Assessing the status of temperate reefs in Gulf St Vincent III: Evaluation and description of methodologies

A report to the Environment Protection Authority

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Table of contents

Index of Tables and figures

EXECUTIVE OVERVIEW

Background

A variety of different methods may be used for surveying marine systems, to provide information about the structure and status of the resident communities. In conjunction with process oriented studies the information obtained from these surveys can be used to improve our understanding of these systems and the spatial and temporal scales at which major ecosystem processes operate. A sound understanding of these issues is essential to ensure the effective management of our marine environment.

Scope

This report describes a set of non-destructive sampling methodologies and considers the extent to which they can be applied to provide information about the structure of temperate reef communities in Gulf St Vincent, South Australia. These methods are currently being further modified and developed in an ongoing project being run jointly with the conservation council as part of the Reef Watch community monitoring program.

Approach

This study trialed three non-destructive sampling protocols which focus on different aspects of temperate reef systems.

- The Line Intercept Transect (LIT) method was used to survey the sessile macro-benthos that forms the major structural components of temperate reef systems.
- A non-destructive quadrat method was used for the non-algal sessile and sedentary biota.
- A visual census method was used to assess mobile biota.

Findings

- The LIT method proved to be the best method for differentiating reefs on the basis of the dominant taxa (on a percent cover basis) making up the reef communities. The method can be employed with a varying degree of taxonomic resolution and so may be adapted for use by trained professionals or by novice/untrained divers. Because it focuses on the community dominants the LIT method is ideal for picking up large scale/structural changes in reef systems.
- The LIT method does not provide good information about species that have low percentage cover and it is therefore not suitable for the assessment of cryptic or small sedentary taxa that do not dominate systems in terms of biomass or cover. For these taxa non-destructive quadrat sampling is the most appropriate protocol.
- Visual assessment of fish communities is appropriate for studies with a particular focus on fish (eg fishery surveys) but is not sensitive to underlying changes in the overall composition of reef communities.

Recommendations

- Efforts should be concentrated on the development of the LIT method for use in the long-term monitoring of changes in reef systems. This method is particularly suitable for implementation by community groups.
- The quadrat method should be used as a tool for investigations of a more specific nature, especially those that require a focus on specific sessile or sedentary taxa.
- Fish visual census should be used for the assessment of changes in fish populations of particular interest.

EVALUATION OF SURVEY METHODOLOGIES

1. Introduction

A variety of different methods may be used for surveying marine systems, to provide information about the structure and status of the resident communities. In conjunction with process oriented studies, the information obtained from these surveys can be used to improve our understanding of these systems and the spatial and temporal scales at which major ecosystem processes operate. A sound understanding of these issues is essential to ensure the effective management of our marine environment.

Historically the methods used for the assessment of marine systems have included both destructive and non-destructive techniques. In any given situation the measurements taken depend upon the specific questions being asked and the extent to which the process of making the measurements can be allowed to impact upon the system. This report describes a set of non-destructive sampling methodologies and considers the extent to which they can be applied to provide information about the structure of temperate reef communities in Gulf St Vincent, South Australia. These methods are currently being further modified and developed in an ongoing project being run jointly with the conservation council[1] as part of the Reef Watch community monitoring program.

[1]Details of the LIT, non destructive quadrat and fish visual census methods have been provided to the conservation council (Reef Watch group) and are being used as the basis for the development of community monitoring programs.

2. Background to field methods

2.1. Evaluation of methodologies

Testing a sampling methodology in the field can be done by comparing community estimates with those obtained from another sampling technique. Ideally comparisons could be made with results of a definitive community census which would provide close to absolute values against which the sampling method could be tested. Unfortunately such a census is not feasible because of the time involved (Turner 1995). Comparing estimates with those obtained from another accepted technique is therefore the only practical possibility.

Comparisons of estimates to those obtained using alternative methods are much faster and have been used effectively in previous studies (Chiappone and Sullivan 1991, Sullivan and Chiappone 1992). These studies tend to gauge efficiency in terms of the ability to discriminate between community structures. This direct comparison can be used to demonstrate the degree of similarity between methods but gives little indication as to whether either method is faithfully reproducing information about the system. As a result an assumption must be made regarding the quality of data from the accepted method (Turner 1995).

This study trialed three methods of non destructive sampling which focus on different aspects of the ecosystems examined. The LIT method was used to survey the sessile macro-benthos that forms the major structural components of temperate reef systems. A non-destructive quadrat method was used for the non-algal sessile and sedentary biota and a visual census method was used to assess mobile biota. Details of the application of these methods are contained in Appendices A to C.

2.2. Destructive Quadrat Harvesting

Destructive quadrat harvesting has become the most common method for surveying subtidal marine algal systems because it minimises the amount of time spent under water (Littler and Littler, 1985). The technique involves the placement of quadrats on the substrate and lifeforms of interest within the quadrat are then harvested and placed in labelled bags. These bags are returned to the laboratory where they can be sorted into taxa and counted and/or weighed to obtain a quantitative measure (no. of individuals or biomass) per unit area (Littler and Littler, 1985).

In many cases the choice of the sample size is based almost solely on intuition and tradition rather than on a quantitative assessment of the appropriateness of the sampling regime to extract faithful information about the system (Andrew and Mapstone, 1987). The most widely used quadrat size in marine systems is a square quadrat of 0.25 metre area (Andrew and Mapstone, 1987), however there is a lot of deviation from this in the literature. For example, previous work in South Australia by Shepherd and Womersley (1970) used a 0.1 m^2 round quadrat whereas Collings (1996) used a 1 m^2 square quadrat.

A major problem with destructive harvesting is the resultant damage to the system (De Wreede, 1984). While destructive quadrat sampling may be an effective way of surveying an area, it's impact on that area may outweigh it's usefulness. This is particularly so in areas of high conservation status (eg areas which contain rare species), or areas which are to be repeatedly sampled (such as those subject to ongoing monitoring). While small scale disturbances are an important part of patch dynamics in marine communities (Scheil and Foster, 1986), destructive sampling is more likely to confound results and lead to changes in community structure through changes in the disturbance regime (Turner 1995). In the context of the aims of this study, this type of sampling is not considered a viable option, and therefore an alternative that is non-destructive is needed.

This project has aimed to develop a methodology capable of collecting good quality environmental data using non-destructive methods. These methods should also be able to be developed for use by persons from community groups and other organizations with limited biological training and understanding. Work described in this report relates to an evaluation of the non-destructive methods developed.

2.3. Line Intercept Transecting

The Line Intercept Transect (LIT) method provides a basis for obtaining quantitative measures on the percentage cover of sessile benthic organisms without destructive harvest. Turner (1995) has provided a detailed discussion of the appropriateness of the LIT method to the assessment of macro-algal dominated marine benthic systems. In summary, LIT has traditionally been used only in terrestrial (eg Webb *et al.*, 1970) or marine systems (eg Reichelt *et al.*, 1986) in which one can assume that individuals are not overlapping (Muttlak and Sadooghi-Alvandi, 1993, Lucas and Seber, 1977). On the face of it this would not apply to macro-algal dominated systems in which the community is multi-layered. Nevertheless, in a detailed study based around reefal systems at West Island South Australia, Turner (1995) demonstrated that LIT was faster and just as effective in determining community structure as the more generally used destructive harvesting proposed by Littler and Littler (1985). Further, given that LIT is non-destructive it was felt that, particularly in sensitive habitats, this provided a much more responsible approach to ecosystem assessment.

