BACK to BASICS


Camouflage Grouper, *Epinephelus polyphekadion* Yvonne Sadovy

TRAINING MODULE FOR THE

MANAGEMENT & CONSERVATION

OF REEF FISHES IMPORTANT FOR FOOD

2013

How can I

...measure the length of a fish?

...count fish in a spawning aggregation?

...calculate Catch per Unit Effort?

...manage my fishery sustainably?

...know the reproductive season?

...learn about the fishery from the fishermen?

...have fish in future?

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Images provided by Dipa Devi, Liu Min, Jack Randall, Patrick L. Colin, and as otherwise indicated

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WHY THIS MANUAL?

The purpose of this set of guidelines is to outline, using scientific principles and local knowledge, simple approaches for understanding aspects of the biology and ecology of food fish species of special interest, or that may be particularly vulnerable to overfishing.

Coral reefs sustain millions of people across the planet as a source of nutritious and readily available food and as a means of livelihood. Hundreds of thousands of people pay for a glimpse of the beauty of reefs and iconic and charismatic species are a source of inspiration, tradition and folklore. Despite such importance, few reefs or reef fisheries are sustainably managed and many are degraded and overfished. Loss of productivity in these fisheries can be devastating to many communities around the world with serious cultural and food security implications that accompany the loss of a major food source. In extreme cases, species can be threatened to the extent that recovery is unlikely.

Major challenges to maintaining or recovering degraded coral reefs and their compromised fisheries range from the lack of sufficient biological or fishery information at the species level, low enforcement capacity and few alternatives to fishing, to the increasing need for cash and seafood and limited research capacity. And these challenges are growing along with population growth, expanding international demand for seafood, and new practices such as the newly recognized 'capture-based aquaculture' whereby large numbers of juvenile fish are taken from the wild, along with massive volumes of fish feed, for 'fish farming' operations.

Yet collecting information and applying management does not have to be prohibitively expensive, time-consuming or difficult, or require a laboratory or costly research vessel. Much can be learned from simple, inexpensive and easy-to-use approaches. Add to this, clear goals for the fishery combined with adequate education, and communities and local government can understand and protect their interests, and assess the outcomes of management. In an intensely globalized seafood trade and market, source countries will be increasingly challenged to protect their own interests and marine resources.

The guidelines cover the collection of basic fishery data that provide indicators of the status of the fishery and options for management. Information is included on mariculture operations because fish farming is rapidly growing in importance and much still depends heavily on wild populations, and hence needs management. Detailed techniques requiring significant laboratory facilities or training such as age and growth, molecular work and fishery modeling, are not covered. Groupers and the Napoleon wrasse are used to illustrate concepts discussed but these are applicable across reef fishes.

For full details of methodology, relevant literature should be consulted: citations of useful literature and web-based links are provided (ANNEX 5)

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Introduction

Objective

To understand the *size of sexual maturation*, *sex ratio* and *spawning season* of key target coral reef food fish species. Note that these can vary with geographic location and hence location-specific studies are advisable for best management planning. The information is important for sustainable management for two reasons.

1.1 Reproductive biology study: sexual maturation, spawning seasonality and sex ratio

Reproduction is fundamental to life and this is no less true for fishes. This means that fisheries need to be managed in a way that ensures that sufficient fish reproduce frequently and effectively enough to maintain (or recover if necessary) a fished population. Fish species vary enormously in their reproductive biology, such as size and age of sexual maturation, the manner, place and season of spawning, etc. Understanding their reproductive biology enables the development of simple but effective approaches to ensure that target populations continue to replace themselves and supply the fishery in the long term.

For successful reproduction, two things must happen: (1) sufficient juveniles must survive to adulthood, and (2) sufficient adult males and females must successfully spawn to produce the next generation. Hence, knowledge of the size of sexual maturation and where, when and how reproduction occurs is important. If reproduction is compromised this could be a sign of overfishing with serious implications for the long-term persistence of the fishery (Section 4.1).

(1) Most fisheries seek to avoid catching too many immature fish to ensure that enough individuals become adults and reproduce to sustain the population, so the size of sexual maturation should be known. Also, if an increasingly higher proportion of fish catch takes immature individuals over time, this is often a sign of 'biological' overfishing (if changes in gear type or fishing location cannot explain the change in size of capture). If immature fish must be part of the fishery, i.e. are specifically targeted (as in the capture of juveniles for mariculture 'grow-out' or for certain species in the aquarium trade - see Section 2.3), then management adjustments should ensure that sufficient babies survive to sexual maturity to replenish the population on a long-term basis.

(2) Once fish have become sexually mature, ensuring that enough adults reproduce is essential for populations to persist. This is why many fisheries

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REPRODUCTIVE STUDIES

what, how, when and where to sample? ***To determine reproductive parameters several decisions are needed:*** (1) which species to study (if the fishery if multispecies); (2) how to sample the fish, i.e. how many fish should be sampled and what measurements should be made; (3) how often and how long should fish be sampled for; (4) where to sample the fish; and (5) how to handle and use the information collected.

have minimum size limits to reduce the catch of small sized fish, at least until they can reach the size of reproduction. Some fisheries even protect the largest females in the fishery since these have exponentially more eggs than smaller ones and so are particularly important for reproduction. As we learn more about coral reef fish reproduction and fisheries we find that there are other things to consider. For example, in the case of the lucrative live reef fish trade, spawning aggregations are sometimes targeted removing many ripe (gravid) females just before they spawn. This is a wasteful practice in the live fish fishery since such fish tend to be easily stressed and have high levels of mortality. It may also compromise a fishery if a large proportion of the year's reproducing females, live or dead, is removed.

Some fisheries may protect species during the reproductive season so that they can spawn undisturbed. Examples include protection of spawning aggregation seasons, or places (see Section 1.2 & 3.2) or protection of gravid females (similar to the protection of 'berried' lobsters, i.e. females carrying eggs). Some species are known to change sex from male to female, or female to male, as they grow larger. If fisheries focus too much on the largest fish available in such species, or the commercial market prefers a certain size of fish (such as 'plate-sized' fish for Chinese restaurants 0.5 - 1kg), a sex bias can occur if size and sex are associated. Hence, in some cases it is useful to determine sex ratios.

Fish Sampling Based on specific fishery or conservation objectives a decision is first made regarding species to be collected. Simple and obvious as it may sound, correct identification of the target fish is essential *so correct identification of the species must be a top priority*. For many fishes this will be easy but for some important groups it can be quite a challenge; groupers (Epinephelidae) are a good example. Also many species can look different if live or dead, and juveniles may differ from their adults. Many good guides are now widely available as well as online databases. An example of a guide for the live reef food fish trade highlights some of the similarities among the brown-coloured grouper species (Fig. 1)

Fish sampling is a key part of reproductive biology studies and requires planning and decisions about how long to sample for, how many fish to sample, which fish to sample and what information should be collected. *To learn about seasonality of spawning, fish should usually be sampled throughout the year with a focus on adult size individuals. For size of sexual maturation, a wide range of sizes should be collected to encompass both immature and mature size ranges.* There may need to be a small budget to purchase fish samples or fishers or sellers may allow workers to measure and weigh fish, and remove the gonads (reproductive organs) for free if these are usually discarded (or sellers may accept a nominal fee for these). Samples may be obtained in fish markets, from traders or fishers, or by direct sampling of wild fish. Fresh or freshly frozen fish are needed to obtain gonads in good condition and when there are many fish available for sampling a worker must decide which fish and how many to sample. Care is needed to ensure that the appropriate size range of fish is sampled for the study objective, and websites such as **www.Fishbase.org** or IUCN red list assessments (**www.iucnredlist.org**) might include species-specific guidance.

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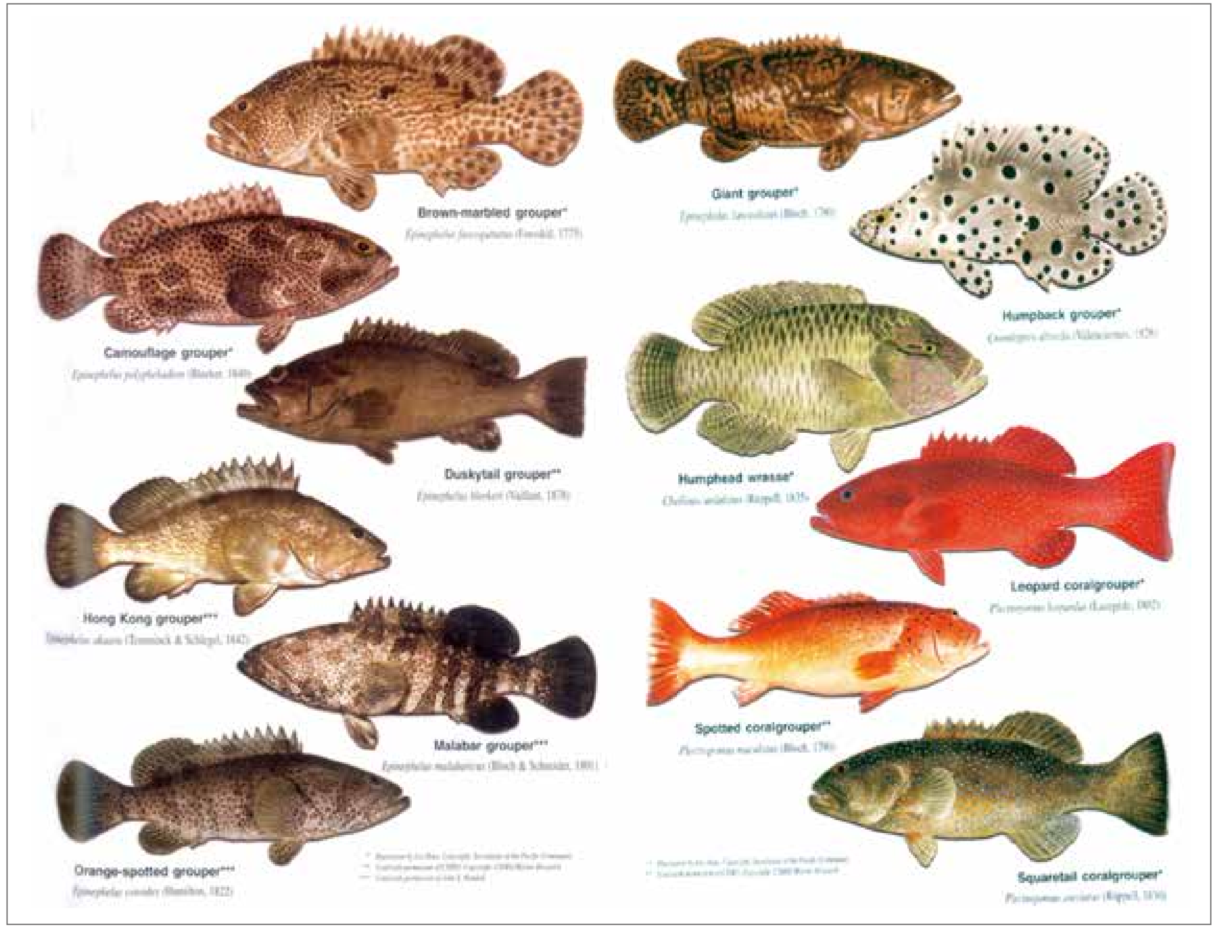

Fig. 1 Whether sampling from markets or from fishermen, make sure your species identifications are correct; shown here are many of the fishes in the international live fish trade and several species (lefthand side) are hard to distinguish (Sadovy et al. 2003)

What measurements to record? Typically four measurements are taken from fish samples for reproductive and body size parameters; total length (TL) and standard length (SL) in mm or cm (be consistent), body weight (BW) and gonad (i.e. reproductive organ - ovary in female and testis in male) weight (GW) in g or kg (be consistent). The diagram (Fig. 2) indicates how to take measurements. Lengths are from the front of the closed mouth to the end of the vertebral column in the tail (SL) or to the very end of the closed tail for TL. The end of the vertebral column can be located by bending the tail sideways – the 'crease' point marks the end of the vertebrae. The accuracy of measurements depends on the working conditions (rushed and cramped in a fish market or boat, or cool and comfortable in a laboratory) and the types of weighing balance and tape available. TL and BW data should be recorded on prepared spread/datasheets (like EXCEL), with additional columns for date, location, sex, GW, standard length (SL); having an extra column to make notes is handy. Note that it is very useful to have SL, TL and BW measurements for all fish so that so you can later convert information between them,

i.e. determine the TL if only SL is available, etc. (Fig. 3). Some studies provide such conversions for specific areas which could be used as guidance if no local conversion equation is available (e.g. Kulbicki et al. 2005).

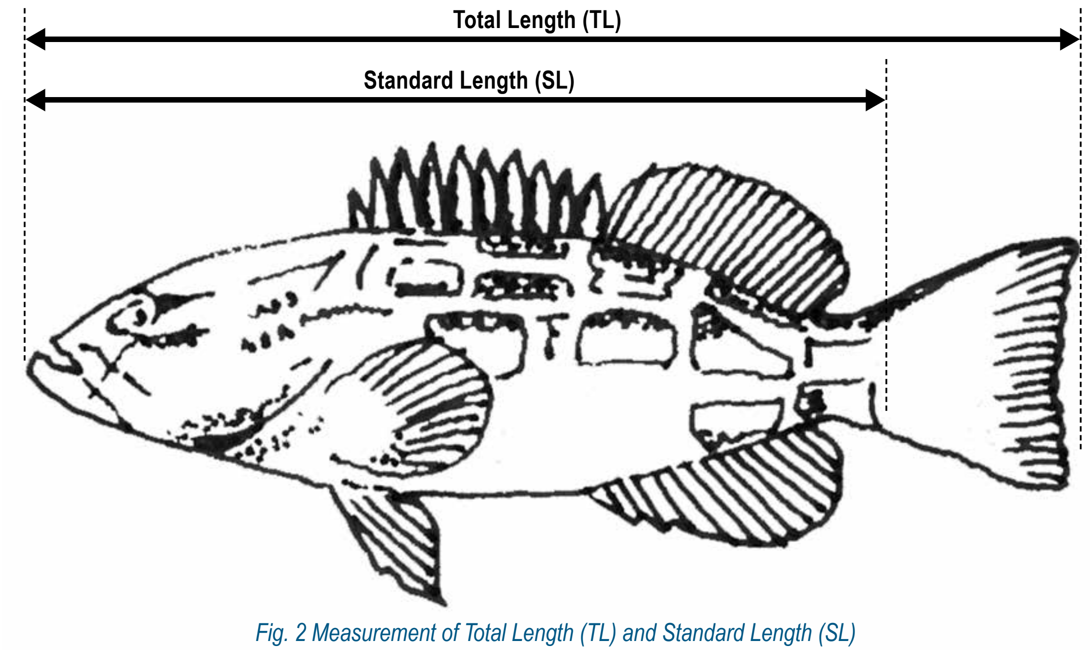

Fig. 2 Measurement of Total Length (TL) and Standard Length (SL)

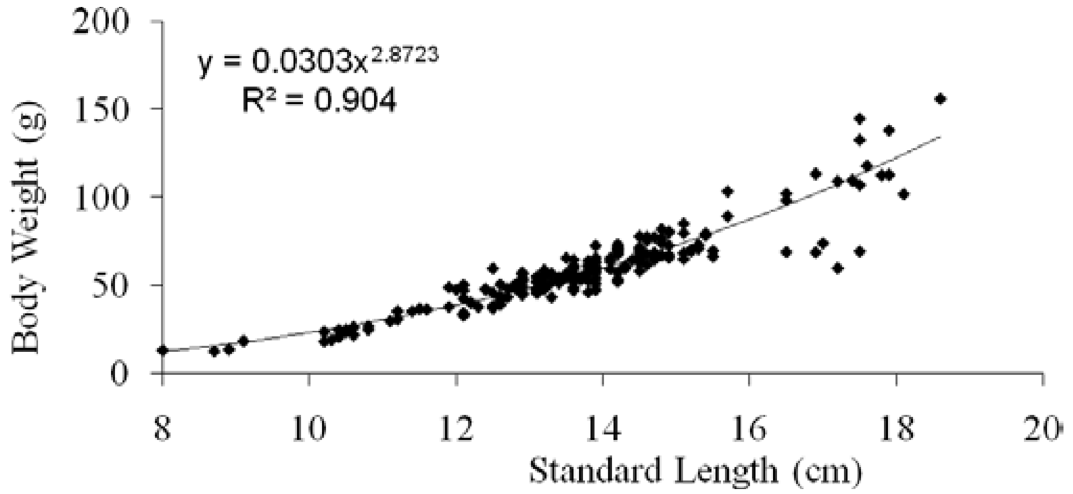

Fig. 3 Often a worker may have access to one body size measurement, such as standard length, but need another, such as weight. For such conversions simple graphs can be plotted. Each point is a single fish for which was measured both the weight and the length. Conversion can be done by looking at the curve or by using the equation.

