Department of Agriculture, Fisheries and Forestry
Fisheries Queensland

Fisheries Long Term Monitoring Program

Coral Reef Fin Fish

1999–2004

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PLEASE NOTE: This publication describes methods used by Fisheries Queensland scientists between 1999 and 2004 to undertake Underwater Visual Census and collect data on fish abundance and species composition. Much of this publication was compiled between 1999–2000. It is published to inform users of the protocols used to collect data over this time period.

Contents

Acronyms

AIMS	Australian Institute of Marine Science
CRC Reef	Cooperative Research Centre for the Great Barrier Reef World Heritage Area
GBRMPA	Great Barrier Reef Marine Park Authority
GLM	General Linear model
GPS	Global Positioning System
LTMP	Long Term Monitoring Program, Fisheries Queensland part of Department of Agriculture, Fisheries and Forestry
NFC	Northern Fisheries Centre, Cairns
UVC	Underwater Visual Census

Rationale

The commercial reef line fishery on the Great Barrier Reef is valued at approximately $30–50 million per year with coral trout (*Plectropomus* spp.) accounting for around 60% of the demersal catch in 2009 (DEEDI 2011). Coral trout are also one of the top four recreational angling fish in northern Queensland (Roy Morgan Research 1996; Cormack 1997). Four species of coral trout are commonly observed on the Great Barrier Reef (Randall and Hoese 1986). The common coral trout *Plectropomus leopardus* (Lacepède 1802) is by far the most abundant of these, followed by, in decreasing order of abundance: the bluespotted coral trout or Chinese footballer trout, *P. laevis* which is more common on northern outer shelf reefs; the barcheek coral trout *P. maculatus*, common on inshore reefs; and the considerably rarer passionfruit coral trout, *P. areolatus* (Ayling and Ayling 1986a). *P. laevis* has two colour morphs (Figure 1) – the pale (white/yellow) black saddled form commonly called the Chinese footballer trout and the dark form sometimes with faint black saddle and distinct blue spots commonly called the bluespotted coral trout. *P. leopardus* dominate commercial catches (Mapstone *et al*. 1996), though the commercial fisher logbooks do not record coral trout at a species level.

Other major components of the reef line fishery include redthroat emperor (*Lethrinus miniatus*) and stripey snapper (*Lutjanus carponotatus*) (Mapstone *et al*. 1996). Two additional species highly prized by the live fish trade (Lau and Parry-Jones 1999) are humphead Maori wrasse (*Cheilinus undulatus*) and barramundi cod (*Cromileptes altivelis*). The red bass, *Lutjanus bohar*, Moses snapper, *L. russellii*, and spangled emperor, *Lethrinus nebulosus* have also been included in the list of species to be surveyed as they are taken by recreational, commercial and indigenous fishers and/or are adequately surveyed by Underwater Visual Census (UVC) while requiring little or no extra effort to survey.

This long term monitoring of the reef fishery aims to monitor the population densities of these key target species. The clear water associated with coral reefs and relative ease with which the target species can be sighted lends these species to effective use of UVC, a completely fishery – independent measure of reef fish abundance. Furthermore, this technique has been subject to rigorous evaluation for fisheries stock assessment purposes in previous Queensland government projects (e.g. Samoilys and Carlos 1992, 2000; Samoilys 1992, 1997a; Samoilys *et al.* 1995).

Transects (50 x 5 m) have been established as one of two suitable UVC methods for most species targeted by the Great Barrier Reef line fishery. The UVC techniques have been tested for accuracy in estimations of mobile or roving serranids (*Plectropomus*), lutjanids (*Lutjanus* spp.) and lethrinids (*Lethrinus* spp.) Accuracy was 68-78% for the plectropomids and roving lutjanids (including *L. carponotatus*) and 45% for lethrinids (Samoilys and Carlos 1992, 2000). Insufficient data were available to assess the accuracy of 50 x 5 m transects for *Cheilinus undulatus* and *Cromileptes altivelis*, suggesting the spatial unit size may be inappropriate. Nevertheless, it is considered valuable to include these species as a trial, considering their conservation value and value for public display aquaria.

Objectives

The objectives of the Long Term Monitoring Program (LTMP) for the reef fishery are:

- to provide fishery-independent estimates of relative population abundance and biomass
- to provide size frequency estimates of population structure

for coral trout and other fishery target species at selected reefs in the Cairns and Central regions of the Great Barrier Reef (see Table 2).

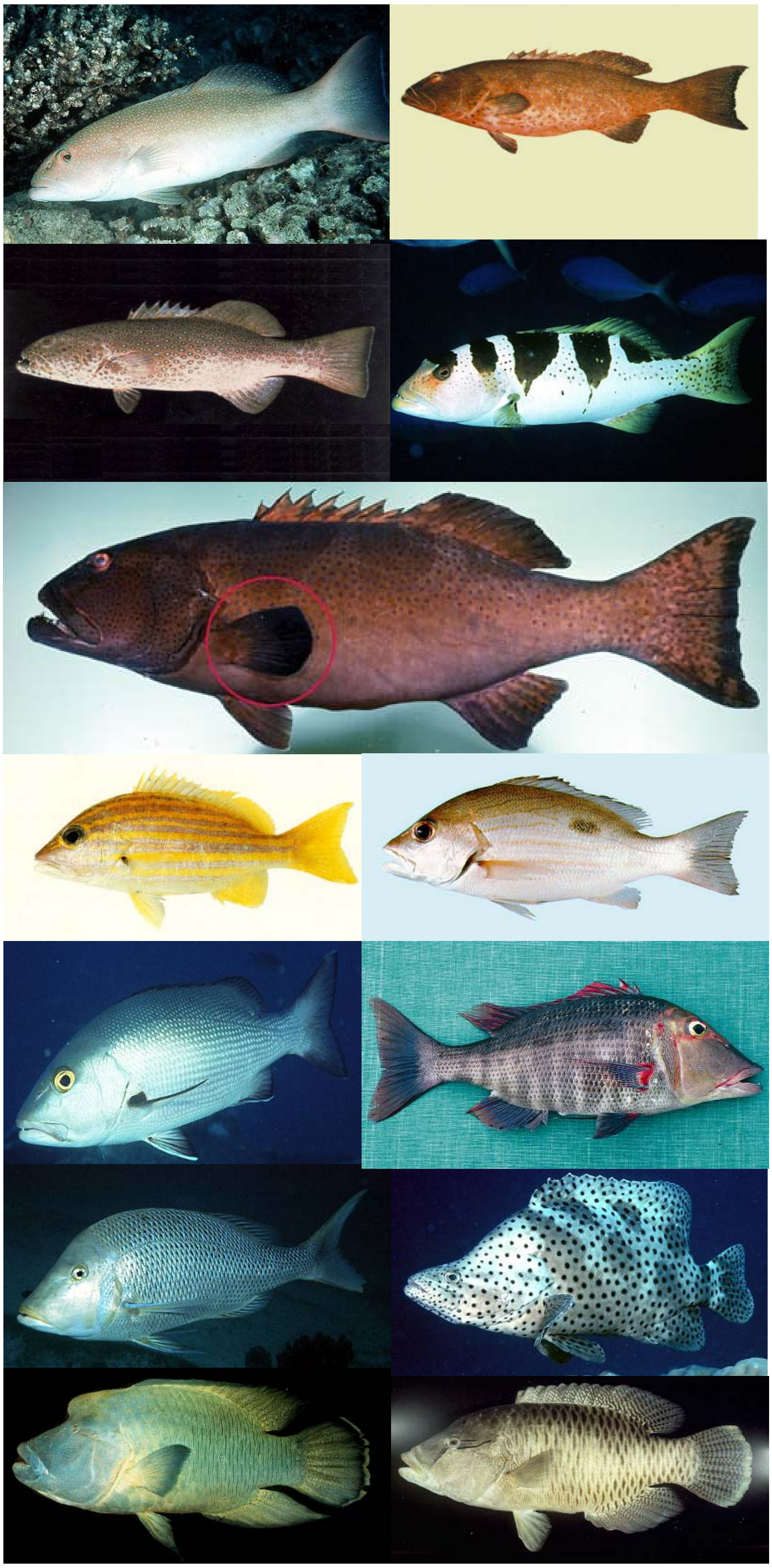


Figure 1. Left to right and top to bottom, *Plectropomus leopardus, P. maculatus, P. areolatus, P. laevis* (Chinese footballer morph) and *P. laevis* (bluespotted morph, image by J.E. Randall), *Lutjanus carponotatus, L. russellii, L. bohar, Lethrinus miniatus, L. nebulosus, Cromileptes altivelis,* adult *Cheilinus undulatus* and a juvenile *C. undulatus.*

Monitoring procedures

PLEASE NOTE: This publication describes methods used by Fisheries Queensland scientists between 1999 and 2004 to undertake Underwater Visual Census and collect data on fish relative abundance and species composition. Much of this publication was compiled between 1999–2000. It is published to inform users of the protocols used to collect data up to 2004.

