6. Implementing management

6.1 INFORMATION FOR MANAGEMENT

6.1.1 Overview of the harvested species

Definition

Simple surveys and literature searches to understand the ecology of sea cucumbers in the fishery and the past and current exploitation by fishers.

The information should give the resource manager an understanding of the range of species harvested, their basic biology (e.g. size-at-maturity, behaviours and preferred habitats), their value and distribution in the fishery (Figure 13; Section 3.1).

Uses

Basic surveys and reviews of the literature will allow the manager to interpret and apply results from stock surveys and to gauge the ability of various species to respond to management measures. A simple inventory of species and exports will reveal whether the fishery is multispecies and whether there is a mixture of species of high, medium and low value.

Information on the distribution of species within the fishery allows the manager to correctly assign size limits and to understand fishing activity. The manager should understand how local names correspond to various species (see Annex 10.1). Although individual species can be grouped, generally each species must be treated separately.

Limitations

Fishers may not have as many names for species as scientists describe them. In this case, local names might combine several similar species or incorrectly describe species.

The range of species collected by fishers will not generally reflect the full range of species available, so an initial overview of this nature will not thoroughly describe the available resource. Also, the economic value of each species from local sale price may poorly reflect the true international values (see Section 6.1.5).

How to implement

Managers should be confident they understand what species can be found in the fishery. Information should be gathered on the distribution of each species to know if these are endemic and whether their distributions are locally restricted. The preferred habitat of each commercial species should be understood.

The basic drivers for fishing effort should be understood. Are some species sought after more than others, and why? Information should also be collected to describe the main constraints of fishers and exporters.

Field guides published by reputable agencies will give an overview of the identification of species and the habitats in which they generally occur (see *Examples and lessons learned* below). Published reviews should be consulted in addition to local reports and studies.

The manager should prepare a ranked list of export species by value. Experienced ecologists or taxonomists should be contacted to verify the species names and that fisheries agencies are assigning the correct scientific name to the sea cucumbers in their fishery.

It is also desirable to obtain a general preliminary indication of the stock abundance of species in the fishery through the use of simple indicators (Friedman *et al.*, 2008a).

These indicators could be gathered from evaluating the general state of sea cucumber populations using rapid underwater census, sociological surveys and export data. Indicators could be, for example, a recent change in the species composition of sea cucumbers exported or reports from fishers that certain species are harder to find.

EXAMPLES AND LESSONS LEARNED

Identification guides and other information resources

PACIFIC REGION

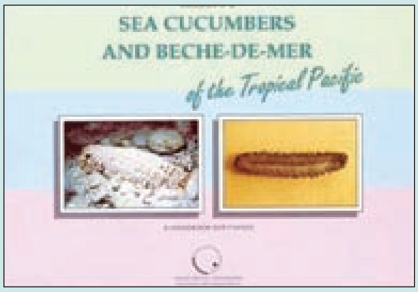
The Secretariat of the Pacific Community (SPC), a regional inter-governmental agency, publishes descriptive posters and informative books, booklets and reports to inform stakeholders about issues relevant to sea cucumber ecology, the fishery and post-harvest processing.

Beche-de-mer information bulletin

A periodical that has been running regular editions since 1990 and generally includes a diverse range of articles on all sea cucumber issues. All articles and abstracts published in the SPC Beche-de-mer Information Bulletin can be consulted at:
www.spc.int:coastfish/news/search_bdm.asp

Pacific Island sea cucumbers and beche-de-mer identification cards

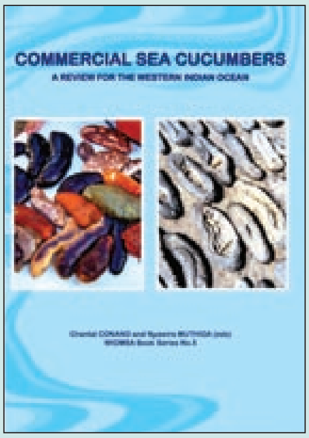
A pocket-sized waterproof identification guide presenting 21 important sea cucumber species from the Pacific Islands region. A card for each species gives a colour underwater photograph of the live animal on one side and photographs (ventral and dorsal views) of the dried animal (beche-de-mer) on the other side. It also contains some basic information on the species (preferred habitat and depth, average sizes) and a short description of the dried product. Additional information on beche-de-mer processing and sea cucumber biology is given at the end of the publication. The guide is available at:
www.spc.int/coastfish/fishing/bdm-id/bdm-idcards.htm