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Where the fish can be sampled?

Landing ports, retail markets or wet markets are all good sites to obtain samples. Preliminary discussions with local residents are useful to determine the best times and places to look for samples. A basic understanding of the fishery is very important; for example different fishing gears or locations may produce different sizes and species of fish, while sellers or traders might only be interested in certain fish sizes and sort their fish before sale. Building a good relationship with fish sellers, traders or fishers will be valuable, and explaining why you are doing the study is important.

How many samples are sufficient and which fish to choose?

Sampling depends mainly on study objectives but fish availability and cost may be important considerations. For many reproductive studies, 20-30 fish collected per month is a typical target. Rare or threatened species might be particularly challenging to find, or expensive to buy. In many cases, workers must visit sampling sites more than once per month to obtain sufficient samples, or visit many landing sites or sample catches from different gears. If the worker is lucky enough to have choice, then decisions need to be made about which fish to select, i.e. subsampling is necessary. *For reproductive seasonality, sufficient larger fish are needed to have enough adults for the study throughout the year.* If, on the other hand, one study aim is to know the *typical sizes of fish in the fishery* (see Section 2.2), then sampling all fish or conducting random sub-sampling is important. Workers should check to see whether fish have been sorted by size prior to their sampling point (e.g. small fish might be sold in one place, maybe for cage grow-out, and large fish in another, maybe for export) to work out the best sampling method that characterizes the catch size range and frequencies in each size class.

Size-frequency distributions and length-weight relationships

Size frequency (i.e. the number of fish of different sizes taken in the fishery or area of interest) and length-weight relationships (Fig. 3) can be used to evaluate changes in body sizes over time that could be due to fishing or other impacts, the size of fish being exploited relative to sexual maturation (e.g. the proportion of juveniles and adults in the fisheries - see above), gear selectivity, and habitat association with size, among other things. Possible causes of changes in size frequency distributions over time include inter-annual variation in recruitment strength, fishing pressure, and changes in gear type, etc. For a comprehensive understanding of size frequency distributions of long-lived species over time, large sample sizes (many hundreds of fish annually) collected in a standardized and non-selective way over a long period is advisable. A consistently reduced average size, and loss of the larger fish in the area, etc., are strong indications of fishery induced effects and possible overfishing (Section 3.1).


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Fig. 4 Ripe gonad of leopard coral trout – the U-shaped light pink structure (left) – occurs ventral to the swimbladder. In very ripe ovaries, the eggs are clearly visible and fill most of the abdominal cavity-see white mass (right).


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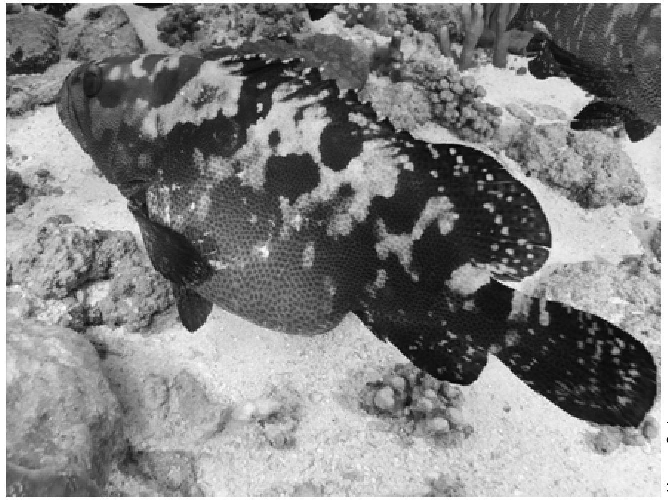
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Fig. 5 Ripe males close to spawning time will show free-running white sperm (the streak of 'milt') when the belly is gently pressed (left). Live ripe females just before spawning look distinctively swollen (but see Fig. 9) (right).

Gonads and Gonadosomatic Index (GSI) The condition of the gonads of ripe adults in some species can be readily detected even in live animals. Females just prior to spawning will look large and expanded, while gentle pressure on the abdomen of both sexes will cause sperm and eggs to be extruded (Fig. 5). The GSI is an index of the relationship between the gonad weight and the body weight. It is a quick and easy means (once gonad weight GW, and body weight, BW, have been obtained) to determine readiness for spawning. It can be used to indicate (1) the spawning season and (2) the size of sexual maturation.

GSI is useful to determine the *spawning season* because, as the fish gonad ripens in readiness for spawning - especially noticeable in females -- it increases in size and weight as the cells mature and grow (Fig. 4 & 5). After spawning, the gonad becomes much smaller and lighter. Since body weight remains about the same, the relationship between gonad and body weight changes over the annual reproductive season (Figs. 7 and 8).

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Fig. 6 The sudden appearance in markets of many ripe (swollen) fish is a sign of the reproductive season for some species; in this case, the camouflage grouper, Epinephelus polyphekadion.

GSI study for *spawning seasonality* requires monthly gonad collections over at least a year to ensure full coverage of spawning and non-spawning periods. Regular monitoring of catches might reveal a large increase in ripe fish which is another indication of the spawning season (Fig. 6). Females provide the most detailed information on the spawning season because ovaries usually change much more in size than testes (Fig. 7). Based on a plot of GSI against month there is usually a clear peak indicating the spawning season. In some cases, there may be more than one peak, indicating the species has more than one spawning season. Some species spawn throughout the year in which case the GSI is constantly elevated or highly variable. Only mature sized fish should be used for determining seasonality since the gonads of immature fish will show no seasonal signal for reproduction. The following formula is used to calculate GSI as a percentage: GSI% = GW / (BW - GW) x 100.

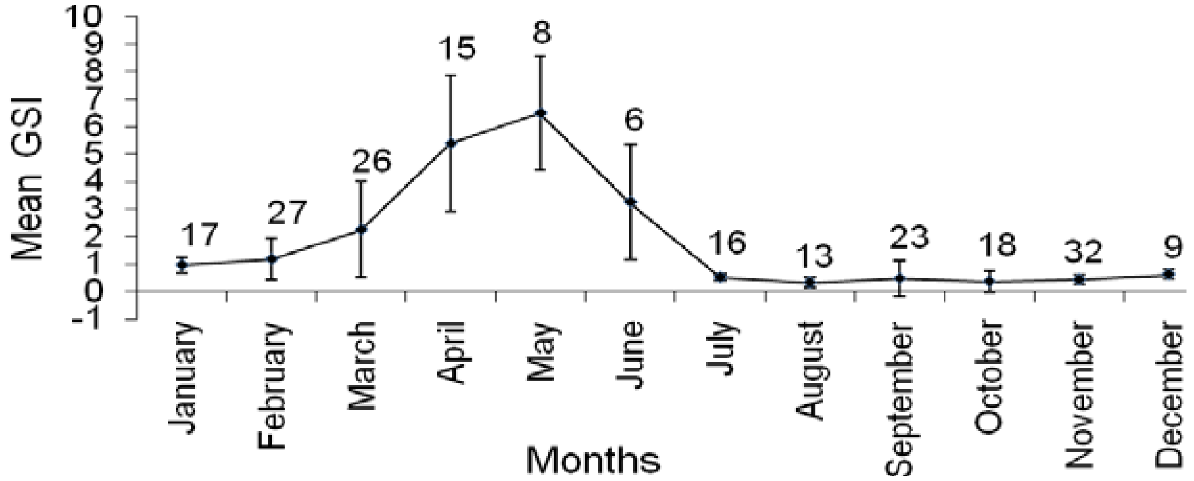

Fig. 7 Changes in ovary GSI between March and June indicating spawning for this species between these months. Mean monthly GSI of females with standard deviations (vertical bars) is plotted to show monthly variation. Numbers on top of bars represent sample size. Only adults are included in graphic. In this species, male GSI remains between 1 and 2 throughout the year so its GSI is not used.

GSI is useful for determining *size at sexual maturation* because the gonads of juvenile, immature, fishes are very small relative to body weight (Fig. 8, below 65 cm TL). If there are GSI data for a large size range of fish over at least 12 months (to ensure the reproductive season is covered), then a plot of GSI against body size will show a large increase in GSI at the size of sexual maturation (Fig. 8).

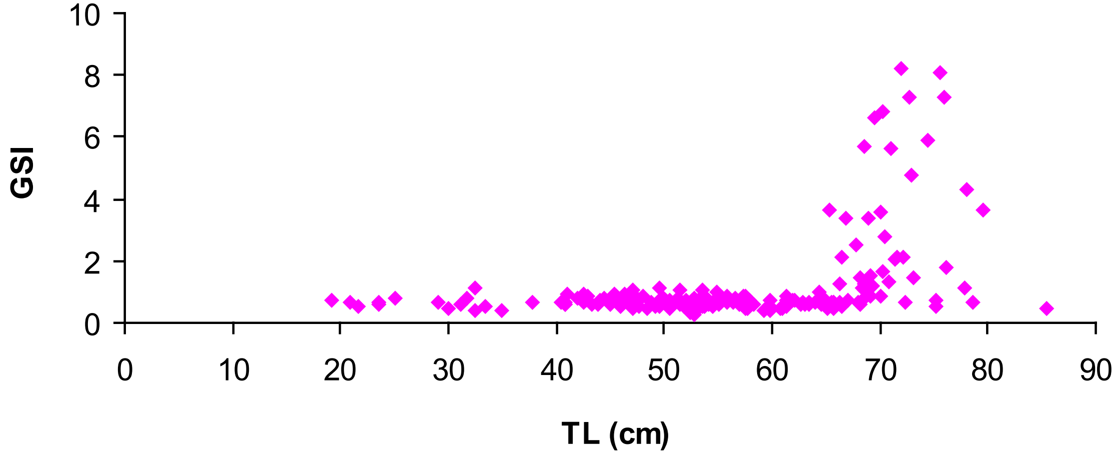

Fig. 8 GSI plotted against body size. The body size (TL) at which the GSI increases, indicates the size of sexual maturation; in this case about 65 cm TL.

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Fig. 9 Beware, all that is swollen is not necessarily a result of eggs. This grouper looks very fat (see Fig. 5) but when opened up, the swelling is clearly caused by a recently eaten crab.

Data Analysis

The SL, TL, BW and GW measurements can provide information for size-frequency distributions, length-weight and TL-SL relationships, etc., which allow for conversions between measurement types (Fig. 3), and calculation of the GSI (see above). Simple plots of the various parameters of interest can be made using data spreadsheets such as EXCEL.

1.2 Identification of spawning sites and/or times using traditional knowledge

Introduction

One distinctive mode of reproduction shared by many coral reef fishes is the ‘spawning aggregation’. These are typically large gatherings of males and females that form, just for the purpose of spawning, at specific sites and times, are often highly predictable and are frequently a focus of fishing activity or mark fishing ‘seasons’ (Fig. 10). For many commercial reef fishes this is the only time that reproduction occurs so it is very important that aggregations continue to form and are not fished so excessively that they cease to form. Without the aggregations, many of these species would experience lowered reproductive rates thereby reducing the fishery. Indeed, among documented exploited aggregations, about 60 % are believed to be under decline or have disappeared due to lack of management (Fig. 11). Other than a few chance discoveries by biologists or sports divers, spawning aggregations are ‘discovered’ from the knowledge of fishers. Local and traditional knowledge has become an important source of fishery information and history in areas where such information is not formally or regularly collected by the government and seeking that knowledge is important to do appropriately and respectfully.

Fig. 10 Spawning aggregations of camouflage grouper, Epinephelus polyphekadion, in the Pacific can involve many thousands of fish that gather briefly each year to reproduce.

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(1) Knowledge of the timing and place of spawning is often useful and sometimes essential for successful fishery management and for conservation planning. For fishes that form spawning aggregations, commercial levels of fishing invariably lead to aggregation declines if they are unmanaged. In extreme cases, aggregations will cease to form and the associated fishery will collapse. Since aggregations produce the young for the next generation, they thereby support the fishery. Suitable protection of aggregations can be achieved by managing fishing activity as well as by conservation action that specifically protects the times and places of fishing.

(2) In most places there is little or no information available on spawning aggregations and poor understanding of the importance of their management. Yet they occur in coral reef ecosystems around the world and many form the basis of ‘seasonal’ fisheries because of the multiple fish that periodically become so easy to find and catch. When these fisheries served only subsistence needs, aggregations were usually sustained but when aggregation-fishing increased for commercial purposes, many aggregations declined. Although little is known in fishing communities about the vulnerability of aggregations to fishing, many fishers have detailed knowledge on the time and place of spawning. Fishers might be willing to share their knowledge if interviewed in a suitable manner with an understanding of why it is important for their fishery to conserve these times and places.

Objective

To determine by interview, through *the collection of local traditional knowledge*, the sites and/or times of spawning (reproduction) in reef fishes of commercial, subsistence or conservation interest. This information is valuable to *assess the current status of aggregations, and their history in the fishery*.

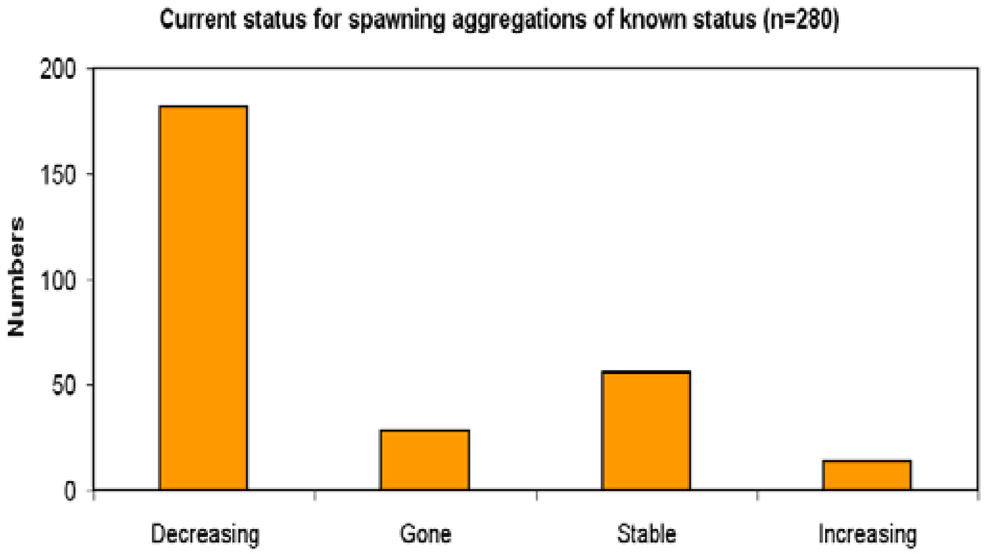

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Fig. 11 Status of 280 exploited reef fish spawning aggregations globally based on interviews and direct observation; the majority are undergoing decline due to overfishing. www.SCRFA.org (Sadovy de Mitcheson et al 2008)

Procedure Most spawning aggregations are discovered as a result of information provided by fishers. A systematic approach to revealing the presence of aggregations in a region is through semi-structured fisher interviews. Presented are guidelines and a simple interview survey framework (ANNEX 1) that can be adapted to a wide range of situations. Information must be collected on a species-specific basis because even closely related species can differ substantially in their reproductive habits. For this work it is strongly recommended to have at hand photos of the animals of interest and detailed maps of the area(s) under discussion.