2.4. Non destructive quadrats

Non-destructive quadrat sampling is done by placing a quadrat of given size over the substratum. All unitary organisms within the area circumscribed by the quadrat are then counted to provide a quantitative measure of the abundance of each taxa/group within that area. Results are then presented as number per unit area (generally $n.m^{-2}$).

2.5. Fish visual census

There are two main categories of underwater fish census. In strip transects, all individual within a specified area (fixed path width) are counted. In line transects, all individuals are counted regardless of distance from the observer. With this latter method, the probability of sighting declines with distance, but a much greater area can be surveyed. Total density is obtained by correcting the number observed, based on the probability of sighting for a given distance.

Strip transects are most often employed, often along a depth contour, fixed compass direction or demarcated path. The precision and accuracy of strip transects for small reef fishes is a function of transect length relative to the abundance and patchiness of the species examined (Sale and Sharp 1983). In general precision increases with increased transect length, but abundance estimates may decrease as transect width increases.

There is a growing literature on the use of underwater visual census and the best way to obtain accurate estimates of abundance (eg Samoilys 1992, Sale and Sharp 1983). Problems are considerable, however, particularly with respect to differences in the behaviour of different species. For example, Harmelin-Vivien *et al.* (1985) noted lower fish abundance when consecutive visual surveys were conducted in the same area.

3. Results and Discussion - critical evaluation of assessment protocols

3.1. LIT

In general we found the LIT method provided good quality quantitative data for temperate reef systems. Its simple application also makes it easily adaptable for data collection by community groups and organizations whose personnel have limited biological training. In our view, these factors plus the low impact nature of the technique make it most suitable for the long-term monitoring of temperate reef systems.

The LIT method proved to be straightforward in its field application and allowed a rapid assessment. However, in areas lacking the larger dominant brown algae it was more time consuming. Time taken is largely a matter of the resolution at which the system is sampled (3 cm in the current study) and depends on the requirements of individual studies.

The use of simple lifeform categories was generally successful. It minimized training time and meant that divers in the field could classify even those taxa that they had never previously encountered by using the simple criteria set out in table 2 of Appendix A.

The use of lifeform levels of classification provides little taxonomic resolution, and therefore cannot be used in broad-based biodiversity assessments. This study has however, shown it can be used to detect differences in broad community structure between reefs. In the context of monitoring the health of ecosystems it is reasonable to expect that this method would be capable of detecting changes in key structural attributes of the reef over time. Once changes in the condition of a system have been identified, other methods could be used to elucidate the nature of the change.

Initial lifeform groupings used in this study was probably insufficient in some ways. The grouping of all brown robust algae (BRROB) included species of algae that were rather different in nature. *Ecklonia radiata*, which dominates the southern reefs (in particular Noarlunga), is structurally quite different to other community dominant brown algae such as *Cystophora* spp. and *Sargassum* spp.

To resolve this shortcoming we recommend that the brown robust (BRROB) lifeform category should be broken into two separate categories to represent the different physical characteristics of these algae. Brown robust algae with flattened blades could be listed as BRFLAT. This category represents taxa such as *Ecklonia* generally found across a broad range of physical conditions, although in the Adelaide metropolitan region more commonly in the higher energy habitats. Brown robust algae that have a branched structure more common to lower energy habitats could be listed as BRBRANCH. This category would include species of both *Cystophora* and *Sargassum*. For surveys of areas outside the Adelaide metropolitan region a third category for floating brown algae (BRFLOAT) is recommended for taxa such as *Macrocystis* spp. or *Phyllospora comosa* which are representative of another lifeform.

Although we have shown that the use of lifeform categories does provide sufficient resolution for characterising reefs, some benefit may be derived from recording information about the actual species present as community dominants. Surveys by organisations with trained personnel may well be carried out with a greater level of taxonomic resolution (either to genus or species level for dominant taxa) and thereby provide much more detail about the structure of these communities. Cheshire and Rowling (1996), for example, used the LIT method to survey the reef at Penneshaw using a generic level of classification for community dominants.

Data for this survey was collected from only one type of habitat represented at each reef. Similar topographic characteristics were sought at each reef in an effort to maintain consistency throughout the study. Due to the differing nature of the reefs surveyed this was not always possible. Noarlunga in particular displayed different topographic characteristics, and this was evident in the results from LIT data. All other reefs were surveyed on reef tops. The reef top at Noarlunga however is intertidal, therefore, to sample at sufficient depth it was necessary to choose a reef slope.

It should also be recognized that one reef may contain a number of habitat types. Due to time and economic constraints it is not always possible to survey all habitat types present. While sampling one type may give an indication of the condition of the reef as a whole, different habitats may be affected in different ways by anthropogenic impacts. Where resources are sufficient, survey of the different habitats present within a reef could be quite useful in monitoring the reef's health. For example, in the case of Noarlunga it would be desirable to collect information from the communities on the top and inshore sides of the reef.

This study only focussed on surfaces with inclinations ranging from flat to approximately forty-five degrees. Communities on near vertical surfaces of the reef would be quite different in nature to those on flat surfaces, and as such would also be worthy of investigation in their own right. Adaptation of both the LIT and quadrat methods used in this study could be made in order to sample such surfaces.

3.2. Quadrat

Like the LIT method, the non-destructive quadrat sampling method suited the goals of this study in that it was low impact and easily applicable in the field. The quadrat method was however more difficult to apply in respect of the identification of various taxa. While algal communities can be divided into lifeform categories, which have meaning in ecological terms, based on several simple to understand morphological concepts, this is not so easy for sessile/sedentary fauna. The taxonomic categories used for the quadrat method need to be memorised. This makes the quadrat method more difficult to implement in terms of training and may introduce greater errors in classification between divers.

The quadrat sampling was carried out on the same transect lines as the LIT survey, however, the patterns in the distribution of the sessile and sedentary taxa identified did not vary in the same way as the taxa quantified using the LIT surveys. There were no clear associations between reefs in terms of the abundance of taxa assessed using the quadrat surveys.

The lack of any clear differentiation of the metropolitan reefs, when using data obtained from quadrat surveys (Cheshire *et al.* 1998a), may indicate the method in its current form lacks statistical power. Alternatively there may not be any real difference between the sessile/sedentary communities on the different reefs. The scales of observation and statistical power are two factors that need to be considered when assessing this apparent lack of differentiation.

The quadrat method samples the reef community at a different spatial scale to the LIT method. Although the LIT method seems to indicate that the reef communities are in fact different in structure at the larger scale (Cheshire *et al.* 1998a), this in no way suggests that these differences should be manifested at the level examined by the quadrat method. More detailed knowledge of the various organisms being surveyed and particularly how they are associated with the algal community would allow investigators to make educated decisions about the suitability of the various taxa in the differentiation of reefs and in indicating their status. This represents another level of investigation and is dependent on the particular goals of individual studies.