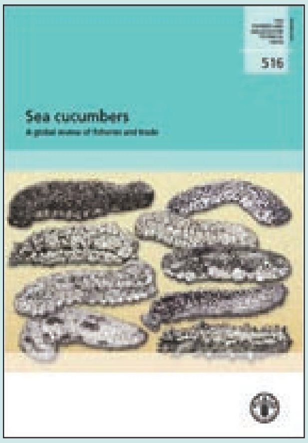
Sea cucumbers and beche-de-mer of the Tropical Pacific: A handbook for fishers

In this third edition of the handbook, 15 of the most common commercial species of tropical sea cucumbers are described and the methods used for their processing, grading and marketing are detailed. It is interesting to note that many species that belonged to the "medium" or "low value" categories in 1994 would be placed in "higher value" categories today, which is a sign of the increased demand and high level of exploitation of commercial sea cucumbers worldwide. The handbook is available at:
www.spc.int/coastfish/fishing/bdm_hdbook18/hdbook18e.htm

Commercial holothurians of the tropical Pacific
This poster illustrates 28 species of commercial holothurians in tropical waters of the Pacific Ocean. For each species the known geographical distribution is indicated along with a number of key identification features and commercial value. The poster is available at:
www.spc.int/coastfish/fishing/posters/images_posters/holothurians.jpg
K. Friedman.



INDIAN OCEAN REGION
The Western Indian Ocean Marine Science Association (WIOMSA) has recently published a book on the fisheries, the state of knowledge and the needs for managing sea cucumber fisheries in the main countries in the region. The book is available from:
secretariat@wiomsa.org
C. Conand.



GLOBAL
The Food and Agriculture Organization (FAO) has recently released a review document on the population status, fishery and trade of sea cucumbers worldwide through the collation and analysis of the available information from five regions, covering known sea cucumber fishing grounds: temperate areas of the Northern Hemisphere; Latin America and the Caribbean; Africa and Indian Ocean; Asia; and Western Central Pacific. The publication is available from:
www.fao.org/docrep/011/i0375e/i0375e00.htm

6.1.2 Fishery-independent stock surveys

Definition

A process of collecting and analyzing data on the sea cucumber populations through surveys that are divorced from fishers or the animals they have collected.

Most often, fishery-independent surveys comprise underwater visual census (UVC) of sea cucumber densities (e.g. via counts of animals in replicate randomly allocated transects) and later analysis of abundance, diversity and distribution.

Uses

The collection and analysis of data on the densities, distribution and sizes of sea cucumber species in the fishery will form a basis for understanding the relative "health" of the stocks (i.e. whether animals are abundant or not; or "stock status"). The estimates of densities of commercial species over broad areas (i.e. tens to hundreds of hectares) will be principal in evaluating whether stocks in some sites or regions are depleted (Uthicke, Welch and Benzie, 2004; Skewes *et al*., 2006; Friedman *et al*., 2008b; Purcell, Gossuin and Agudo, 2009a). At a finer level, underwater survey data will indicate which species are rare or critically stressed by fishing. The field data may also be used to calculate the total number (Kaly *et al*., 2007) or biomass (Skewes *et al*., 2002; Aumeeruddy *et al*., 2005) of sea cucumbers in a region or fishery. Such measures could be used for periodically evaluate the management strategy in relation to target reference points (see Section 3.4). While the ability to monitor abundance reliably does not guarantee sustainable outcomes, it certainly makes them more likely (Hilborn, Orensanz and Parma, 2005). More broadly, the surveys allow for comparisons to stocks in other fisheries (Friedman *et al*., 2008b; Kinch *et al*., 2008a).