General notes on interviewing There are many publications on interviewing techniques and it is not the intention of these guidelines to train in such techniques, other than to briefly draw attention to important considerations for interviewing. The interviewee should be selected carefully; usually he/she will be recommended or widely known in the community to be an experienced fisher of reef fishes. For details on interview techniques and considerations refer to ANNEX 1. In some cases traders will be knowledgeable, while those who clean the fish (often wives) may know more about the gonads than the fishers themselves.

Interviewers must be properly prepared The interviewer should be knowledgeable about the species of interest, be able to identify them, know something about the fishery, understand about spawning aggregations (how do these differ from fish 'schools' for example), and be generally prepared not only to collect information but to provide useful information. *The interview is an excellent opportunity for information exchange and should not be one-way process* (i.e. just asking questions). If the interviewer does not know about the fishery and species, he/she will not gain the respect of the interviewee and will not be able to evaluate whether the interview is proceeding in a meaningful way or provide useful information. For example, the experience of a fisher who dives and uses a spear could be very different from one who only uses hook and line; as an interviewer you need to be aware of such different experiences of the fishery and how these may affect the experiences and responses of the interviewee (Fig. 12)

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Fig. 12 Interviewees in Palau and Indonesia along with photos of local fishes and a map.

Is the species caught in spawning aggregations?

A critical early component of the interview is to establish whether the fisher knows of species that aggregate to spawn and whether he/she catches such species in spawning aggregations. To do this the interviewer needs to determine BOTH that the species of interest is *caught in an aggregation* (i.e. a temporary increase in fish numbers) and that *it is spawning* (i.e. reproductively active). BOTH pieces of information are needed because a

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species can gather for feeding, or may be a typically schooling species that does not gather just for spawning. See a sample interview framework in ANNEX 1– this can be adapted for local circumstances.

When and where is the aggregation?

In general what you want to know is *which species* show clear evidence of forming spawning aggregations, *what evidence* there is (i.e. why fishers think there is both aggregation and spawning), *where the aggregation(s) forms* (marked clearly on a map), *the months during which the aggregation(s) forms*, and any other information of interest about the aggregation site and timing, including fishing activity (e.g. number of boats, number of fishermen, gears used).

Have aggregation catches changed over time?

You may want to reconstruct the history of the fishery on spawning aggregations to know how catches may have changed over time, relative to catches today. Such information is important to determine whether management of fishing activity is needed, or may be relevant to Marine Protected Area (MPA) design. If the landings from the aggregation are declining, then there might be problems that need to be addressed. For example, if the interviewee has fished for 20 years at the same aggregation site, you can ask about catches (per trip, day, or whatever) when he/she first fished the site, then 10 years later/ago, or whenever the person can remember well (maybe identify a wedding, or a birth), and then in the most recent fishing trip to the site. Also, ask how many other boats were at the site in the early days and then more recently. What you are aiming for is some indication of any trends in catch per unit of effort, catches and fishing effort over time (Section 2.1) at a known site for known species to understand the history of the aggregation fishery. Interviews should be conducted with multiple fishers in the community and interview results discussed with the community on completion.

Keep interviews simple, short, interesting and concise

In addition to the interview forms the interviewer can be aided by photos and maps to confirm species identifications (note that local names for fish species can vary a lot) and to assist in locating any spawning sites reported. Take interesting information to hand out to the community if available – use the interview to exchange views and provide information.

Confidentiality and respecting information provided

Information obtained from interviews will most likely come from fishing areas important to families and communities. Given how easy it is to fish out an aggregation, *interviewers should only use the information with the purpose of improving the fishery or fish population*. Interviewees should be advised about how their information will be used. Release of site-specific information into the public domain could result in outside interests learning about the aggregations and possibly moving in to fish them, and should be avoided. *Every effort must be made to respect and safeguard information provided by fishers*.

1.3 Abundance of target species in the field; fishery-independent information

Introduction

Management planning depends, in large part, on knowing something about the size of the target population. With this information, combined with reproductive biology and perhaps the history of the fishery, it is possible to estimate the potential for population growth and then to make decisions about catch rates likely to be sustainable. Abundance can be estimated in several ways, either by developing a method that provides an estimate of **absolute abundance or density,** as described here, and which is *fishery-independent*. For reef fishes, this method usually requires counting fish in the field over a known area. For fished species, the 'catch per unit of effort' (CPUE-see Section 2) is used as a measure of relative abundance and is particularly useful for following any changes in catch over time (in the form of CPUE) that might signal changes in population numbers indirectly (Section 3). The CPUE method is addressed in Section 2.1, and is usually fishery-dependent. Fishery-independent data are very important because they can provide a better indication of population condition than can fishery-dependent data which are complicated by such confounding factors as gear selectivity. Density information is also difficult to collect with fishing gears. While there are many methodologies available

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for the underwater survey of relatively sedentary medium to small-sized reef fishes (ANNEX 5), few are available for large, wide-ranging and particularly uncommon species. Hence this section focuses on the latter category since many commercial species, and several of conservation concern, are large, wide-ranging and challenging to survey. Three cases studies are provided for illustration.

Procedure

Estimation of the abundance/density of a reef fish species in the field depends on two pieces of information (1) the density (number per unit area) of the species as determined by underwater visual census (UVC), (2) the area of the habitat of the species in the region of interest, i.e. the area of reef habitat that the species of interest is associated with. It is often important to know the sizes of individuals, information that can be used to track possible changes in sizes over time, habitat associations by size or developmental phase. The numbers of adults, and sex ratio if possible, are important to quantify reproductive individuals contributing to the next generation. Sex ratios can be determined if males and females are differently coloured or have obvious behavioural differences.

Methods for the estimation of numbers and sizes of fish and calculation of both fish densities and reef areas are relatively simple and can be conducted following simple training and using inexpensive techniques. Even reef areas over extensive regions can be readily assessed from access to various tools on the Internet nowadays, such as satellite imagery. As for any scientific method, care is needed in developing the sampling protocol so that reliable data can be collected, survey locations clearly mapped, and sufficient reef area covered to gain a robust sample. Full details of surveys must be documented to allow for follow-up surveys in future. UVC methods can be particularly effective when the focus is one or a few species (rather than multiple species), since searching the reef for species that are uncommon or may not be readily spotted needs full concentration that is not possible if multiple species are being surveyed simultaneously. One species will be used to illustrate some of the challenges of, and new methods available for, UVC of highly mobile uncommon species, the Napoleon wrasse ***(Cheilinus undulatus).***

Objectives

To outline methods of underwater visual census (UVC) surveys for estimating the **absolute abundance and density** of key target species of interest for fisheries assessment in the geographic/fished area of interest for management in a fishery-independent manner. Particular attention is paid to methods for *mobile and/or uncommon species*.

Techniques

The basic techniques for underwater visual census (UVC) and for estimating fish size underwater are well-described in various books and publications which should be referred to for details (see ANNEX 5). For each location and target species, a sampling protocol should be developed and this requires planning and perhaps preliminary surveys to establish the best way to conduct UVC for each location and species. Key questions to address are: (1) where to do the surveys; (2) how many surveys to do in each location; (3) how many locations to survey; (4) when to do the surveys; and (5) length and width of the transect survey line. It is also essential that there is no doubt over species identification and that training in fish size estimation has been conducted if sizes are to be assessed (ANNEXES 2 & 4).

Where and when to survey?

The area of interest should be identified. Decisions will have to be made regarding what depth ranges to survey and what particular habitat. Regarding ***where*** to survey; for species that occupy a wide range of depths, as is the case for many coral reef fishes, surveys will typically have to cover the shallower part of their range (<20m or so) for safety and time reasons, so selection of the appropriate habitat(s) is very important. This is acceptable for initial abundance estimates since most fish are likely to be more heavily fished in shallower waters leading to conservative numbers. However experimental fishing could be conducted in deeper waters. Note that juvenile and adult habitats may differ. Regarding *when* to survey; visual surveys should usually be conducted during daylight hours (dawn and dusk lighting might be more difficult visually) and during appropriate weather conditions/seasons. Note that some species spawn in aggregations and migrate to aggregation sites temporarily (for days, weeks and possibly a few months) at certain times of the day or year; such information should be factored into sampling design.

How many locations to survey and how many surveys in each location, and size of survey transect line?

"The number of replicates, or sample size, is an essential component of the experimental design of any visual census sampling programme. If the sample size is too small the power to detect differences among means is likely to be very low or inadequate, and if the sample size is too large effort is wasted. The maximum number of replicates is based on factors such as time, money, materials and feasibility. The minimum number of replicates can be defined in terms of resolving power, i.e. the power to detect change in fish abundance" (Samoilys and Carlos 2000). *But most important of all is that sufficient samples, in terms of locations to survey, number of surveys in each location and length of each UVC survey, for a scientifically robust result to be achieved*.

Strip or line transects for reef fish surveys typically run for 50-150 m along a temporarily deployed tape and the width of the transect is usually between 5 and 10 m (i.e. from 2.5 to 5 m either side of the transect). They can be conducted on SCUBA or snorkeling. Note that in some cases, as for wide-ranging species, transects have to be considerably longer in order to get a representative sample, even many km (see Fig. 13 and ANNEX 2). In such cases, laying down a line on the substrate is impractical and a Global Positioning System (GPS) can be used as a 'virtual' transect with a larger transect width (adjustable according to prevailing conditions). The combination of the transect length (L) and width (W) allow an estimate of density number of fish per unit area (L x W) to be made.

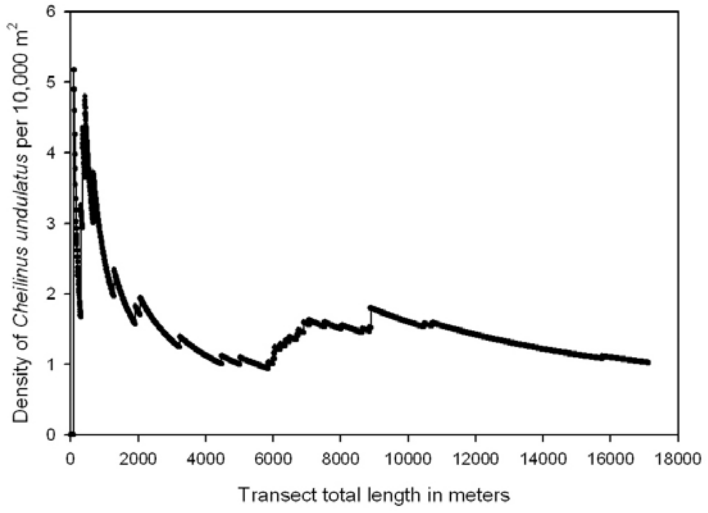

Fig. 13 Cumulative mean density (per 10,000 m2) of Napoleon wrasse with total distance surveyed at one survey location. The value eventually reaches a relatively stable value after about 14 km of transect distance. This would be the minimum distance to obtain a representative density estimate for the species.

Estimation of fish sizes

Estimating of fish length underwater can be accurate to within about 10-15% for an experienced observer. However training is needed to obtain that accuracy and regular practice.

Estimation of reef area

To scale up the density estimates collected by the UVC to enable abundance estimates of the target fish species in the region of interest, a calculation is needed of the reef habitat relevant to the study species. Using free satellite images, available online, simple techniques can be used to produce approximate reef areas.

Case Study 1

Medium-sized species, somewhat mobile (e.g. leopard coral trout, *Plectropomus leopardus*) (Samoilys and Carlos, 2000)

The leopard coral trout is readily observed underwater and therefore very suitable for UVC work in the shallower (i.e. accessible to snorkel or diving) parts of its range. The species has the same coloration throughout life and is easy to identify underwater. Its size of sexual maturation is about 30 cm TL and it can grow to about 120 cm SL. It can resemble several other ***Plectropomus species*** but is readily distinguished by the blue ring around the eye and the small blue spots on its body (Fig. 14).

Because of the need for representative samples and because of the high variability inherent in fish density UVC estimates Samoilys and Carlos ***recommend that at least 10 replicates*** be used to quantify the coral trout. Standard UVC methods for reef fishes can provide rapid estimates of relative abundance, biomass, and length frequency distributions of reef fishes. If both juveniles and adults are to be surveyed then different habitats would have to be sampled with sufficient replicates conducted in each habitat type to be representative. Potential sources of error must always be considered and the data analysed to ensure that sufficient samples have been taken. The depth limitations of safe SCUBA diving mean that deeper waters, often the last refuges for species taken in coastal reef fisheries, are likely to be under-sampled by fishery-independent approaches that involve in-water censuses. To sample deeper waters, mixed gas diving or appropriate collection methods such as experimental fishing would need to be applied.

SECTION 1 - BIOLOGY

Thierry Chan

J. E. Randall

Fig. 14 Leopard coral trout in a tank and as it is seen in the field. Distinguishing characteristics are the very small blue dots on the body and the blue ring around the eye.

Case Study 2

Uncommon wide-ranging species, highly mobile (e.g. Napoleon wrasse) (Sadovy et al. 2006)

The Napoleon wrasse is a large reef fish that can reach 200 cm TL. It passes through different colour phases as it grows (Fig. 15). The species is distinguished by the two dark eye slashes that run behind the eye and are present in all colour phases. Its size of sexual maturation is about 40 cm TL. Since the species is large and wide-ranging, standard UVC methods that involve the laying down of transect lines are not practical and, although the same in principle, have been adapted to accommodate the much longer transects required using GPS (Fig.13; ANNEX 2).

Robert Myers and J. E. Randall

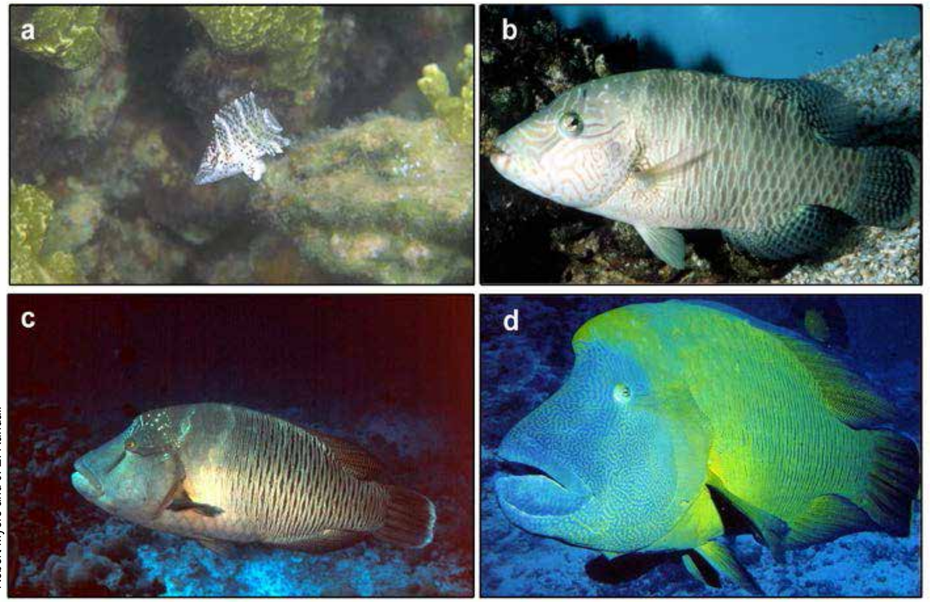

Fig. 15 Four colour phases of Napoleon wrasse with growth, from small 7cm (a) to large 1.5m (d). Adults are (c) and (d)

The "GPS (Global Positioning System) Density Survey" method of UVC is particularly well suited to assessing abundance of *uncommon and wide-ranging species*, such as the Napoleon wrasse. Even in relatively undisturbed regions, this fish is among the least common of commercially significant reef fishes. Conventional underwater visual survey (UVC) techniques (typically 50 to 150 m long transects) based on deploying measuring tapes are unsuitable for document the abundance of these reef fish because considerably longer transects need to be used. ANNEX 3 outlines the methodology and equipment needed. The GPS can be placed in a simple waterproof housing and towed by snorkeler or attached to a line by a SCUBA diver (Fig. 16).

