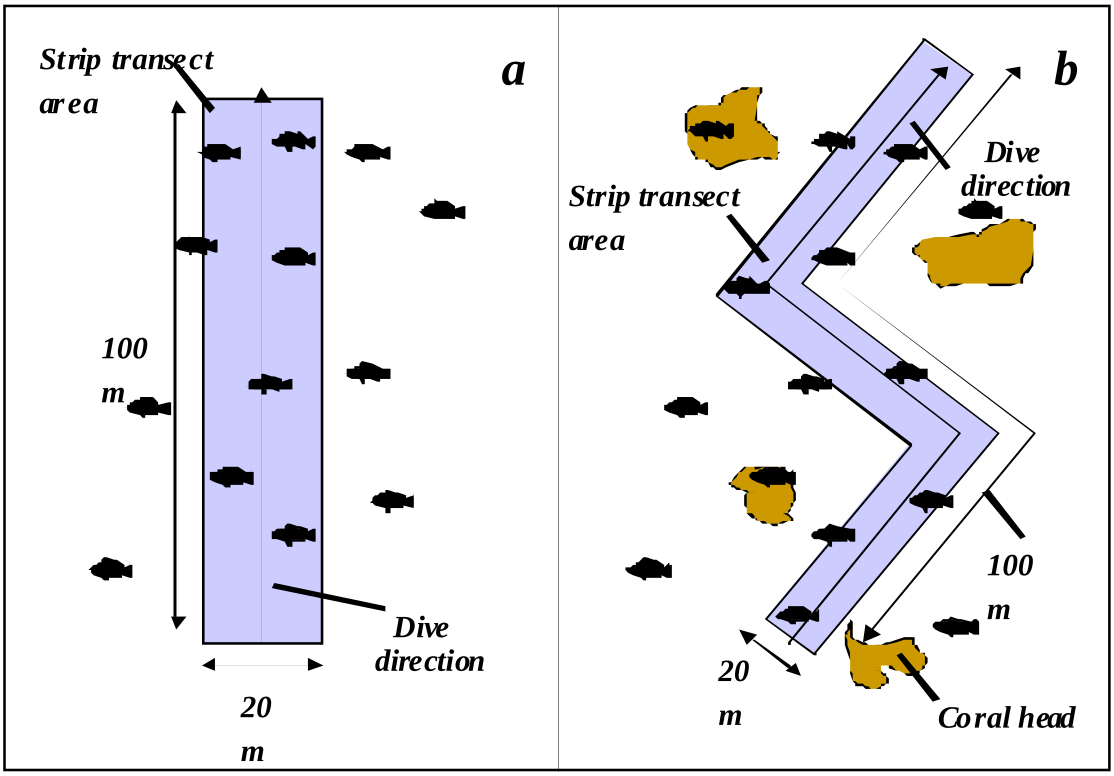


Figure 8. Fixed transects in (a) a homogeneous reef environment and (b) a reef environment dominated by high coral heads. Note the total distance and width of both transects is equal.

7 Estimating size structure

As commercial fisheries are often selective for larger fish and because fishing pressure reduces the life expectancy, and therefore length, of fish, a decreasing average length of fish in the population is an early warning for over-exploitation. Hence, estimating length of fish during UVC at spawning aggregations provides valuable information on the status of the population. Note that average body length of fish at a GSA may also vary due to natural factors, such as variation in year class strength or in growth. Nevertheless, a continuous decreasing trend in average body length in a fished population, such as shown in Figure 9, is a cause for concern for fishery managers.

Length estimation requires additional training of observers (see Appendix 2), especially since objects appear larger than above water when viewed through a diving mask underwater. Most field practitioners estimate length directly by eye, and some use a 1 m wide T-shaped bar constructed of 1.27 cm PVC pipe marked with 5 cm increments for reference (Nemeth 2005). Some researchers use laser pointers as a measuring aid (see Colin et al 2003).

Length estimations should all be in centimeters Total Length (TL), which is the length from the tip of the snout to the tip (end) of the tail.

Estimating lengths for all fishes in an aggregation is possible during a single dive for aggregations containing up to about 200 fish. For aggregations or transects containing more than this, it is recommended to estimate lengths of a sub-sample of 200 to 250 fish that are randomly selected while swimming through the entire transect. Trained observers can easily achieve this. A sample of 200-250 length estimates is sufficient to get a good indication of the length frequency distribution of all the fish in the transect.

Forms for recording observations on size structure are provided in Appendix 3.

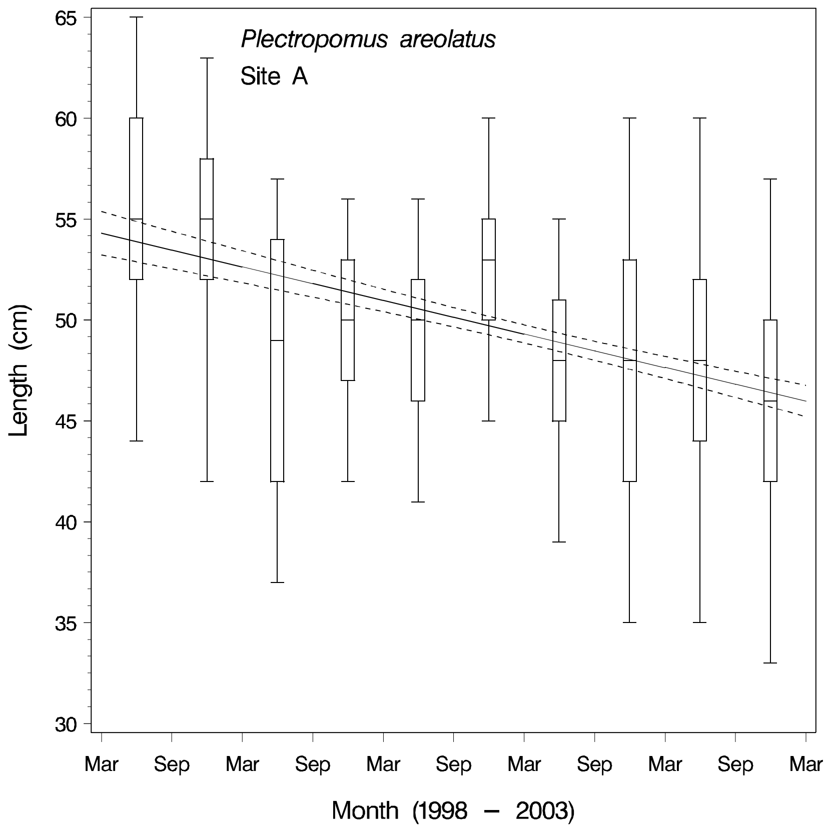


Figure 9. Decreasing trend in body length of *P. areolatus* at site 'A', a spawning aggregation site in Komodo National Park, Indonesia. Box-and-whisker plots represent 5th, 25th, 50th, 75th and 95th percentiles of body length observations grouped in six-month intervals (March – August, September – February, etc.). The solid trend line was fitted with linear regression analysis (body length vs. date), whereas dashed lines represent 95% confidence limits of the mean (P<0.0001, n=810).

8 Describing behaviors and signs indicative for imminent spawning

There have been few scientific observations of spawning of the three grouper species in the wild, possibly because two species (*E. fuscoguttatus* and *E. polyphekadion*) are believed to spawn at night and because actual spawning may last a few hours only. *E. fuscoguttatus* kept in fish pens in Indonesia spawn at night, mostly between 9 pm and midnight (Sudaryanto, Meyer & Mous 2004), but it is unknown if *E. fuscoguttatus* in the wild also follow this pattern. Gonad studies of *E. polyphekadion* in Micronesia have confirmed that this species spawns at night as well (Rhodes & Sadovy, 2002). In contrast, local fishers in Melanesia report that spawning of *P. areolatus* takes place during the day (Johannes 1989) or at dusk and dawn (Hamilton et al 2004). There was a single observation of spawning *P. areolatus* in Komodo National Park, Indonesia, which occurred during in the morning of July 1, 2000 (new moon) (J.S. Pet, pers. comm.).

In areas where aggregations form during full moon periods in shallow water with minimal current, direct observations of spawning may be possible. However, in areas where fish spawn during new moon in deep water and strong currents, the chances of witnessing spawning are greatly reduced. In such situations, SCUBA diving may be too risky for the monitoring team.

Therefore, other indicators must be used to determine whether a concentration of groupers has formed for spawning. Gonad analysis and fisher interviews are both excellent methods (see Section 4). Also, the size of the aggregation (up to several thousand!) by itself may be an indication of spawning, since these three species are not known to aggregate in such large numbers for any other purpose than spawning. In situations where gonad analysis and fisher interviews cannot be used, the function of the aggregation (i.e. feeding or schooling versus spawning) can be confirmed by recording and analyzing the occurrence of certain types of behavior or signs. These behaviors and signs include changes in body coloration that are typical for fish that are about to spawn, or presence of fish with swollen bellies from hydrated eggs. By analyzing temporal changes in the occurrence of these behaviors and signs, supporting evidence for the timing of the spawning season can be obtained.

Note that some researchers feel that current understanding of behavior of fish is still too scanty to apply this method. Therefore, observers are encouraged to take additional notes on behavioral patterns that may corroborate or contradict patterns described below, and to vigilantly look for opportunities to conduct gonad analysis.

8.1 Types of behaviors and signs that are indicative for imminent spawning

The types of behavior, besides spawning itself, used to determine GSA activity include (1) aggression between individuals (including territorial disputes), which is often associated with changes in body color; (2) courtship between sexes; and (3) presence of gravid females. Obviously, (3) is a sign rather than a behavior, but it can be observed and analyzed as such together with (1) and (2).

Aggression, typically associated with territorial disputes among males, often results in clear bite-marks on the fish (patchy scrape marks in *Epinephelus* sp. and puncture fang marks in *P. areolatus*). Aggression can also be deduced from behaviors such as chasing, biting, fighting and body color change. For all three species, the color of large parts of the body may pale rapidly, contrasting with the dark extremities of the fins. For *E. fuscoguttatus*, the pale color is most apparent on the lips, chin, cheeks, belly and tailfin (Figure 10). For *E. polyphekadion* and *P. areolatus* most of the body turns very pale with *E. polyphekadion* showing a clearly contrasting black saddle on the caudal peduncle (Figure 11, Figure 12) and *P. areolatus* showing a clear black margin around the tailfin (Figure 13). *P. areolatus* females in the spawning aggregation have a purple-olive color with very clear spots and tailfin with a lighter margin. *P. areolatus* has six distinct color phases, three of which are shown in Figure 14.

Color change in males during courtship is similar to that displayed during fighting with other males. When courting, males swim in a very distinct manner: on their side while wobbling and quivering. On the days just prior to spawning, females have swollen bellies that are particularly obvious (see Figure 11).

Generally speaking, males of the three grouper species discussed are larger than females although there is size overlap between the sexes.

8.2 Using occurrence of behaviors and signs to help define the spawning season

Imminent spawning is indicated when the relative frequency of occurrence (RFOO) of the aforementioned behaviors and signs increases to at least three times the RFOO commonly observed in the population. The *increase* in RFOO, rather than the actual value of RFOO, is particularly important for aggression, as this behavior may not always be associated with reproductive behavior. The RFOO is calculated as the frequency of occurrence of aforementioned behaviors divided by the total number of fish observed.

The following is a hypothetical example of how RFOO can be used to determine that spawning is imminent. Suppose that generally two occurrences of each of the above behaviors are recorded in 50 fish present at a GSA site. If during a certain month 180 fish are found at the same site, and if 25 occurrences of each of the above behaviors were recorded, this would qualify as a sign of imminent spawning because RFOO increased more than threefold (from 0.04 to 0.139). However, if instead six occurrences would have been recorded in an aggregation of 150 fish, this would NOT have qualified as a sign of imminent spawning, because RFOO = 6/150 = 2/50 = 0.04 .The case is strongest when RFOO of all three behaviors increase threefold, and weakest if only ‘aggression’ shows such increase.

Figure 10. Color change in *E. fuscoguttatus* during intra-specific aggression. The aggressive male on the left just chased off the fish on the right. Clearly shown are the white lips, chin, cheeks, belly and tailfin with black margin (photo by B. Kahn).

Figure 11. Behavior and body characteristics used for determining imminent spawning in *E. polyphekadion* (from left to right): grouping; territorial disputes, and; gravid female (photos by A. Smith)

Figure 12. Color change in *E. polyphekadion*, presumably males, during territorial aggression is shown in the fish on the right. Note the black saddle on the caudal peduncle (photo by K. Rhodes).

Figure 13. Color change in *P. areolatus* after aggressive interaction. Clearly shown are the partially pale body and tail fin with the black dorsal, anal and pelvic fins and black margin of the tailfin. Males turn even paler when quivering and courting a female.

Figure 14. Three of six color phases in *P. areolatus* (from left to right): bicolor (males and females); camouflage (males and females); yellow/green phase (females) (photo A. Smith).