Species / Habitat Details

The LTMP coral reef fin fish monitoring is being conducted in the Cairns, Townsville and Mackay regions of the six regions defined in the Fisheries (Coral Reef Fin Fish) Management Plan 2003 (Figure 2), following Mapstone *et al.* (1996).

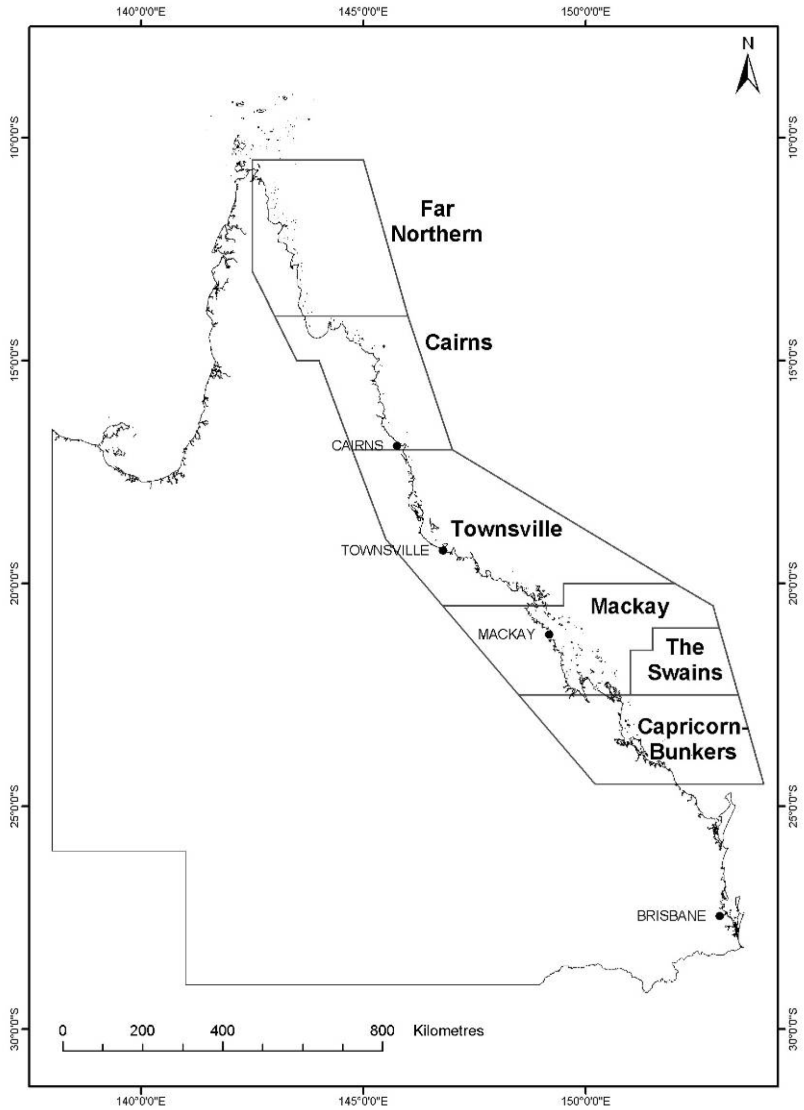


Figure 2. Coral Reef Fin Fish Management regions of the Great Barrier Reef. Regions follow those defined by Mapstone *et al*. (1996).

The species selected for monitoring are listed in Table 1, the example datasheets are provided in Appendix 1 and pictures can be found in Figure 1.

Table 1. Species monitored annually under the Long Term Monitoring Program Underwater Visual Census.

Family	Species	Common name
Serranidae	*Plectropomus leopardus* *P. laevis* *P. maculatus* *P. areolatus* *Cromileptes altivelis*	common coral trout Chinese footballer/bluespotted trout barcheek coral trout passionfruit coral trout barramundi cod
Lutjanidae	*Lutjanus carponotatus* *L. russellii* *L. bohar*	stripey snapper Moses snapper red bass
Lethrinidae	*Lethrinus miniatus* *L. nebulosus*	redthroat emperor spangled emperor
Labridae	*Cheilinus undulatus*	humphead Maori wrasse

Times, Sites and Transects

The program focuses on 20 reefs through the Cairns and Central Sections using the Great Barrier Reef Marine Park Authority (GBRMPA) Zoning (Table 2). Reefs have been selected across three continental shelf positions (inner, mid, outer) and three GBRMPA protection zones (closed to fishing - “green”, open to fishing - “blue” or “yellow”).

The primary factor used to select reefs is the availability of historic UVC data on *Plectropomus leopardus* (the dominant species in the fishery) from those reefs (various Ayling & Ayling reports 1982-1998; Ayling *et al*. 2000). Other considerations were the Australian Institute of Marine Science (AIMS) long-term monitoring program (Sweatman *et al*. 1998) which collects regular data on coral cover and the wider fish community, thereby providing important ongoing data on the broader status of these reefs. Eighteen of the 20 reefs in Table 2 have been surveyed for *P. leopardus* by Ayling at least three times between 1999 and 2000, and in many cases since the early 1980s (Ayling *et al.* 2000). Fish on nine of these reef have also been monitored annually by AIMS since 1992 (Table 2). Thus, the LTMP data builds on a well established dataset.

On each reef, study sites, approximately 350 m in length, were positioned uniformly along the reefal habitat of the back slope and marked using a differential Global Positioning System (GPS) during the first survey in 1999. Sites are located over continuous reef slope or large “bommie” habitats and areas where greater than 20% of substrate habitat is sand have been avoided to maximise survey effort over habitat likely to contain species being surveyed. Logistically difficult areas to sample (i.e. water > 12 m or < 3 m deep), or where currents are too strong were excluded from site selection. Back reefs were chosen to ensure that sites could be worked in most weather conditions to maximise continuity in the time series of data collected and thus providing more reliable relative estimates of population abundances.

The primary focus of the program is to monitor relative population density and size frequency through time, that is, to focus on collecting temporal data rather than spatial data. Because of the high natural variability in fish counts on coral reefs (Samoilys and Carlos 2000; Samoilys 1997a) the use of fixed sites is recommended to achieve this goal. Returning to the same sites each year will help reduce inter-annual variability associated with spatial heterogeneity and will thereby improve the precision and the accuracy of relative population estimates. It should be noted that the use of fixed sites to represent the reefs will not provide estimates of total population size for the reef, but will give estimates of relative population sizes for the back reef, determined from representative areas (*sites*) of the reef. The greater the number of sites selected on the back reef, the better the estimate of population density represents back reef populations. Current Departmental SCUBA diving practices restrict the number of sites staff can survey to four per day (four accents). Based on this and limited time available in the field, a survey of one reef per day, with four sites per reef has been designed.

Table 2. Reefs to be monitored, showing Great Barrier Reef Marine Park Authority (GBRMPA) zoning status and inclusion in Australian Institute of Marine Science (AIMS) monitoring program. F/B = fish & benthos surveys, M = manta tow surveys by AIMS. GBRMPA zones: A = Marine Park A (open to fishing), B = Marine Park B (closed to fishing); A & B = mixed zoning. Arrows indicate a change in zoning in the last 15 years. Reefs marked [a] have *not* been surveyed by Ayling and Ayling during the last 15 years.