Yvonne Sadovy

Fig. 16 Simple and inexpensive equipment enable GPS-based UVC to be conducted either snorkeling or on SCUBA on uncommon and wide-ranging species requiring long transects (Fig. 13). The GPS unit (Garmin model) is placed in a home-made PVC container that is screwed to a narrow pipe weighted to keep it upright once the buoy (white on left and yellow on right) in added for flotation.

A key decision in developing a sampling protocol for a species of interest is what habitat to sample and how to present results so that workers in future can redo the survey if necessary. Study aims are an important determinant as are practical and safety considerations. In the case of the Napoleon wrasse the decision was to survey the adults. Since all adults of the species, as far as is known, will use the shelf edge/dropoff area on a regular basis for reproduction and since this is a very easy habitat type to consistently identify, we surveyed shelf edge areas by SCUBA or snorkel, whatever was appropriate and the simplest option at the time for the survey location. Should we have opted to survey for juveniles we would have selected the preferred juvenile habitat for the species and sampled accordingly (i.e. further inshore and in the appropriate algal/coral habitat) mostly by snorkeling. Once the GPS data have been downloaded, they can be plotted on a satellite image (available free online) of the surveyed area, allowing for resurveys in future (Fig. 17). Snorkeling allows for much more flexibility, longer periods in the water and is safer and easier to use than SCUBA. The methods can be compared to ensure consistency.

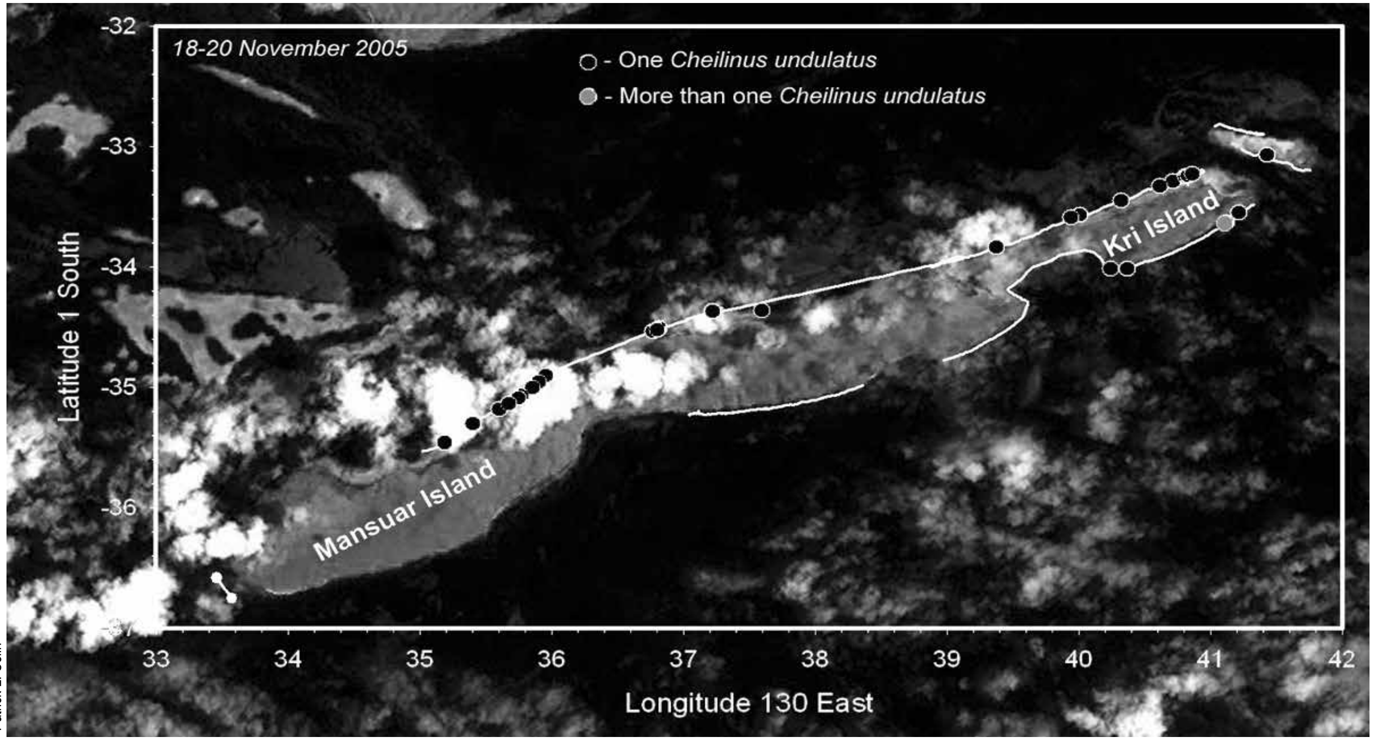

Fig. 17 Landsat satellite image for one survey track for Napoleon wrasse adults in Indonesia using the shelf edge habitat. The white lines along the island shore are the swim survey tracks and can be easily replicated in future studies. Locations of C. undulatus are noted by the circles. See ANNEX 2.

Case Study 3 Surveying fish in demersal spawning aggregations (Colin et al., 2003)

Spawning aggregations are the main way in which many commercially important reef fishes reproduce. They typically involve large numbers of fish coming together for short periods of time during the same period at the same reef site every year (Fig. 10). This can be a very good opportunity to do a fishery-independent survey of the aggregating fish which can represent a large proportion of the adults in the population in some species. Much has been learned over the last decade about the effective monitoring of spawning aggregations and how challenging this is to do effectively.

During the reproductive seasons aggregation sites can be dynamic places; aggregation sites can be used by multiple species which may occupy different areas within the same site, the sexes can have different patterns of arrival and departure, and peak numbers could be different for different species by month and according to the lunar cycle, with peaks for a given species also varying each year, number of fish can change markedly from one day to the next, densities may vary considerably across a particular aggregation site and within a single monthly spawning season. Many aggregation sites may be quite large, exposed to strong currents, or occur in deep waters, making them difficult to survey in their entirety or for very long, due to safety or logistics considerations. Sometimes sites are difficult to access far from shore or expensive.

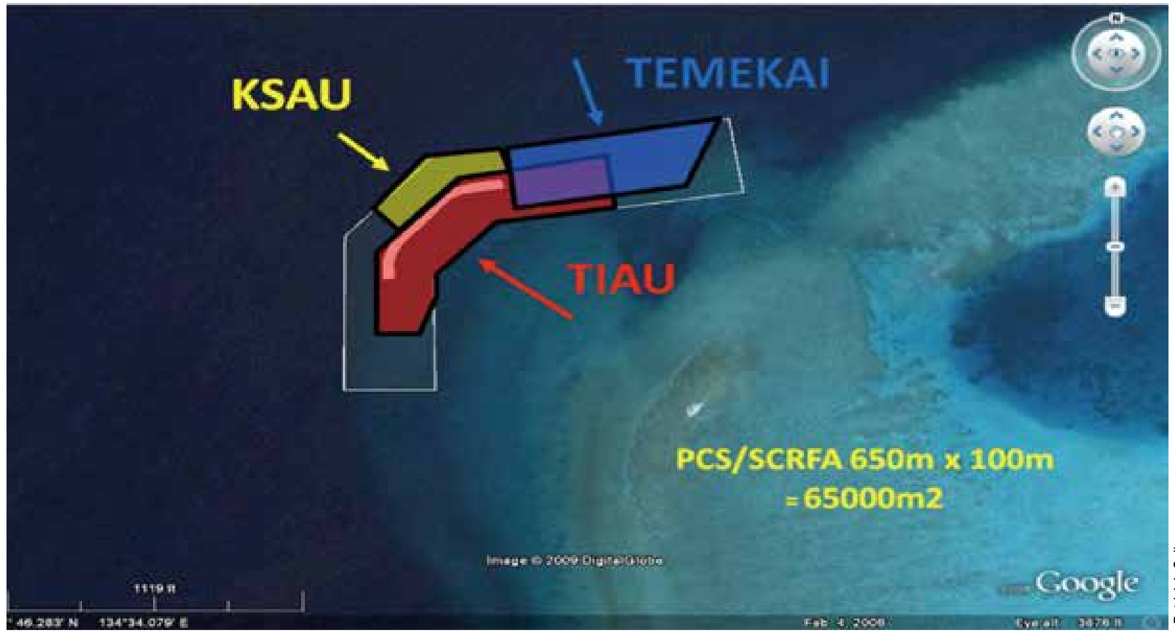

Fig. 18. Geo-referenced image of an aggregation site with three grouper species using local names (red is Plectropomus areolatus-tiau; yellow is Epinephelus polyphekadion-ksau; blue is E. fuscoguttatus-temekai) The full area covering all three species was surveyed (within the white box) by UVC.

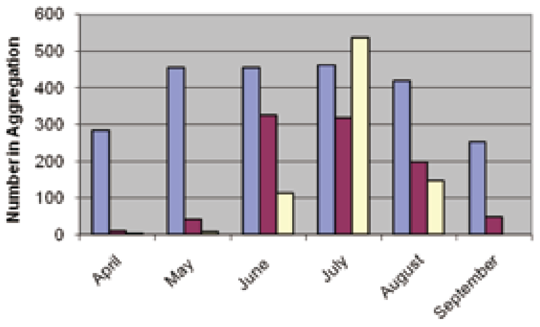

Fig. 19 Number of ***P. areolatus*** *(mauve);* ***E. fuscoguttatus****, (red) and* ***E. polyphekadion*** *(pale white) recorded on the single peak aggregation day each month that spawning aggregations formed in 2009 for each species at the site shown in Fig. 18.*

Monitoring decisions require knowledge of the whole aggregation site (GPS surveys can be used to plot out the site), and the aggregation locations of the species of interest (Fig. 18). Then it is important to know the main reproductive season to know which month (Fig. 19) (and also the time in each month) to focus the sampling activity. Then the divers must work out where to put the survey transects--ideally with some permanent markers so that the same transects can be repeated in different years. Ideally the whole site should be surveyed rather than just a part of the whole site. The distance apart that the divers swim doing these transects should be determined by the conditions, such as current, visibility, fish behaviour, diver experience, etc. (Fig. 20). Fishes that aggregate over the substrate and stay close to the substrate are relatively easy to count (as in the present example of a **demersal** aggregation). But some species form massive balls up in the water column (**three dimensional** aggregation) which makes for a very challenging sampling situation. For more details see ANNEX 4.

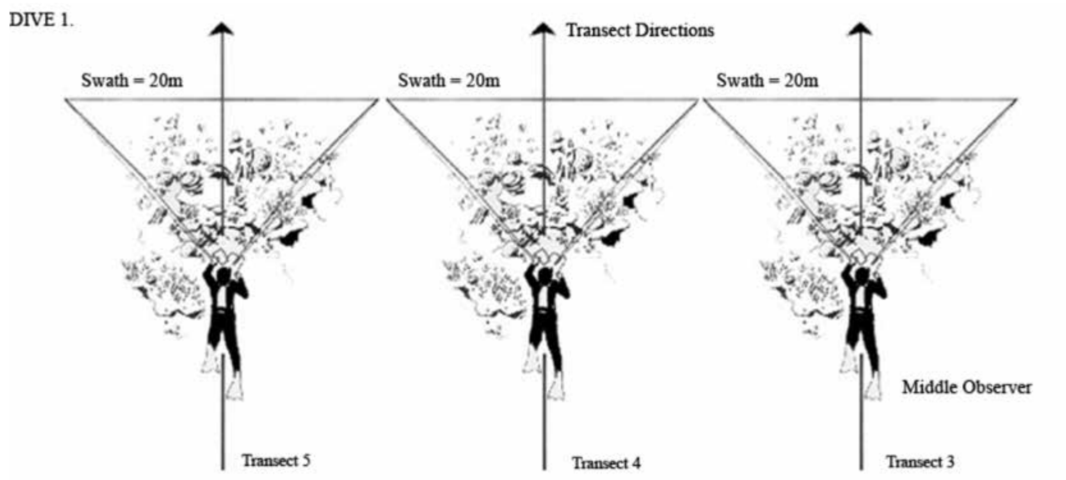

Fig. 20 Diver observers lined up perpendicular to the reef slope and parallel to each other on three respective transects. Each diver swims high above the reef and surveys fish 10 m to either side of the transect line. Shorter distances are needed if the visibility is not good or fish are hard to see. Divers on adjacent transects must keep in visual contact to ensure that they do not double count fish that lie between them. Image: Scottie Kieffer

SECTION 2 - FISHERY

Introduction

Yvonne Sadovy

Fig. 21 Fisher landing his daily catch of grouper as he returns to port

2.1 Estimation of catch, effort and catch per unit of effort (CPUE): fishery-dependent information

Exploited reef fishes typically need management especially when they are exploited for commercial reasons (rather than just for subsistence although even some subsistence fisheries might need to be managed). For management, information may be needed on some or all of the following--target species, both in terms of its biological characteristics (Section 1), fishing activity in terms of numbers and sizes of fish removed each year, fishing sector(s) (including culture operations, dead or live fish for international and domestic trade, gear type used, etc.), numbers of fishers/boats/gear, fishing area, and species composition in the case of multi-species fisheries. Information on bycatch (non-target) species may also be of interest. Information on catch over time, especially combined with knowing the amount of fishing effort used to get that catch (number of fishers, time spent fishing, area fished, etc.), provides an important indication of the condition of the fishery in the form of Catch Per Unit of Effort (CPUE). Much can be learned of the history of a fishery, in the absence of formally collected data or long term studies, by interviewing the fishing community (Fig. 21).

In most coral reef fisheries information on catches is not regularly or consistently collected, if collected at all, and so often special studies must be designed to gather the information needed for management or to determine the fishery condition. Sometimes fishery departments just collect information on species composition and landings (i.e. the weight of different fish species that are taken to markets or brought in by fishers) but on nothing else. Sometimes many species are lumped into one category (e.g. just groupers rather than by separate grouper species). Studies to collect the necessary information can be done by students, by NGOs, by government departments and can also be collected directly from fishers as Traditional (or Local) Knowledge (Section 1.2).

Objective

Estimation of the volume (weight) of target fish species removed annually

Procedure To produce a reasonable estimate of the amount of fish caught and or landed by fishing requires decisions about when and where to collect information and these are all determined by the reason (the why) for collecting data on catches. Once the study objectives, or aims, are clear then a sampling design can be developed. Since it is not possible to follow every fisher every day of the year and observe everything he or she catches, decisions are needed regarding how to SUBSAMPLE catches to gain enough information to make the estimate of annual catch. Typically, there are three types of information likely to be needed; (1) number of fishers, (2) average catch (could be total catch or focus on a particular species of interest) per fishing trip per fisher (or equivalent), which could in addition include, (3) information on discarded catches or catch that may not make it to the sampling point. Places that studies are often done are landing points/ports, wholesale or retail markets (may be the same as the landing point), direct sampling on board fisher vessels or interviews with fishermen in home communities. Often a combination of approaches to obtaining data will be used. The appropriate formula estimating annual catch would be something like:

Annual catch (weight; by species or combination of species) = Number fishers x average catch per fisher per fishing trip (including bycatch, etc.) x average number of fishing trips [if total catch for the year per fisher is known this can be multiplied by fisher number]

Determining the number of fishers, compared to many other information requirements in fisheries studies, is usually relatively easy and common sense. It may be possible to use the number of fishing licences issued, conduct counts at the dock or landing site (appropriately timed according to local fishing operations), or carry out interviews in local/regional communities, etc.

Determining catch per fisher for the year can be done by estimating his or her total annual catch (maybe using government records), or, more commonly, requires estimation of an average or typical catch per fishing trip (either of all the species caught per trip or just of species of interest).

If average catch per trip is estimated then the number of trips per year is also needed. Total catch would obviously be number of trips multiplied by the average catch per trip. Information can be collected by multiple visits to landing points (SUBSAMPLING) to count fishers and inspect catches directly. Data collection trips should be done multiple times at different times of year and day and involve sampling fishers using different types of gear (because catches may vary seasonally, whether day or night, by gear, etc.). This means that sampling will be done many times in a year at times appropriately selected for the fishery. Another way to collect similar data is by interviewing fishers directly (Fig. 21).