8.3 Merits of video recording

Underwater video recordings can be very useful since they allow the monitoring team to review their assessments, looking for nuances in behavior and assessing the accuracy of data. The ability to view aggregations in slow motion or frame-by-frame enhances understanding of the situation. Video also allows recording of aggressive behavior, color changes, bite-marks, courtship, gravid females, changes in habitat, and other occurrences at the aggregation site

Video recordings of GSA can also be used for training of new monitoring staff. Last but not least, collected footage is great material for outreach programs.

9 Designing a monitoring protocol

Sections 6, 7 and 8 explain how to measure abundance, size structure and behavior using UVC. This section explains how to combine these three methods into a single sampling protocol. Advice is provided on determining timing and frequency of sampling, and which GSA sites to sample if there is more than one site in the area of interest. Protocols will differ between situations depending on the characteristics of the aggregation (particularly size), and available resources (personnel, funds). This section provides some general guidelines, and a specific example of a monitoring protocol developed for a large and complex aggregation is provided in the Appendix 1.

9.1 Timing of field work in relation to formation of grouper spawning aggregations

GSA abundance varies between years, between months within years, between days within months and even within single days (Johannes et al., 1999; Rhodes & Sadovy 2002). Months of highest abundance are referred to as ‘peak’ months (Figure 15).

Abundance changes daily within spawning months (Figure 16). 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. Duration of ‘build-up’ and ‘decline’ periods range from as short as several days to as long as two weeks, and the duration of these periods varies between locations and species.

Spawning day(s) for our target species usually fall on full or new moon of each month of the spawning season, or one to three days before. Therefore, monitoring should be conducted at least one full week before both new and full moon for several months of the presumed aggregation season in order to identify the most reliable day to record peaks in aggregation abundance.

Finally, abundance estimates may change within days during the spawning period. Highest abundance is thought to be during the afternoon or evening periods when most fish have come out of hiding, and some experts find that lowest abundance is usually around noon. Fish in GSAs are also most active during the afternoon and evening, which is when courtship and aggressive behavior can best be observed. Therefore, afternoons are best for monitoring, when conditions (i.e. tidal currents) allow. Where safety precautions allow, for instance in areas without strong currents, monitoring in the evening would also be an option.

Because of the temporal variations in abundance, practitioners must be consistent in timing of monitoring activities with respect to month, lunar date and time of day. Only in this way can valid comparisons be made over time. If the monitoring objective is to compare peak abundance between years for management decision-making, practitioners must first identify the seasons that are most likely to include the month of peak abundance. Since the timing of peak abundance may vary from year to year, monitoring must comprise a period of several months around the most likely peak month. For example, based on the hypothetical data shown below (Figure 15 and Figure 16), monitoring should be conducted around the full moon during the months of July and August, possibly with extra months at beginning and end of this period to allow for variations in seasonality.

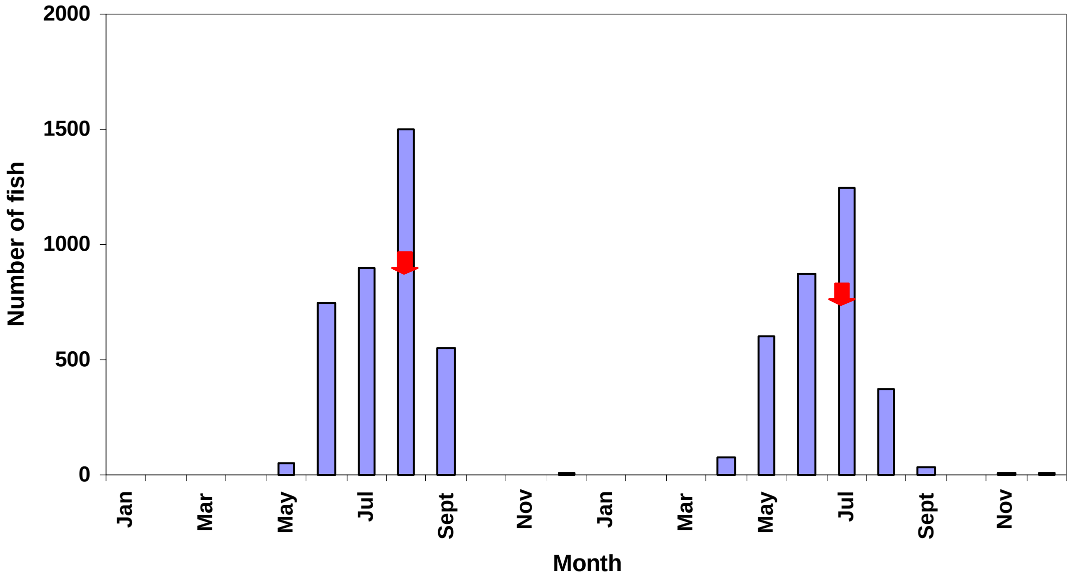


Figure 15. Seasonal variation in fish abundance on spawning sites, demonstrating between-year variation in timing of initial month of aggregation formation and peak aggregation month. The peak aggregation month is August in Year 1 and July in Year 2, detected by monthly monitoring.

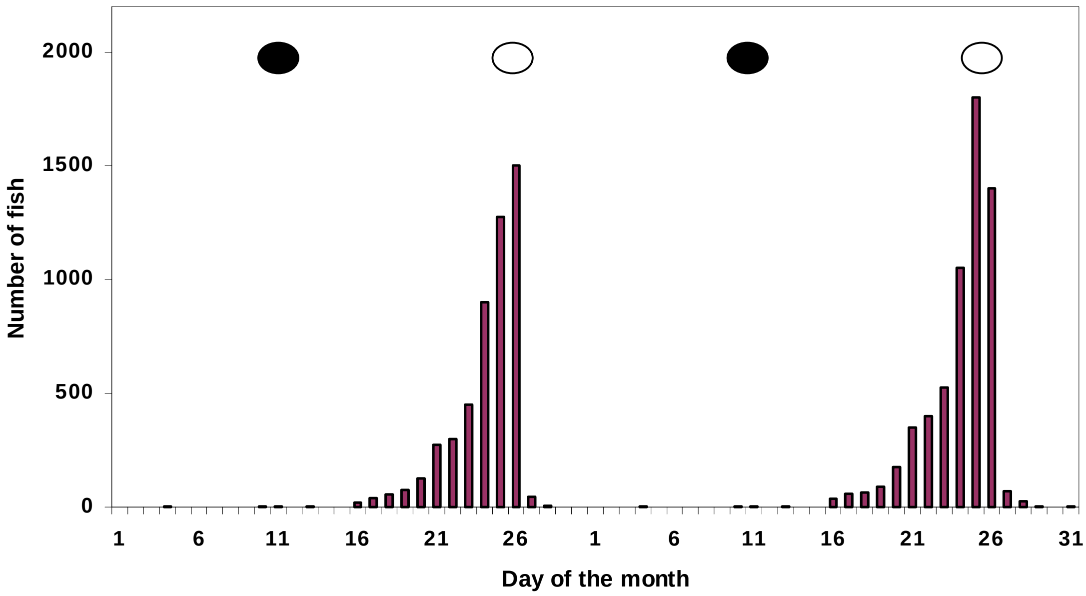


Figure 16. A typical pattern in aggregation build-up and decline. In this hypothetical example spawning occurs around full moon.

9.2 What if there is more than one grouper spawning aggregation site?

Often, the area of interest may have more than one known GSA site. If resources are limited a decision must be made regarding which sites can be monitored. The following approach is recommended:

Step 1: Assess how many field days you can afford with available time and resources.

Step 2: Determine the minimum number of days required for each site and when (see Section 9.1)

Step 3: If the number of days required to survey all sites exceeds the number of available field days, select highest priority sites for monitoring using the following criteria:

- Aggregation size (if the area of interest has large and small GSAs, large GSAs are a higher priority for monitoring).
- Threat level (threatened GSAs are a high priority for monitoring to assess whether management is required).
- Management status (sites where management is implemented are a high priority for monitoring, because they require assessment of management performance as well as guidance for adaptive management).
- Cost and practicality of monitoring (deep sites exposed to strong currents may be difficult to monitor and sites far from the home base of the monitoring team may be too expensive to monitor regularly).

9.3 Taking observations on abundance, size structure and behavior

Since dive safety procedures require monitoring on SCUBA by buddy pairs, at least two divers are available for taking observations. This means that tasks can be divided between the two divers. One observer can count fish for estimating abundance, while the other can estimate fish sizes and make behavioral observations. Estimating abundance is the most important and difficult task and should not be mixed with other tasks. When three divers are available for each transect, one diver can be allocated to each of the three tasks (estimating abundance, size estimation and behavioral observations).

10 Data handling for abundance, length frequency and behavioral observations

In sections 6-9, UVC methods are provided for estimating abundance, length-frequency distributions and relative frequency of behaviors. This section provides guidance on recording, processing and interpreting data from those surveys.

10.1 Data recording and field forms

An example of a field form for recording abundance is presented in Figure 18. This field form is designed to record data from one species and one transect. To maintain sufficient accuracy, observers should not attempt to count more than one species at a time or on any one dive. The header of the form contains, amongst others, specifics on the place (site and transect) and time that monitoring took place. Lunar dates correspond to days 1 through 30 on the lunar calendar, with new moon = Day 1 and full moon = Day 15. The lunar date increases by 1 day until Day 30, which corresponds to the day before new moon. This information can be found in any nautical almanac. Time should be given as military time (i.e. 0000 to 2400 hrs). Visibility is estimated as the distance (in m) that divers can see underwater horizontally. The body of the form contains the observations on abundance. While the observer swims along the transect he or she tallies the number of groups of fish containing 1, 5, 10, 20, or 50 fish. The column with totals is filled in after the dive.

An example of a field form for recording length-frequencies is presented in Figure 18 (bottom panel). This form is designed to record data from one species and one transect at the time – observations from additional species and transects need to be entered on separate forms. The header of the form contains the same information as the abundance recording form. Individual lengths for each fish are tallied for each size category of 5 cm width.

Observations on spawning or spawning behavior are tallied as number of individual observations on the bottom of the form for recording length frequency. This form is designed for the situation where one observer takes observations on both length-frequency and behavior. If a separate observer takes observations on behavior only, he or she can use a second copy of the field form.

Figure 17. Slates made out of PVC pipes that are put over the lower arm of the observer. This type of slate is convenient for use in areas that are prone to strong currents.

Instead of normal flat slates, PVC pipes can be used for UVC data recording in areas with strong currents (Figure 17). Field forms are photocopied or printed on plastic paper (preferably with a laser printer). Data are recorded underwater with pencil. Field forms can be re-used once data after data have been copied.

Site No: ____________ Time: ____________ Date: ____________

Species: ____________ Transect No.: ____________

Observer name: ____________ Visibility: ____________

Lunar date: ____

Group	Frequency	Total
1		
5		
10		
20		
50		
Total		

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 18. Field forms for recording abundance (top) and length-frequency and behavior (bottom) during UVC at a grouper spawning aggregation site. Full-sized versions for photocopying are included in Appendix 3.

10.2 Data processing

Scientists often apply sophisticated statistical methods to analyze data from GSAs, but simple data processing methods can also provide useful information for management. Spreadsheet programs such as Microsoft Office Excel greatly facilitate computation, but each of these calculations can also be conducted using a calculator. Basic data processing involves the following steps:

1. Calculating total abundance at the site.
2. Calculating the length-frequency distribution from all fish at the site.
3. Calculating the relative frequency of occurrence of behaviors at the site.
4. Graphing data to facilitate interpretation.

This section provides simple formulas and examples for each of these calculations, whereas interpretation of results is discussed in Section 10.3.

Calculating total abundance

If a single transect is used to assess an aggregation, total abundance at the site can be calculated as

$$\text{number of fish in transect} \times \frac{\text{total area of the GSA site}}{\text{area of the transect}} \quad \text{[Formula 2]}$$

This computation is based on the assumption that the transect is representative of the GSA as a whole. The term (total area of the GSA site) / (area of the transect) is sometimes called a raising factor. As mentioned earlier, the total area of transects should be 10% of the GSA site or more, and therefore this raising factor should be lower than 10. If the raising factor is higher than 10, more transects should be added.

Note that if more than one transect is counted, the 'number of fish in the transect' becomes the 'number of fish in all transects', whereas the 'surface area of the transect' becomes 'the sum of the surface areas of all transects'. For example, if there are three transects (tr1, tr2 and tr3) computation of total abundance becomes:

$$(\text{number of fish in tr1} + \text{number of fish in tr2} + \text{number of fish in tr3}) \times \frac{\text{total area of the GSA site}}{\text{area tr1} + \text{area tr2} + \text{area tr3}}$$

[Formula 3]

This computation is based on the assumption that all transects combined are representative of the GSA as a whole.