In cases where long-term marine reserves are evaluated, the surveys furnish benchmarks of virgin stock densities. These estimates can be used to calculate virgin biomass of the fishery, which may be used for defining TACs (e.g. Skewes *et al*., 2002; Aumeeruddy *et al*., 2005). The benchmarks of virgin densities can also be used to indicate depletion of stocks on fished areas in the absence of comparative historical data (Kaly *et al*., 2007; Purcell, Gossuin and Agudo, 2009a).

The community composition of sea cucumber species can be described (Aumeeruddy *et al*., 2005; Purcell, Gossuin and Agudo, 2009a). Direct comparison of this information with the landings from fishers will show the level of selectivity by fishers, which cannot be easily gained otherwise. The range of species and their prevalence in the field are used to calculate diversity indices for the communities, which are important for conservation management and choice of sites for marine reserves.

Population surveys can be conducted at the same sites repeatedly to monitor the response of stocks to a certain fishery pressure or management measures (Schroeter *et al*., 2001; Skewes *et al*., 2006). The surveys provide a direct method for determining changes in the status of the resource over time. Assessments to understand population status through regular ongoing monitoring are referred to as "stock monitoring".

Limitations

Foremost, population surveys by underwater visual census are relatively costly and time-consuming. They most often require two experienced divers trained in sampling and species identification, a boat driver and a suitable boat. Personnel time is probably the greatest cost, and this is increased by boat costs, fuel and the equipment for diving and safety. Many months may be needed for a team to adequately assess stocks in a fishery – roughly 30–50 transects can be surveyed by a team of three in a day, which may correspond to just one site of 100–200 hectares (see Purcell, Gossuin and Agudo, 2009a).

Fishery officers/technicians are often not appropriately trained in sampling design to be able to conduct surveys scientifically or to identify all species in the field. There may be as many as 30 or 40 species in the sea cucumber communities. Grouping species may be seen as one solution, but it can backfire on fisheries managers when depleted or rare species are determined to be abundant because other species are included in the counts. Misidentification of species may likewise confound the correct distribution of species in the fishery. Likewise, a lack of synchronisation and training of survey teams can create irreparable errors in data sets that prevent certain analyses (Kaly *et al*., 2007).

While the data from population surveys can be averaged to provide estimates of density of each species in different habitats, this does not reveal abundances over broad areas. Estimates of abundance will mostly be calculated through integration of the data with Geographical Information Systems (GIS), which requires a high level of technical competence. The satellite or aerial imagery for enabling the GIS packages to calculate surface area of habitats in which sea cucumbers were counted can be costly or not accessible.

Estimations of population densities or abundance derived from population surveys do not always allow the determination of a TAC. For instance, it may still be unclear what virgin biomass would be if the stocks were not fished. However, TACs can be set through knowledge of the abundance of sea cucumber populations in the fishery, or "stock status" (see Section 5.4), which can be estimated using fishery-independent surveys.

How to implement

The information needed for fishery-independent stock surveys of sea cucumbers relates mainly to population surveys in the field and analyses of data. A list of species that can be found in the country should be well established and verified by taxonomists or experienced ecologists. Likewise, the manager will need to define the habitats and depths in which sea cucumbers are fished and in which the commercial species may occur. This information can be obtained from fishers and field guidebooks and published reports. In many cases, it may be best get advice from, or hire, specialists who have experience in designing and coordinating underwater population surveys.

Before starting field surveys, managers must choose what precision they want from the study and what questions they hope to answer. The spatial limits of the fishery should be defined and may include remote reefs visited infrequently by fishers. Other preliminary questions include:

- Do surveys need only indicate stock health in broad terms or will they be used to estimate biomass and density of each species over the whole fishery?
- How many sites will be surveyed?
- Will the sites be re-censused over time?
- Will marine reserves be surveyed?
- What is the annual budget to cover costs of field surveys?