Further investigation is necessary to determine whether the intensity of sampling used in these surveys (eight 25 cm^2 quadrats on each of six transects per site) is sufficient to detect differences in this type of community.

3.3. Fish visual census

One difficulty with the visual census approach is that it requires divers who are experienced in the taxonomy of the local fish populations and who are able to rapidly identify and record species during surveys. However, since the object of this study is to develop rapid and cost effective ways to assess the status of reefs, it is perhaps unreasonable to expect that the costs of employing personnel with such expertise can be borne on a continuing basis. As a result the approach adopted for this study was to survey abundances for groups of fish at the levels of their common names. This level of recognition makes training of divers simpler since divers with knowledge of fish at this level are more common.

The data from this study showed little differentiation between reefs (Cheshire *et al.* 1998a). A number of factors, which may have contributed to this lack of discrimination, became evident during the study.

A survey of this scale must be carried out over a time frame of several weeks, and it is therefore likely (as in the case of this study) that sampling will be carried out in a wide variety of conditions. This has the potential to affect results at two levels. Firstly, varying conditions will affect a diver's ability to accurately make fish identifications and counts. Some sites were surveyed in calm conditions with visibility of 10 m and more while others were surveyed in less than 5 m visibility and significant surge. Strong surge reduces the divers concentration on the task of counting fish, while poor visibility decreases the probability of them seeing some fish species.

Varying conditions may also affect the data in another way; different fish species may behave differently in different conditions. Further investigation of the behaviour of different fish in relation to varying environmental conditions is necessary. The presence of divers may also effect fish; English *et al.* (1994) note that some fish may be attracted to divers during a survey while others may be scared away.

A second approach to this kind of survey is to focus attention on a few key fish taxa. Taxa could be chosen to suit the question being asked but may include species subject to recreational or commercial exploitation or those considered to represent an important ecological component of the reef system (this latter requires specific definition but typically may relate to numerical dominance or alternatively keystone roles).

The mobility of various fish taxa also needs to be taken into consideration. Analysis of data with all fish taxa present means results will be influenced by a level of "noise" resulting from variability of abundances of fish which may not be specifically associated with the various reefs, but are in fact migratory.

The analysis of data for this study was carried out after the exclusion of a number of taxa which were migratory and were therefore considered to have no association with particular reefs. However, some of the taxa included have wide home ranges and may travel between a number of reefs.

Several factors in the application of this method also have the potential to influence results. Along a 50 m transect, particularly on days with poor visibility there is a potential to count the same fish twice as a result of a fish swimming in and out of the field of view of the diver at various points along the transect.

Absolute counts were used for this study. This proved to be easily carried out in most cases, however occasionally very high abundances of certain species were encountered. This was particularly the case for the dredge and barge. When numbers exceed 20 - 30 estimates of numbers become less accurate. Fast moving schools of fish were also often difficult to accurately count. These inaccuracies introduce a potential for variability in sampling, particularly between divers. It is therefore considered that for future surveys $\log_4$ abundance categories may be more suitable as recommended in the initial report (Cheshire *et al.* 1998b).

4. Indices for the assessment of reef status

4.1. Background

Assessment of ecosystems generally comprises the measurement of a variety of parameters which, when considered together, describe the physical, chemical and biological properties of the system. In any given case the choice of parameters is dependent upon the specific questions being asked and the extent to which the process of making the measurements can be allowed to impact upon the system. In the following, information is presented on a series of water quality parameters and abiotic and biotic indices of reef health.

4.2. Water quality parameters

Water quality is clearly important in determining the health status of reefs. Womersley and King (1990) define three groups of environmental factors into which water quality parameters fall, these are, dynamic, physical and chemical factors. Dynamic factors relate to water movement, including tidal movement, currents, upwelling, and wind, wave and storm action. Physical factors include parameters such as temperature and turbidity or sedimentation. Chemical factors include salinity, nutrient levels, availability ie of gases (eg O_2 and CO_2), pH and pollutants (eg heavy metals and organochlorins).

Water quality however, is not necessarily easy to measure. Most parameters are highly variable in time and space and spot measurements (based on physical and/or chemical parameters) are rarely meaningful. Any sampling program therefore, needs to be cognisant of that variability. An assessment of water quality should be undertaken using an appropriately structured sampling program which deals with both the spatial and temporal scales of variability.

The following section is intended to provide an indication of which water quality parameters can be measured and how they should be measured. It should however be recognised that the sort of sampling program that one develops for looking at the biota, will in all probability not be compatible with a sampling program for looking at water quality.

4.2.1. Dynamic parameters

4.2.1.1.Water Motion

Quantification of water movement and direction is important if modelling of the reef environment is proposed. Water motion is also worth measuring for its inherent role in sedimentation, scour, feeding, and reproduction. There are a number of types of water motion that can be measured. Measuring water volume transport facilitates analysis of community metabolism and ecology. Acoustic profilers can provide instantaneous measures of the current direction and magnitude. Current meters (eg Inter-ocean current meter, type S4) can be placed to record over either short or long periods of time the current flow and direction. These two latter techniques can be quite expensive in terms of the equipment required and, although useful, were not used for this study.

A qualitative measure of current flow and direction can be obtained by simply timing the drift rate of plankton or bits of algae across a known distance and then recording the direction of flow. This type of measure is handy as it requires only a compass, watch and pencil/slate, and is therefore considered quite compatible with the community based approach to monitoring envisaged for these techniques. In a similar manner, particles can be video-taped and velocity can be measured at a later date. This may prove to be even easier if used in conjunction with video transects. Digital flow meters (eg General Oceanics) can also be useful after calibration. These meters only reflect flow and not direction.

Qualitative measurements of total water motion can be determined by simply measuring how fast a substance will dissolve. This measure is qualitative as high particulate levels increase scour and dissolution rate as will any motion on the part of the substance. High variability is likely, but even these rough measurements will provide a simple measure of total water motion that can be compared both temporally and spatially.

4.2.2. Physical parameters

4.2.2.1.Temperature

A temperature depth profile may be taken at the time of sampling in order to provide thermocline information for that day. This type of information is not immediately useful in determining the status of a reef but should be an integral part of any long-term data set because changes over the long-term can be indicative of shifts in hydrographic conditions which may have important influences on reef systems. The accuracy of the measure should be $\pm 0.1^{o}$ C. Determination of water temperatures can be made simply by using a mercury thermometer during a dive or in water samples collected from discrete depths. Mercury thermometers, while inexpensive, are also fragile and the risk of breakage and leakage of mercury into the environment has to be considered in the design of a sampling strategy. The use of other types of thermometers (alcohol, digital, watch, etc) should be discouraged unless careful calibration is included in the protocol. The ideal system, however, is a sonde/data logger (discussed below) that can be lowered to the bottom from the boat and then pulled back into the boat. This type of system records the temperature every second and downloads the information into the data logger. This information can be printed out or downloaded into any type of computer via a RS232 connection.