A calculation example for three transects:

total surface area of the GSA site = 25,000 m^2

surface area of each transect = 2000 m^2 (100 m long and 20 m wide)

number of fish in transect 1 = 153

number of fish in transect 2 = 98

number of fish in transect 3 = 123

Therefore total abundance is (153 + 98 + 123) X (25,000 / (3 X 2000)) = 374 X 4.167 = 1,558

Calculating the length-frequency distribution of all fish in the GSA

The length-frequency distribution of all fish in the GSA can be calculated by first calculating a length-frequency distribution where the number of fish in each size class is expressed as a proportion of all fish included in the length-frequency sample:

$$\text{proportion of fish in a size class (e.g. 36 – 40 cm)} = \frac{\text{number of fish in that size class}}{\text{number of fish in all size classes}}$$

[Formula 4a]

This can be converted to a length-frequency distribution of all fish at the GSA using the following formula:

$$\text{total number of fish in a size class} = \text{total abundance} \times \text{proportion of fish in that size class}$$

[Formula 4b]

A calculation example:

Subsample of fish for which length estimates were obtained:	Hence, the total number of fish in each size class becomes:
fish in size class 36 – 40 = 1	total fish in size class 36 – 40 = (1 / 153) X 1,558 = 10
fish in size class 41 – 45 = 15	total fish in size class 41 – 45 = (15 / 153) X 1,558 = 153
fish in size class 46 – 50 = 17	total fish in size class 46 – 50 = (17 / 153) X 1,558 = 173
fish in size class 51 – 55 = 21	total fish in size class 51 – 55 = 214
fish in size class 56 – 60 = 30	total fish in size class 56 – 60 = 305
fish in size class 61 – 65 = 26	total fish in size class 61 – 65 = 265
fish in size class 66 – 70 = 23	total fish in size class 66 – 70 = 234
fish in size class 71 – 75 = 15	total fish in size class 71 – 75 = 153
fish in size class 76 – 80 = 5	total fish in size class 76 – 80 = 51
total fish in transect = 153	
total abundance = 1,558	

Calculating relative frequency of occurrence

The relative frequency of occurrence (RFOO) of a behavior is calculated by dividing the occurrence of a certain behavior with the total number of fish observed. Note that for the purposes of this manual, presence of a gravid female is considered a behavior. Hence, the formula for calculating RFOO is:

$$\text{RFOO of a behavior (e.g. courtship)} = \frac{\text{number of fish showing that behavior}}{\text{total number of fish observed}}$$ [Formula 5].

A calculation example:

Observation on fish in the transect:	Calculation of RFOO:
fish showing spawning: 0	$RFOO_{spawning} = 0 / 153 = 0$
fish showing aggression: 12	$RFOO_{aggression} = 12 / 153 = 0.078$
fish showing courtship: 23	$RFOO_{courtship} = 23 / 153 = 0.15$
number of gravid females: 55	$RFOO_{gravid} = 55 / 153 = 0.36$
total number of fish observed: 153	

10.3 Presentation and interpretation of data from baseline surveys and long-term monitoring programs

Timely and clear feed-back to managers (or co-managing users) on the status of GSA's can make all the difference between losing or conserving an aggregation and associated fishery. This section provides guidance on how to present and interpret data in an insightful and useful manner. The graphs presented in this section, though based on fictitious data, provide examples of what real data may look like. Monitoring teams may use these graphs as guidance to make similar graphs based on their own data.

Baseline surveys

The first year of conducting UVC will provide practitioners with baseline information on spatial and temporal patterns within GSA sites, which can be used to develop an efficient long-term monitoring program. The minimum information required is a detailed map of GSA sites and locations, including site dimensions and aggregation areas. The baseline survey 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 based on temporal patterns of abundance and relatively frequency of occurrence of key behaviors. It is also important to present length-frequency distributions, which become more meaningful for management after several years of monitoring when trends become apparent. Examples of how to clearly present baseline data are presented in Figure 19, Figure 20, Figure 21 and Figure 22. An interpretation of the data is provided in the caption for each figure.

Long-term monitoring

Long-term monitoring provides information on trends in aggregation abundance and size distribution for decision-making in management. Fish populations experience short- to medium-term natural fluctuations and only long-term monitoring, covering a period of more than 5-10 years, can 'tease out' trends that are meaningful for management. Variations in abundance between years can be caused by a number of factors, such as fishing, as well as natural variations in year class strength and mortality. Furthermore, changes in sampling design may cause variance in abundance estimations – a reason for keeping the monitoring program consistent throughout the years. Because of the variety of possible factors that may cause year-to-year variation, long term trends must be interpreted with caution. Examples of how to clearly present data from long term monitoring are presented in Figure 23, Figure 24 and Figure 25. An interpretation of the data is provided in the caption for each figure.

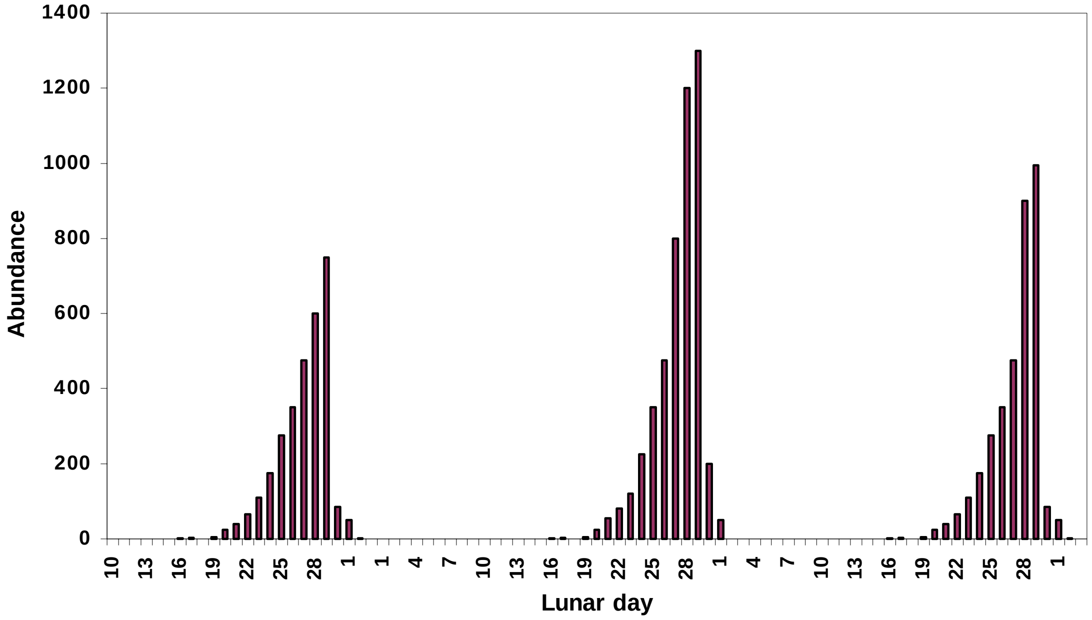


Figure 19. Hypothetical results from a baseline UVC, showing how abundance at the GSA site varies with lunar day. There is a consistent pattern in the lunar days, with day 29 exhibiting peak abundance. Monitoring for this species is best conducted on lunar day 29.

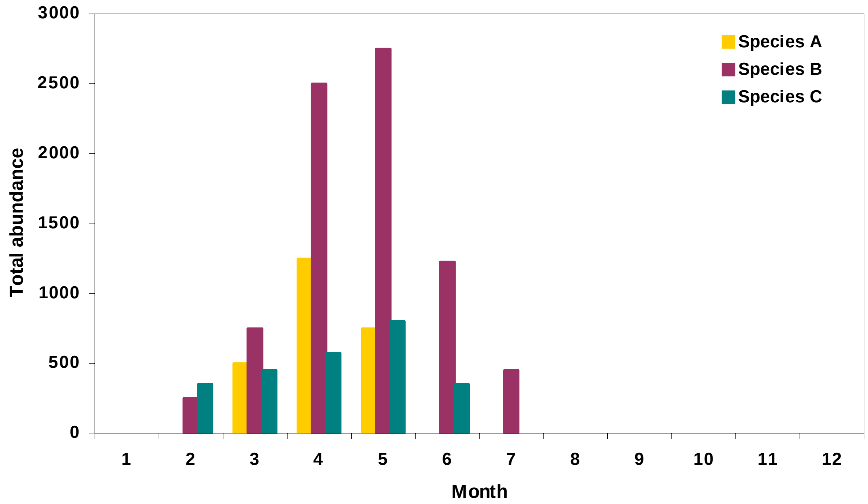


Figure 20. Hypothetical results from a baseline UVC, showing variation in the timing and duration of the spawning season among three species. Note that maximum abundance occurs on different months for different species. These results suggest that long-term monitoring should be conducted from months 1 to 8, since aggregation timing may move one month either way in different years. If time and resources are limited, monitoring should occur around peak months only (months 3 to 6).

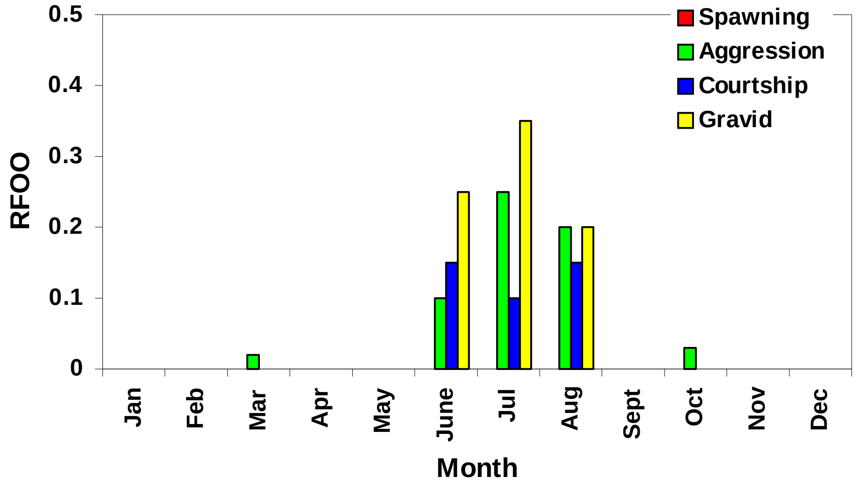


Figure 21. Hypothetical results from a baseline UVC, showing the relative frequency of occurrence of four behaviors and signs that are indicative for spawning. The more than three-fold increase in the relative frequency of occurrence of these behaviors in the period June – August indicates that spawning took place in those months. Therefore, long term monitoring should focus on those months.

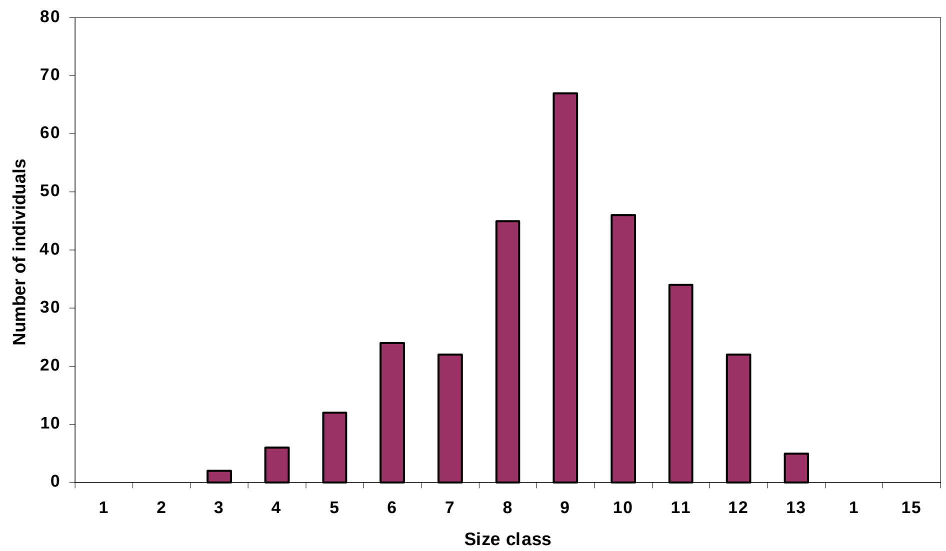


Figure 22. Hypothetical results from a baseline UVC, showing the length frequency of one of the grouper species during a peak aggregation month. This single length-frequency distribution provides some information on the status of the GSA (especially if it can be compared with other populations of the same species elsewhere). However, long-term monitoring provides better information on the status of the GSA. In particular a trend towards smaller individuals may signal over-exploitation, requiring management action. Note that changes from year to year may also occur because of differences in survey time relative to the time when the smaller females and larger males arrive at the GSA site or because of natural variations in year class strength.