The answers to these questions will structure the design for the field surveys. Data collection should be on the spatial scale appropriate to the biology of the target animals (i.e. the sea cucumbers being fished) and the structure of the fishing communities (Hilborn, 2004). Where possible, the costs of surveys should be recovered from revenue of the fishery (FAO, 1995). "Power analyses" can help to show how many sampling units (e.g. transects) are needed per habitat strata, or per site (Skewes *et al.*, 2002; Aumeeruddy *et al.*, 2005; Kaly *et al.*, 2007). In some cases, it may be sufficient for fishers or other community members to do simple counts and measurements of sea cucumbers in a structured way to monitor stocks.

Survey design will also depend on whether the purpose is periodic monitoring or a "once-off" estimation of densities or abundance. For monitoring purposes, perhaps fewer surveys (e.g. belt transects) are needed. For periodic monitoring of stock abundance/density, fixed transect (or "station") sampling may be preferred to random sampling designs. In this case, the replicate transects/stations should be physically marked so that the same tracts of sea floor can be surveyed again in the future.

The design of underwater field surveys should correspond to the resolution of population estimates required for developing the management plan. Several different approaches have been used in fishery-independent stock surveys:

- *Estimation of total stock abundance*: Surveys can be broadly-spaced within the whole fishery in order to estimate stock size and biomass, which can be used in the calculation of MSY (Skewes *et al.*, 2002; Aumeeruddy *et al.*, 2005). The fishing area is defined and survey stations are allocated randomly in predefined habitat strata. Representative areas across the entire fishery need to be surveyed and each area should have an equal chance of being sampled. This approach can provide a good estimation of the abundance of commercial holothurians (as a group) across the fishery. However, it does not provide estimates of mean density at any particular site and may require a lage number of surveys.

- *Estimation of stock abundance at particular sites*: Surveys may be grouped at sites of interest to the fishery managers, such as in marine reserves or reefs frequented by fishers (Purcell, Gossuin and Agudo, 2009a). The sites are chosen then the underwater surveys are positioned randomly within predefined habitat zones once at the site. This approach gives relatively good estimates of sea cucumbers at the species level, provides precise estimates of abundance of whole reefs or parts of reefs and can be used for monitoring. However, it cannot be used to accurately estimate the abundance of holothurians in an entire fishery.
- *Estimation of comparative abundance:* Surveys may be conducted over broad areas in habitats most utilized by fishers, to gain a measure of abundance in comparison with other localities (Friedman *et al.*, 2008b – broad-scale surveys). Long (~300 m) transects are surveyed to cover a large area of fishing grounds in certain reef habitats. This approach is time-efficient and indicates the broad status of sea cucumber populations. However, "the haphazard measures taken in main fishing grounds are indicative of stock health in these locations only and should not be extrapolated across all habitats within a study site to gain population estimates" (Friedman *et al.*, 2008b).
- *Estimation of densities of sea cucumber aggregations:* Surveys can show the densities of sea cucumbers in aggregations in particular areas within sites (e.g. Friedman *et al.*, 2008b – fine-scale surveys). Sites are nominated by fishers or by finding dense aggregations of sea cucumbers. Short (40 m) transects are then placed close together within the aggregation. These estimates cannot be extrapolated beyond those aggregations to describe abundances at whole sites (e.g. reefs) or within a whole fishery (Friedman *et al.*, 2008b).

Field scientists or technicians should decide on the boundaries of each site and how large of an area is to be surveyed (Skewes *et al*., 2002; Aumeeruddy *et al*., 2005). There is a logical trade-off in the size of sites; they need to be small enough to reliably estimate populations but large enough to draw some generalities over reasonable spatial scales. The different habitats in which the sea cucumbers occur should be defined and preferably sampled in a stratified way in the field (Skewes *et al*., 2002; Aumeeruddy *et al*., 2005; Purcell, Gossuin and Agudo, 2009a).