Reef	Latitude	Longitude	GBRMPA zone	AIMS site
Cairns Section				
Lizard Is	14°39'	145°27'	A & B	F/B M
MacGillivrays	14°39'	145°29'	B	F/B M
Eyrie	14°42'	145°23'	B → A	M
Escape	15°51'	145°49'	B → A	M
St. Crispin	16°05'	145°51'	A	F/B M
Norman	16°26'	146°00'	A→ B	M
Hastings	16°31'	146°01'	A & B	F/B M
Arlington	16°40'	146°03'	A	M
Channel	16°57'	146°27'	B→ A	
Wardle	17°26'	146°32'	B→ A	M
Central Section				
Bramble	18°26'	146°43'	A	M
Dip	18°25'	147°27'	B	F/B M
Faraday	18°26'	147°21'	B	
Yankee	18°34'	147°30'	B	
John Brewer	18°37'	147°03'	A	F/B M
Lodestone	18°42'	147°06'	A	
Davies	18°50'	147°38'	A	F/B M
Kangaroo [a]	19°16'	148°33'	B	M
Black [a]	19°42'	149°22'	A	F/B M
Hardy	19°49'	149°14'	B	F/B M

Transects are randomly deployed rather than being fixed (cf. rationale for fixed sites above, and cf. AIMS fixed transects) in order to match sampling unit size (250 m^2) with the movement habits of the species being monitored. *P. leopardus* are known to range in the order of 2 km and associate with reef areas of at least 2000 m^2 (Samoilys 1997b) therefore fixing transects would reduce surveys' ability to be representative of the whole site. Also, data from random transects can be analysed by a range of statistics that are readily available and are relatively easy to understand.

Samoilys and Carlos (2000) recommended ten replicate transects be taken for optimal precision for the species being monitored, however, six replicate transects have been selected here in order to increase the number of sites that can be surveyed and thereby improve the measure of population density on the reef's back slope.

Surveys will be standardised to the northerly season (~ Oct to Dec) and off the new moon period (NM ± 2 days, 5 days in total). This takes advantage of the good weather conditions and avoids confounding problems with coral trout spawning aggregations (Samoilys 1997c). Field trips operate out of the Northern Fisheries Centre (NFC) and two 13 day trips are usually undertaken with a short break in the middle that coincides with the new moon. Surveys should be conducted during daylight hours when coral trout are most active (approximately 8:00 – 5:00).

Notification of survey

Public notification of upcoming field work should include Coastwatch, Queensland Boating and Fisheries Patrol, GBRMPA and the local community media.

Gear and equipment

The UVC of target species in the Coral Reef Fin Fish Fishery is conducted on SCUBA using standardised methods (Samoilys 1997a; Samoilys and Carlos 2000). A team of three certified SCUBA diver supervisors are required: two observers in the water and a dive supervisor in the boat. The diving team should rotate roles as Observer One, Observer Two and Dive Supervisor.

An equipment list can be found in Operational Resources Section and includes standard SCUBA equipment for each diver as specified in the Departmental Diving Operations Manual (Coles *et al.* 2011). Long surface intervals between dives are required to reduce the residual nitrogen level in divers (see dive and vessel plan, Appendix 2, Appendix 3). Vessel safety equipment should also be carried as required by law and as specified in Departmental standards.

In addition a mother boat is required to sleep team of three, plus crew and to tow a tender (dinghy) vessel from which UVC counts are done. The Gwendolyn May is usually booked for this purpose through the NFC Station Manager.

Physical Parameters

Cloud cover (0–8); wind (knots & direction) and tide (height and ebb or flood — entered later) are recorded for each site while time of day, minimum and maximum depth and water visibility are all recorded for each transect (see Appendix 1). Cloud cover is visually estimated by splitting the sky into four segments and estimating the amount of cloud cover in each to a fraction out of eighths.

Deployment UVC surveys

The order in which reefs, sites within reefs, and the order and location of transects within sites are surveyed should be random to minimise bias and maintain independence between replicates. In reality, random orders and locations are time consuming and extremely costly. It is generally agreed that a haphazard selection for UVC surveys is acceptable (Samoilys 1992).

Each transect will takes approximately six minutes (three minutes for the census), therefore each anchorage consists of one ~ 45 minute dive. The duration of each census (transect) is standardised, because there are biases associated with the time spent in the census area (e.g. fish attracted to or repelled by the divers (Watson *et al*. 1995; Samoilys 1997a; Samoilys and Carlos 2000). The time should be the minimum required to search the census area completely, since, the longer the census the greater the problems of interference from divers and incoming fish. When conducting a visual census the researcher is attempting to simulate an ***instantaneous "snap-shot" count*** i.e. in zero time. This is not possible in reality, as it takes a finite amount of time to search the census area and count the fish. During the training period in 1999, a three minute interval for each census was found to be adequate.

Anchorage at each site should be haphazard and should be somewhere in the middle of the site (using GPS). Ideally, transects should be placed randomly within the site but should also sample the habitat where fish can be expected to be found. The method suggested for selection of transect location for the reef fish surveys is to visually assess the site from the boat before entering the water, looking for where continuous habitat can be found in a depth range from 3–12 m, and identify where large patches of sand are in order to avoid them.

Six replicate 50 x 5 m transects are then randomly deployed in each of the four study sites. Generally, three transects are run in one direction, one after the other, and then repeated in the opposite direction (see Figure 4). It is easier to leave the tape measure from each transect laid out and wind them up on return. Once in the water, observers should swim ten fin beats away from the anchor line towards the habitat viewed from the boat to distance themselves from the disturbance caused by anchoring. The starting location of each transect should also be randomly selected (e.g. using a fixed number of fin beats). Transects are run parallel to the reef edge within a depth range of 3–9 m (maximum depth set at 12 m due to the constraints of repetitive SCUBA diving). If at some point after a transect has been started it becomes obvious that the transect will pass over an extensive area of sand (>20% of the transect), the observers should make a turn in the transect and complete the remainder of the transect over reefal habitat with the intension of maximising the amount of reefal habitat surveyed.

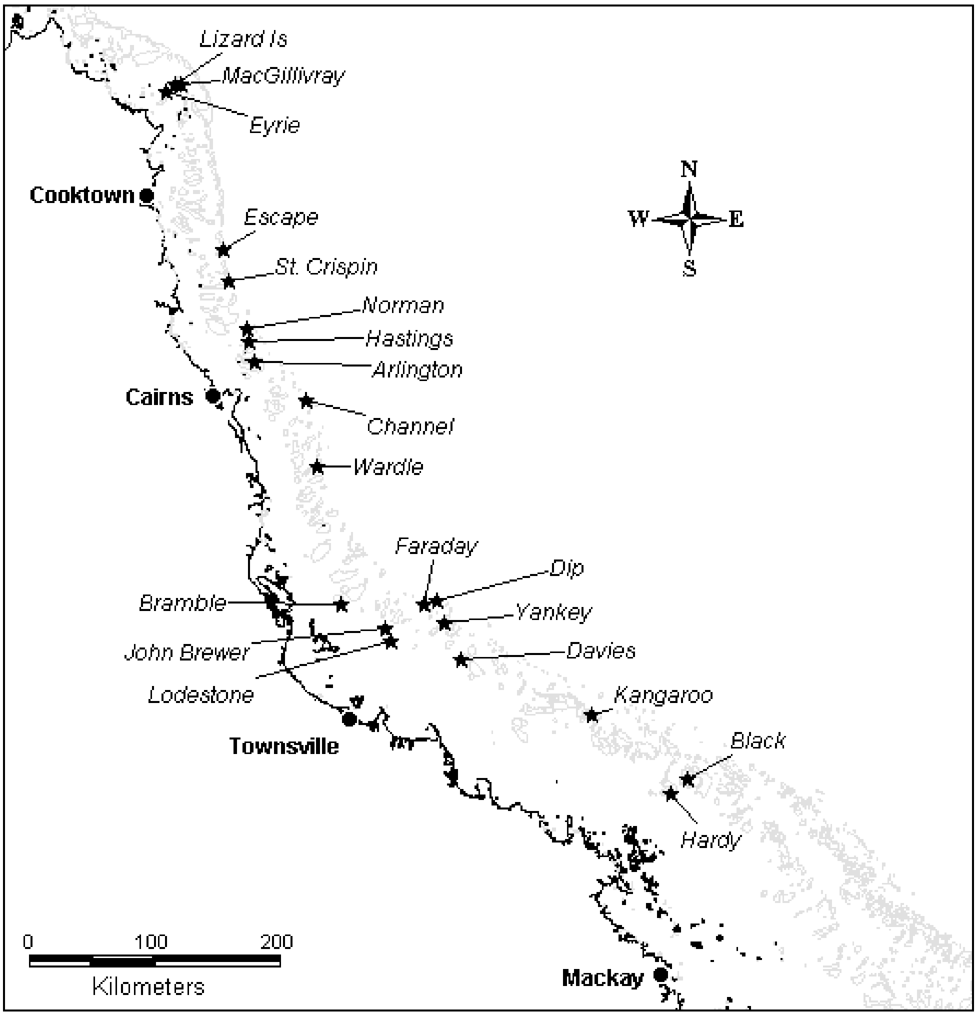


Figure 3. Reefs to be monitored as part of the Long Term Monitoring Program of Coral Reef Fin Fish.