Remember that one major reason for knowing the amount of fish landed each year is to calculate the production of the fishery. Hence the major interest is in everything that is removed from the sea, not just what turns up at the sampling point. For example, information may be needed on bycatch (i.e. unwanted catch that is discarded before reaching port), retained/ unsold catch (i.e. fish kept for family use and not landed), mortalities (for example if live fish are the target, dead fish may be discarded and not reach port or the sampling site) and catch that is not landed at the sampling/study location for other reasons (such as sales directly to hotels or exporters, sale of undersize fish to culture zones for grow-out, etc.). *In general, the sampling protocol must be developed according to an understanding of the local operation dynamics of the fishery of interest. Also sufficient sample trips must be conducted to catch the sum of information that describes the fishery (see about the importance of sample size below).* Supplementary sampling might be necessary depending on trade dynamics. For example sampling of restaurants, culture zones, etc. creel surveys are necessary to estimate volumes. For more on fish culturing see Section 2.3. In determining average catch, attention may need to be paid not only to weight landed but there might be interest in species composition and sizes of fish landed (Section 2.2).

Objective

Estimation of Catch per Unit of Effort (CPUE)

Catch per Unit of Effort, CPUE, is a commonly used indication of relative abundance of fish in a fishery, and is the most common way of expressing the abundance of fish in the fishery. This kind of approximation is necessary because it is very rare that all fish in a fishery can actually be counted. Fish numbers are important because they tell us something about the condition of fish population. *In using CPUE the major assumption is that CPUE and fish abundance are proportional. Hence, if the population is getting smaller, the CPUE should decline and that might indicate overfishing (but see an important exception below; hyperstability).*

Having a long-term dataset of CPUE can provide a valuable perspective on the history of the fishery (see below), which, in turn, provides an important perspective on its overall condition. CPUE data can be used to compare fisheries over time or across space because CPUE is standardized (i.e. it is a typical catch for a defined unit of effort). Knowing CPUE is very important because it is possible for catch to actually increase or stay the same while CPUE declines. What happens to the CPUE rather than just the catch is a much more reliable indication of what is actually happening to the fish population. This is because even if a fishery appears to be stable (as judged by overall landings) it might actually be declining and only appears to be stable because more and more fishers are entering the fishery or existing fishers are trying harder and travelling further to catch fish or might have introduced more efficient gears to maintain catches (Fig. 22). *CPUE trend over time is an extremely important indication of fishery condition and must be standardized for a given gear and fishing trip type so that it can be compared across time and space.*

To estimate CPUE it is typical to use a combination of observation of fishing operations to determine catch (in total or by focal species) for specific gear types, and interview fishers or look at logbooks to determine fishing effort. CPUE is usually expressed as a weight of catch described by gear type, by fisher day, or by boat (etc., etc.) according to the fishery. Most importantly the information must be collected in a standardized and consistent way, ideally over the long-term, to allow for

SECTION 2 - FISHERY

cross-comparisons. The way in which they are standardized will depend on how fishers operate so understanding the fishery dynamics is very important for designed the data collection. For example, for a specific gear type such as fish trap or hook and line, it might be possible to record catch (in kg) per hook (or per line or per trap) per hour or per day. Or total (or species-specific) catch per boat per day, or catch per fisher per day. If catch per day is estimated, the interviewer would have to make sure that the number of hours fished in a typical 'day' is the same for each interview, or find a way to standardize the fishing time. Again, much is common sense and simply depends on the worker understanding the fishery and adjusting questions/observations accordingly.

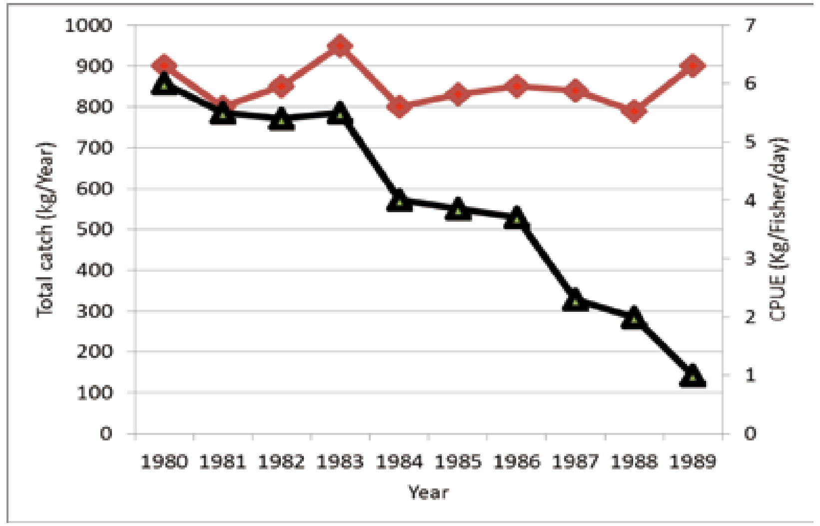

Fig. 22 Between 1980 and 1990 the landings of a grouper species (red line) in this fishery stayed constant in the fishery but its CPUE (black line) declined. The population was actually declining (as shown by the dropping CPUE-a measure of fish abundance) but because fishers were fishing further and longer, they managed to maintain the landings (red line) hiding the decline (black line). Because nothing was done to manage this fishery and reverse the CPUE decline the fishery eventually collapsed.

There are many ways in which CPUE can be expressed and careful planning and discussion is needed before collecting this information because its value is in being standardized over the long-term to allow for comparisons. The objectives of the study should also be kept in mind, i.e. why are the data being collected? For example, if workers record CPUE as fish (kg) per hook per day in the first survey, then for a second survey record fish (kg) per boat per hour, then these two estimates cannot be compared (like you cannot compare apples with oranges). Also, if the fishery includes several different gear types, then a CPUE measure for each gear type is needed. For example, for fish traps CPUE could be fish (kg) per trap per haul, or for speargun fish (kg) per fisher per hour.

To ensure that sufficient interviews are conducted for a representative indication of CPUE, a graph of cumulative mean (average) CPUE can be simply plotted against number of interviews. The point at which the graph stabilizes (i.e. flattens out), indicates when sufficient interviews have been conducted - in this case about 20 interviews were needed (Fig. 23).

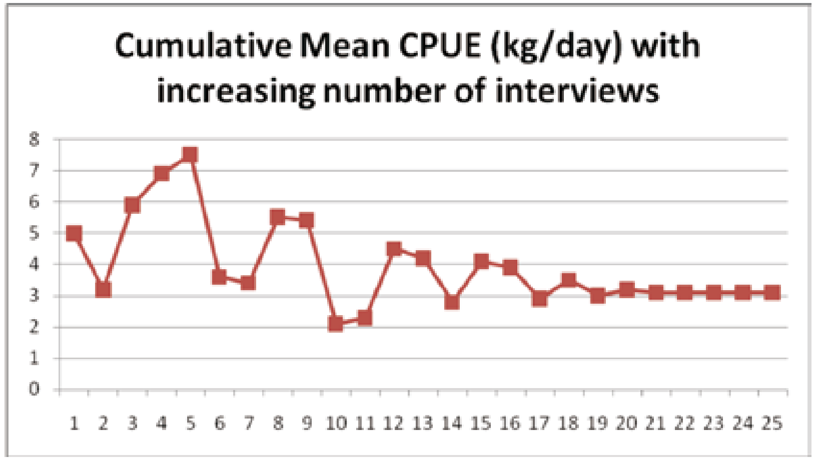

Fig. 23 With successive interviews (x-axis covers 25 successive interviews) the mean CPUE reported by the fisher (y-axis in kg/day) for species of interest will begin to stabilize. When it does, then you know you have interviewed enough fishers for a representative measure of CPUE; in this case about 3 kg/day/fisher. About 20 interviews (20 different fishers in this case) had to be interviewed to get this representative measure of mean catch.

There is one important situation when CPUE does not necessarily provide a good indication of the condition of a fishery and that is known as 'hyperstability'. Recall that the key assumption for using CPUE as a measure of fish abundance is the assumption that the two measures are directly related. There are a few cases when this is not necessarily the case. In coral reef fisheries, the most likely one to be encountered is in the case of information that comes from fishing spawning aggregations. If CPUE is based on fishery-dependent data from fish taken at the aggregations (see Section 1.2) it is very likely to overestimate fish population abundance. The reason for this is that fish become easier to catch when they change their behaviour and are all gathered together in the same place to reproduce. Even as the overall population declines, they will still aggregate and catches will remain high until the population has dropped to low levels when a sudden 'crash' might occur (Fig. 24 and 33). Hence for species that aggregate to spawn, CPUE should be determined outside of the aggregation period to get a better indication of population condition. Alternatively, in-water, fishery-independent surveys can be conducted on aggregation sites (see Case Study 3 above and ANNEX 4).

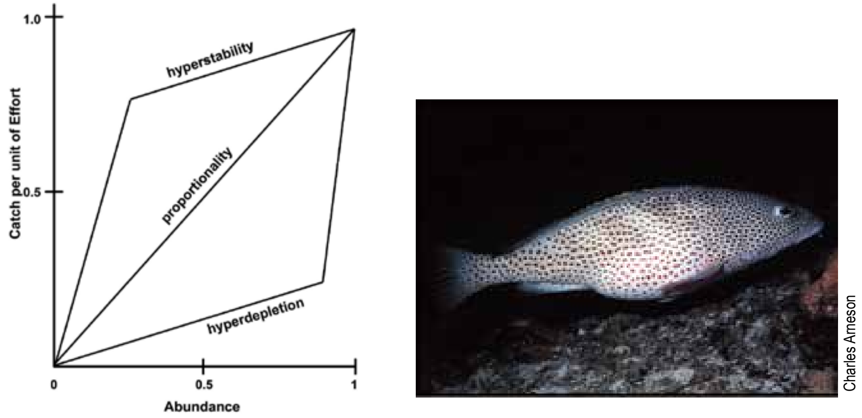

Fig. 24 Relationship between CPUE and fish abundance. For CPUE to be a good indication of population condition, their relationship should be proportional (the middle straight line). In some circumstances, fisher or fish behaviour may change making fish easier or harder to catch than usual. For aggregating species caught in aggregations where they are easy to catch, CPUE may remain high even as the fish population is actually declining (hyperstability line). The female on the right is full of eggs about to spawn in an aggregation

SECTION 2 - FISHERY

For almost all coral reef fisheries there exist no long-term data sets of the kind available for many industrial scale cold-water fisheries. This is due to a combination of factors: the low perceived economic value of individual species; the small budgets and limited manpower resources in the fisheries departments of developing countries; and also because the many fishing communities and landing sites and the multiple species fished make regular and standardized sampling a major challenge. This means that much of the history of the fishery and knowledge of fishing grounds is only available from the memories and understanding of fishers themselves, particularly those who have a long experience; the patriarchs.

Information on the history, and changing condition, of coastal tropical fisheries have been extensively collected using interviews and is very valuable for recognizing trends. Such information can be collected by interviews (see Section 1.2) that are appropriately focused on the aspects of the fishery of interest. As indicated in the earlier section on interviews, it is critical that interviewers understand the local context of the fishery before attempting to conduct interviews and that they respect any confidentiality issues involved.

In addition to the history and perceived condition of a fishery, other valuable information can be obtained by interviews. Such could include the fishing grounds being used and any changes in these over time. Concerns about poaching or about the fishery in general, opinions from communities about their own resources can also be collected.

Bycatch and fishing history

Introduction

Objective

Understand the history of the fishery and the fishing grounds

2.2 Species and size composition of catches determined from market samples/retail outlets

Knowing the species and sizes of fishes being fished or marketed is a very important aspect of describing and understanding a fishery. To collect this information requires the ability to identify species and distinguish different species from each other that can look very similar (and also look different live and dead). And it requires the measuring of fish body sizes in a way that provides a representative and meaningful description of the sizes of fishes being landed (this involves selecting which fish and how many fish to measure) and how these might relate to the fish sizes being removed from the sea. Fish size can be important for assessing the condition of a fishery; typically (but not always), fish sizes decline over time if overfishing is occurring (see Section 3.1).

Objective

To determine the species composition of catches or retail sales

Procedure

Two things are important; correct identification of species and sufficient sampling to get a good indication of species composition. For example, one or two market visits is almost certainly not enough to find all the species that are caught or enter a market. And 1,000 visits would be unreasonable. Most fisheries have seasonal variability in species landed so some sampling is needed throughout the year, or at least during different seasons. So how many visits is enough? I will address this question below.

Species identification can be easy for some species and a challenge for other species groups. For example, in the two figures below, several grouper species are shown that are sometimes confused with each other (Figs. 25 & 26). Moreover, the coloration of these species can be quite different live and dead. Two of the species shown in these two figures are also in the tank of live fish in Fig. 28. Which two? To ensure good species identification, fish guides or experts must be consulted. Also useful as a readily accessible reference is www.Fishbase.org. Sometimes fish will have to be purchased to allow for detailed examination to identify the species.


Dipa Devi

Fig. 25 Plectropomus areolatus, squaretailed grouper, on left (note brown rings around blue spots on body) and coral trout P. leopardus on the right – tiny blue dots on body with no rings. Compare the colour of the dead coral tout, above left, with a live one in which you can clearly see the blue rings around the eyes (Fig. 14)

Dipa Devi

Fig. 26 *Epinephelus fuscoguttatus*, brown-marbled grouper, on left (note bulkiness of body) and *E. polyphekadion*, camouflage grouper, on the right which looks very similar. The brown-marbled grouper also has a concave profile between the eyes not shared by the camouflage grouper and grows much bigger.

An important decision with fish catch or market sampling is to work out how many visits to the market are necessary to adequately describe the species composition on retail sale, or catches that must be sampled from different fishers to get a representative indication of species catch composition. For species composition, you need to continue sampling until additional samples will yield no more species (Fig. 27). To work this out, you could plot a cumulative species curve by number of visits. Once the curve flattens, then you have a representative sample of species diversity and do not need more samples. Careful planning is needed since this cumulative curve exercise may have to be repeated for each gear type (because different gears can take different species), or by season, etc. It is also possible that time of day is important. If catches come in during the early morning, favoured species are likely to be sold first so care is needed to select appropriate times to sample. Having a small camera readily available is very useful.

It is also important, if the study objective is to know the species composition of the fisher's catch but the only access point for sampling fish is in the retail fish market, to know how well market sales represent fishers' catches. For example, a fisher might split his catch between the market, restaurants and hotels in which case hotels and restaurants must be sampled. If live fish are

being caught for export, market-sized fish might go directly to exporters (and not local markets with dead fish) while undersized fish might be destined for captive grow-out cages (Section 2.3). In some cases fishers will take certain species home and do not sell them. Also, in the case of rare or threatened species catches might be very infrequent or regulations may make fishers secretive. In all such situations, interviews with fishers will be extremely important for establishing the design of the study.

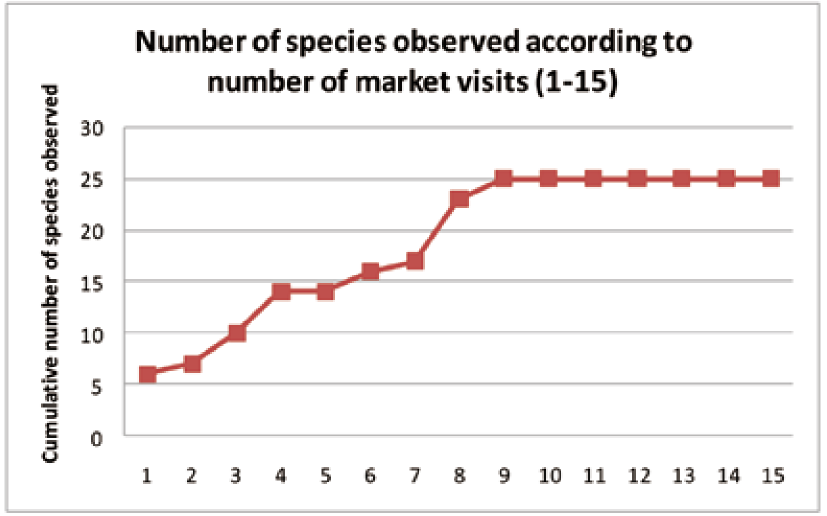

Fig. 27 To ensure that sufficient market visits (x –axis here shows 15 market visits) for a representative sample, make a cumulative plot of the total species observed with increasing number of visits. When the curve clearly flattens off you have sampled all the fish species. In this case at least 10 market visits were required.