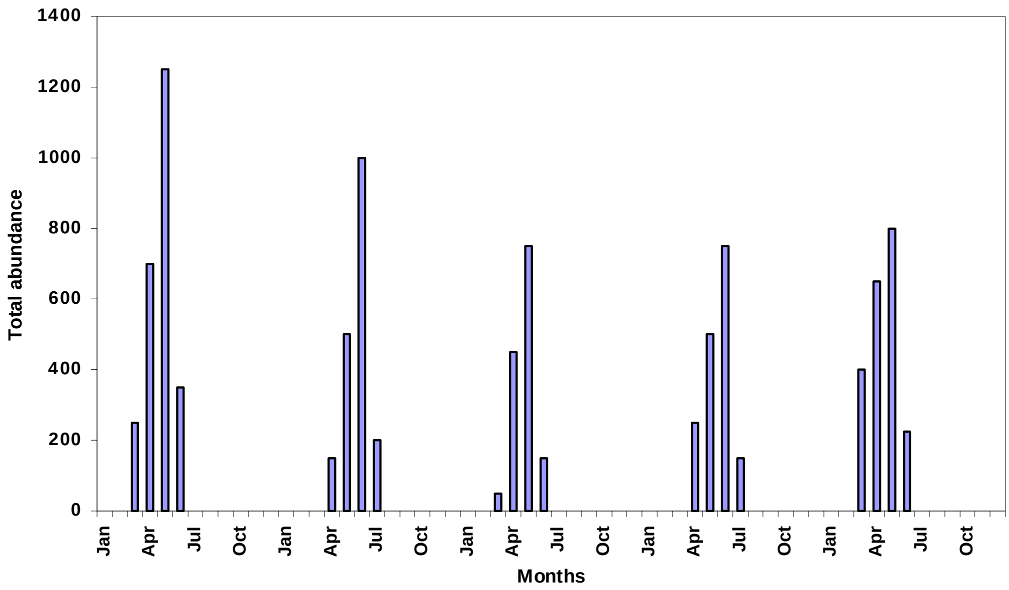


Figure 23. Hypothetical results from long-term monitoring of a GSA, showing consistency in the number of months within the spawning season, but variation in the onset of aggregation formation. Furthermore, the results suggest that abundance decreases in the first three years, after which abundance seems to stabilize.

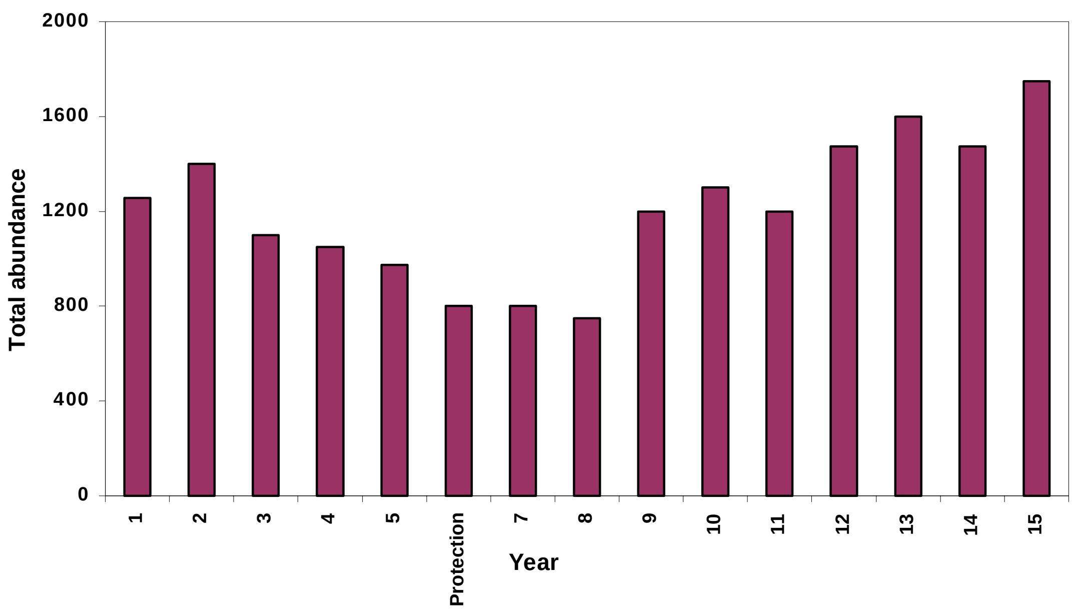


Figure 24. Hypothetical results from long-term monitoring of a GSA site that was closed for fishing in year 6. After the closure abundance increased, suggesting that this management measure was effective.

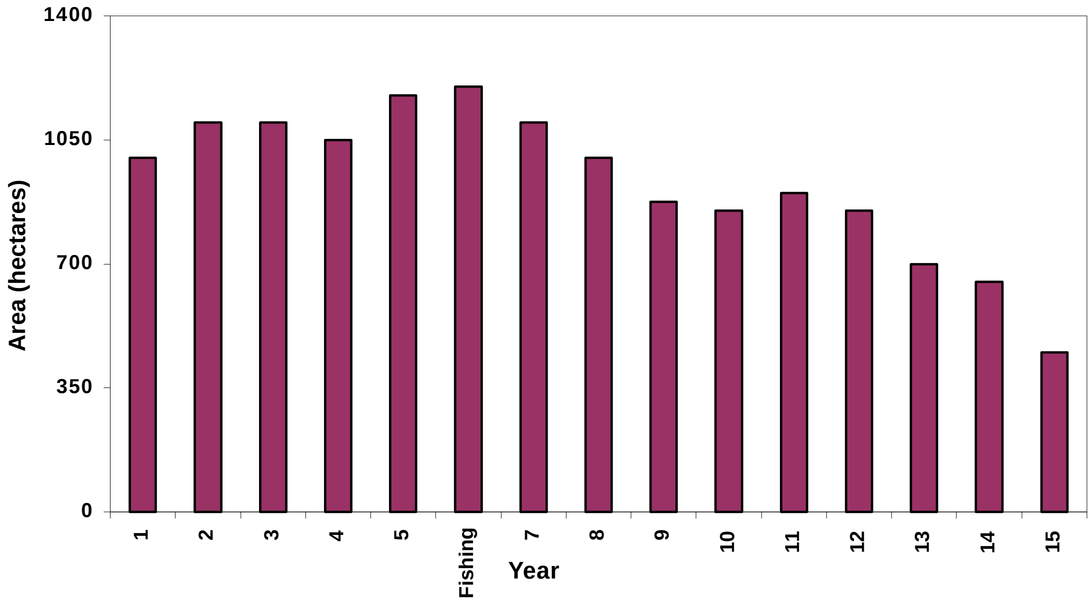


Figure 25. Hypothetical results from a long-term monitoring program of a managed GSA site, where every year the area of the GSA was measured. After the management allowed for fishing in year 6, aggregation area decreased. This suggests that this level of fishing intensity cannot be sustained, and that therefore fishing may have to be ceased. These results are cause for concern, but before final conclusions can be drawn these data should be combined with fish abundance measures to confirm that the number of fish in the aggregation is decreasing.

11 Reporting results

After data analysis has been completed, an important task remains: reporting and dissemination of results to various audiences. The monitoring team, sometimes assisted by communication specialists, plays an important role in this process.

The following sections describe how to develop a communication strategy for reporting results, including information requirements from different audiences and which communication tools may be used to reach those audiences.

11.1 Developing a communication strategy

In reporting results, it is very important that results are presented in the most appropriate format for the target audience (Table 3). Often, monitoring results are published in scientific, peer-reviewed journals. While this may be appropriate for reaching a scientific audience, it is not the best way to reach others (including resource managers, policy makers, and users) who rarely read scientific papers.

The best approach is to develop a communication strategy that clearly identifies:

- target audiences;
- information requirements (key messages to be disseminated);
- communication tools (the best methods for the target audience); and
- dissemination plan (when and how frequently the messages should be disseminated).

The communication strategy should also consider costs. Given the importance of reporting results to key stakeholders, a significant part of the total monitoring budget should be allocated to this task.

Table 3. Most appropriate communication tools (rows) for target audiences (columns).

	Resource 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			
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, e-mail lists		X	X	X[2]	X	X

Notes
1. The 'general public' here includes media that provide information to the general public
2. Only users that have access to the Internet

11.2 Target audiences

Natural resource managers and policy makers

Managers are one of the most important audiences, since they will use the information to make management decisions regarding the resource. The following information is most relevant to managers:

- Status of, and trends in, the spawning population (abundance, size composition and species composition).
- 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 may have resulted in a decrease in abundance in the spawning aggregations at sites X, Y and Z'
- Implications for 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 stocks recover: (1) Expand no-take zones around the aggregation site, (2) ban all fishery on the spawning aggregation site, (3) restrict dive tourism, etc.'.
- In situations where managers are also managing the monitoring team, operational issues and logistic challenges for monitoring are also relevant.

Only if information reaches the manager in time can it be used to make management decisions. A concise report produced in a timely manner is much more useful than a more complete report that took a lot longer to prepare! If dramatic changes are detected during the monitoring program, it may even be necessary to notify managers immediately, long before a technical report is finalized. As managers often need quick access to information, and because they usually do not have time to read reports in detail, it is important to include an executive summary in the report that summarizes major conclusions and management recommendations as bullet points. For higher-level managers and policy makers it is important to include a cover letter when sending the report, which summarizes one or two major conclusions and recommendations to gain their attention and increase their interest in reading the report.

Peers (colleagues and other monitoring teams)

All too often, reports are forwarded only to the direct supervisor or manager of the monitoring team and do not reach peers or other stakeholders who need to see them. It is important to share findings with colleagues who are involved in other components of a conservation program (surveillance, community outreach etc.). Furthermore, monitoring teams who are doing similar work at other sites should be regularly updated on progress and key findings, which provide great learning opportunities for both parties.

Scientists

Monitoring teams must frequently communicate with scientists who work in the same field, and share technical reports with scientists with whom there has been previous correspondence. Direct communication with scientists who are not directly involved in the monitoring program can help tremendously by putting monitoring results in a broader context. 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 publications in scientific and technical journals, and by presentations at scientific conferences. 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 to assist with this process.

Users

It is essential that resource users (eg fishermen, tourist operators etc) are involved in the management of the resources on which they depend. This means that resource managers and users must develop a common understanding of the state and trends in the resource, and monitoring results play a pivotal role in this process. Users generally do not require as much detail as managers, but as their knowledge of the resources can be considerable and they can often absorb more technical or local information than other groups such as 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 they require and how this information should be presented. Usually, donors require operational information that documents how the money was spent, and provides detail on how the information was collected rather than the results themselves. 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 these reports. For reasons of efficiency, information for reports to donors should be gleaned from other communications as much as possible.

General public

The ‘general public’ includes all groups in society that do not have a direct stake in the resources that are being monitored. As such, this audience requires much less detailed information than the audiences listed above. As the general public are generally interested in nature, the monitoring program may provide an opportunity to bring management issues to the attention of the general public. In many organizations, a Communications Expert coordinates outreach to the general public, and the monitoring team is only required to provide information for press releases. Nevertheless, the monitoring team should take a pro-active role by informing Communications Experts about any findings or results that may be of interest to the general public.

11.3 Communication tools

Personal contact

Direct personal contact includes, besides talking to people in person, attending or holding meetings, 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 communicate the results of the monitoring program, and to receive direct feedback from stakeholders. 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.

Technical reports

Technical reports are often the primary means of reporting monitoring results to many audiences, and should be produced at least annually. The report should describe results from the most recent monitoring period, and compare those results with previous monitoring periods, as well as with results from similar monitoring programs in the region.

Technical reports should comprise the following components:

- A Title should be used that clearly describes the contents of the report, including the name of the study area, species monitored, and the monitoring period. For example, “Spawning and aggregations of groupers (Serranidae) and Napoleon wrasse (Labridae) in the Komodo National Park. Monitoring Report March 1998 – March 2001.”
- A Table of contents,
- An Executive summary that summarizes key findings and recommendations in a few pages. The executive summary may include a selection of some of the most insightful figures from the Results section of the report
- An Abstract that summarizes the field work and main conclusions in ca. 200 words. The abstract should be stand-alone, i.e. the reader should be able to distill the gist of the report from the abstract alone.
- The Introduction should describe the objectives of the monitoring program, and some background information (including species monitored, the history of the site and the fishery, general descriptions of the spawning aggregations and their vulnerability).
- The Methods should describe where, when, how, and who did the monitoring. This section should include an illustration of the site (if public knowledge) and the general location of

transects within the site. It is important to note specifics on the months, days, time and lunar phase that monitoring was conducted.

- The Results should provide the main findings of the monitoring program with results summarized in tables and graphs with some written explanations for each.
- The Discussion should provide an unbiased interpretation of results and an opportunity to make recommendations for management. References can also be made to the results of other similar monitoring programs to provide support for the interpretation of results.
- The References should provide citations for the reports, manuals and scientific papers referenced in the report.
- Appendices may be included to present samples of field forms, activities reports, expense reports, raw data in tabular format etc.
- Acknowledgements are important to recognize assistance from peers, technical advisors, supporting agencies, donors, and implementing partner organizations.

Scientific publications

Benefits of publishing 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. Each scientific journal has a specific formats they use, which can be obtained directly from the journal itself, usually in the 'Instructions to authors' section.