At the start of the transect, Observer Two attaches the tape measure to the substrate, indicates the commencement of the count to Observer One, and starts the stopwatch. Observer Two maintains a constant swimming speed (e.g.. ~17 m/min) and lays out the tape in a straight line while Observer One records the fish within the transect area. Observer One zig zags across the width of the transect searching for fish that may be partly hidden under coral. The size of fish is estimated to the nearest centimetre fork length for target species within transect area and recorded on datasheets printed on underwater paper (Appendix 1). The minimum size of fish to be recorded is fixed at 11 cm Fork Length because of difficulty in estimation of a wide range of sizes (Bellwood and Alcala 1988). This size limit will exclude some juveniles of species being surveyed but this will be consistent across years surveyed. The data will provide estimates of relative population abundance (number of fish per unit area of reef slope) and size frequency distributions. Any fish that enter the census area after the stop watch has started are *not* included.

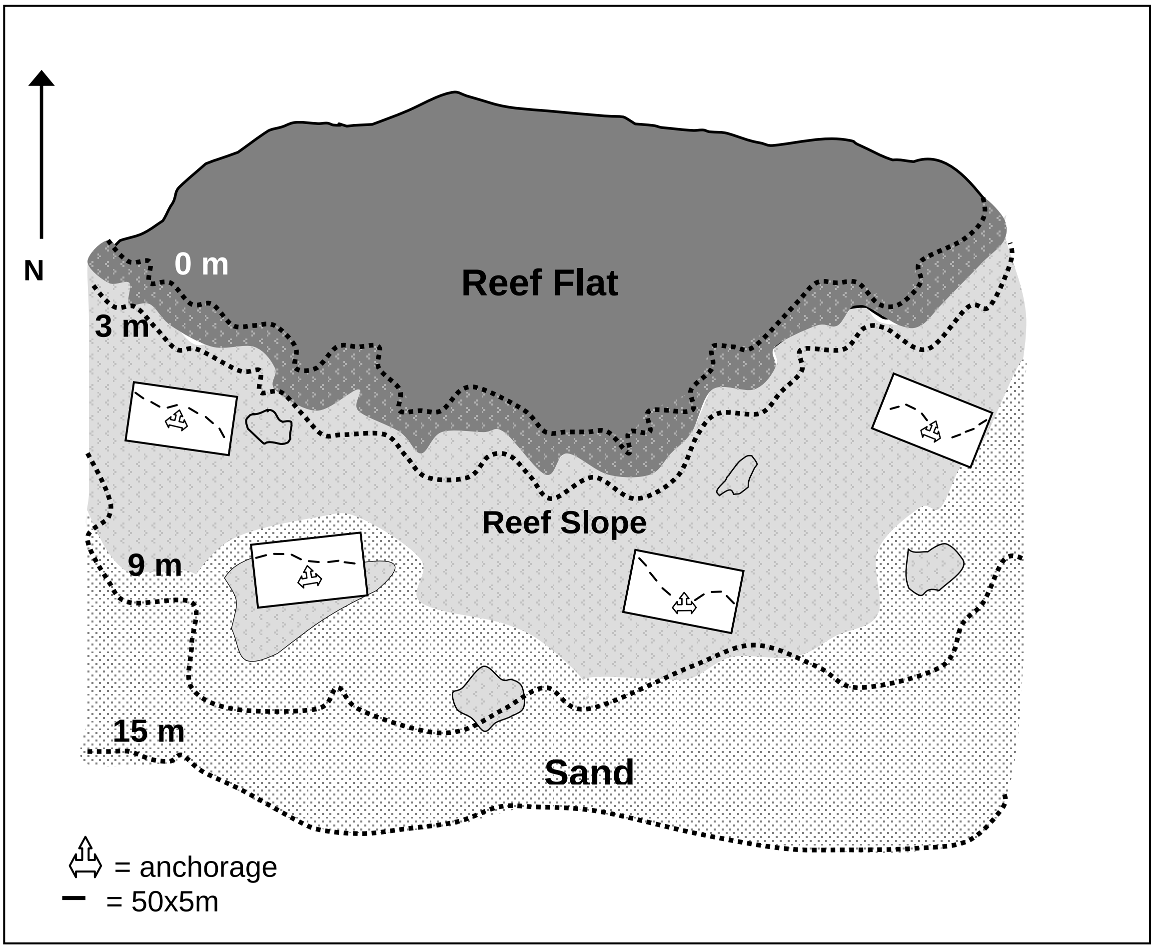


Figure 4. Typical location of study sites and transects on the back slope of an outer shelf reef.

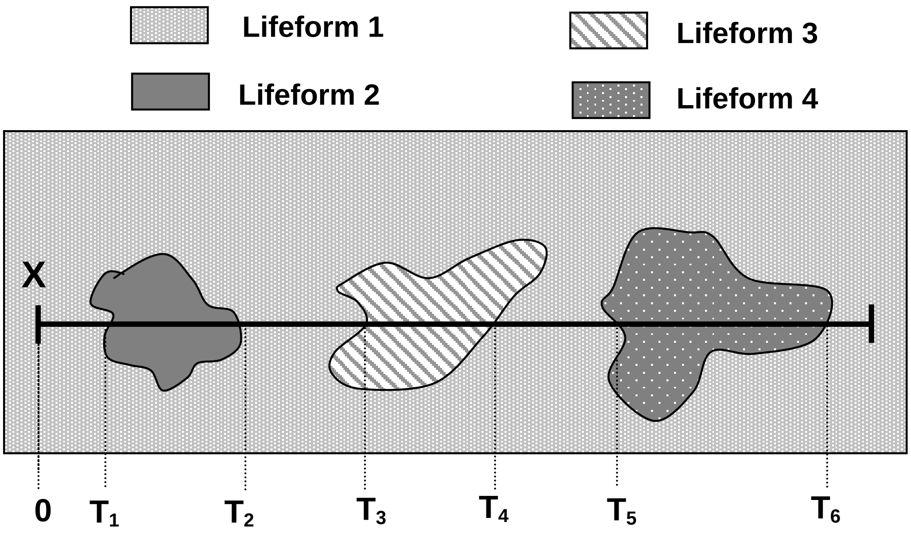
When the end of the 50 m tape measure is reached, Observer Two signals the end of the count to Observer One. The tape measure is left in place and the next transect started at a haphazardly selected point away from the previous transect. On completion of transects in one direction from the anchor, the observers return to wind up the tapes (Observer Two) and measures the percentage cover of different habitat categories (Observer One) beneath a haphazardly chosen 10 m segment of the tape on each transect, using the line intercept method (de Silva 1984; English *et al.* 1994). It is recommended that the first 10 m of the transect is not chosen to avoid any unintentional bias when selecting the start of the transect. The observers also estimate water visibility at this time. Observer One swims ahead and holds up a hand with fingers spread at the beginning of each transect (0 m), while observer two winds in the tape measure until they can distinguish the fingers of Observer One, at which point they note and record the distance left unwound on the tape.

Habitat categories

The line intercept method simply and quickly records the percentage occurrence of the following habitat categories**:** live (hard) coral, dead coral, sand, rubble, sponge, seagrass, algae, soft coral and other. Each habitat category is measured to the nearest 10 cm. Figure 4 illustrates the concept behind the method. Note the two assumptions (English *et al*. 1994) of this method:

- the proportion of each habitat category should be small relative to the length of the transect
- transect length should be small relative to the area being censured.

Calculations of percentage cover are given in Appendix 4 along with definitions of each category and field on the datasheets (See Appendix 4).



Intercept		*Category*
T_1-0	l_1	lifeform 1
T_2-T_1	l_2	lifeform 2
T_3-T_2	l_3	lifeform 1
T_4-T_3	l_4	lifeform 3
T_5-T_4	l_5	lifeform 1
T_6-T_5	l_6	lifeform 4
Y–T_6	l_7	lifeform 1

Figure 4. Calculation of benthic cover (Figure modified from English *et al.* 1997).

Contingency Plans

The Monitoring Team may not be able to survey a particular reef in a given year due to poor weather or on site water conditions (such as low visibility or strong currents). Some extra time is available in the trip schedule to allow for weather, however this is only 1 or 2 days overall.