4.2.2.2.Turbidity

Turbidity is often assumed to be a primary component of reef health survey techniques as excessive turbidity is often correlated with higher sedimentation rates. The YSI sonde incorporates a nephelometer in the sensor package, however, previous results have been found to be insensitive. The Secchi disk provides a very simple method of gaining a visual index of water clarity.

The Secchi disk is named after the Italian physicist Angelo Secchi who published on this technique in 1886 (in Presisendorfer 1986). The disk itself is 30 cm in diameter and is attached to a non-stretch line in the center. The disk is then lowered vertically into the water, with the disk remaining horizontal, until the disk disappears from sight. This disappearance depth is inversely proportional to the amount of organic and inorganic particles in the water.

Due to the low cost and simple application of this method, it is the most obvious choice for long-term use, particularly if community groups are involved in data collection. Natural levels of particulate matter vary within and between seasons and systems. Long-term monitoring at specific sites using this method provides the best base line for the detection of overall changes in the turbidity at particular sites.

4.2.2.3.Sediment analysis/traps

Excessive sedimentation can adversely affect the structure and function of reef ecosystems by altering both physical and biological processes. There are a huge variety of shapes and sizes for sediment traps (Gardner 1980a, b; Gulickson 1982; Butman et al. 1986 – all in Coyer and Witman 1990). The basic principle behind all of the designs is to collect sediments as they sink through the water column. It has been established that simple cylinders provide the best form for sediment traps in all types of water, be it stagnant or turbulent, limnic or marine, as funnels generally undertrap and bottles overtrap the actual flux of particles in moving waters (Hakanson *et. al.*, 1989). Circular shaped traps also avoid corner effects in omnidirectionally circulating waters (Blomqvist & Kofoed, 1981). Some traps will incorporate fixatives within the sample bottles to ensure that organisms neither create or deplete sediments. Sediment traps give an indication of sedimentation rates but do not reflect the degree of re-suspension and/or horizontal transport of sediments. Horizontal sediments traps or vertical traps with baffles can provide estimates of horizontal transport.

Traps can be set up by deploying them on the first dive at a site, and then collecting them on the last dive. A two to three day interval may be sufficient to determine sedimentation rates. These traps can be constructed of PVC tubes (a minimum height:diameter ratio of 2:3 is advised). It is recommended that these traps be constructed within a weighted rack so that the entire array can be placed either onto the reef or the adjacent substrate with minimal disturbance. The rack is constructed out of rebar and weighted down with 5 kg additional weight (to minimize movement). The PVC tube(s) are then attached to the rack. Plugs (of appropriate diameter) are used to seal the tubes prior to deployment and collection. Due to the weight of the array, the racks should be lowered and recovered from the boat and not carried by the divers.

Sediment analysis examines the grain size distribution of settled sediments. Sediments are collected by cores or grabs and then sieved through a sequential sieve series to provide grain size information. Cores can be collected around a reef by using 50 cc syringes with the front end removed. The syringe is pushed into the substrate and then withdrawn; the plunger will hold the core in place. The entire core/syringe/plunger should then be placed into a labelled plastic bag and the bag sealed (Ziploc bags work well - ensure that all excess water is removed before sealing). Analysis of sediment on the reef itself can also be gathered with a syringe (intact). The material is sucked up with the syringe and the syringe is then placed into a labelled plastic bag. Sample sizes will be much smaller with this technique. Samples should be taken at random sites along the transect line.

4.2.3. Chemical parameters

4.2.3.1. Salinity

Salinity measurements are used to determine haloclines within the water column and to identify the intrusion of fresh water or different seawater masses into the reef system. As with temperature, there are a number of instruments for measuring salinity, the most inexpensive of which is the refractometer. These hand held devices can be purchased from commercial suppliers (approximately $300-500) and can read 0.1 ‰ or 0.01 ‰ accuracy. While inexpensive and simple, the refractometer method was not used for this study as the refractometer represents an additional small piece of fragile equipment and requires pipettes. The preferred alternative to the refractometer is a sonde/data logger system (see below).

4.2.3.2. pH

Seawater is an excellent buffering agent, but when the pH of the system is altered significantly, the chemical processes can likewise be dramatically affected. For instance, the carbon dioxide-carbonic acid-bicarbonate system is generally in equilibrium. A shift in the pH could result in a shift in the quantity of CO_2. Determination of pH in the water column should be made during the sampling procedure. Accuracy of this measurement can vary depending upon the instrumentation utilised. A pH meter is a simple method that can give accurate readings to 3 significant figures. It is suggested that accuracy to two significant figures is more than adequate as small shifts (+ 0.1) are not going to have much affect on the reef system. Since the pH scale is a logarithmic scale, a shift $\pm$ 1 unit is a 10 fold difference and this difference may have an effect on the reef system.

4.2.3.3. Oxygen

The use of an oxygen electrode (polarographic method) yields an instantaneous measure of oxygen. This method is simple and can provide continuous readings. There are two types of oxygen electrodes (membrane covered solid electrodes and wide-bore dropping-mercury electrodes) of which the more common is the membrane covered electrode. This type of electrode is present in the sonde systems described below.

4.2.3.4.Total Organic Carbon

Methods for determining TOC levels involve very detailed and exacting analyses and the oceanographic community has yet to agree on a standardised methodology.

4.2.3.5.Phosphorus

There are two primary types of phosphorus in seawater (reactive and total, with the difference between these two being the total organic phosphorus content). There are a number of factors that make the use of this parameter difficult. These factors include the rapid processing time required (within 2 hours of collection), the large sample volume required (at least 4 litres), the dedication of glassware to this analysis, the fact that standards decay and have to be generated fresh for each run, and several others (reviewed in Pilson 1978). Analytical methods to determine dissolved phosphorus can also be found in Strickland and Parsons (1972). Colorimetric analysis will normally require a spectrophotometer with a 10 cm light path and the processing of about 50 mL of seawater per sample analysis.

4.2.3.6.Nitrogen

Nitrogen levels are important in seawater systems, but levels of nitrogenous compounds are often extremely low and difficult to measure with any type of easily available equipment. Analytical methods to determine dissolved nitrogen can be found in Strickland and Parsons (1972).

4.2.3.7.Heavy metals, organochlorins

Mineralogical analysis requires the use of X-ray fluorescence; heavy metals are analysed with a Inductively Coupled Plasma Atomic Emission Spectrophotometer (except for Mercury which is analysed with a Vapour Generation Atomic Absorption Spectrophotometer). Organic analysis requires Capillary Gas Chromatography using Flame Ionisation Detection, Thermionic Specific Detection, Electron Capture Detection and Mass Spectrometry. Organotin analysis is done via an electrically heated quartz furnace atomic absorption spectrophotometer.