Objective

To determine size composition of fish taken from the fishery or in the retail sector

Procedure

Sampling fish in markets for size can be a challenge in terms of getting sufficient samples for length measurements for the less common fish, and for having the time to measure and identify fishes in a busy market situation. Often there is nowhere to write easily, little time to do measuring and conditions can be hot, crowded, rushed and noisy. For these reasons, workers need to be very clear and focused on what information they need and be sure that they can readily identify the species they are interested in. Having a camera and ruler (or some other indication of scale) can be invaluable.

Body sizes can be determined by measuring the sizes of identified species in samples in markets or in fishers' catches. But other sampling locations may be available or appropriate (see species composition above). Sizes are generally measured as total length and, if large numbers of fish are available for sampling, then subsamples should be taken randomly (see below). It is important to be consistent.

Ideally, an appropriate time for sampling should be selected, i.e. when the market is not too busy and the worker will not be a nuisance to the seller. If possible it is best to sample shortly after fish have come into the market, or been landed by fishers, to ensure that all target species of interest are sampled sufficiently. In some cases be aware that fish of different sizes might be sorted into different lots. Note that, as for species composition, interviews may be necessary with traders or fishers to develop a sampling method that truly represents the catches or retail sector (see previous Section).

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Fig. 28 Sampling of fish for size can be done in markets (left) in display aquaria (right) or directly from fishers' catches (Fig. 21).

An important decision with fish catch or market sampling is to work out the sampling methodology to adequately describe the target species size-frequency composition on retail sale, or catches that must be sampled from different fishers. Five other questions are also relevant for target species: (1) how many fish should I measure and which fish; (2) how shall I do the measurements; (3) when should I do the measurements; (4) what should I do if there are not enough fish (rare or threatened species)? (5) what do I do if there are too many fish and I have to select a subsample? Size data must be species-specific (of course, it is meaningless to mix species) and so the first step is to confirm species identification. *As for any study, methodology should be clearly reported so that other people could repeat the work if necessary or for comparison at a later date*.

1. Normally, several hundred fish need to be measured and selected randomly from available fish to ensure a big enough sample that represents catches/sales (Fig. 29).
2. Measurements can be done with a ruler or other object that gives scale. They can be detailed (to the nearest mm, cm, 10 cm, etc.) or assigned according to size categories (small, medium, large, etc.) depending on circumstances. As a general rule the greater the detail the better. For live fish, a ruler can be placed against the fish tank and the magnification factor accounted for.
3. Measurements should ideally be done when they do not disturb general activities and before catches have been split up or otherwise sorted by size.
4. If there are not enough fish, you may need to visit the market or landing site more times or more frequently to obtain a large enough sample size, or to make a request to be advised when the target species is available to measure.
5. If there are so many fish that you have to select a subsample, then this needs to be done systematically and as randomly as possible until you have a large enough sample size. It is very important not to specifically pre-select sizes for measurement.

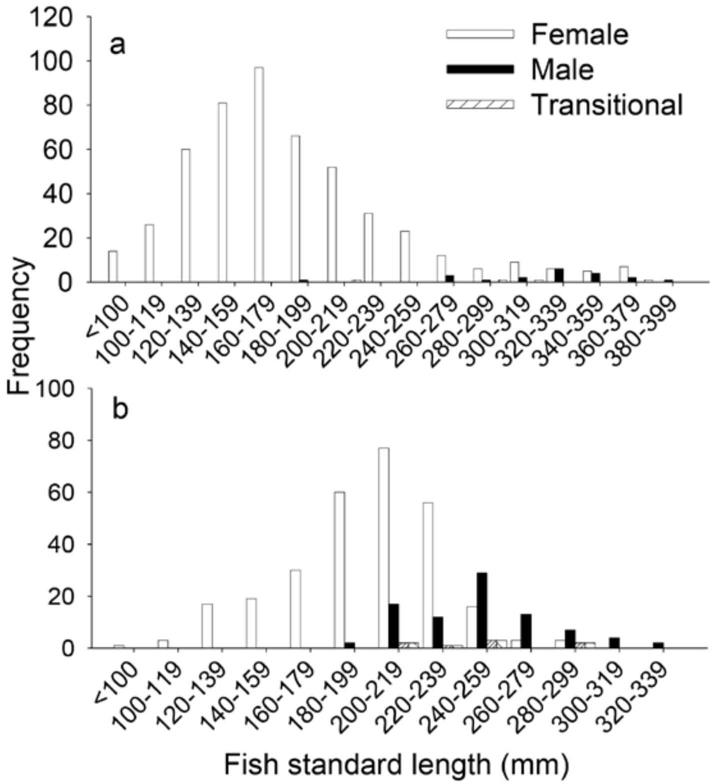

Fig. 29 Size data plotted from fish of a target grouper species from two locations a, and b, one fished heavily (a) and one fished lightly (b). Note that sample sizes include many hundreds of fish to get a clear picture of sizes in catches, In this case the sexes can be distinguished but most frequently all fish are combined for a size plot. Note that there are larger fish and relatively more males in the lightly fished area (b).

2.3 Capture-Based Aquaculture (CBA)

Introduction A growing activity over the last few decades for coral reef fishes is the grow-out in captivity of wild-caught juveniles which are kept, usually in floating cages, until they reach marketable sizes. This activity is now defined by FAO (Food and Agriculture Organisation of the United Nations) as Capture-Based Aquaculture, or CBA. Since CBA involves both culture operations and wild capture fisheries, it requires application of good practice standards for both mariculture (marine fish farming) and capture fisheries (Lovatelli and Holthus 2008). CBA of reef fishes has developed largely as a response to overfishing and declining populations of immediately available marketable sized fish. As the larger, preferred, fish sizes become less available, smaller fish that were caught during fishing operations, instead of being returned to the water to grow, were kept and put in cages where they were fed and maintained to market size (Fig. 30). These cage operations have proliferated and, while some in developing countries are now also provided with hatchery-produced juveniles, many are still stocked with wild-caught fish. A particularly intense CBA in Southeast Asia is associated with the grow-out of reef species for the LRFT, most of which end up in restaurants in Mainland China and Hong Kong.

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Fig. 30 Captive grow-out of juvenile reef fishes until marketable size (Napoleon fish left) typically is done in small cages for months to years (left). Fish may be taken from the wild at a range of sizes but are typically long post-settlement. (right)

CBA as currently practiced for reef fish species, mainly groupers but also some snappers (Lutjanidae), grunts (Pomadaysiidae), wrasses (Labridae) and rabbitfishes (Siganidae) amongst others, usually involves a capture fishery that focuses on the catch of juveniles or post-settlement larvae that are placed (usually) in privately owned cages and maintained by feeding until they grow to market size. In the case of wild-caught fish, most of which are carnivorous, small individuals are typically fed with other wild-caught fish species. These feed fish are usually caught locally in the area of mariculture grow-out operations and may come from trawl bycatch or from reef fish species (Fig. 31). Since CBA involves the capture of wild fish, data collection and management are usually required to avoid overfishing. The risk with CBA based on wild-caught juveniles is that, if too many are removed few fish might be allowed to reach adulthood in the wild with the potential to severely compromise the reproductive potential of the target population. Hence, information is needed on catch volumes of fish destined for CBA, their sizes, mortality and growth rates to be able to ensure that such fisheries are sustainably managed (FAO 2011), just as for any other fishery. Information is also needed on the impact of the grow-out activities on water quality and the provenance and volume involved of the feed fish in the case of carnivorous species. This latter is important because sometimes the feed fish used are the same species as those also used for human consumption in culture areas.

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Fig. 31 Most reef fishes undergoing CBA are carnivorous and depend on other fishes as feed. These can come from trawler bycatch (left) or from other reef fishes. After reaching marketable size – about 0.5-1 kg - they are sent to restaurants or exported. Most grow-out operations are family affairs (right).

Objective

To document catches and grow-out parameters for CBA and determine the volume and type of fish feed

Procedure

When significant numbers of wild-caught fish are destined for CBA it is usually necessary to manage the associated fishery of juveniles and this typically requires collection of data on the fishery and grow-out operations including feed. Collection of information can be done as already described for fisheries with the addition of the need to determine the numbers of animals destined for captive grow-out and the volume of feed. Interviews with fishers may be needed since post-larvae, juveniles or sub-adults will generally bypass usual retail markets and may not be easy to sample. Information can be collected by interview or direct examination of catches or captive grow-out operations to determine CPUE, fish size data and volumes (weight/number) of fish involved. If there is interest in complete catch information to determine the condition of the fish population, it may be necessary to also collect information on the mortality rates between capture and reaching the culture operation since these might be considerable. It might also be of interest to know the mortality rates in captivity (to work to reduce these if they are high, and hence wasteful of the animals), how long animals are kept in captivity, and also to gain some idea of the amount and type of fish being used as feed and its provenance. The latter would be particularly relevant for consideration of ecosystem-based management. Some interviews may also have to be conducted with the fish culturists who may or may not be the same as the fishers and a different fishing sector is probably involved in obtaining or providing fish feed. Where does that feed come from and does it involve significant quantities of fish that could otherwise be used to feed people? Such considerations are important when looking at food security issues generally.

Section 3.0 - Overfishing Indicators and Options

3.1 Indicators of overfishing

Introduction Fishery science and models involve some quite sophisticated ways of examining the condition of fisheries. These models often need the input of data that are very difficult to come by in most multispecies tropical coastal fisheries. *Fortunately, there are also some relatively simple indicators that can be applied using basic information that can be collected easily using some of the methods already described in this manual*. These indicators range from changes in sizes of target species, changes in catch composition, changes in the behaviour (time spent fishing, use of fishing grounds) by fisher, changes in catch volumes, changes in CPUE, etc. This information can be collected by a combination of regular monitoring, specific studies and by fisher or community interviews and experiences of others involved in the fishery such as fishery officers, traders, etc. For a more detailed examination of fisheries without the need to develop the full complexity of per recruit or other models, If enough information has been collected on fishing effort and catches from the fishery for multiple years it might be possible to get an idea of the Maximum Sustainable Yield for the fishery. There are also some interesting new approaches that allow for the use of simple life-history data (known as life-history invariants) to indicate aspects of fishery status. These two areas, MSY and invariants will only be briefly covered for guidance.

Objective

To collect and/or assess information that can be used as simple indicators of fishery condition.

Procedure

Simple indictors or indications of fishery condition are features of catch, usually and ideally involving trends over time. However, in examining any patterns or trends it is very important for workers to eliminate explanations for what they observe that may not be directly related to fish population condition. These can include possible changes in the habits or interests of fishers, seasonal components or market forces that might affect the catches selected but do not necessarily reflect anything particular about the species condition. *There are at least SEVEN simple indicators of fishery condition* which are covered below. However, it is also important to stress that these are INDICATORS ONLY and that more in-depth assessments might be necessary to establish fishery condition (see Section 3.4). The methods to collect the appropriate information outlined below have already been covered in this manual.

- Changes in body size over time - for example a constant decline in average body size -- is a possible sign of overfishing. If a fishery ultimately is catching only juvenile fish then there may not be sufficient adults remaining to replenish the population (Fig. 29).
- Changes in catch composition unassociated with change in fishing practices - for example, species that are naturally more vulnerable to fishing because of their biology may disappear first from a fishery (see Section 3.3). Examples would be the longer living, later maturing species like top predators (sharks, groupers, etc.). *HOWEVER, it is very important that species composition is done on a species (e.g. individual grouper species), not species group (e.g. all groupers), basis. This is because larger more vulnerable species in that group might decline first leading to temporary increases in smaller species of the group because of reduced predation pressure. If only 'groupers' are identified to family level, this kind of change would not be detected and the most vulnerable species could become threatened.*
- Changes in catches or catch rate (or CPUE) – can be produced by changes in the number of fish in a fish population. It can also be associated with seasonal pulses in catches due to spawning aggregations when fish become particularly easy to catch for a short period of time due to the formation of large reproductive gatherings (Fig. 32).

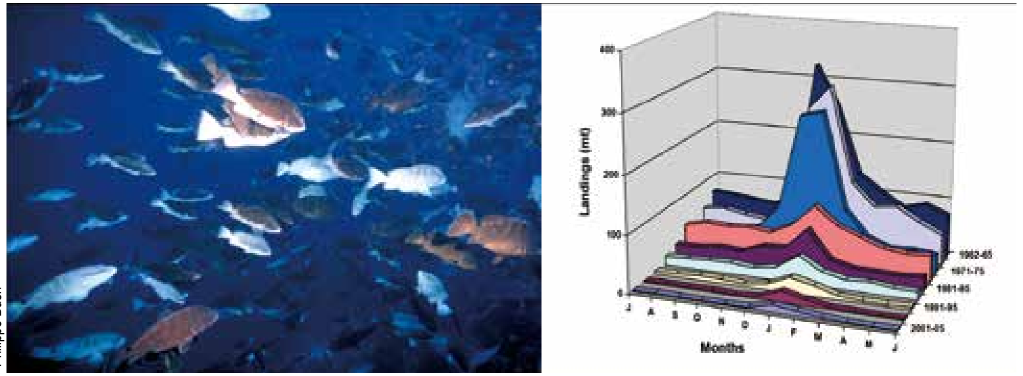

Fig. 32 The Nassau grouper, Epinephelus striatus, (left) spawns in aggregations that occur from December to February (data from Cuba; Claro et al., 2008) (right). Almost all fish came from the aggregations until they collapsed. The dataset of monthly landings from the 1960s provides an unusually detailed picture of the country's fishery for this species.

- Changes in market forces – changes in patterns of demand for certain fish sizes or species may occur due to development of activities such as tourism or the export market. Such new markets may result in changes in preferred target species or even sizes of fish (for example restaurants may prefer certain size ranges of fish as in the case of the LRFT) (Fig. 28).
- Changes in behaviour by fishers – by fishing for longer each day/week/month or by travelling further or fishing over a wider area than before simply to maintain their catches are all indications that overfishing might be occurring.
- Public/fisher perception – for a range of reasons there might be a general perception by the community that the fishery is changing; this might require follow up.
- Results of commissioned or one-off studies – sometimes studies are conducted on fisheries or key species of interest that can highlight specific issues about the fishery.

3.2 Options to reduce overfishing

Introduction

If biological overfishing is occurring, i.e. too many fish are being taken too quickly for their populations to recover from fishing, there are a number of management measures that can be introduced. Which measures are selected will depend on the target species, enforcement capacity, funding and manpower availability, information available and acceptance by fishing communities and the public. *Also increasingly important are decisions about how to best use the limited natural resources of seafood available. Options range from prioritizing local food security, to control of supply to the tourism sector to minimizing exports to ensure benefits for the local community come first.*

Objective

Identify fishery management options for consideration.

Procedure

This section identifies the major classes of available management options. *There are two fundamental types of fishery management, input controls and output controls, and these should be applied according to fishery objectives and the specific characteristics, opportunities and constraints of the fishery.*

Input controls

- Limit the number of licences given to fishers - such that the fishing effort does not exceed available resources, i.e. there that there will not be too many fishers chasing too few fish. The costs of the licences could be used to partly offset the cost of research or enforcement.
- Limit the number of fishing vessels or number of gears - allowed to fish for a particular resource or area.
- Control the number of grow-out cages - in areas where juvenile grow-out (CBA) is common or intensive to avoid overfishing of juveniles.
- Spawning aggregations, especially if fished commercially, need to be managed – there are several options that range from spatial protection of the aggregation site either permanently or temporarily, or seasonal protection of the aggregation site or the species in general during the spawning season.
- Education – ensure that the public and fishing communities are fully aware of the need to manage resources and understand why this is important for long-term fishery sustainability Fig. 33).