If not all sites are surveyed on a given reef, the data should be considered as missing and a detailed discussion of the circumstances and which sites were and were not done should be recorded in the trip report for that reef. If however, a site is surveyed and at some point during the dive the dive is cancelled (e.g. increasing current, decreasing visibility, equipment problems) then Observer One should note in the transect column which transects were not done and a brief reason why, e.g. “Not done: strong current”. Again, further detail can then be recorded in the trip sheet for that reef.

In the case that a site is being surveyed and some data cannot be recorded, such as depth, time, visibility of fish length, then observer one should make a note on the datasheet indicating the datum was not collected. This is usually done by marking a –1 in the appropriate cell / box. Why this information could not be collected should then be described in more detail in the trip sheet for that reef.

If during the lifetime of the program, access to a reef is lost (i.e. reef closure) then a replacement study reef may be sought. The selection of the new reef should be based on available historic information on fisheries resources on that reef in the same way the current reefs were chosen. These new areas will then be incorporated into the annual surveys.

Additional contingency plans will be developed as situations arise and will be reported in updated versions of this manual.

Data Compilation

Timetables

The datasheets should be checked for legibility and completeness by the regional coordinator within 10 days returning to the laboratory. The datasheets should then be photocopied and the copies mailed to the database coordinator in Brisbane.

It is the database coordinators responsibility to ensure the data are entered within four weeks of being received, then printed out and mailed back to the regional coordinator for checking. The regional coordinator will ensure that verification is completed within two weeks of receipt. The verified data should then be mailed back to the database coordinator and errors fixed within one week of from when the data are received.

Data analysis should be completed within four weeks of receiving verified data. The fishery status report can then be generated within the next four weeks resulting in a total data collection to reporting phase of 17 weeks.

By December each year the regional coordinator should ensure the reporting requirements for the animal ethics permit have been fulfilled. The regional coordinator should also ensure the Marine Parks permitting reporting requirements are fulfilled with four weeks of the expiry date of each five year permit.

Data Processing Requirements

The following three analyses are also recommended (in addition to standard analyses by Condition & Trend Unit):

1. Calculate precision and power from six replicate transects per study site to ensure replication level is adequate. Revise sampling design if necessary.
2. Compare monitoring team's density estimates to those obtained by Ayling during the same period for the Cooperative Research Centre for the Great Barrier Reef World Heritage Area (CRC Reef) Effects of Fishing Project, (Leader: Bruce Mapstone) to assess accuracy of new observers.
3. Incorporate results from 1999 into analysis of Ayling's historic data (Ayling *et al.* 2000), particularly for the Cairns reefs since these reefs have not been surveyed since the early 1990s.

Data Analysis

Trends in Relative Abundance

Data collected over the long term for reef fish species are to facilitate periodic stock assessment of the resources independent of fisheries catch data. Density estimates generated from UVC can be analysed using Time Series Analysis techniques. General Linear Modelling (GLM) and Regression Analysis should be investigated and can provide information indicative of fishery trends on the reefs surveyed. Density estimates from each reef can only be compared to that reef with trends in populations on each reef not independent of the previous years data. When several years of data are available more complex techniques such as Auto Regressive Integrated Moving Average models (ARIMA) and State Space Models may also be useful in assessing these data.

Note that several years' data will be required before these analyses can be preformed with confidence. If possible, this information should be analysed in conjunction with historic and current survey data collected by the CRC reef and AIMS on the same reefs to improve confidence in trends observed.

The use of GLMs must be considered to reduce the variability in observations caused by differences between observers, visibility of water at the site and the potential affect of other co-variates such as temperature, depth, fished and unfished reefs, latitude, current stress, southern oscillation index etc.

Trends in Population Structure

Recruitment strength and trends in population structure of reef fishes can be investigated through cohort analysis techniques. Virtual population analysis techniques can be carried out annually to observe trends in population parameters such as fishing and natural mortality rates and recruitment. Information generated from the fisheries independent surveys should then be compared with industry catch information. As for abundance, several years' data will be required before analyses can be preformed with confidence and where possible include survey data collected by the CRC Reef Effects of Line Fishing Project and AIMS on the same reefs.

Fisheries Dependant Data

Fisheries dependant information should be obtainable from the Condition and Trends Unit, based on Commercial and Recreational Fishery Information System (CFISH and RFISH) data. This will allowing comparison of fisheries dependant and independent trends and improve the confidence in trends obtained.

Benthic Cover

Benthic cover should be considered as a co-variate of fish density. Using GLM, the variability associated with benthic cover may be assessable. If possible, comparison should be drawn to AIMS benthic cover data for each reef also.

Report Requirements

- Density estimates for each reef should be reported annually including detail at the site and transect level for each species.
- Size class information should include the size of each fish as well as the number of fish grouped into 5 cm size classes.
- Data on co-variates should be provided at the transect level so analysis can be preformed i.e. Reef, Site, Transect, Visibility, Benthic Cover categories, Depth etc.
- Permit reporting requirements should also be followed.

Training and Safety

Staff Requirements and Certification Needs

- Current First Aid Certification
- Marine radio certification
- Coxswains ticket
- SCUBA: registered on the Departmental Dive Registration (e.g. Rescue Diver minimum)
- Dive medical: as per A.S. 2299

SCUBA diving will be done in accordance with the Departmental Dive Manual (Coles *et al*. 2011) and national standards.

A copy of each person's dive medical, dive certification, up to date dive logbook and current first aid must be filed with the Departmental dive coordinator before the training can be started. In some cases it may be necessary to check a person's dive history or competence by discussing these issues with previous dive buddies (see their dive log). If the observers have not dived in the past three months, as is often the case, observers will need to do work up dives or assessment dives with a Departmental dive supervisor, in accordance with the Departmental dive manual (Coles *et al*. 2011). Work up and assessment dives must be done before observers can undertake any dive training or surveys. A dive plan must be submitted to the dive coordinator for approval before the training can be undertaken. A second dive plan is also required for the survey period.

All other safety issues relating to vessels working offshore will be the responsibility of the vessel skipper. In addition, the monitoring team will follow the Departmental Remote Area Policy.

Underwater Visual Census Training

New observers must be carefully trained in species identification, counting fish, size estimation, pacing the swim and identification of benthic flora and fauna before collecting data for the reef fish monitoring program.

Location

Training takes place from Green Island and access to the research station there must be booked through the NFC station manager. Access and research station guide are obtained from the station manager. Care must be taken to undertake training when tides are appropriate, that is, high water during the middle of the day so training can be done on snorkel in the shallow sandy areas on the reef flat.

Transport to the island can be booked through Great Adventures™. Check that there is space to accommodate all training equipment onboard. Some equipment may need be transported on an earlier or later ferry. It is useful to notify the Green Island Resort staff that a training session is being held, particularly the dive shop where scuba tank refills can be obtained.

There are several suitable dive sites around Green Island and local knowledge should be sought from staff who have worked in the area before. Polarised sunglasses will aid in locating reef patches from the boat.

Species identification

Observers must be completely familiar with all the species (11) being surveyed, any similar species and their distinguishing features. With a little time all species can be easily distinguished. Divers without much experience in reef fish identification should spend an extra day or two training on this skill. If a permit can be obtained, spear fishing would be an ideal way to learn the species and their behaviours as well as refine size estimation skills.

Lutjanus russellii can be confused with *L. fulvus* and *L. monostigma*. One feature that distinguishes these species is the colour of the caudal fin with *L. russellii* being grey to black compared to the red and yellow tail of *L. fulvus* and *L. monostigma*, respectively (see pictures in Fig. 1, Randall *et al.* 1990).

Juvenile *Cheilinus undulatus* can be distinguished from *Cheilinus trilobatus*, a similar wrasse species, by colour pattern with *C. trilobatus* having three small dark spots in a row midlaterally on the posterior part of body (Randall *et al.* 1990). Head shape is also a very useful feature in all but the smallest fish.

Plectropomus species can be distinguished from most other serranid species by noting the shape of the caudal fin which is close to truncate in plectropomids while being rounded in most other species. For the inexperienced care should be taken to distinguish various *Cephalopholis* species e.g. *C. argus*, *C. cyanostigma*, *C. microprion* and *C. miniata*,

The distinguishing characteristics of species within the genus *Plectropomus* (such as size, shape and pattern of blue spots) can vary among individuals and locations. An additional feature to aid in distinguishing *P. laevis* from *P. leopardus* is the former has dark pectoral fins while the later does not (Fig. 1). Approaching the new moon during the spawning season, male trout often display spawning colours. Figure 5 shows the spawning colours of some *Plectropomus* species.