4.2.4. YSI SONDE

The YSI SONDE system is field portable and is capable of taking instantaneous measurements of dissolved oxygen, salinity, temperature, depth, and turbidity. The operation of the SONDE is simple, the unit is lowered to the bottom and then slowly raised to the surface. All measurements are logged into the data logger which can store up to 100 sites and over 80,000 readings. The System can hold 999 separate runs and all results are shown on the display during recording. Information can be downloaded directly to a printer or to a computer.

The dissolved oxygen probe is a membrane-covered electrode, self stirring and can measure dissolved oxygen levels from 0 - 20 mg/l ±0.03 mg/l.

The salinity is computed from the temperature and the uncompensated conductivity measurement and has a range from 0-50 ppt ± 0.1 ppt.

The range for depth measurements is 0-65 m ± 0.5 m.

Turbidity is measured in nephelometric Turbidity Units (NTU) with an accuracy of ± 0.05 NTU.

Temperature range is -5 to 50 °C + 0.4 °C.

It is recommended that turbidity also be measured with a Secchi disk. The Secchi disk is lowered over the side of the boat within one hour of noon and the depth where the disk disappears (determined by marking the line in 0.5 m intervals) is recorded. Cloud cover (if any) and sea state should also be recorded.

4.3. Abiotic parameters

4.3.1.1.Physical structure/habitat

Mapping of the physical structure/habitat can be done by diver census, 35 mm photography, video transects, and actual measurement of the substrate. Limitations of these methods are as follows:

- diver census: qualitative and highly variable
- 35mm photography: quadrats limited by size and number of quadrats, water clarity and quality of images
- video transects: (useful but limited by water clarity, image quality, and variances in distance from substrate
- actual substrate measurements: time consuming and difficult to extrapolate.

In this study a method proposed by Aronson *et al.* (1994) was used to gain an index of the complexity (C) C is calculated as C = 1 - d/L, where d is the horizontal distance covered by a conformed chain (measured against the transect tape) and L is its length when fully extended (eg Aronson and Harms 1985; Hubbard *et al.* 1990 - and others in Aronson *et al.* 1994). This chain can be any length with links approximately 15 mm long. The chain is placed against the substratum and conformed to the contours of the substratum. The index gives an estimate of topographic complexity.

This method provided estimates of complexity which appeared meaningful in the context of the study as a whole, and was simple to implement in the field. In addition, the only equipment needed in addition to that required for other survey methods mentioned above was a chain. It is therefore considered ideal for use by community groups for collecting large baseline datasets on the topographic characteristics for reefs that are being monitored.

4.4. Biotic indices

The development of a set of indices for characterizing reefs, which could be easily assessed, particularly for community groups, would be a particularly useful tool. The application of the two sorts of indices that could be used (indicator species or taxa, and multivariate indices of community status) is subject to a number of difficulties in the context of temperate reefs (see Cheshire *et al.* 1998a for a more detailed discussion).

Cheshire *et al.* (1998a) propose however, that a phaeophycean (brown algal) dominated macro-algal canopy is the defining feature of southern Australian subtidal reef systems, and as such, the degree to which this is true for any particular reef could be used as an indicator of its health or status.

A major finding in this study was that differences in reef community structure were apparent between the northern and southern metropolitan beaches, based mainly on the percent cover of dominant brown algae. These differences were attributed to a number of potential impacts including metropolitan stormwater runoff and sewage outfall. This indicates that percent cover of robust brown algae may provide a good general index of reef health on southern Australian reefs (for a more detailed discussion see Cheshire *et al.* 1998a).

Assessments of the percent cover of "robust brown algae" using the LIT method is a relatively straightforward exercise, which could be carried out by community groups. This form of assessment would identify long-term shifts in the community patterns of the dominant feature of a system (brown algae) and thus identify areas that may require more intensive investigation.

5. Conclusions

The LIT method proved to be the best method for differentiating reefs on the basis of the dominant taxa (on a percent cover basis) making up the reef communities. The method can be employed with a varying degree of taxonomic resolution and so may be adapted for use by trained professionals or by novice/untrained divers. Because it focuses on the community dominants the LIT method is ideal for picking up large scale/structural changes in reef systems.

The LIT method does not provide good information about species that have low percentage cover and it is therefore not suitable for the assessment of cryptic or small sedentary taxa which do not dominate systems in biomass or cover terms. For these taxa alternative protocols need to be employed (such as non-destructive quadrat sampling).

The quadrat method used in this study showed some differences between communities of sedentary flora and fauna, however, the degree to which these differences could be interpreted was somewhat less than that experienced with the LIT method. This suggests that although useful, the method might be better suited to more intense investigation, particularly those targeting important species (eg invasive species).

Visual assessment of fish communities are considered to be appropriate for studies with a particular focus on fish (eg fishery surveys) but are not sensitive to underlying changes in the composition of the reef communities.

6. Recommendations

- Efforts should be concentrated on the development of the LIT method (Appendix A) for use in the long-term monitoring of changes in reefal habitats/community structure. This method is particularly useful for implementation by community groups.
- The quadrat method should be used more as a tool for investigation of a more specific nature, especially those that require a focus on specific sessile or sedentary taxa.
- Fish visual census could be used for the assessment of changes in populations of target species of particular interest.

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9. Appendix A- Methodology for the Line Intercept Transect (LIT) sampling.

9.1. Abstract

Line intercept transect (LIT) is a term used to describe one approach to the survey of marine benthic habitats. Previously it has been used extensively in the survey of both terrestrial ecosystems and coral reefs throughout the Great Barrier Reef and Indo-Malayan archipelago. More recently LIT has been modified and trialed for use in the assessment of temperate rocky reefs in Southern Australia. The major strength of the technique is in its ease of use and the fact that it provides good quality data on the nature of communities on reefs. Importantly, the method is non-destructive and therefore suitable for surveys of ecologically sensitive habitats.

Data are collected by pairs of divers who lay out a line (rope or tape) across the seabed. Divers start at one end of the line and then work their way along the line recording the points at which the lifeforms (animals and plants) underneath the line change from one type (lifeform) to another. These data can then be summarised to provide information on the percent of the reef covered by each lifeform. This information can then be analysed or interpreted to develop our understanding about the status of the reef communities.

9.2. Background

The LIT method described in the following has been adapted largely from that described by English *et al.* (1994) for the survey of tropical marine resources. The adaptations where developed in a research program by Turner (1995) who undertook a broad based comparison of the methods with traditional techniques for surveying macroalgal dominated temperate reef systems. Turner concluded that the method was much easier to apply than most traditional techniques, was capable of providing useful information about the structure of reef communities and had the important advantage of being non-destructive.

LIT is only one method which can be used for the rapid, quantitative assessment of temperate reef communities. It needs to be understood that a complete assessment of any reef system will require the collection of information at different scales (in time and space) each of which may require the use of alternative approaches for the collection of data. Nevertheless, in a broad range of reef surveys, LIT has been able to consistently provide a lot of useful information relatively quickly and economically and is therefore a very good method for use by community groups.

Whereas LIT can be applied at any level of taxonomic resolution the following discussion assumes that it will be undertaken using lifeform classifications. This ensures that it can be more generally used by individuals/groups who may have only limited expertise in the identification of reef biota (animals and plants).