Press releases

Press releases are required if it is expected that there will be considerable interest from the general public for a particular issue that involves a GSA. This is particularly important for issues that are urgent and possibly controversial, when it is important that all communications are clear, consistent and accurate. 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 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 sheets

Information sheets provide general information on the monitoring program including objectives, how it is carried out, and key findings. Usually they are intended for awareness raisinge rather than for disseminating technical information, however information sheets are also a great way to provide a quick update to various audiences while the technical report is being finalized. Information sheets are usually up-dated once every two years or more, and must contain a clear reference to where more information on the monitoring program can be obtained.

Fact sheets and leaflets

Fact sheets differ from information sheets in that they contain less narrative and more technical information. Fact sheets are often produced to inform users and field staff on characteristics of a vulnerable species, or on regulations pertaining to a certain area. Care must be taken that the contents are up-to-date, especially where the information relates to regulations 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.

Newsletters

Some organizations issue newsletters (mostly quarterly) that provide updates on the organization, their projects, the people working in the organization, and upcoming events. If such a newsletter exists, the monitoring team should make it a matter of routine to 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 boards

Bulletin boards can be an effective way to disseminate newsletters, information sheets, fact sheets and leaflets, especially in rural areas. 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 maintaining bulletin boards, they do need to be aware where bulletin boards are placed and consider whether the may be helpful to disseminate information on the monitoring program.

Television and radio broadcasts

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 key findings of the monitoring program

Web sites and e-mail lists

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 in this way, which excludes most resource users in remote 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 additional work required by project staff. E-mail lists - compilations of e-mail addresses, often organized by area of interest – are a great way to to more directly reach out to target audiences. The advantage over websites is that the targeted audience receives the information along with other e-mails, saving the receiving party the trouble of going on-line to visit a website. E-mail lists are not suitable to distribute large documents if some of the recipients have a slow or unreliable Internet connection. Dissemination of information through the Internet may save costs for photocopying and printing.

12 Training

Any monitoring program should begin with training to ensure that the monitoring team has the necessary skills and expertise to conduct monitoring with a reasonable degree of accuracy. This should include training on species identification, mapping, estimating abundance and size, behavioral observations, and assessing gonad maturity stages. Training should also include data recording and processing, as well as presentation and interpretation of results. Training for UVC of GSAs should begin with sessions on the land, followed by training sessions underwater.

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 conduct a UVC monitoring program. Those practitioners who manage to gain the skills to conduct UVC of GSA must also undergo occasional re-training to refresh, 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 monitoring period (often just before the start of the groupers' reproductive period).

Initial training should be undertaken with an experienced trainer, who can demonstrate methods, answer any questions the team may have, and help streamline procedures to suit local conditions. Subsequent extercises to refresh monitoring skills may be conducted independently by the monitoring team.

The sections below provide guidance for conducting training for monitoring GSAs of *E. fuscoguttatus, E. polyphekadion* and *P. areolatus*. Materials required for training are listed in Appendix 2.

12.1 Species identification

Training in species identification can be achieved in several ways. First, the trainer and trainees should go through the photographs and key features described for each species in Sections 3 and 8. Trainees should also consult fish identification guides and video footage presented during the training sessions, which will provide more detailed information on identification characteristics, life history attributes and distribution of these species.

Once the trainees have learned to identify the species, their skills in this area should be tested using underwater observations in the field (verified by trainer), fresh fish samples from the markets, and plastic fishes during size training (see below).

12.2 Identifying spawning periods and sites

The trainer and trainees will go through Section 4 of the manual, and discuss how to conduct interviews with local fishers. Issues to be discussed should include questions to ask, how to ask them, and how to interpret the answers.

They will also revise methods for identifying gonad maturity stages (using photographs in the manual and samples of fresh fish). Once the trainees have learned to identify gonad maturity stages, their skills should be tested using new fish samples from markets.

12.3 Mapping sites

Site mapping will be conducted during the initial stages of training. This will focus on locating aggregation boundaries and estimating the GSA area, and identifying locations to place transects as described in Sections 5, 6 and in Appendix 1. Trainees will learn how to place markers at key boundary locations (e.g. corners, top, bottom, sides), how to take measurements to be used to calculate area, and how to calculate areas for different shaped GSAs. Once mapped, trainees will identify the number and location of transects required to survey the area.

12.4 Estimating abundance

Estimating fish abundance is the most important aspect of monitoring GSAs and training is critical to ensure counts are reasonably accurate. Since conditions in a GSA are hard to reproduce on land or underwater, the best way to train for estimating abundance is by conducting counts in actual GSAs. This can be done underwater on GSA sites during training sessions with skilled and experienced practitioners as trainers, but also on the land using video recordings of GSAs. During training dives, skilled monitors will make counts with trainees along transects in the GSA site. The results are then compared to assess the skill level of the trainee. Training should continue until the recordings of trainee match those of the trainer. Simultaneously, video recordings can made to determine actual abundance and analyze trainee performance.

12.5 Estimating length

Wooden fish models (Figure 26) are used for length estimation training both on land (dry training) and underwater (wet training). Models are measured in cm total length (TL). Dry training is conducted first, using wooden models to introduce concepts (e.g. total length and measuring in cm) and begin practicing length estimation.

If available, commercially caught fish from markets can also be used for training in both 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 the species and estimated length. Their estimates are later validated by the trainer. Samples are kept on ice and used regularly throughout the training session.

Plastic fish models (Figure 27) of varying lengths can also be used in dry training, combining length estimation with species identification training. This training is conducted by holding up plastic fish models in succession while trainees record species 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.

After trainees become proficient at size estimation on land, they proceed to 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 28) 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 to determine if their estimate is is within 5 cm above or below the actual TL. This will allow the trainee to judge his or her performance and make corrections before proceeding to the second row of 'fish'. The procedure is repeated twice daily until trainees can estimate at least 75% of the lengths correctly to within 5 cm above or below the actual TL.

Verifying fish sizes during surveying can be done using two simple methods. The first method is to place fish cutouts of known size at several locations along the transect, so that estimates can be verified along the way. The sizes of the cut-outs must match the typical size range of the fish population. A second method is to measure areas recently vacated by a fish. For example, a grouper may be laying on coral. Note where the fish is sitting and 'mark' the spot visually. Once the fish has moved away, go over and measure the place where the fish was laying. The data recording slate can be used as a reference for length estimation.

Figure 26. Wooden fish models used in dry and underwater training for length estimation.

Figure 27. Plastic fish models used in dry training of species identification and length estimation.

12.6 Describing behaviors and signs indicative for spawning

The trainer and trainees will go through photographs and key features described for each species in Section 8, using additional images where available. Underwater video footage can also be used to train in identification of spawning behaviors.

12.7 Data handling

The trainer and trainees will review Section 10 and Appendix 1 of this manual on data handling, including data recording and processing, as well as presentation and interpretation. They will then use these methods to process the data collected during the training session, to obtain practical experience handling real data they have collected.

12.8 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:

- Reliably identify all target species;
- Accurately count fish within transects, as determined by comparing trainee counts with those by an experienced trainer or comparing counts with those obtained from video tapes;
- Accurately estimate fish lengths to within 5 cm above or below the actual TL;
- Recognize spawning behavior and identify maturity stages in gonad development;

At least two persons on each monitoring team must meet these minimum requirements. Note that even qualified members of the monitoring team must re-train before each monitoring season. Undoubtedly, not all trainees will meet these minimum requirements after the first training and these trainees should not monitor until their skill levels improve. At least one member of the monitoring team needs to be able to record, process, present and interpret monitoring data.

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 (less than 5 cm above or below the actual fish length) 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. Assess 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 75% 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 28. 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.

References and resources

Scientific monitoring manuals

Colin P.L., Sadovy Y.J., & Domeier M.L. (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)

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.

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 (http://www/spc.org.nc)

Samoilys M. (ed). (1997). Manual for Assessing Fish Stocks on Pacific Coral Reefs. Dept. of Primary Industries, GPO Box 46, Brisbane, Queensland 4001. ISBN 0812-000, ISBN 0-7242-6774-3.

Cited publications and reports

Bunce L., Townsley P., Pomeroy R. & Pollnac R. (2000). Socioeconomic manual for coral reef management. Global Coral Reef Monitoring Network, Australian Inst. Marine Science, Townsville, Australia, 251 p.

Bunce L. & Pomeroy B. (2003). Socioeconomic Monitoring Guidelines For Coastal Managers In Southeast Asia: SOCMON SEA. World Commission on Protected Areas and Australian Institute of Marine Science, Townsville, Australia. 82p.

Froese, R. & Pauly D., Eds. (2000). FishBase 2000: concepts, design and data sources. ICLARM, Los Baños, Laguna, Philippines. 344 p

Hamilton, R.J., Matawai M. & Potuku T. (2004). Spawning aggregations of coral reef fish in New Ireland and Manus Province, Papua New Guinea. – A local knowledge field survey report. Report prepared for The Nature Conservancy, Pacific Island Countries Coastal Marine Program. 107 pp. Draft.

Johannes, R.E. (1989). Spawning aggregations of the grouper *Plectropomus areolatus* (Ruppell) in the Solomon Islands. 751-755. In: Proceedings of the 6th International Coral Reef Symposium, Vol 2, Townsville, Australia.

Nemeth, R. (2005). Population characteristics of a recovering US Virgin Islands red hind spawning aggregation following protection. Marine Ecology Progress Series 286: 81-97

Pet, J.S., Muljadi A., & Rhodes K. (2001). TNC Pohnpei Training Workshop Grouper Spawning Aggregation Site (SPAGS) - Conservation and Monitoring. Report from the TNC Coastal and Marine Program, Bali, Indonesia. 40 p.

Rhodes, K.L. & Sadovy Y. (2002). Temporal and spatial trends in spawning aggregations of camouflage grouper, Epinephelus polyphekadion, in Pohnpei,Micronesia. Environmental Biology of Fishers 63; 27-39.

Sadovy, Y. & M.L. Domeier 2005. Are aggregation fisheries sustainable: reef fish fisheries as a case study? Coral Reefs *in press.*

Sudaryanto, Meyer T. & Mous P.J. 2004. Natural spawning of three species of grouper in floating cages at a pilot broodstock facility at Komodo, Flores, Indonesia. Live Reef Fish Information Bulletin 12. p. 21-26

Internet resources

The Internet is a tremendous resource, and we advise to use a search engine (e.g www.google.com, search.yahoo.com, search.msn.com, www.altavista.com etc.), to find the latest information from groups working on marine conservation and spawning aggregations. Following well-established websites have downloadable materials or searchable databases pertaining to spawning aggregations:

depts.washington.edu/mpanews/. Maintained by Marine Affairs Research and Education, School of Marine Affairs, University of Washington. Home of the monthly newsletter ‘MPA News’.

www.aims.gov.au. Maintained by the Australian Institute of Marine Science. Includes downloadable Standard Operating Procedures for reef surveys.

www.conserveonline.org. Maintained by The Nature Conservancy. Includes downloadable reports on spawning aggregations and the live reef fish trade.

www.fishbase.org. Maintained by the WorldFish Center. This global information system on fishes contains data on most fishes known to science.

www.gbrmpa.gov.au. Maintained by the Great Barrier Reef Marine Park Authority. Has information and downloadable reports on spawning aggregation sites on the Great Barrier Reef.

www.komodonationalpark.org. Maintained by Komodo National Park authority in cooperation with The Nature Conservancy. Besides general information on the Park and its management, this website contains a wealth of reports and publications as downloadables.

www.reefbase.org. Maintained by the WorldFish Center and ICRAN.Includes downloadable publications, pictures and data on the world’s coral reefs.

www.scrfa.org. Maintained by the Society for the Conservation of Reef Fish Aggregations. This website has a searchable database on spawning aggregations. Downloadables include the SCRFA manual (Colin et al. 2003) and the SCRFA newsletter.

www.spc.int/coastfish/News/LRF/lrf.htm. Maintained by the Secretariat of the Pacific Community Coastal Fisheries Program. Home of the SPC Live Reef Fish Information Bulletin

www.tnc-seacmpa..org. Maintained by The Nature Conservancy’s Southeast Asia Center for Marine Protected Areas, and home of this manual. Besides general information on the Park and its management, this website contains a wealth of reports and publications on marine conservation in Indonesia as downloadables

www.worldfishcenter.org. Maintained by the WorldFish Center. Includes a searchable library on the world’s fisheries.

List of figures and tables

Appendix 1 Example of monitoring a hypothetical large grouper aggregation

The following example is loosely modeled on a real GSA in Pohnpei as described in Pet, Muljadi & Rhodes (2001).