Size estimation

Five days should be set aside to train new observers in size estimation before they collect data. A set of wooden fish models ranging from 11 cm to 120 cm in size (at 1–2 cm intervals) are used to train observers to estimate fish sizes within all size ranges (Bell *et al*. 1985; Samoilys 1997a). Models are strung end to end along thin ropes that are anchored in shallow water where trainee observers record their estimated lengths on snorkel. Each trial run involves a sub-set of 50 models selected randomly from the whole set. The actual length is marked on the back of each fish model to aid in training. Trainee observers swim along the line of models at a distance of 2–3 m, estimating the length of the wooden fish and recording the data with pencil and slate. At the end of each trial the data are plotted to examine biases in relation to size class (Figure 6 and Figure 7). For example, less accurate estimates for the largest fish will be easily seen by the scatter of points in a regression type plot (e.g. actual size against estimated size, Figure 6) and the degree of error can be seen for the different sizes in a scatter plot of the differences of the estimate from the actual length of wooden fish (Figure 7). Training is continued until estimates are within +/- 5 cm 90% of the time. This usually involves around six trials (Samoilys 1997a).

Experienced observers require re-training prior to each year’s survey. This takes approximately half a day.

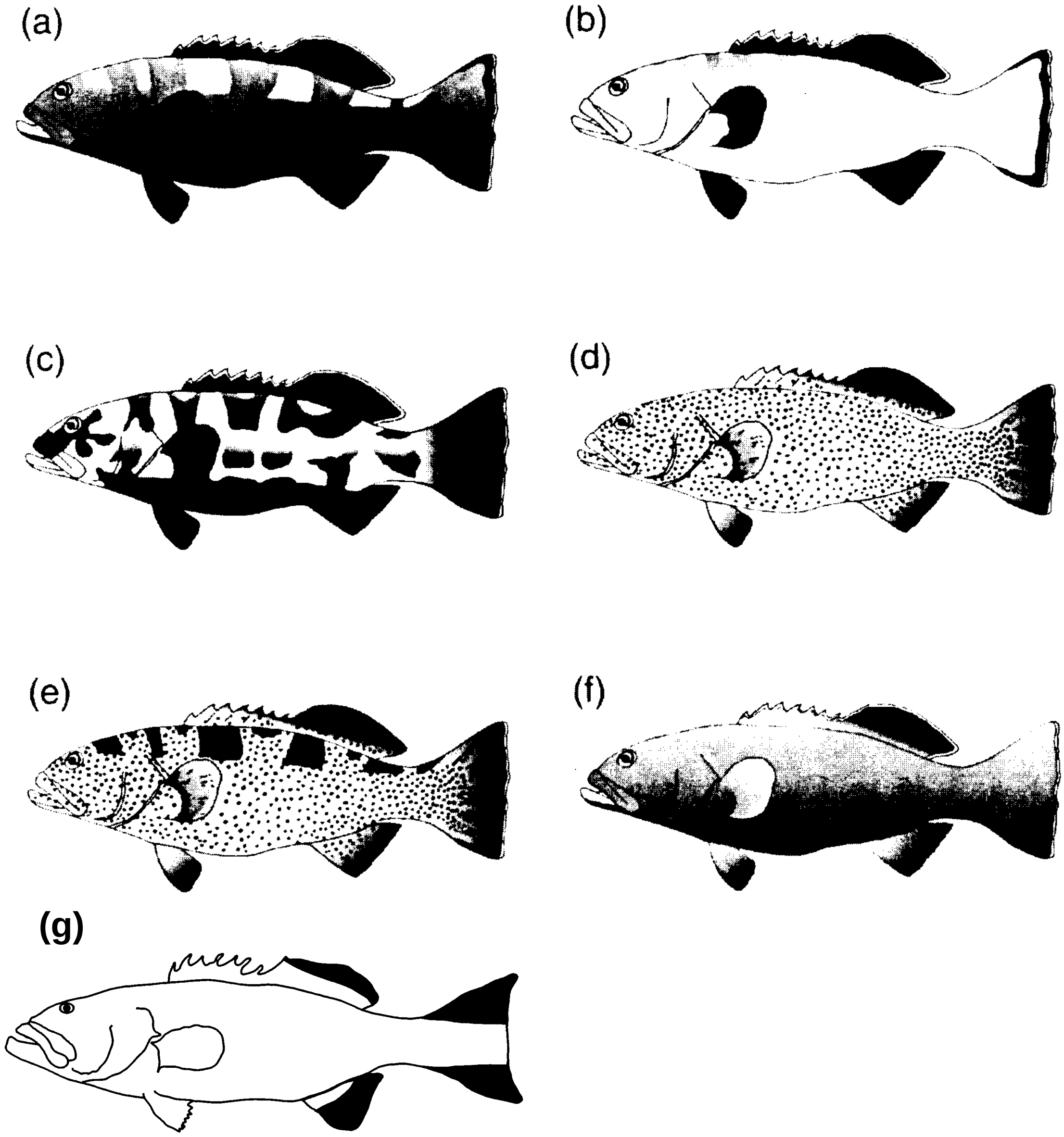


Figure 5. Spawning colours of *Plectropomus areolatus* (a-f - source: Johannes *et al*. 1999) and male *P. leopardus* (g - source: Samoilys and Squire 1994).

Tip: While undertaking UVC surveys, observers can often check estimations by observing the location of the head and tail of a fish close to a background, swimming over and using the data board to check the estimated size against the actual size of the fish. When this is done the recorded estimated size should not be adjusted unless the estimation >+/- 5 cm. If the estimation is out by more than 5 cm, recorded the correct size and mark the record with an asterisk (this will allow this point to be identified as an accurately measured fish when being entered into the database).

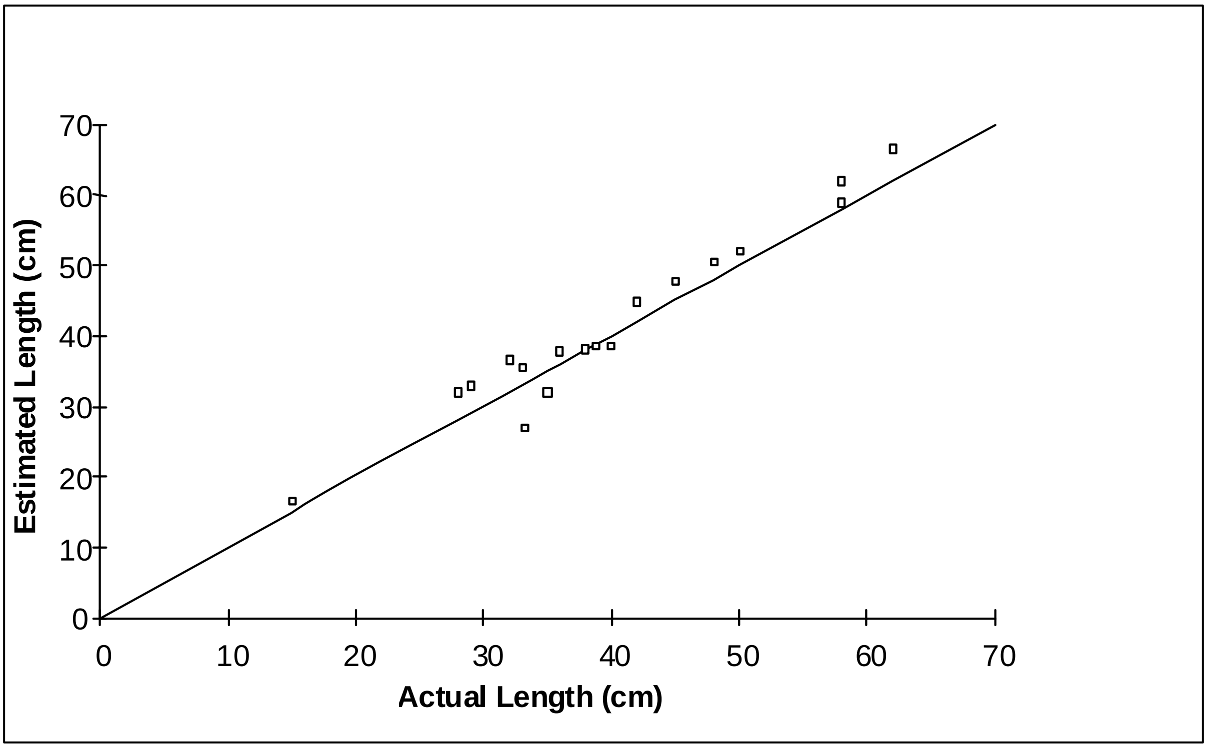


Figure 6. Fish length estimations from plywood models by an experienced observer (redrawn from Samoilys and Carlos 1992).