The general theory underlying the use of the LIT method is summarised by English *et al.* (1994). In brief it relies on the principle that a line layed out across the substratum will overlay a representative collection of reef lifeforms. By calculating the length of the line intercepted by each lifeform their percentage cover can be then be determined (by representing these lengths as a percentage of the total length of the line).

Furthermore, because the actual location of each of the lifeforms along the transect is recorded, we can obtain valuable information on the spatial relationships between different biotic components. Together this information can be used to provide a picture of the status of the living communities on the reef which in turn can be used as a basis for comparing differences between locations or of changes through time.

9.3. Advantages

- The line intercept transect (LIT) method is non-destructive.
- LIT is easy to implement and does not require expensive equipment.
- LIT's provides quantitative data on cover which is a useful biological index.
- The use of lifeform categories enables information about the major structural elements of the reef to be obtained by people with a limited amount of training in the identification of marine benthic organisms.
- The use of lifeform categories allows comparisons of the status of reefs from geographically distant areas where few species may be found in common.

9.4. Disadvantages

- The use of lifeform levels of classification provides little taxonomic resolution and therefore cannot be used in broad-based biodiversity assessments.
- Percentage cover does not provide a consistent proxy for other indices such as standing biomass or abundance.

9.5. Logistics

9.5.1. Personnel

- A team of at least 3 people is required comprising 2 divers (working together) and a surface support person.
- Divers need to undertake training in the identification of the lifeforms. Ideally training should be carried out in the field (see below) and is undertaken to ensure consistency in the information recorded by different people.
- Divers need to be aware of the need to carefully monitor their bottom times. It is easy to lose track of time when making detailed observations.

9.5.2. Equipment

- Except in very shallow water the method requires divers to operate on SCUBA or hookah.
- Each dive team requires 1 fibreglass surveying tape or non-buoyant rope marked at 1 m intervals. This line should be 20 m in length and have a hook and/or light line at each end so that it can be attached to the seabed either by tying off to reef protuberances or to weights.
- Each diver requires a 1 m stainless steel ruler marked at 1 cm intervals and weighted with 1.5 kg lead.
- Each diver requires an underwater slate (A4 underwater paper is recommended) and pencils (tied to the slate, sharpened at both ends). Each diver records data onto this sheet which should be pre-printed using waterproof ink (**do not print using an ink-jet or bubble-jet printer)** or manually ruled up using a pencil**.** The easiest approach is to photocopy the data sheet labelled (LIT-1) in appendix A onto architectural drafting film or permanent paper (waterproof).

9.5.3. Maintenance

- All equipment should be washed in freshwater immediately after use. Stainless steel rulers can be lightly oiled or sprayed with CRC (or similar). The data sheets should be washed in freshwater to get rid of salt and then pegged onto a line to dry.

9.6. Site selection

To undertake a complete assessment of any reef it is necessary to determine the range of sites present on the reef. This requires a consideration of a number of issues including the overall size of the reef system. Importantly, however rather than trying to cover the whole reef with a number of *ad-hoc* surveys it is better to obtain replicate transects from one or more specific sites on the reef. In order to make a quantitative assessment it is better to have 5 replicate transects from one site rather than a single transect from each of five sites.

- A site is defined as a place on the reef which has a generally consistent physical environment. This should include a consideration of:

  1. **Substrate type** - preferably a rocky habitat with little or no sand (you can account for small sand patches by recording them as a pseudo lifeform).
  2. **Depth** - all transects should be run at around the same depth. Depth should be constant across the length of a transect. Ideally surveys should only be conducted at depths representing multiples of 5 m (5m, 10m 15m etc). Depth is defined as depth below mean low water.
  3. **Aspect** - all transects should be run across a surface with a relatively consistent aspect (vertical surface, horizontal surface, 45 degree angle surface).
  4. **Exposure** - all transects for a given site should have similar exposure to prevailing wave or tidal flows (ie either on the exposed or leeward side of the reef).

  It needs to be recognised that no two areas where a transect can be run are identical so this requires a degree of judgement. Problems from inconsistencies between transects can be addressed by carefully recording relevant data about the transects on the data sheets.

- If it is intended to repeatedly monitor a given site then it is important to mark the site in such a way that it can be relocated at a future date. Star pickets may be wedged into crevices on the reef and will survive for a few years. Plastic cattle ear tags can be attached to the picket to provide a label if required.

9.7. General procedure

The general approach involves laying a transect line across the substratum and then recording the points along that line at which the nature of the benthic communities change (Figure 1).

- The twenty metre guide-tape/rope is placed over the substratum and secured at either end to minimize movement. When laying out the transect rope or tape, care should be taken not to disturb the area, particularly with fins.
- One diver then moves to the start of the line the other to the 10 m mark on the line.
- The divers record the metre mark in the first row of the METRE column on their data sheets (Form LIT-1). Diver one records 0 m and diver 2 records 10 m.
- Each diver places their 1 m weighted ruler over the substratum so that it is roughly aligned to the guide tape. The first diver ensures that the end of their ruler (0 cm) is aligned with the 0 m mark on the guide tape. The second diver ensures that the end of their ruler (0 cm) is aligned with the 10 m mark on the guide tape. The use of the weighted ruler pins any loose plants down and overcomes the problem of macroalgae or seagrasses moving around under the influence of waves and currents (this is particularly important in shallow or wave exposed sites).
- Each diver then writes down in the third column of their data sheet (labelled LIFEFORM) the name of the lifeform at the start of their ruler (eg TURF, note that examples of each lifeform

are shown in Plates 1 to 11 at the end of this appendix). This will identify the dominant lifeform on this portion of the transect.

- The diver then scans along the ruler until they find a point at which the dominant lifeform (immediately under the ruler) changes. The point at which the change occurs is called the *transition point*. The diver records the measurement (in cm) at which the transition occurs by writing this in the column labelled TRANSITION (Form LIT-1).
- The diver then records the name of the lifeform that is found in the next portion of the ruler in the next row of the LIFEFORM column.
- The diver looks for the next transition point and records the value in the TRANSITION column. The last two steps are repeated until the end of the ruler is reached. The diver should always work along the same edge of their ruler.
- On reaching the end of the ruler the diver records the value of 100 cm in the TRANSITION field (even if the current lifeform continues on past the end of the ruler).
- The ruler is moved so that the beginning is aligned with the end point of the last placement and so that the ruler is roughly aligned with the guide tape.
- The above process is then repeated with the diver recording the start position of the ruler in the METRE column, the lifeform in the LIFEFORM column and the point on the ruler at which the next transition occurs in the TRANSITION column.
- Information should be recorded with a spatial resolution of 3 cm. This means that if a lifeform is found for a contiguous distance of less than 3 cm it is not recorded.
- If the bottom topography suddenly changes (eg a crevice or change in depth) resulting in a gap of 20 cm or more between the ruler and the lifeforms growing under it, then the diver records DDD (missing data) in the LIFEFORM column. The diver then continues to scan along the ruler until it again comes into close proximity with the benthos (less than 20 cm) and record that point as the TRANSITION.