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 target species, which form aggregations that are adjacent to each other, but are consistently spatially segregated (as commonly observed in multi-species GSA). The three aggregations are adjacent to each other with only minor overlap of species at the shared borders. After a preliminary site survey and subsequent site mapping, the spawning aggregation site dimensions, are determined for transect design. All three aggregations form along the wall and extend onto the slope at the bottom of the wall Only the *P. areolatus* aggregation extends onto the reef flat (Figure 29). The *E. fuscoguttatus* aggregation (Figure 30, top panel) extends horizontally for 1000 ft and ranges from 70 ft (top of aggregation) to 140 ft deep (bottom of aggregation). The *E. polyphekadion* aggregation (Figure 30, bottom panel) runs horizontally for 360 ft along the wall and ranges from 70 to 140 ft deep. The aggregation of *P. areolatus* (Figure 31) extends along the reef for 1700 ft horizontally and from 30 ft (reef top) to 140 ft deep.

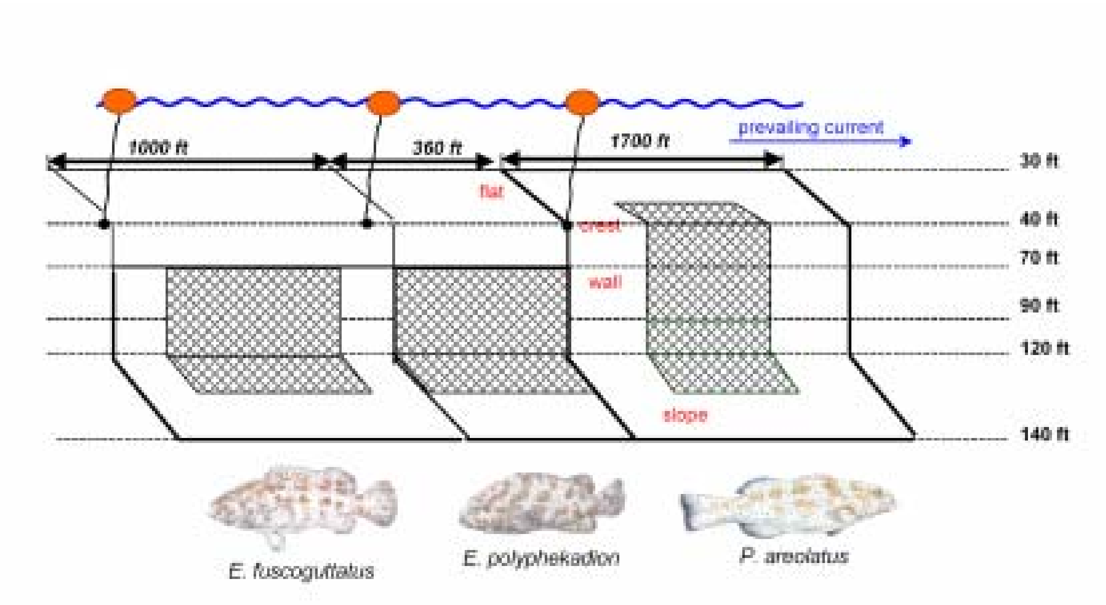


Figure 29. Hypothetical (but realistic) spawning aggregation site of *E. fuscoguttatus*, *E. polyphekadion* and *P. areolatus,*each marked with a buoy. Areas with bold delination are the areas occupied by the aggregation of each species. Shaded areas represent the sub-sample areas.

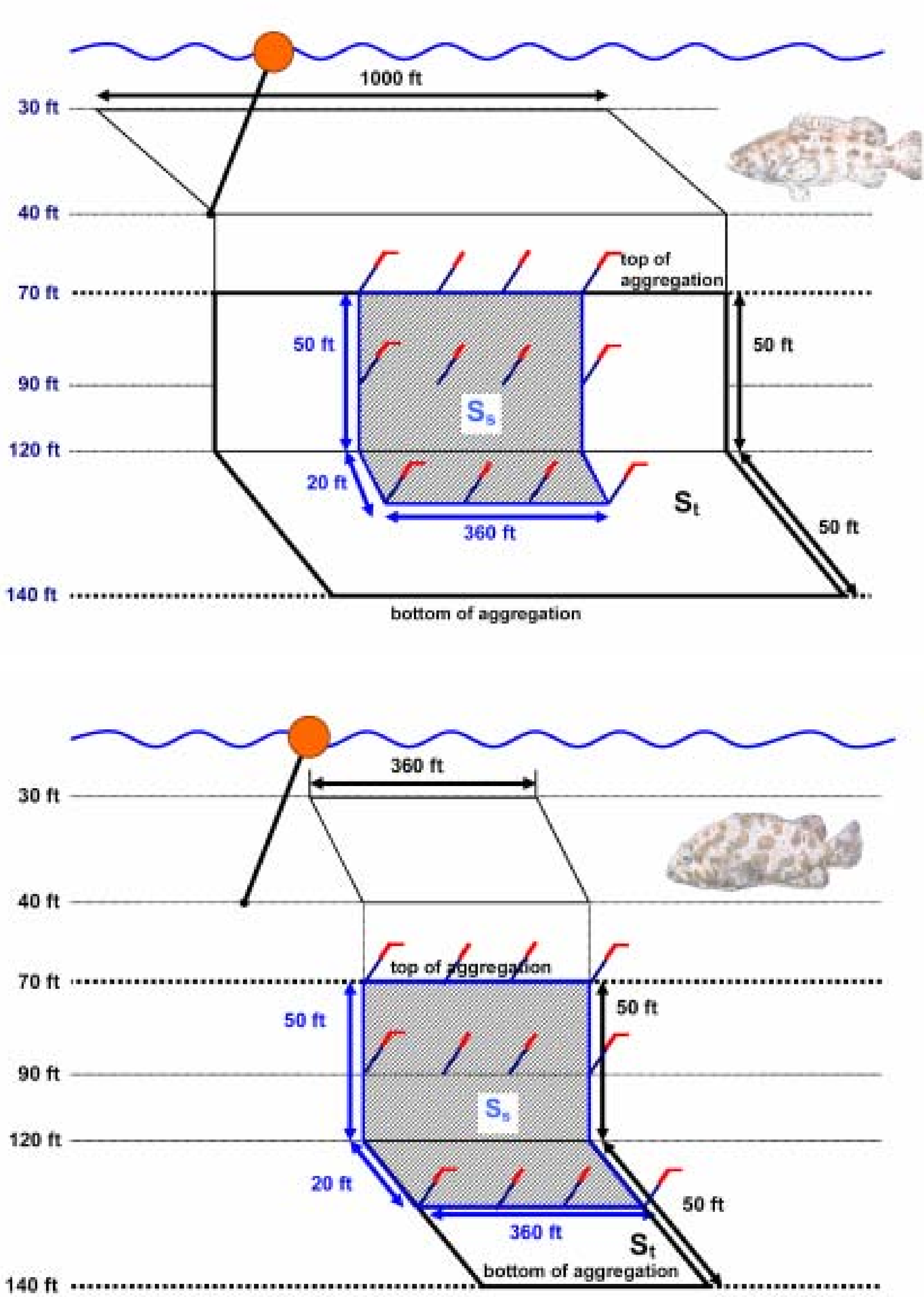


Figure 30. Part of the GSA site occupied by *E. fuscoguttatus* (top) and *E. polyphekadion* (bottom). The area delineated with bold black lines is the total surface area of the GSA site, whereas the area delineated in blue is the subsample area. Each subsample area has been marked with re-bars to facilitate counting of fish. See text for further explanation.

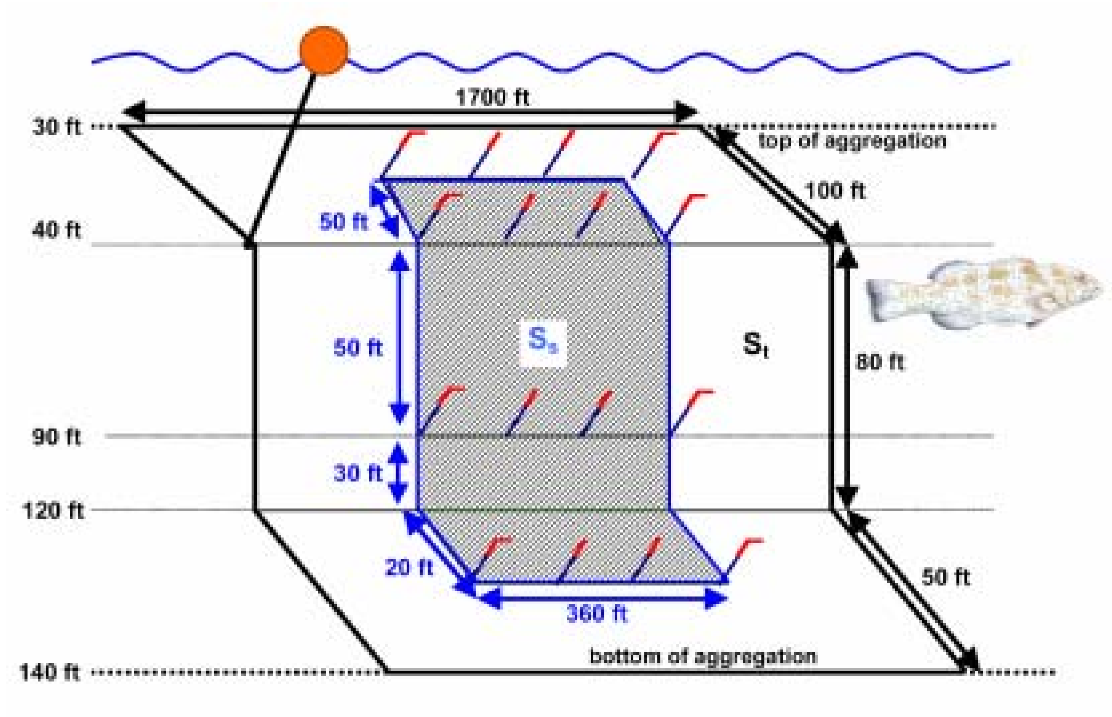


Figure 31. Part of the GSA site occupied by *P. areolatus*. The area delineated with bold black lines is the total surface area of the GSA site (S_t), whereas the area delineated in blue is the subsample area (S_s). The subsample area has been marked with re-bars to facilitate counting of fish. See text for further explanation.

All transects within each aggregation are set at a length of 360 ft, with a total of five dives performed during each month. One transect is set for each of the aggregations of *E. fuscoguttatus* and *E. polyphekadion*, and three transects were set for *P. areolatus*, because this is a much larger aggregation. The transects are marked with re-bar (metal) stakes with survey tape. Permanent mooring buoys are set at 40 ft at the up-current section of each GSA site for ease of location. Visibility at the aggregation is consistently 90-150 ft (30-50 m), which means that transect widths of up to 60 ft (20 m) can be set. Three divers cover each transect (1 dive per transect) during the monitoring period, starting 2 days prior to full moon. One diver (John) records the total number of fish (N_S) in the 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 in the aggregation. Diver 2 (Charles) records frequencies of fish lengths (length frequency distributions or LFD) for about 200 to 250 individuals, focusing on those individuals which are closest by, while also recording frequencies of behavior in the transect. The number of fish in the LFD is N_{LFD}.

In both the *E. fuscoguttatus* and the *E. polyphekadion* aggregations, the divers swim along the markers at 90 feet, at a constant distance from the wall (~ 5m) make their observations on the fish they can see between the upper markers (at 70 feet) and the lower markers (at about 130 feet). John counts all the *E. fuscoguttatus* and *E. polyphekadion* (N_S) between 70 and ~130 ft in the sample area (S_S) along the 360 ft transect. For *P. areolatus* there are three transects: (1) a strip of 50 ft wide at the shallow side of the reef crest; (2) a strip of 50 ft wide, from the reef crest at 40 ft down to a depth of 90 ft along the wall; and (3) a strip of 50 ft wide in the area where the wall levels out to the slop, between a depth of 90 ft and 130 ft. The three sample areas are covered during three separate dives. One dive counts all fish between the 40 feet markers and the markers up on the reef top, the second dive counts all fish between the 40 and 90 ft markers and the third dive counts all the fish from 90 ft down to 120 ft and out from the wall from 120 ft to ~130 ft. Mapping of the aggregation sites is repeated once a year to see if the total surface area (S_T) has changed and to record any changes in the delineation in the aggregation sites. From the total surface area or each aggregation (S_T) and the transect surface area (S_S), raising factors (R_S) can be calculated to estimate the total number of fish in the aggregation (N_T) as $R_S \times N_S$. See Table 4 for details how S_T, S_S and R_S were calculated for this example.

Diver 2 (Charles) records lengths of a sub-sample (N_{LFD}) of about 200-250 fish, focusing on the ones he can clearly and easily distinguish, on the LFD data recording sheet. These length estimation data result in a length frequency distribution for that sub-sample. The LFD_S in the sample area can be calculated by multiplying with another raising factor, $R_{LFD} = N_S/N_{LFD}$. The number per length class in the LFD of the total aggregation (N_L) can be estimated as $n_{LFD} \times R_{LFD} \times R_S$, where n_{LFD} represents the number of fish per length class in the sub-sample. The total number on the aggregation on any date is calculated as the sum over all length classes for that date: $N_T = SUM(N_L)$.