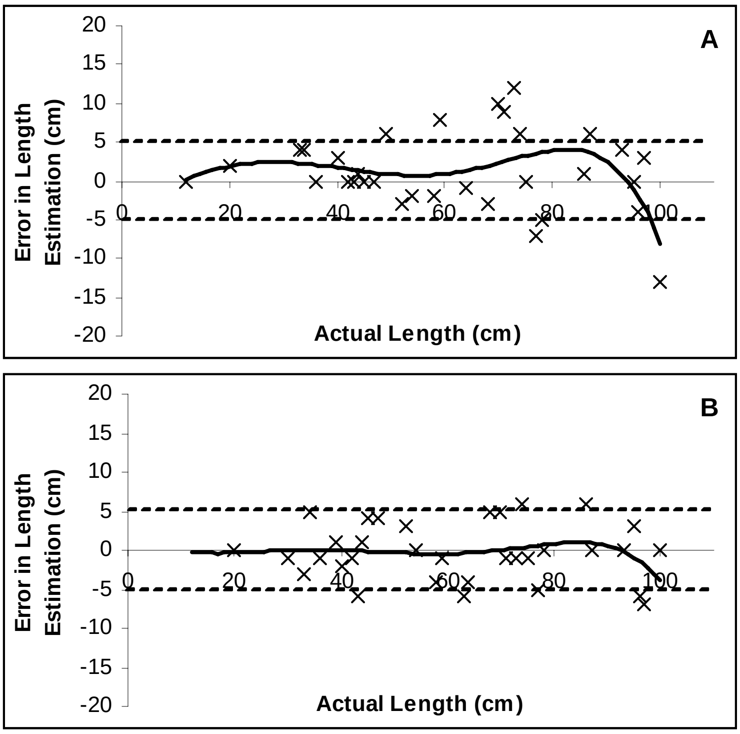


Figure 7. Scatter plots illustrating under- and over-estimation of lengths of plywood fish models. A is after the first trial run and B is after two trial runs, with the observer having viewed the results of their first trial (A). See text for notes on interpretation of these graphs.

Other techniques for examining error in size estimation during training include fitting a high order polynomial to a plot of difference between actual and estimated sizes of wooden fish models (see trend line in Figure 7). In many cases this will allow an observer to see patterns in their estimation, such as over estimation of smaller or larger fish with mid-range fish being under estimated etc. However, care should be taken using this technique as most computer programs will fit a polynomial to the data even if this is not appropriate and therefore may provide misleading trend lines. An example of this is when a trend line indicates an overestimation of smaller fish where there are actually no fish estimated in this size range. Although high order polynomial plots are useful their interpretation needs care.

Counting fish

Transects are conducted in the normal fashion (see Deployment UVC surveys) by both trainee observers and an experienced observer in the same area. Paired t-tests are run to compare the density estimates. Training continues until no significant differences are detected between the experienced observer and the trainee ($p<0.05$).

Tip: When encountering a large school of fish during a count it is often easier to count in groups of five fish of similar size.

Pacing

Observer Two must practice swimming at the right pace for the transect. This is crucial as slight differences in swimming speed can result in large errors in transect swimming time. Observer Two should aim to finish exactly on three minutes with a maximum error of +/- 5 seconds. Observer One should regularly look back to check on where Observer Two is and thereby check his/her swimming and searching speed time as well as verifying the imaginary transect line ahead.

Benthic Flora and Fauna

Because of the simple definitions of benthic habitat (Appendix 5) used in this survey, a basic understanding of benthic flora and fauna categories is expected of fisheries staff. Following reading of the definitions staff are given the opportunity to practice their habitat line transect to allow confident application during surveys.

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Appendices

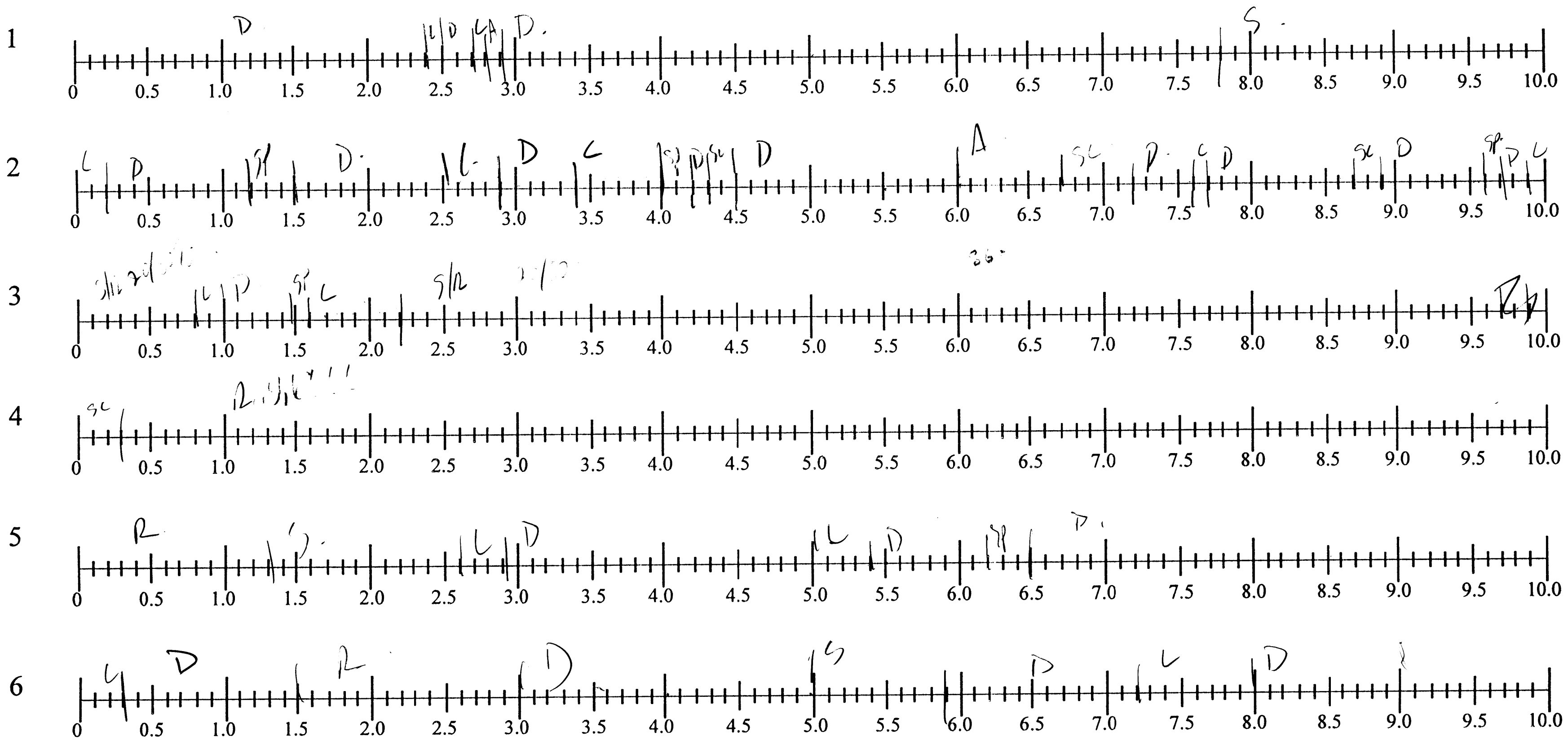
Appendix 1. An Underwater Visual Census and habitat data collection sheets completed as an example.