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Fig. 33 Working with communities is an essential part of successful management both from what is learned from fishers (both men and women!) and by what can be communicated through workshops, training and education.

- Spatial protection - of part of the fishing area to allow part of the population of interest a chance to recover; spatial protection can be permanent or temporary. Sites of special importance to the species can be considered for species protection such as spawning, nursery or feeding areas. Sites selected should be large enough and biologically meaningful for the species rather than just convenient or places of least dispute.
- Seasonal protection – can help protect species when they are particularly vulnerable to fishing (spawning aggregation) or which act as nursery areas.

Output controls

- Establish a catch quota – this is a quantity of fish of the target species that can be removed sustainably each year by the fishery of interest. A quota could be reached part way through the year prompting early closure of the fishery. This measure requires particularly close monitoring of catches.
- Control for fish size landed – size limits are very important for protecting juvenile fish and ensuring that enough of them survive to reproduce (minimum size limits) (Fig. 34). Maximum size limits can help to protect the larger fish which might be males in protogynous (change sex from male to female) species (in such species males are usually fewer than females but sufficient males are needed for reproduction) or the largest females which have disproportionately more eggs than smaller females.

Section 3.0 - Overfishing Indicators and Options

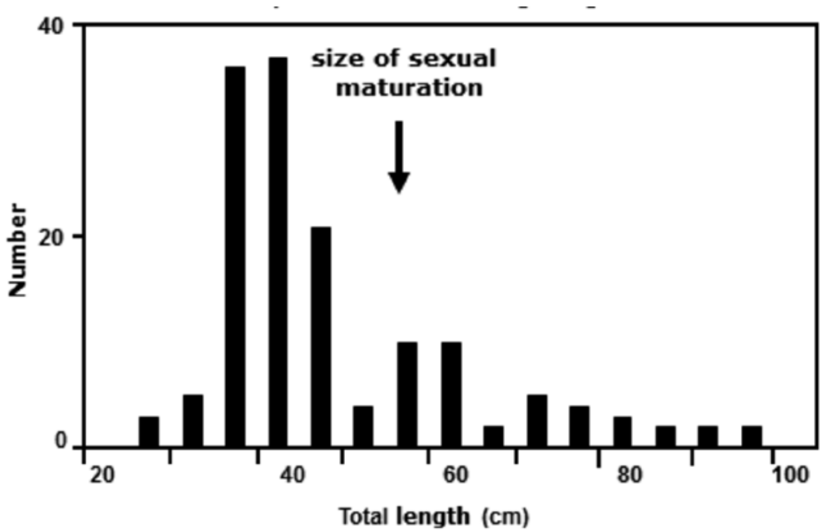

Fig. 34 If most of the fish on sale in markets or caught by fishers are below the size of sexual maturation, there may be a problem with the fishery, especially if the proportion of immature fish has increased over time.

- Consider where the fish are best used - increasingly there will have to be decisions about the objectives of the fishery i.e. what are the priority uses for available seafood resources. These range from local food security, to tourism to export for the international market. Rarely can all three demand sectors be sustained in the long-term without management.
- Moratorium - a complete ban on fishing, either temporarily or permanently, can be introduced when overfishing is considered to be a serious problem or in the case of threatened species (see below).
- Other measures that can help with enforcement include: cessation of buying by government ice plants during protected seasons or of sizes that are below the minimum allowable size and retail sales during protected seasons.

3.3 Threatened species; importance and conservation options

Introduction

Some fishes are particularly susceptible to man's activities such as overfishing because of their biology such as long life, late sexual maturation, etc. For such species it may be very easy to remove too many fish too quickly for their populations to sustain themselves. If fishing is uncontrolled and too intense on such species then their populations can

Section 3.0 - Overfishing Indicators and Options

be pushed down to very low levels possibly making it difficult for them to recover. Some such species may be particularly highly desired because customers will pay top prices for them, such as the Napoleon fish, and that means that fishers might be very keen to find them. Species considered to be of threatened status (i.e. according to the criteria of the IUCN Red List www.IUCN.org), and particularly vulnerable to fishing pressure may need special management measures and considerations. If species are threatened by international trade, like the Napoleon fish and others in the LRFT such as the square-tailed coralgrouper, then they might be protected by national legislation or listed on the Convention on International Trade in Endangered Species (CITES; www.CITES.org) (Fig. 35).

Objective

Identify and conserve threatened species

Fig. 35 Two reef fish species that are listed as threatened on the IUCN Red List are the Napoleon fish, Cheilinus undulatus (left)-this species is also on CITES Appendix II, and the square-tailed coralgrouper, Plectropomus areolatus (right). Both species need to be considered for conservation action.

Procedure

There are standard ways to assess conservation status of fishes, the best and most widely accepted being the categories and criteria of the IUCN Red List (http://www.iucnredlist.org/technical-documents/categories-and-criteria/2001-categories-criteria). The International Union for Conservation of Nature (IUCN) also has many Specialist Groups of experts in different taxa and who can assist with different species assessments (search the IUCN website for taxa of interest). The IUCN publishes online the conservation status of all species that have been given a global assessment. However, many countries conduct national or regional level assessments to determine the conservation status of their own species using a regionally adapted process based on the IUCN criteria. If species are considered to be of conservation concern, then appropriate management options (see above) can be considered to allow for recovery. Appropriate protective legislation may also have to be considered.

3.4 Maximum Sustainable Yield and Life-History Invariants

Background

It is explicitly not the intention of this manual to include detailed stock assessments because these are usually not possible for multispecies tropical reef fish fisheries due to poor data availability. However, with sufficient catch (yield or production or landings) information over a number of years for known levels of effort (could be measured by number of fishers, number of boats, etc.) it is possible to describe a yield 'curve' (Fig. 36) which provides an indication of MSY (Maximum Sustainable Yield) the theoretically maximum yield biologically possible on a sustainable basis. MSY is not a conservative or safe target for fisheries which should always strive to have fishing effort less than fmsy (Fig. 36).

If species in a fishery have been described for basic life-history parameters, like age or length at maturity, asymptotic length, natural mortality estimates, etc., and fishing impacts size composition of target species, it is possible to, relatively cheaply, make approximations about expected reproductive output that can be used for management (for details see Jensen 1996, Prince et al. 2013).

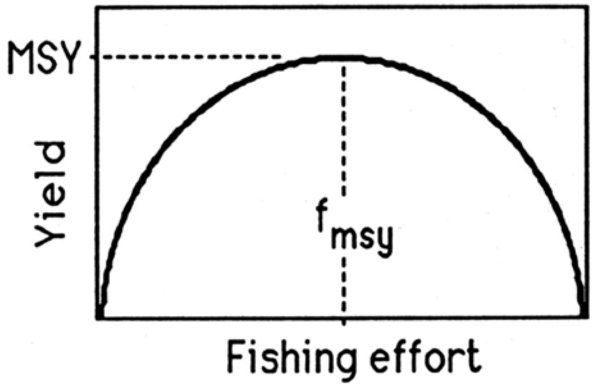

Fig. 36 Graph of yield (=production, such as annual landings) against Fishing effort (f) (such as number of boats, fishers, gears, etc.). The maximum yield is the maximum theoretical catch that can be taken on a sustainable basis. Note, however, that this is not a conservative measure and that Fishing effort should stay to the left of the fmsy line.

ANNEX 1

Main Reference

Draft Interview outline

SAMPLE INTERVIEW/QUESTIONNAIRE FRAMEWORK FOR LOCAL KNOWLEDGE OF SPAWNING AGGREGATIONS AND TIPS FOR CONDUCTING INTERVIEWS (see also Section 1.2)

Hamilton, R., Sadovy de Mitcheson, Y & Aguilar-Perera, A. 2012. Chapter 10 - The role of local ecological knowledge in the conservation and management of reef fish spawning aggregations. Pp. 331-369. In Y. Sadovy de Mitcheson and P.L. Colin (eds.). 2012. Reef Fish Spawning Aggregations: Biology, Research and Management, Fish & Fisheries Series 35: pp. 64 Springer Science+Business Media B.V

Interview Number:
Date:
Place (village region and country details):
*
Interviewee Name and Interviewer Name
How long have you been fishing?
What percentage of living comes from fishing?
This provides an indication of how important fishing is to the interviewee and hence how engaged and knowledgeable he might be regarding the interview process.
*
Main fishing gear/fishing method (number of trips per week, boat and engine size, fishes alone or with others, other relevant details on fishing practices including changes in those practices over time and the reasons for such changes). This is useful to determine where fishing might be occurring and to check against the species likely to be caught and provides a general background of the fishing activity of the interviewee.
*
Main fishing area – to be marked on a detailed map – any obvious changes in fishing area over time should be explained
*
Main species taken with the main fishing gear (if there is time and several gears are used extensively, questions can be separated into main gear types and can document any changing gear use over time). Species list should be English or locally accepted common names or Latin names.
NOTE: any fishery questions should try to include an indication of effort, the aim being to standardize numbers over time. Examples include catch rates in fish per day, per fishing trip, per net haul, etc. at different points in time during the fisherman's fishing career.
*
Once the species composition of the catches have been established, ask whether any of the species are caught in particularly large numbers at certain times of the year only **OR** whether the fisherman recalls any of the species with lots of eggs at certain times of the year. The **KEY** here is to establish <u>both reproductive activity and some kind of seasonality</u> or change in fish behaviour during the reproductive period.
*
Ask then about patterns in ALL CATCHES over time – i.e. not just in aggregating species. If there have been declines in fish sizes or numbers, ask which species have declined most and why the declines have occurred. Ask if the interviewee is concerned and what measures might be taken to improve the situation.
*
Ask if there are any regulations of any sort in effect for the fishery/if so, are they enforced?
*
ALSO, it is important that the interviews are an opportunity for you to explain the importance and significance of aggregations, i.e., to give something back.
*
FINALLY, be sure to ask whether the interviewee has any questions for you or about the project and provide relevant, useful and interesting information on the fishery if relevant.

TIPS FOR CONDUCTING INTERVIEWS

1. **Preparing for a trip**
- Clearly and concisely determine the intention/objective of interview-based study.
- Obtain necessary permits and establish contacts or community permissions as well as understand local social protocols.
- Conduct meetings or give presentations to collaborators or government officials regarding purpose and relevance of work.
- Conduct background reading to prepare yourself about the fishery and fish species so that you can also provide information on the species and assess information quality during interviews. Inform yourself not just of Nassau grouper but of aggregating species in general and experiences from overseas with aggregations.
- Learn the local names of the fish if necessary; they can change a lot, even between villages; names can also refer to species groups and not just species. Note that different names might apply to different life history stages or colour phases of the same species.
- Prepare cards with photos of fish from the area, both live and dead to accommodate different experiences of the species.
- Purchase or prepare good maps of the area.
- Careful selection of interviewees and areas, stratified sampling if possible
- Need to select appropriate vocabulary– be sure that key words or concepts are clearly conveyed in ways that will be unambiguously understood.
- Decide how to deal with reward giving, if any. Differences in local practices can mean that giving rewards/incentive is sometimes insulting and sometimes expected. Culturally appropriate items (*coffee, batteries, cigarettes, sweets, biscuits, pencils etc.*) can show appreciation for time spent but should not be the incentive for the interview. Care is needed.
- Ensure proper dress codes – many communities are traditional and expect certain behaviour especially by females.
- Carefully select interviewers – knowledgeable about the resource, the fishery and the community, patient, open-minded and communicative. It is very important that interviewers are prepared to discuss their findings to communities, provide useful information to interviewees and gain their respect. Need to be knowledgeable on relevant issues internationally, including general matters of fishery management options.
- Consider filming interviews, with permission, for later media or educational activities.

2. **During a trip**
- Make clear to the interviewee what the interview is about, why you are requesting it and what you will do with the information.
- Continually work to establish your own credibility – you will get respect and better responses – would be useful to be introduced by credible people – make it clear that you respect the knowledge of interviewees
- Use open ended and semi-structured questions during interviews and while participating in fishing, etc.
- Go fishing when possible with interviewee and inspect fish/catches when possible.
- Prepare minimum subset of questions that are the most important to conduct: fishers might be tired and not have much time or patience.
- Be courteous and respectful and try to be engaging.
- Focus clearly on one species at a time and confirm species with photos.
- Ask about opinions and likely causes of observed trends.
- Decide whether to conduct group or one-on-one interviews?
- Be open-minded and allow time for conversations to go off in multiple directions but also focus on the key questions you intend to cover – this is another reason the interviewer must have a sound knowledge of the subject.
- Be patient and prepared to be flexible with your travel schedule – i.e. spend extra time in an area if it proves productive, or move on early if necessary.
- Repeat questions in different ways to check reliability of interviewees.
- Use every opportunity to exchange information and discuss interesting aspects of the life history of locally taken species.
- Ask comparative questions, i.e. 'more or less fish than before?' and pick large time periods for temporal comparisons (such as decades). If you ask about proportions or percentages, make sure that this concept is understood.
- May have to talk about maximum or best catches since average or typical catches may not be well understood or not remembered.
- Don't just ask which species spawn and when; interviewees may have no idea about this even if they have seen spawning. Ask instead about the direct and indirect indicators of spawning such as seasonal highs in landings, eggs, concentrations, etc., good and bad seasons for catches. Ask about presence of eggs, moon phase, etc., behavioural or colour changes, etc. Adjust questions according to fishing method.
- Could work with local Government/NGOs who will later be involved in management but not those who usually enforce or get taxes.
- It may be better to leave sensitive issues, like income, out of biological surveys
- Make a note about possible reliability or otherwise of interviewee
- Don't assume that everybody can easily read a map or have good recall.
- Write down notes immediately – also allows for refining and going back to responses before leaving an area. Especially important if recording interviews.
- Seek opinion about why changes occur if changes are noted.
- Be sensitive about difficulties that might arise due to gender difficulties of interviewer/ee.

3. **Follow-up to a trip**
- Follow up with any promises made to communities/individuals.
- Produce a report that is shared with communities and collaborators.

- Give presentations on outcomes of work and indicate how to apply the findings.
- If appropriate, talk about outcomes in various media while respecting confidentiality f information collected.
- For non-nationals, be available even having left the country for providing additional information.
- Follow up with educational materials if necessary.
- Be sure to reflect back to the communities visited, in the appropriate format, the outcomes of the interviews and the broader implications of the study findings.

ANNEX 2

METHOD FOR ESTIMATING ABUNDANCE OF WIDE-RANGING UNCOMMON FISHES (see also Section 1.3)

Main Reference

Sadovy, Y (Editor). 2006. Development of fisheries management tools for trade in humphead wrasse, Cheilinus undulatus, in compliance with Article IV of CITES. IUCN Groupers & Wrasses Specialist Group. Final Report April 2006, 103 pp. Work by TRAFFIC-East Asia and Patrick L. Colin, consultant. http://www.cites.org/common/com/ac/22/EFS-AC22-Inf05.pdf

Introduction

The GPS density survey method uses a "position logging" GPS receiver in a water proof floating housing which is towed on the surface by the observer. It can be used snorkeling (towed behind the swimmer) or SCUBA diving (GPS float deployed from diver reel). The observer carries a waterproof watch synchronized to the second with the time displayed by the GPS receiver. Fish within a predetermined distance either side of the swim track are surveyed by swimming along a reef feature or in a relatively straight line at a steady pace or drifting with currents. The time any target fish is observed is recorded on an underwater slate, as well as the estimated standard length (based on training for estimating length underwater). The GPS method is suitable also when there are currents because the swimmer can move with the current.

When the logged data from the GPS are downloaded using Garmin Map Source World Map software (or other similar for other brands of GPS receivers that are readily available; http://www.garmin.com), this provides a continuous track of the survey swim and, within the accuracy limits of the GPS, a permanent record of the area surveyed, allowing for replication of the survey transect in the future. The survey track and positions of individual fish along that track can be plotted on habitat maps, satellite images or other backgrounds to provide a visual display of fish numbers and dispersal against a habitat image providing insights into the relationship between the fish and the environment. Satellite images can be obtained free of charge from: Institute for Marine Remote Sensing Millenium Coral Reef Mapping Project (NASA Landsat Archive) http://imars.usf.edu/MC/index.html.