Multiple, randomly-placed sampling units will be required for estimating population abundance at sites. The following sampling methods can be used to census sea cucumbers:

- Circular sampling units, when densities of individuals are relatively high (e.g. Hearn *et al*., 2005).
- Belt transects, overlaying a band of the sea floor, are more commonly used for surveys. They may range from 50 to 200 m or more in length. Transect width is usually between 1 and 5 m, depending on habitat complexity and confidence in sighting animals (see Skewes *et al*., 2002).
- The manta-tow method for transect surveys (Figure 27) is efficient at covering a large amount of the benthos with least effort. Tow speeds should be slow enough (e.g. 2–3 km h^{-1}) to allow the observer (generally free-diving) to confidently count all animals.
- SCUBA divers may simply swim along transects in habitats that are too complex, too deep, too turbid or too exposed for manta-tow (Purcell, Gossuin and Agudo, 2009a) (Figure 28). In such cases, a "hip-chain" (or "chainman") device can be used to measure transect length, which improves sampling efficiency of the field team (Leeworthy and Skewes, 2007).

FIGURE 27
A skin diver counts sea cucumbers within a 2 m wide belt transect on a shallow tropical reef flat. The manta board he holds has a data sheet and collection bag and is towed behind a boat at slow speed

PHOTO: S.W. PURCELL

FIGURE 28
Two SCUBA divers surveying sea cucumbers on soft sediments in deep water. One diver reels out a measuring tape to standardize transect lengths

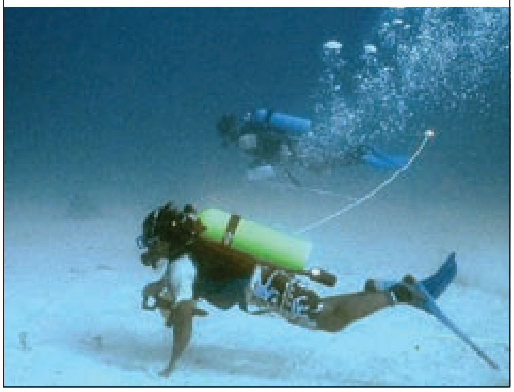


PHOTO: M. LINCOLN-SMITH (CARDNO ECOLOGY LAB)

- Remote video equipment can be used for surveying sea cucumbers in very deep habitats (Aumeeruddy *et al.*, 2005).

To estimate abundance (number of animals over large areas) the average density of each species in each habitat is multiplied by the surface area of each habitat. The latter of these measures is estimated by GIS technology using imagery from satellites or aerial photographs (see Purcell, Gossuin and Agudo, 2009a). Since some species may occur in multiple habitats, the abundance estimates (and errors) from each habitat in a site need to be pooled to give an overall estimate of abundance.

Although individual species can be grouped in survey records, generally each species should be counted separately in field surveys. It is an advantage to measure some representative individuals of each species at each site, as these data can indicate fishing pressure through comparison with unfished sites or baseline data. The size measurements provide for size-frequency analysis, from which the regularity of recruitment can be inferred (Skewes *et al.*, 2006). Other variables about the habitats and substrata can also be collected at the same time, which can provide for informative analyses or comparisons (Skewes *et al.*, 2006; Kaly *et al.*, 2007; Purcell, Gossuin and Agudo, 2009a).

The technical competencies of the fisheries staff need to meet the demands of both underwater population surveys and the archiving and analysis of data. For example, stratified sampling is a concept that may be difficult for field teams to fully understand (Kaly *et al.*, 2007). Are the technicians well educated and trained to design the surveys, collect the data, construct or manage a database and analyse data? Managers should seek templates from other studies on what data to collect and should consider help from development and non-government agencies with appropriate expertise.