Figure 1. Schematic view of benthos showing LIT.

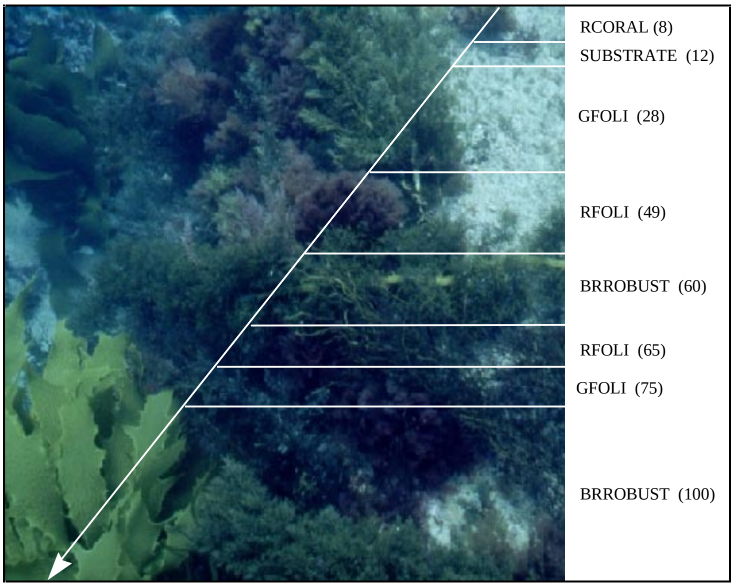

Table 1 Example of data recorded from LIT shown in Figure 1.

Transect	Metre	Transition	Lifeform	Species
1	4	8	RCORAL	Unknown
		12	SUBSTRATE	
		28	GFOLI	Caulerpa
		49	RFOLI	Asparagopsis
		60	BRBRANCH	Cystophera
		65	RFOLI	Asparagopsis
		75	GFOLI	Caulerpa
		100	BRFLAT	Ecklonia

9.7.1. Diver training

9.7.1.1.Overview

It is important to ensure that different divers record the same information about the benthos. In order to ensure that this happens divers should be trained in the methodology. Diver training should consist of instruction in the use of the technique followed by field training including calibration. Divers need to become familiar with the LIT method, the terminology used to distinguish various lifeforms and the use of the key for identification (Table 2). Training should involve the following steps:

- Introduction to the method including an explanation of the importance of obtaining repeatable quantitative measurements.
- Introduction to the terminology to ensure a common understanding of terms and concepts.
- Introduction to the biota likely to be encountered including a general consideration of their basic biology (note that examples of each lifeform are shown in Plates 1 to 11 at the end of this appendix).
- Simulated transects on land to familiarise divers with the method and equipment.
- Field identification of lifeforms. Field based exercises to introduce divers to the lifeforms and to develop skills in assigning different organisms to the various lifeform categories.
- Field practice and calibration of divers. Field calibration of divers should be carried out in a location which has a variety of biota, but is relatively simple for diving (ie good conditions with little or no surge/wave action). This allows divers to become familiar with the use of the technique underwater.

9.7.1.2.Identification of lifeforms

Algae can be classified into different lifeforms based on colour, size, shape and texture. Table 2 has been setup to provide users with a field key to the algal lifeforms. This table should be copied onto underwater paper and taken with divers to use as a ready reference for field identifications. To use this table firstly decide to which colour group the alga belongs and then use information about the size, shape and texture to choose the correct row. For example a green alga (choose column green) which is 12 cm high, has a bushy morphology and is soft in texture (choose row 5) ⇒ LIFEFORM=GFOLI.

Table 2. Algal lifeform identification chart. Identify the column based on the colour of the alga and then use the information about size, shape and texture to define the relevant row. The lifeform code is shown in the cells with the grey background.

Morphology			Colour		
Size (cm)	**Shape**	**Texture**	**Red**	**Green**	**Brown**
<2 cm	Fine feathery	Soft / slimy	**TURF**	**TURF**	**TURF**
	Surface crust	Hard	**RENC**	**-**	**BRENC**
2 - 7	Branched and spiky or fern like	Hard, brittle	**RCORAL**	**-**	**-**
2 - 20	Membranous / sheet like / sack like	Soft may be slimy	**RMEM**	**GMEM**	**BRMEM**
2 - 20	Bushy, frequently branched	Soft	**RFOLI**	**GFOLI**	**BRFOLI**
2 - 20	Flattened and rounded or fan shaped	Firm	**RLOBE**	**GLOBE**	**BRLOBE**
2 - >100	Robust, branched with robust or leaf like blades	Leathery, tough	**RROB**	**-**	**-**
10-200+	Robust, flattened blades may be corrugated or smooth with well defined stalk at base	Leathery, tough	**-**	**-**	**BRFLAT**
10-100+	Robust, branched often bushy inappearance. One or more tough central stalks	Leathery, tough	**-**	**-**	**BRBRANCH**
2 - 20	Lumpy or spherical	Firm	**-**	**GLUMP**	**-**

Table 3 gives a definition of each of the lifeform codes used and lists some of the representative taxa it covers. Table 4 gives a list of lifeform codes for the non - algal taxa surveyed.

Table 3. Algal lifeforms with representative species

Lifeform code	Description	Representative taxa
BRENC	Brown encrusting algae	*Ralfsia*
BRFOLI	Brown foliaceous algae	*Halopteris, Cladostephus, Lobospira*
BRFLAT	Brown robust algae with large flattened blades (much broader than thick) - not membranous because very robust	*Ecklonia, Durvillaea, Macrocystis*
BRBRANCH	Brown robust algae with highly branched habit (blades not much broader than they are thick)	*Cystophora spp, Sargassum, Caulocystis, Acrocarpia, Scytothalia, Seirococcus, Xiphophora*
BRLOBE	Brown lobed algae	*Zonaria, Padina, Turbinaria, Lobophora*
BRMEM	Brown membranous algae	*Scytosiphon,*
TURF	Turfing algae (all colours)	*Sphacelaria, Ectocarpus, Ceriamium, Cladophora*
GFOLI	Green foliaceous algae	*Caulerpa spp, Cladophora, Chaetomorpha, Apjohnia, Codium, Bryopsis*
GLOBE	Green lobed algae	*Dictyosphaeria, Avrainvillea*
GLUMP	Green lumpy algae	*Codium spp*
GMEM	Green membranous algae	*Ulva spp*
RCORAL	Red coralline algae	*Corallina, Metagonialithon,*
RENC	Red encrusting algae	*Sporolithon*
RFOLI	Red foliaceous algae	*Plocamium, Phacelocarpus, Nizymenia, Gelidium, Pterocladia*
RROB	Red robust algae	*Osmundaria, Lenormandia*
RLOBE	Red lobed algae	*Peyssonnelia*
RMEM	Red membranous algae	*Gloiosacchion, Pachydictyon*

Table 4. List of animal lifeform codes and associated taxa. Lifeform codes in bold type represent those which are commonly found using the LIT method. Those underlined occur frequently.