Diver 2 (Charles) also records frequency of occurrence of behaviors and signs indicative for spawning (spawning proxies) in the sample area (FOO_S) This is multiplied during data processing with the raising factor $R_S = S_T/S_S$ for each species to result in the *FOO* per spawning proxy for each species. After this the relative frequency of occurrence (*RFOO*) is calculated as FOO/N_T.

Table 4. Total surface areas (S_T) of each aggregation site, surface areas of transects (S_S) and raising factor (R_S) that is used to calculate the total number of fish in each aggregation (N_T) from the number of fish counted in each transect (N_S)

Aggregation	**Total surface area (S_T)**	**Tran-sect**	**Transect surface area (S_s)**	**Raising factor $R_S = S_T/S_S$**
E. fuscoguttatus (Figure 30, top)	100,000 ft^2 [1000*(50+50)].	1	25,200 ft^2 [360*(50+20)]	3.97 [100,000/25,200]
E. polyphekadion (Figure 30, bottom)	36,000 ft^2 [(360*(50+50))]	1	25,200 ft^2 [360*(50+20)]	1.43 [36,000/25,200].
P. areolatus (Figure 31)	391,000 ft^2 [1700*(100+80+50)]	1	18,000 ft^2 [50*360]	7.24 [391,000/54,000]
		2	18,000 ft^2 [50*360]	
		3	18,000 ft^2 [(30+20)*360]	
		1,2,3 com-bined	54,000 ft^2	

Data recording

An example of data recording is given on to the prepared data recording worksheets and GSA example for Isla Pacifica. Simple coding is used to input data for site, transect number and lunar date. The Isla Pacifica site, for example, is given as #1, but can be any unique number to identify individual sites. The number should only be used for that site. Transect number corresponds to the transect number *for that species' aggregation only*. For example, in our example, *E. fuscoguttatus* has only one transect and transect number is #1.

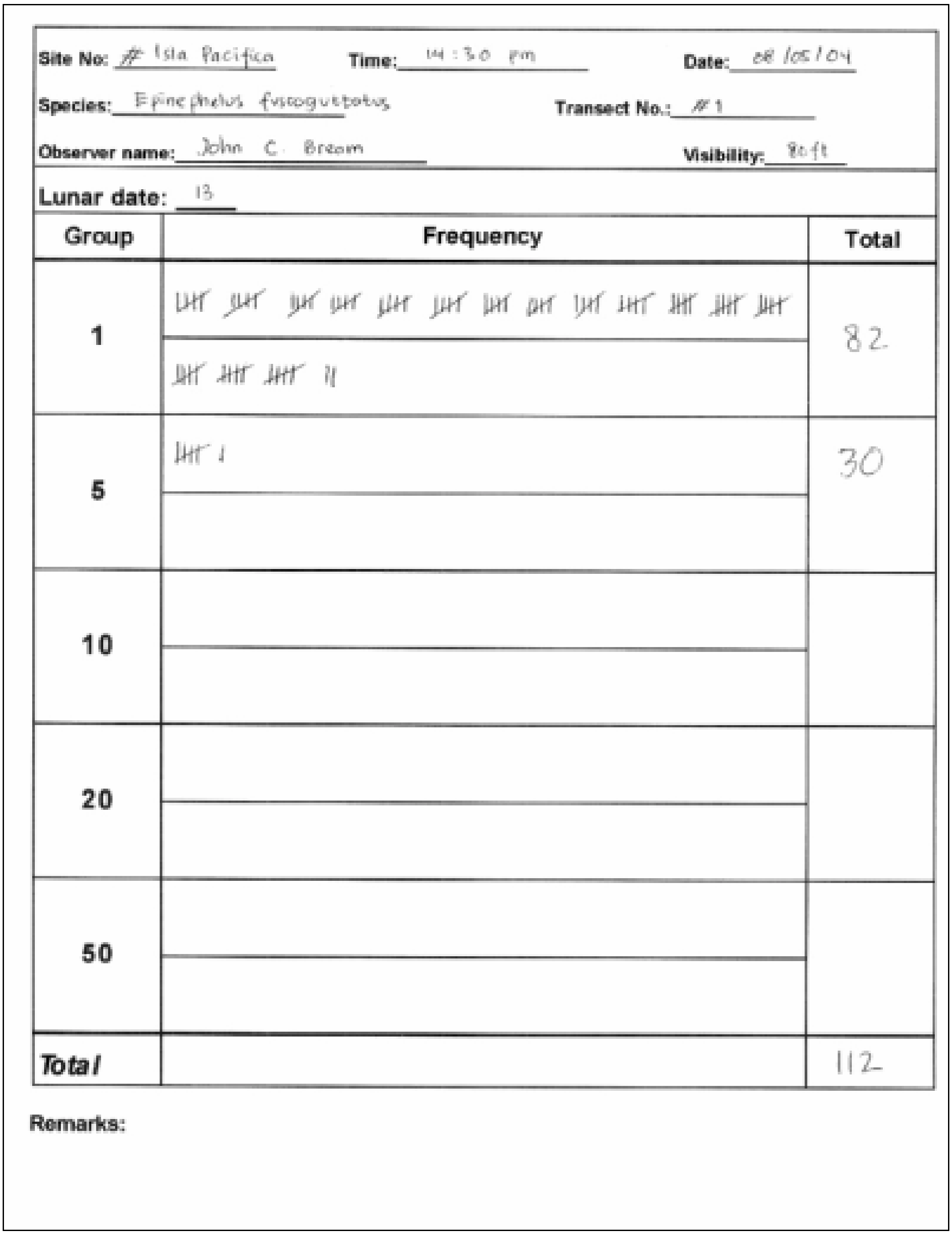
For *P. areolatus*, transect numbers 1, 2 and 3 would be given to the three separate transects. Lunar dates correspond to days 1 through 30 on the lunar calendar, with new moon = Day 1 and full moon = 15. The lunar day increases by 1 day until Day 30, which corresponds to the day before new moon, which again begins at Day 1. Calendar dates, species, visibility and observer are written normally. Time should be given as military time (e.g. 0000 to 2400 hrs).

For abundance estimation, counts are recorded in groups between 1 and 50 with a single tick mark for each fish group. For example, 82 individual and 6 groups of 5 individuals *E. fuscoguttatus* were recorded at Site 1 (Isla Pacifica), transect 1 at 14:30 p.m. on May 8, 2004 (Figure 32). The lunar date was 13, two days prior to the full moon.

Similarly, for length frequency, site, transect number and lunar date are coded as before, while other data on observer, time, visibility and species are written normally. Individual lengths for each fish are ticked as a single mark in each size category, which appears in 5 cm increments. An example of findings for Site 1 (Isla Pacifica) taken in transect 1 at 1430 hrs on 8 May 2004 (lunar date=13) by Charlie Toonah shows eight fish observed that measured between 41-45 cm total length (Figure 33). NB: Length recording should all be in centimeters total length (TL), which is the length from the tip of the snout to the tip of the tail.

Finally, observations on spawning or spawning behavior, recorded by the length frequency estimator are tallied as number of individual observations. If a third diver is on the team, this person can record behavior and act as a buddy for the other team members.

Figure 34 and Figure 35 show how data on *E. polyphekadion*, collected during the afternoon of that field day, could have looked like.


Site No: # Isla Pacifica Time: 14:30 pm Date: 08/05/04

Species: Epinephelus fuscoguttatus Transect No.: #1

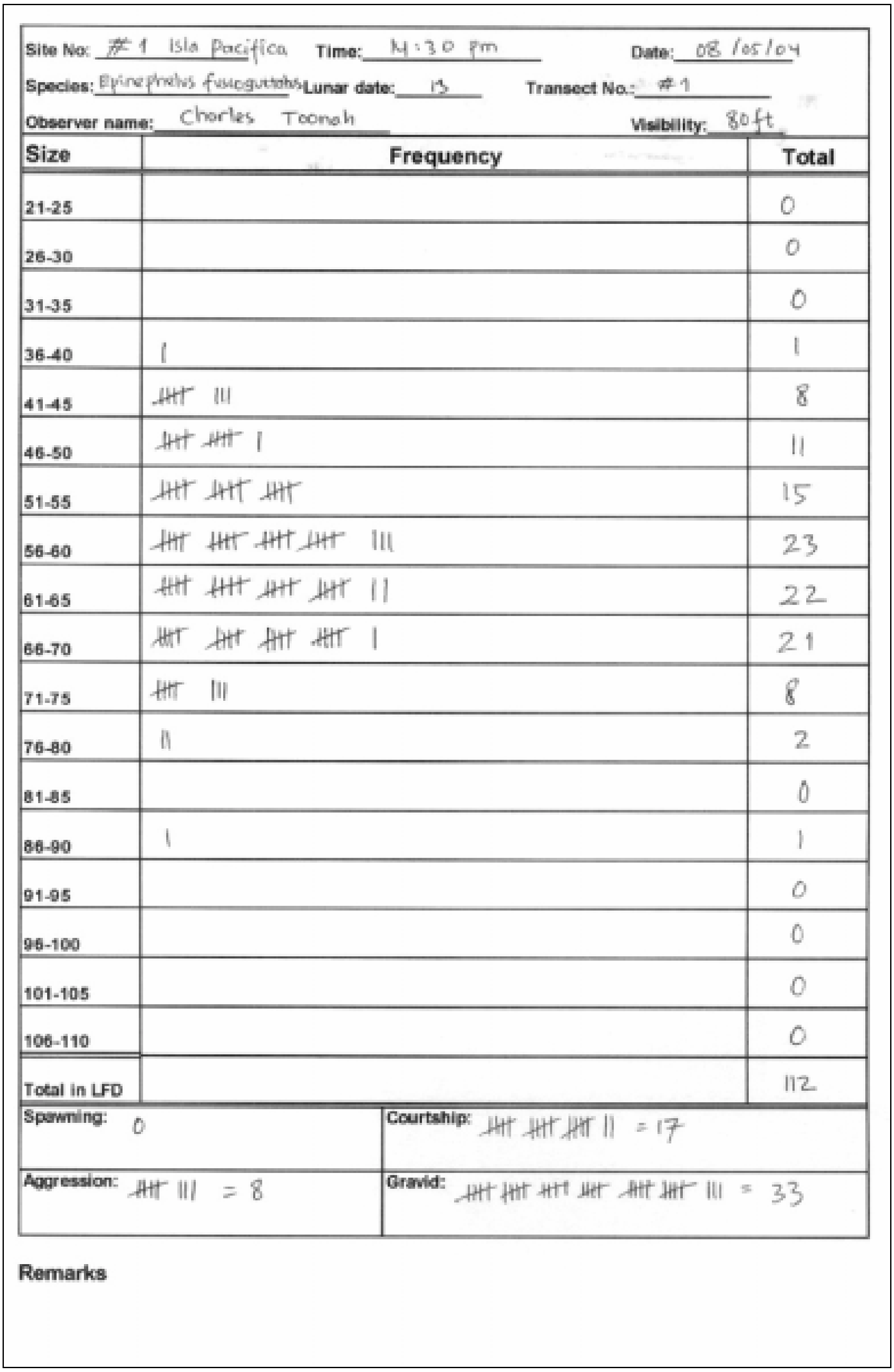
Observer name: John C. Bream Visibility: 80 ft

Lunar date: 13

Group	Frequency	Total
1	卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌	82
	卌 卌 卌 ||	
5	卌 |	30
10		
20		
50		
Total		112

Remarks:

Figure 32. Abundance data recorded on the GSA for *Epinephelus fuscoguttatus*.