EXAMPLES AND LESSONS LEARNED

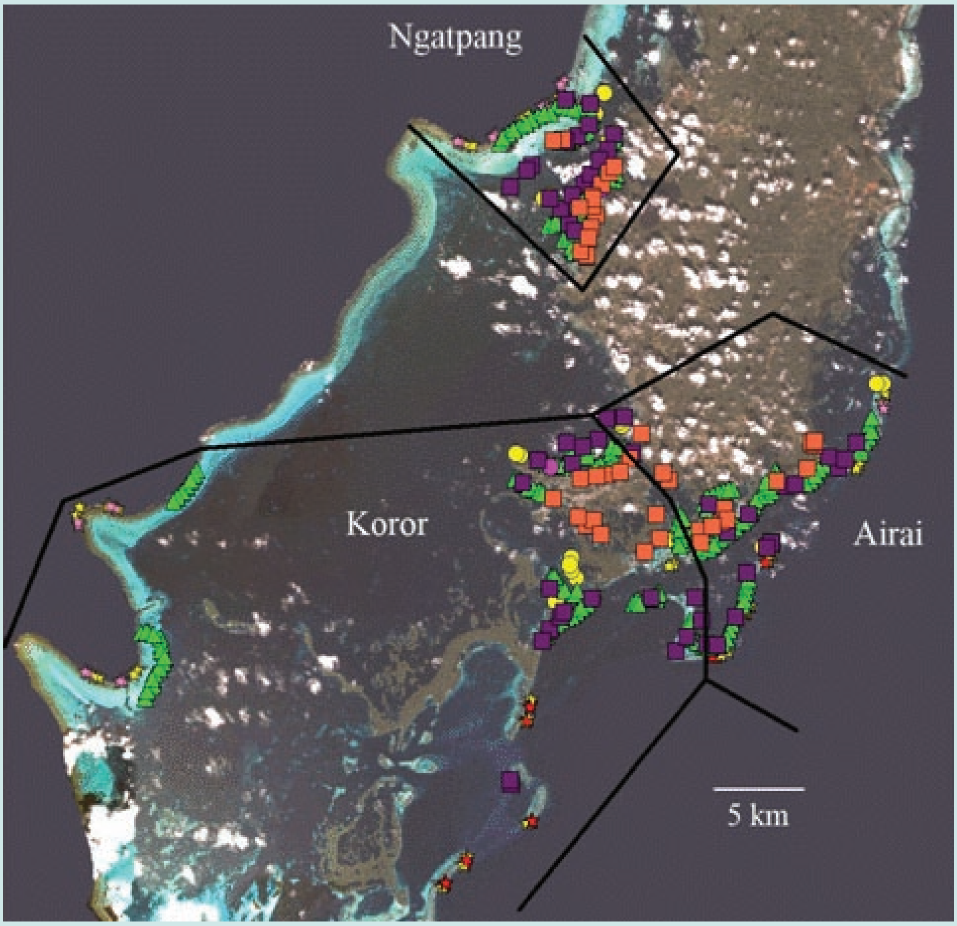
Galápagos Islands, Ecuador

Since the reopening of the sea cucumber fishing seasons in 1999, fishery-independent surveys have been carried out before and after each season. These surveys include fished and non-fished sites in the six islands where the activity takes place (Española, Fernandina, Floreana, Isabela, Santa Cruz and San Cristobal). The surveying team generally includes members of the fishing sector, Galápagos National Park Service, Charles Darwin Foundation and

naturalist guides. The fishery was closed for 22 months during 2005 to 2007 on the basis of the survey results that showed a general population decline. The surveys were instrumental in showing a major recruitment event in 1999, but poor recruitment in other years.
Source: V. Toral-Granda.

Pacific-wide PROCFish surveys

The PROCFish program of the Secretariat of the Pacific Community (SPC) has conducted standardized surveys of most commercial invertebrate species, including sea cucumbers, in 17 countries and territories of the Pacific (e.g. Friedman *et al.*, 2008b). Ten different methods are used, including time-period assessment on snorkel or SCUBA, manta-tow and belt transect surveys. For sea cucumber surveys, the surface area of each replicate census varies from 40 to about 754 m^2. The assessed surface area of each study site was roughly 10 ha, depending on the size of the site and the number of habitats being assessed.