Usually, the surveys are conducted along a given reef feature, such as the edge of the reef slope or a given depth contour along a sloping outer reef face, but surveys can be conducted in other habitats, for example if juvenile numbers are of interest. Since the GPS tracks are latitude-longitude referenced, these surveys can be repeated at a future date by any qualified observer. In most cases fish were surveyed 10 m either side of the swim track for a total survey width or 'swath' of 20 m, with each meter of track swim resulting in the survey of 20 square meters of bottom area. It is important, however, that the water visibility is good enough for this 'swath'; practice with measuring the 'swath' underwater using a measuring tape will assist the swimmer in judging the distances to be surveyed either side of the virtual transect line.

Snorkel versus SCUBA surveys: GPS density surveys can be done either snorkeling or SCUBA diving. Snorkeling surveys often allow the observer to cover a greater area per unit time through a faster survey swim speed and usually a greater overall distance in a day, produce less disturbance to the fishes (no bubbles or noise) and are not limited in total survey time by the amount of air contained within the diving tank. The infrastructure necessary to support SCUBA diving may not be available in many areas. Disadvantages to snorkel surveys include the inability to survey much below 15-20 m depth (depending on the visibility), the surface may have reduced visibility compared to deeper water, and it is often harder to distinguish some species when viewed from above (the normal situation when snorkeling) rather than from the side (when SCUBA diving).

The main benefit of SCUBA diving surveys over snorkeling is that the observers can range deeper. Many reef fishes range well below the safe depth limits for SCUBA divers or would not be readily seen by snorkelers on the surface. However, many uncommon fish are shy and easily disturbed, especially in areas where much spearfishing occurs, and tend to maintain their distance or actively swim away from SCUBA divers. The disturbance factor of the noise and bubbles of SCUBA divers is an important consideration in any survey and ideally observers should be familiar with techniques to minimize disturbance while diving. **To ensure there is no bias of one survey method over another, both snorkel and SCUBA surveys can be done in the same location and results compared.**

It seems optimal to combine extensive snorkeling surveys with a more limited number of SCUBA surveys for many reef fish species. Snorkeling is low-tech, inexpensive, does not require extensive training, and is inherently safer than SCUBA diving. Many more people can snorkel than SCUBA. Some fish could be missed in a "snorkel-only" survey, but the basic questions of abundance of juveniles and adults, occurrence of spawning aggregations and fish distribution with habitat can be answered just as well by snorkel surveys as SCUBA under appropriate conditions.

How much distance should be covered for a representative sample? It is critical that a long enough transect (i.e. sufficient distance) has been covered to get a representative sample of abundance in a particular location and that enough locations have been sampled in the study area of interest. To ensure that sufficient distance has been covered (this can be many kilometres for some species), a cumulative plot of density with distance covered is needed and surveys can be completed once the density has stabilized. A separate decision has to be made to determine how many different survey sites will be covered in the region of interest.

GPS UVC Survey Trip Check List

Dive Equipment
Regulator with hoses and gauges
Dive Computer
Extra dive computer batteries
Wet Suit
Mask, fins, booties, snorkels
Snorkel holder
Extra masks and snorkels
Weight belt with clips
Extra weight belt for snorkeling with clip
Extra brass clips
Flasher light
Safety Sausage
U/W flashlight
Stinger hood for shallow work (also protection from the sun)
Gloves

GPS Survey Equipment
GPS floats (3)
Reels (2)
Extra screws for housings.
GPS units (4)
AA batteries, enough for one set (2) each day per GPS
Download cable (2)
Computer and charger
Plug adapters for Indonesia
Garmin world map software

General Supplies
Tools
Extension cords
Knife
Scissors
Filament tape
Package tape
Marine adhesives
Pens, etc.
Sandpaper for slates
Language books
Calculator
Cheater plus
1 liter plastic bottles``
UW slates and UW paper, pencils, string, tape
Flash memory for back up
Short nylon line tether for snorkeling (to attach GPS float to)
Electric tester meter
Maps and other charts
Swiss Army Knife
Tie wraps
Electrical tape
Whirl Paks
Label paper
Notepads
Cleanser for slates
Towels
Dessicant
Envelopes/Stationary
Extra copies Garmin software (2)
Rubber bands

UW Photography
Camera and Strobe housing

Personal Items
As needed
Housing spare parts
AA batteries
Card reader
Extra port
Silicone grease
Download cable for card reader
Extra flash card
Extra o-rings
Extra camera battery

ANNEX 3

SPECIAL CONSIDERATIONS RELATED TO THE LIVE REEF FISH TRADE (LRFT)
(see also sections 2.3, 3.2 and 3.3)

Main Reference

Sadovy, Y.J., T.J. Donaldson, T.R. Graham, F. McGilvray, G.J. Muldoon, M.J. Phillips, M.A. Rimmer, A. Smith, & B. Yeeting. 2003. The Live Reef Food Fish Trade While Stocks Last. Manila: Asian Development Bank. 147 pp. (available online:/www.adb.org/publications/while-stocks-last-live-reef-food-fish-trade

Introduction

The international live reef food fish trade (LRFT) has grown steadily over the last 20 years and now sources fishes from much of Southeast Asia's reefs and well into the Pacific Ocean, as far as Tonga and into the Indian Ocean to the Maldives for demand centres in Asia, particularly Chinese communities. Species preferred for this trade are typically predators at the top of their food chain. They include a relatively small number of species, particularly groupers, of the genera *Plectropomus* and *Epinephelus*, a few wrasses, particularly the humphead, Napoleon or Maori wrasse, *Cheilinus undulatus*, and some species of snapper (lutjanid), emperor (lethrinid), etc. Two biological characteristics that typify many of these species and make them particularly vulnerable to fishing in general and to the high demand from the LRFT, in particular, are long life and aggregation-spawning. In addition, the market demand for fish of certain sizes in the LRFT has important consequences for resource use and the extensive capture of juvenile for Capture-Based Aquaculture (CBA) may be of some concern.

The international LRFT is a lucrative trade and can bring many benefits to communities. However, because of high demand, because this trade often includes species of high food importance to local communities, and because many of the species in trade are naturally very vulnerable to overfishing, they must be managed to bring best benefits to communities and to ensure that the resource base, and hence food security, is undermined.

Size, sexual maturation and the live reef food fish trade: Species in the LRFT are typically long-lived, often more than several decades, and, consistent with such longevity, can take many years to become sexually mature. The implications of this will be illustrated by the specific example of the humphead wrasse (Napoleon fish), *Cheilinus undulatus*. Ageing studies have shown that this species can live at least 30 years, that sexual maturation occurs at about 5 years of age and at around 50 cm total length. This means that this species takes many years to replace fish that are removed and cannot withstand anything other than light fishing pressure. This is a similar situation to many other species in the trade that can also live for several decades, including many groupers.

Being a large species that matures at a large size, however, poses a second problem specifically associated with the demands of the LRFT. In the case of the humphead wrasse, for example, the preferred market size species is under about 50 cm (as determined from regular surveys of Hong Kong's retail markets and the typical plate-size marketed). This means that most humphead wrasse taken are still sexually immature or have only recently matured. If excessively heavy fishing pressure is placed on advanced stage juveniles (which, by definition, have never reproduced but are likely to survive to reproduce) we need to ask where the next generation is going to come from. This problem of market size preferences resulting in the targeting of juveniles is common to large species in the LRFT that tend to mature at bigger absolute sizes than do smaller species. In the case of the humphead wrasse, declines in numbers have been so striking in some countries, that it has been formally proposed for Appendix II of CITES (Convention on International Trade in Endangered Species www.CITES.org). It is listed as threatened on the IUCN Red List of threatened species.

A second relevant consideration is that the growing demand for live fish has prompted a rapid increase in mariculture or fish farming, now known as CBA. This typically, in Southeast Asia, involves the placing of juvenile fish (seed) in captivity and feeding to market size. While some fish come from hatcheries, for many species the 'seed' is captured from the wild and so involves a wild capture fishery of juveniles which needs to be managed as for any other fishery (see Lovatelli and Holthus, 2008) otherwise overfishing can occur because too many juveniles can be removed, leaving too few adults to produce the next generation.

The message is that sufficient fish must be allowed to mature to adult size to maintain populations. Since maturation takes so long, then management must plan far ahead to maintain populations. This is the basis of sound fishery management and planning, which is especially challenging for a fishery of long-lived species because it will be many years before problems created by overfishing will become apparent in the next generation.

A final point concerns the high potential for overfishing, particularly of less common and more vulnerable species as a simple matter of economics. The LRFT is aimed at a market that pays a high price for its fish. It is also a market in which certain species are particularly highly valued, economically, and rarity itself can confer high value. As a rule, fishery economics would tend to dictate that as a fishery declines, at some point it becomes no longer economically feasible to continue fishing (this is the case for industrial scale fisheries that might target a few key species) once populations decline too far because it becomes too expensive to do so. If, however, value increases with rarity (or decline in numbers), then the incentive to fish continues even as population numbers become extremely reduced. This sets the scene for severe reductions of certain species due to continued fishing even as they become rare. It is thus imperative that management of the LRFT includes, as one of its provisions, the capability of excluding from catch or export rare or threatened species.

Spawning aggregations and the live reef fish trade: A second characteristic of the biology of LRFT species is that many aggregate to spawn for brief periods and at specific, and often consistent, locations each year. This reproductive activity may last just a few weeks a year (possibly spread over several months) and makes the species easy to find, and catch, in large numbers. In the Indo-Pacific region the times and places of many aggregations are well-known and many are exploited, including for live fish for export. Since aggregations are likely to be the sole spawning opportunity for many species, if reproductive rates decline due to too few adults, aggregations and egg output for new fish will decline. Heavy targeting can remove a significant proportion of adults in a single aggregation in a single year, and, if such pressures persist, then in just a few years, it may no longer form. *The message is very clear. Spawning aggregations, if targeted at all, can only withstand traditional, small-scale (i.e. low rates of extraction), non-commercial fishing pressure; export or commercial markets are not small-scale in this context.*

To address the problem of aggregation declines, various measures are possible and some have already been implemented in several countries. Aggregation sites can be specifically protected during spawning seasons or incorporated for more permanent protection into marine protected areas (no take areas). Alternatively, at least at commercial scale, fishing can be halted during the spawning season. Small-scale fishing activity, if permitted to continue, could be controlled through limiting access only to local communities and subsistence and traditional fishing.

ANNEX 4

UNDERWATER VISUAL CENSUS OF SPAWNING AGGREGATIONS
(see also Sections 1.2, 1.3 and 3.2)

Main Reference

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. Special Publication No. 1 (Version 1.0), pp. 1-98 (available on line: www.SCRFA.org).

Introduction

This section covers fishery-independent (i.e. non-commercial) data collection of fish numbers in a spawning aggregation using underwater visual census (UVC) methods. This approach can be used whether or not an aggregation is being fished, and, if carefully designed and consistently conducted, will provide reliable information on the number of fish participating in specific aggregations over time and a valuable indication of the status of the aggregation and an indication of the condition of the fishery, in general, of the target species. This method is for use with species that aggregate close to the substrate (demersal); species that aggregate up in the water column in three dimensional 'balls' (three-dimensional) are particularly challenging to assess and require considerable planning and use of video, ideally. This second aggregation type is not covered here. *Note that the surveying of spawning aggregations can be particularly challenging because of rapid changes of fish numbers within short periods of time and the practical considerations of counting large numbers of fish.*

Counting aggregating fish: where, when and how to sample: The only way that fish numbers can be used to reliably assess the effects of fishing or the outcomes of management over time is by using standardized surveys that are comparable over time and across space. If one method is used in one year and another applied the next year, or different methods used in different sites, the results might not be comparable. It is important, therefore to develop a robust sampling protocol by determining the best time of year and month(s) to sample and then work out how best to count the target species on the particular aggregation site. It is important to document the methodology so that it is available for others to use in future when/if the site is resurveyed.

There is no one perfect way to do a UVC survey on an aggregation site. Much will depend on the target species behaviour, water conditions (depth and current), size of the aggregation and the available manpower and diver experience. For example, if the aggregation site is very deep, then the time available for counting will be very limited or if the species tends to hide when divers pass too closely then the behavior of the divers may affect the numbers counted. Once the aggregation site has been identified, the first step is to document its location on a map for future reference (a towed GPS is very useful for this-ANNEX 2). If the site is not widely known to the fishing community or in the country, its location should not be widely advertised to avoid an increase in fishing pressure. A good knowledge of the actual location of the site and its overall dimensions is very important for moving to the next stage, survey design, and to ensure that studies over multiple years are done at exactly the same location.

If the objective is to use UVC to gain a number of maximum numbers of fish aggregating each as one possible indication of the condition of the fishery, *of critical importance is to determine the appropriate time to monitor an aggregation to ensure that you document its build-up, peak numbers and decline; it is also important to have an idea about how many aggregations exist in the area to know how 'representative' the study aggregation is likely to be.* Many aggregating species aggregate for several months in a year and aggregation numbers can vary across months. Within each month aggregation may occur with a lunar cycle over a period of a few to many days. Again, the numbers can change over these lunar cycles, building, peaking and falling, usually quickly after spawning has occurred. If the aggregation site is newly discovered or known from fisher interviews, preliminary studies will have to be conducted to work out the appropriate time frames for sampling to be conducted; in many cases multiple months and multiple days per month may have to be sampled. Moreover, aggregation numbers for just one year can tell you very little about a fishery other than to provide a baseline of information for future comparison. Ideally sampling should be done over the long term (though not necessarily every year) to identify any trends.

Once the appropriate days to sample have been determined it is necessary to establish how the counts will be done. Taking into account the various possible constraints and opportunities, two general circumstances are most likely; (1) the entire site can be sampled and all fish counted (ideal situation) or (2) the site is too large or too difficult to survey in its entirety (too deep, currents too strong, too many fish) and a subsample must be selected. Wherever the sample transects are placed for conducting the UVC, they should be indicated on a map of the whole aggregation so that future studies can follow the same transects. When you conduct the fish counts you will have to estimate how far either side of the transect line you are counting fish (e.g. 2 or 4 or 8, etc. metres either side of the line-this is called the **swath width**). If there are multiple transects, it is best to have several divers to swim in parallel in which case it is important to stay in contact with each other to avoid double counting fish.

1. The number of fish in the aggregation is small enough (hundreds to a few thousands) and the area of the aggregation small enough that it is possible to survey the entire aggregation to count all the fish. ACTION: set a series of transects, ideally using a few permanent underwater marker points so that the same areas can be surveyed repeatedly, and survey the entire site by swimming along the multiple transects, ideally with multiple divers in parallel. Swim slowly enough to minimize disturbing fish.

2. If the number of fish is too big to be able to count all the fish, a subset of the aggregation must be selected to survey and the total number aggregating estimated from that subsample by multiplying up using the total known aggregation area. ACTION: estimate the total area of the aggregating fish (described above). Lay multiple transects at various locations across the aggregation area. This can be done either by random placement or by stratified sampling i.e. according to habitat type or other characteristic that might be important (see Colin et al., 2003 for details). Transect fish counts of known swath width will give you an area estimate for the subsample of fish counted. Estimating the total number of fish in the aggregation will then require you to factor up your known subsample numbers and the area in which they occur to obtain an estimate of total numbers in the entire aggregation.

ANNEX 5

USEFUL REFERENCES

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WEB-BASED RESOURCES

www.FISBASE.org: assist in fish identifications

www.spc.int/coastfish/en/publications/bulletins.html: Secretariat of the Pacific Community Bulletins have a range of information on fisheries and management

www.SCRFA.org: Science and Conservation of Fish Aggregations, publications and methods for studying fish spawning aggregations

www.iucnredlist.org: The Red List of threatened species of flora and fauna-check individual species names for red list assessments

http://www.livefoodfishtrade.org/: International Standard for the trade in Live Reef Food Fish and fish culture

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