Site No: #1 Isla Pacifica Time: 11:30 pm Date: 08/05/04

Species: Epinephelus fuscoguttatus Lunar date: 13 Transect No.: #1

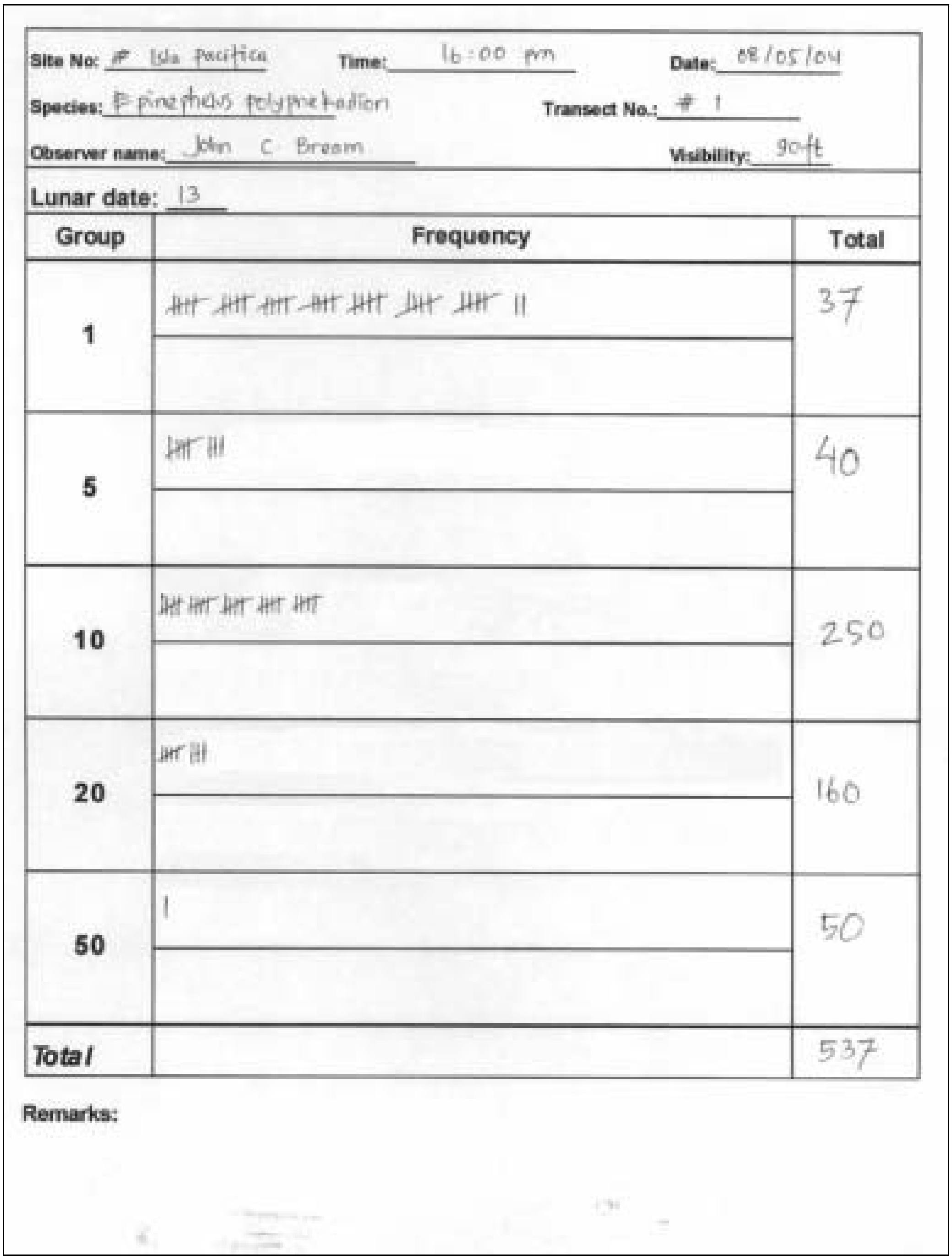
Observer name: Charles Toonah Visibility: 80 ft

Size	Frequency	Total
21-25		0
26-30		0
31-35		0
36-40	|	1
41-45	𝍸 |||	8
46-50	𝍸 𝍸 |	11
51-55	𝍸 𝍸 𝍸	15
56-60	𝍸 𝍸 𝍸 𝍸 |||	23
61-65	𝍸 𝍸 𝍸 𝍸 ||	22
66-70	𝍸 𝍸 𝍸 𝍸 |	21
71-75	𝍸 |||	8
76-80	||	2
81-85		0
86-90	|	1
91-95		0
96-100		0
101-105		0
106-110		0
Total in LFD		112

Spawning: 0	Courtship: 𝍸 𝍸 𝍸 || = 17
Aggression: 𝍸 ||| = 8	Gravid: 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ||| = 33

Remarks

Figure 33. Length frequency and behavior data recorded at the GSA for *Epinephelus fuscoguttatus*.



Site No: # Isla Pacifica Time: 16:00 pm Date: 08/05/04

Species: Epinephelus polyphekadion Transect No.: # 1

Observer name: John C Bream Visibility: 90 ft

Lunar date: 13

Group	Frequency	Total
1		37
5		40
10		250
20		160
50		50
Total		537

Remarks:

Figure 34. Abundance data recorded on the GSA for *Epinephelus polyphekadion*.

Site No: # Isla Pacifica Time: 16 :00 pm Date: 08/05/04

Species: Epinephelus polyphekadion Lunar date: 13 Transect No.: # 1

Observer name: Charlie Teenah Visibility: 90ft

Size	Frequency	Total
21-25	|||	3
26-30	𝍸 𝍸 𝍸 𝍸 𝍸	25
31-35	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ||	37
36-40	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ||||	34
41-45	𝍸 𝍸 𝍸 𝍸 ||||	24
46-50	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 |||	33
51-55	𝍸 𝍸 𝍸 𝍸 𝍸 ||	27
56-60	||	2
61-65		0
66-70		0
71-75		0
76-80		0
81-85		0
86-90		0
91-95		0
96-100		0
101-105		0
106-110		0
Total in LFD		185

Spawning: 0	Courtship: || = 2
Aggression: ||| = 3	Gravid: 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 || = 77

Remarks

Figure 35. Length frequency and behavior data recorded at the GSA for *Epinephelus polyphekadion*

Data entry and processing

Data can be electronically stored and processed in spreadsheet programs such as Microsoft Excel. In this example, data entry for abundance and length frequency distributions (LFD) is done in the file LFD-GSA (Table 5). In this files the data from the transects are raised to estimates for the complete aggregations. The person responsible for data processing enters all information from the data-recording sheet into the data file and adds information on raising factors.

Data entry for the total number of fish in the GSA and calculation of relative frequency of occurrence of various behavior is done in the file BEHAVIOR (Table 6). In these files the data from the transects are raised to estimates for the complete aggregations.

It is normally not necessary to include details on the timing of the dive in the spreadsheet.

Table 5. Abundance and length-frequency data for May 8, 2004, full moon at Isla Pacifica, for *E. fuscoguttatus* and *E. polyphekadion*.

file:	lunar	1=fusco	site	transect	length	number	total	number	raising	raising	total N
LFD-	date	2=poly	no.	number	class	per	number	of fish	factor	factor	fish per
GSA		3=areo			upper	length	of fish	in	LFD	sample	length
NOTE$_1$:	***N_T=SUM(N_L)$_{date}$***				limit	class	in LFD	sample	N_S/N_{LFD}	area	class
NOTE$_2$:	***N_L=n_{LFD}*R_{LFD}*R_S***					in LFD		area		S_T/S_S	
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	1	3.97	4
08/05/04	13	1	1	1	45	8	112	112	1	3.97	32
08/05/04	13	1	1	1	50	11	112	112	1	3.97	44
08/05/04	13	1	1	1	55	15	112	112	1	3.97	60
08/05/04	13	1	1	1	60	23	112	112	1	3.97	91
08/05/04	13	1	1	1	65	22	112	112	1	3.97	87
08/05/04	13	1	1	1	70	21	112	112	1	3.97	83
08/05/04	13	1	1	1	75	8	112	112	1	3.97	32
08/05/04	13	1	1	1	80	2	112	112	1	3.97	8
08/05/04	13	1	1	1	90	1	112	112	1	3.97	4
08/05/04	13	2	1	1	25	3	185	537	2.90	1.43	12
08/05/04	13	2	1	1	30	25	185	537	2.90	1.43	104
08/05/04	13	2	1	1	35	37	185	537	2.90	1.43	154
08/05/04	13	2	1	1	40	34	185	537	2.90	1.43	141
08/05/04	13	2	1	1	45	24	185	537	2.90	1.43	100
08/05/04	13	2	1	1	50	33	185	537	2.90	1.43	137
08/05/04	13	2	1	1	55	27	185	537	2.90	1.43	112
08/05/04	13	2	1	1	60	2	185	537	2.90	1.43	8

Table 6. Behavior data for May 8, 2004, full moon at Isla Pacifica, for *E. fuscoguttatus and E. polyphekadion*.

file:	lunar	1=fusco	site	transect	1=spawning	FOO	raising	FOO	total	relative
BEHAVIOR	date	2=poly	no.	number	2=aggression	in	factor	in	number	FOO
		3=areo			3=courtship	sample	sample	GSA	of fish	in GSA
					4=gravid		S_T/S_S		in GSA	FOO/N_T
date	***noon***	***species***	***site***	***transect***	***behavior***	$\boldsymbol{FOO_S}$	$\boldsymbol{R_S}$	***FOO***	$\boldsymbol{N_T}$	***RFOO***
08/05/04	13	1	1	1	2	8	3.97	32	445	0.07
08/05/04	13	1	1	1	3	17	3.97	67	445	0.15
08/05/04	13	1	1	1	4	33	3.97	131	445	0.29
08/05/04	13	2	1	1	2	3	1.43	4	768	0.01
08/05/04	13	2	1	1	3	2	1.43	3	768	0.00
08/05/04	13	2	1	1	4	77	1.43	110	768	0.14

Appendix 2 Staff, equipment and cost of monitoring

Materials for site mapping

- Local map (bathymetric, topographic, aerial)
- GPS (global positioning satellite receiver
- 100- or 50-m plastic tape measure
- Float markers (to mark beginning, end and along transect or area)
- Rope or twine to hold floats
- Rebar (metal) stakes to mark corners and transects
- Surveyor's tape (colored fluorescent vinyl marker tape)
- Underwater compass

Materials for gonad analysis

- Cannula or ink tube from a ball point pen to take egg samples from ripe females
- Magnifying glass or 10 X eyepiece
- Microscope and microscope slides (optional)

Materials for UVC

- Boat and engine (maintained and sufficiently fueled)
- Dive gear for all monitors, with dive computer and back-up gear (mask, fin, snorkel, BCD, weights and belts, wetsuit, boots, regulator)
- 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)]
- Global Positioning Satellite receiver (GPS)
- Waterproof, laser-printed data sheets, (abundance, length frequency, see below)
- Laser pointer or underwater length reference guide (weighted 1-m or other PVC pipe)
- PVC armbands that for use as slates (1 hole drilled to attach line and pencil)
- Pencils (20 each; composite, not natural wood), sharpeners, erasers (rubber type)
- Duct tape or electrical tape to affix sheets to the PVC armbands
- Sun protection (hat, sunscreen lotion)
- Drinking water

Monitoring personnel for UVC

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

Materials for UVC training – estimation of abundance

- Video camera with underwater housing
- LCD projector or TV monitor
- Projector screen or white sheet

Materials for UVC training – length estimation[1]

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

Materials for UVC training - species identification

- Plastic fish models (see above)
- Market and/or catch samples (20-30 specimens of varying sizes)
- Field or scientific fish identification guides
- Micronesian Reef Fishes, RL Myers
- 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

Video documentaries that contain information on spawning behavior, aggregation ecology and aggregation dynamics

- National Geographic "The Perils of Plectropomus"
- The Nature Conservancy "At the Confluence of Currents"
- National Geographic "Feast of the Giants"
- " The Boom or Bust Syndrome"

Miscellaneous materials for training

- VCR (NTSC/PAL compatible, if available)
- Computer and printer
- Laminator (if available)
- Extension cords (with plug adapters, if needed)
- Multi-outlet power strips
- Whiteboard and markers or chalkboard and chalk
- General office supplies (stapler, hole punch, scotch tape, paper clips, bulldog clips)

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[1] Laser pointers are useful devices for both length estimation training and for verifying estimates during regular monitoring. Two or more laser pointers (prepared for underwater use) are lined up along a bar at fixed distances (e.g. 10 cm). Underwater, the lasers are pointed at the fish, projecting a line of red dots on the body of the fish that can be used as reference points for lenght estimation. The technique is particularly useful if used in combination with a video camera. Note that laser pointers only help to provide accurate estimates if fish can be approached within a few meters and if fish are perpendicular to the array of pointers. See also Colin et al. 2003.

Monitoring costs

The costs of monitoring must be evaluated to assess the cost efficiency of the monitoring in relation to the objectives of the monitoring program. The cost of monitoring depends 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 boat 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

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, or about $170 per day. 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.

Appendix 3 Field forms

The following two pages contain field forms that can be copied on underwater paper for use during the monitoring program.

The first form is for abundance monitoring, where ‘Group’ refers to the number of individuals scored as a single unit (e.g., an observer may score a concentration of 16 fish as three groups of five and one ‘group’ of one individual.

The second form is for monitoring abundance and behavior.

Site No: ________________ **Time:** ___________________ **Date:** _____________

Species: ________________________ **Transect No.:** _______________

Observer name: __________________________ **Visibility:** ________

Lunar date: _____

Group	Frequency	Total
1		
5		
10		
20		
50		
Total		

Remarks:

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:

Remarks

Appendix 4 Version history

Version 0 - Draft for review (August 2004)

Version 1.0 – Draft for review (March 2005)

Version 1.2 – This version (April 2005), after a review by the authors, and including comments from an external expert.

Known issues and planned improvements:

- Add detail on the ‘canulation’ method (Section 4.2)
- Spacing between characters in Formula 2 is wrong because of a software quirk
- More detail on training protocols, especially on benchmarks for trainee performance, would be useful (Section 12).
- Counting in groups of 10, 20 and 50 individuals requires a training protocol and calibration of observers, perhaps through a training video with underwater footage.
- Section on monitoring costs in Appendix 2 needs updating
- Add a glossary