Above: example of coverage of PROCFish/C surveys – Map of the southern part of Palau showing survey stations at three of the sites. Colour codes denote different survey methods used.

In each site, broad scale surveys, using the manta-tow technique, were used to give a broad indication of species' distributions. Twelve manta-tow stations (6 replicates of 300 × 2 m per station at an average towing speed of 2–3 km/h) are made on the reef top and along reef edges of fringing reefs, lagoonal patch reefs and back reefs and the observers recorded all species (identity, number, size estimates) and habitat descriptors. In the general area assessed with manta stations, small-scale surveys are used and comprise a number of adjacent short belt transects to make more precise measurements of size and numbers of sea cucumbers in areas where they were found at high density. Twenty-four benthos belt-transect stations (6 parallel belt transects of 40 × 1 m per stations), were spread over the site, firstly targeting the best aggregations of sea cucumbers and/or habitats (both coral reef areas and sediment areas) recorded during the manta tow stations. In environments where manta tow is usually not possible, such as the surf zone or on the deeper area such as the passages, outer slope or deep lagoon areas, dedicated time-period assessment are used (6 replicates of 5 minutes per stations). Four stations were made on snorkel in the surf zone (1 to 5 m) and 4 stations are made walking on the barrier reef at low tide for the shallow water species such as the medium value *Actinopyga mauritiana*. Four stations are made on SCUBA (15 to 45 m) for the deep water species, such as the high-valued *Holothuria fuscogilva* and *Thelenota ananas.* During these time-period assessments, species of interest and habitat data are recorded, but to keep a good area coverage, little time is spend on measuring individuals. Only small samples of the individuals were measured, the rest were simply counted. Each station is geo-referenced using Global Positioning System (GPS) and count/density maps are produced using GIS software. The typical sea cucumber PROCFish survey is not designed for stock estimates, but inform on the status of resources (e.g. if the stock seems healthy, moderately healthy or depleted), and able comparison across sites, countries and regions.

The regional approach has been useful to understand what was the range of density from unimpacted sites to heavily impacted sites. It allows managers and researchers alike to figure out what potential densities a resource can reach, which in most case is very low and how far from this potential density the resource is.

Source: E. Tardy.

New Caledonia, France

A recent study by the WorldFish Center described the status of the sea cucumber fishery of the main island of La Grande Terre, New Caledonia (Purcell, Gossuin and Agudo, 2009a). Underwater visual censuses (UVCs) estimated the abundances and sizes of sea cucumber communities on a total of 50 lagoon and barrier reef sites, mostly 60–160 ha in area. The populations were surveyed using stratified, replicate, belt transects that were geo-referenced using Global Positioning System (GPS) technology. At each site, approximately 25–30 belt transects were stratified among five habitat types. Transects were 2 m wide, whereas length varied from 50–200 m depending on the habitat. Likewise, equipment and methodologies were adapted to suit the constraints imposed by the habitats: reef crests were surveyed by skindivers in tandem, using handheld GPS to measure transect length (100 m); deep habitats were surveyed by SCUBA divers in tandem using the hip-chain method to measure transect length (50 m); the manta-tow method using onboard GPS to measure transect length (100–200 m) was used with skindivers for other habitats.

The first six individuals of medium- and high-value species encountered along each transect were collected – these were measured (length and width) and weighed on the boat. Animals are left for one minute on the deck of the boat to evacuate seawater before being weighed.

GIS software (MapInfo®) was used to calculate the surface area of sites and of each of the five habitats within each site. The total abundance of each species per site could then be calculated by summing estimates of abundance from all of the habitats. Estimates of densities in the habitat in which each species was found most, for each site, were also calculated. The measurements of representative individuals allowed the calculation of average weights and size-frequency distributions. In this study, both fished and unfished (marine reserve) sites were surveyed, but the abundance estimates were not extrapolated to estimate the global abundances of sea cucumber in the entire fishery.