Observer One: C-[illegible] Date: 21 [illegible] Reef: [illegible] Site: 3 Cloud: 6 /8 Wind: [illegible] Tide: ____________

Position: A: [illegible] 18 24' 59", 147° 27' 10" B: [illegible] 18 25 05", 147° 27' [illegible]"

SHALLOW [illegible]

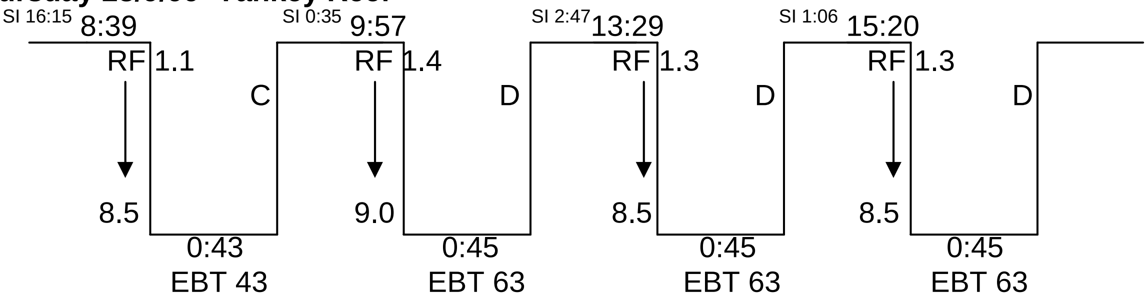
	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5	Transect 6
Time:				9:01	9:04	9:08
Visibility:	19.4	23.2	22.2	22.2	23.0	24.9
Depth (min – max)	4.0 – 9.0	4.0 – 8.0	4.0 – 8.0	4.0 – 9.2	5.0 – 9.5	6.0 – 10.5
***Plectropomus** leopardus*		37		NO FISH	30, 41	28, 37, 23, 33
P. laevis			26			23F, 53
P. maculatus						
P. areolatus						
***Cromileptes** altivelis*						
***Lethrinus** miniatus*					38	
L. nebulosus						
***Lutjanus** carponotatus*						
L. russelli						
L. bohar						
***Cheilinus** undulatus*	80					
Other						



Transect #	Dead coral (D)	Coral (C)	Soft coral (Sc)	Rubble (R)	Sand (S)	Sponge (Sp)	Algae (A)	Seagrass (Sg)
1	75	2	—	—	22	—	1	—
2	64	14	9	—	—	6	7	—
3	5	8	—	68.8	17.2	1.	—	—
4	—	—	3	97	—	—	—	—
5	64	7	—	13	13	3	—	—
6	65	11	—	15	9	—	—	—
Observer 1	CHAD	Reef	[illegible]	Date	24/9/99	Site	3	

Appendix 2. Example of dive profile used during reef fish survey in 1999.

Thursday 23/9/99 Yankey Reef



Out at 16:05. Divers reach RF of 1.0 at 4:05 am.

- SI = Surface interval, RF = repetitive factor, EBT = effective bottom time. Also shown from left to right is dive start time (8:39 am), depth (8.5 m), bottom time (43 minutes) and repetitive dive group (letter).

Appendix 3. Example of a vessel schedule – this one was used in the first reef fish survey during 1999. (NFC = Northern Fisheries Centre)

Week 1 and 2
27/8/99 – 8/9/99, Cairns Section

Date	Reef	Reef No.
26/8/99	Get gear ready at NFC	
27/8/99	Leave port in afternoon	
28/8/99	Channel Reef 8:00am start	1
29/8/99	Arlington	2
30/8/99	Hastings	3
31/8/99	Steam to Lizard Island	
1/9/99	Eyrie Reef	4
2/9/99	Lizard Island	5
3/9/99	Macgillivray Reef	6
4/9/99	Steam to Escape Reef	
5/9/99	Escape Reef	7
6/9/99	St. Crispin Reef	8
7/9/99	Norman Reef, Steam home	9
8/9/99		
9/9/99		
10/9/99		
11/9/99	New Moon	

Week 3 and 4
13/9/99 – 27/9/99, Central Section

Date	Reef	Reef No.
12/9/99		
13/9/99	Leave in Afternoon	
14/9/99	Bramble Reef	10
15/9/99	John Brewer Reef	11
16/9/99	Lodestone Reef	12
17/9/99	Steam to Hardy reef	
18/9/99	Hardy Reef (neap tides)	13
19/9/99	Black Reef	14
20/9/99	Kangaroo Reef	15
21/9/99	Steam to Davies Reef	
22/9/99	Davies Reef	
23/9/99	Yankee Reef	16
24/9/99	Dip Reef	17
25/9/99	Steam to Faraday Reef	18
26/9/99	Faraday Reef	
27/9/99	Wardle Reef, steam home	19
28/9/99	Unpack and NFC	20

Appendix 4. Datasheet Definitions

Two datasheets should be filled in for each dive, one benthic cover datasheet and one UVC datasheet. On the UVC datasheet (Appendix 1), observers record physical parameters, estimated fish sizes, numbers of target species seen. On the Habitat datasheet benthic habitat information is recorded. A copy of a typical completed datasheet is provided as an example in Appendix 1. At the end of each day, datasheets are checked to ensure all categories have been entered correctly and legibly. Percent cover of habitat categories are calculated for each transect at the end of each day (Equation 1). Calculations are as follows:

Equation 1 Modified from English *et al.* 1997.

$$\textbf{Percent cover} = \frac{\text{Total length of category}}{\text{Length of transect (eg } \mathbf{Y}\text{)}} \text{ X } 100$$

Definitions of fields on datasheets

Observer one	the three initials of the person filling in the datasheets. Observer One is responsible for doing the underwater visual census of target fish species and collecting the benthic cover information.
Date	is the day/month/year on which the data were collected.
Reef	is the name of the reef being surveyed currently.
Site	is a value from 1–4 indicating the identifying number of the fixed sites surveyed on each reef.
Transect 1–6	indicates the number of transect and which column to enter the data for that transect into. Transect one is the first transect laid down and six is the last. This means transect one is closest to two and four with transects three and six being at the extremities of each site.
Time	is the 24 hour time that each three minute transect was begun.
Visibility	is the measurement taken by observer two as each tape measure is wound in. This measure is indicative of the difficulty in observing fish and is used as a co-variate in data analysis. The visibility measurement is the straight line distance observer two is away from observers one when observer two can first distinguish between the fingers on observer one's hand while it is being held out away from their body with finger stretched apart.
Depth (max-min)	is the maximum and minimum depth at which fish were observed along each transect given the dimensions of the transect. That is, if observer one is diving at nine meters and is looking along the transect to a depth four meters below then the maximum depth is 13 m. If at some other point along this transect observer one is at seven meters depth and looking three meters up then the minimum depth is 4 m (7 m – 3 m). The maximum and minimum depths are NOT the maximum and minimum depth the observer dives to on a particular dive.
Target species	Beside each of the target species names the estimated length of each fish seen within the transect should be written. Measurement should be in centimetres

	and should only include fish inside the transect. For Barramundi cod, *Cromileptes altivelis*, and humphead Maori wrasse, *Cheilinus undulatus*, fish outside the transect are also recorded. These recording must be denoted in parenthesis e.g. (35 out), for a fish of 35 cm total length observed outside a transect.
Dead coral	is the length of intersection of the transect to the nearest 10 cm with all dead hard coral (scleractinian corals). Dead hard coral with a thin layer of settled out silt or algae is still recorded as dead coral. Dead coral smaller than 30 mm in all dimensions should be recorded as rubble. This value is also the percentage of the transect that this category of benthic cover occupies.
Rubble	is the length of intersection of the transect to the nearest 10 cm with dead hard coral or calcium carbonate of other origin in pieces less than 30 mm in all dimension but greater than 10 mm. This value is also the percentage of the transect that this category of benthic cover occupies.
Sand	is the length of intersection of the transect with calcium carbonate material in pieces less than 10 mm in all dimensions. This category includes dead *Halimeda sp.* This value is also the percentage of the transect that this category of benthic cover occupies.
Coral	is the length of intersection of the transect to the nearest 10 cm with live scleractinian corals, including encrusting corals. This value is also the percentage of the transect that this category of benthic cover occupies.
Soft corals	is the length of intersection of the transect to the nearest 10 cm with live octocorals, including gorgonians. This value is also the percentage of the transect that this category of benthic cover occupies.
Sponges	is the length of intersection of the transect to the nearest 10 cm with any sponges, including boring sponges. This value is also the percentage of the transect that this category of benthic cover occupies.
Algae	is the length of intersection of the transect to the nearest 10 cm with macro algae and coralline algae including live *Halimeda* and encrusting coralline algae such as pink paint. This value is also the percentage of the transect that this category of benthic cover occupies.
Seagrass	is the length of intersection of the transect to the nearest 10 cm with any seagrass. This value is also the percentage of the transect that this category of benthic cover occupies.
Other	is the length of intersection of the transect to the nearest 10 cm with anything not listed above, including tunicates, giant clams, other bivalves, hydroids etc.. This value is also the percentage of the transect that this category of benthic cover occupies.
Total	is the checking column where you check the total of the above defined benthic categories adds up to 100%.