Broad category	Lifeform code	Taxa included
Sponges	**<u>AMOSP</u>**	Amorphous sponges
	<u>DISP</u>	Discreet sponges
Molluscs	**GAST**	Gastropods
	OPIS	Opisthobranchs
	BIV	Bivalves
Ascidians	**COLASC**	Colonial ascidians
	STASC	Stalked ascidians
	<u>OASC</u>	Other ascidians
Echinoderms	**URCHIN**	Urchins
	COSC	Coscinastarias starfish
	CRIN	Crinoids
	STAR	Starfish (all other types)
Worms	TUBPOL	Tube polychaetes
	POL	Other polychaetes
	SABEL	Sabellid worms
	HOLO	Holothurians
Hydroids	HYD	Hydriods
Anemones	ANEM	Anemones
Coral	**CORAL**	Corals
Crustaceans	CRAB	Crabs
	GOOS	Goose barnacles
	CRUS	Other crustaceans

9.7.1.3.In water diver training and calibration

- One or more training transects should be set up for the training and calibration of divers. Initially these should be relatively short (3-5 m). Divers should initially swim the transect in pairs taking turns in identifying the lifeforms that they encounter. With each new lifeform divers should check the identifications with their buddy. This exercise should proceed until both divers are satisfied that they know and agree on all lifeforms along the transect.
- Divers should then move to the start of the transect and lay down the 1 m weighted ruler. Each diver then takes a turn to record the lifeforms and transitions for the 1 m segment.

- At the end of the 1m segment divers should then compare results and resolve uncertainties/mis-identifications. Note that a difference of 3 cm or less in the recording of any transition point is considered acceptable. If larger differences occur divers should ensure that they are both reading the same side of the ruler and that they are sighting from the same angle to ensure that parallax errors are minimised.
- Divers should then repeat the last two steps for each 1 m segment of the training transect. If required additional training transects should be laid out for divers to use in developing their skills.
- On completion of the training transects divers should lay out a calibration transect (5 m) and individually work along it recording data for each 1 m segment. At the end of the transect they should then review the data for the full 5 m length and resolve any discrepancies in recorded data. This exercise may need to be repeated several times before results are consistent between divers.

Data from these training transects should be kept as originally recorded as it can provide important information about sampling variability and the effectiveness of training. Training dives also serve as valuable familiarisation time for divers to become competent at working underwater.

9.7.2. Data recording

- Before each dive, the name of the diver and their buddy should be written on each data sheet. Details about the site and transect location should also be recorded along with relevant data on ambient water/weather conditions.
- Once in the water one diver lays out the transect line. The second diver should record details for the transect. This will include depth, visibility and comments about the general appearance of the site.
- Divers should then proceed to record data for their respective sections of transect in the manner described above, that is, recording lifeform codes and transition points for each of the lifeforms encountered. Divers should take care to record only the organisms directly beneath the ruler (ie top layer), and always work along the same edge of the ruler eg only use the top edge rather than switching from top to bottom. If unsure of an identification a best guess should be recorded along with some notes about the appearance of the organism in question. Once the transect has been completed buddies can help resolve uncertainties for one another.
- Upon completion data sheets and slates should be placed in a catchbag, transect line/tape and rulers retrieved and divers should ascend as per normal.
- Immediately upon completion of the dive the divers should swap slates for checking (or have a dive supervisor check them). Slates should be checked for readability and proper recording of lifeform codes. Any problems encountered should be discussed at this time while they are still fresh in the diver's memory.

9.7.3. Data Processing

Details of the day's diving should be recorded in a diary, and data should be entered into a database. Records should be entered into a data table (in a similar format to Table 1), each with a unique sample identifier, lifeform and transition point. All data entered should be checked and verified by a second person after entry, and data should always be backed up.

9.7.4. Data Analysis

Summary data showing percent coverage of each lifeform can be calculated from the LIT data in the following way:

- Lengths of the transect covered by each lifeform category can be calculated by taking the transition point for each entry and subtracting the previous transition, eg if the transition recorded for RFOLI is 625, and the previous transition is 595, then the length covered by RFOLI is 30 cm.
- For each lifeform category the lengths should then be summed, divided by the total length of the transect minus the amount recorded as "DDD" (no data, see above) and multiplied by 100 to get the percent coverage for that lifeform over the whole transect. This process can be formularised as follows:

$$\text{Percent cover lifeform A} = \frac{\sum L_A}{Y - \sum D} \times 100$$

where $\sum L_A$ = the sum of the individual lengths of lifeform A on the transect,

Y = the total length of the transect and

$\sum D$ = the sum of the lengths where no data was recorded.

Using data from Table 1 for example:

The percent cover of RFOLI = ([49-28] + [65-60]/[100-0 ie no "DDD"]) x 100
(red foliaceous algae)

= (21 + 5/100) x 100

= **26 %**

The Percent cover of GFOLI = ([28 -12] + [75 -65]/[100 - 0]) x 100
(Green foliaceous algae)

= (16 + 10/100) x 100

= **26 %**

The percent cover of BBRANCH = (60 - 49/100) x 100

= **11 %**

9.7.5. Plates

Plate 1: Turfing red algae, an example of TURF

Plate 2: Encrusting red algae, an example of RENC (Taken from Australian Marine Life, Edgar 1997)

Plate 3: *Haliptilon roseum*, an example of RCORAL

Plate 4: *Gracilaria cliftonii*, an example of RFOLI

Plate 5: *Dasya sp.*, an example of RFOLI

Plate 6: *Lobophora variegata*, an example of BRLOBE

Plate 7: *Caulerpa sp.*, an example of GFOLI

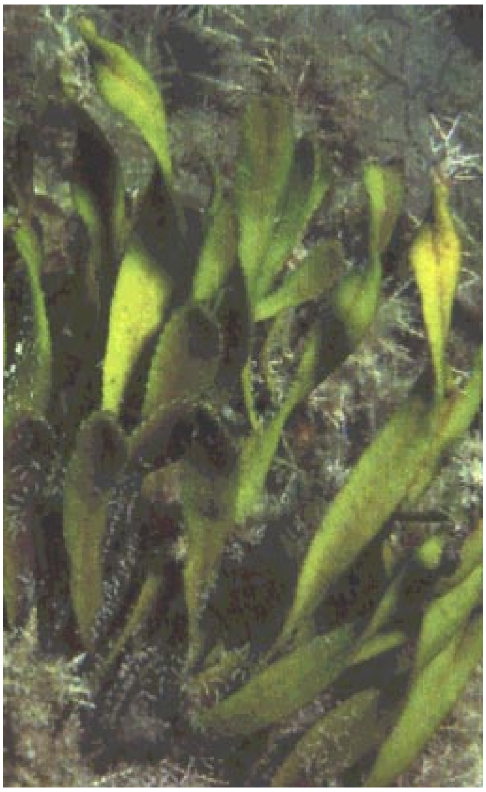

Plate 8: *Osmundaria prolifera*, an example of RROB (Taken from Australian Marine Life, Edgar 1997)

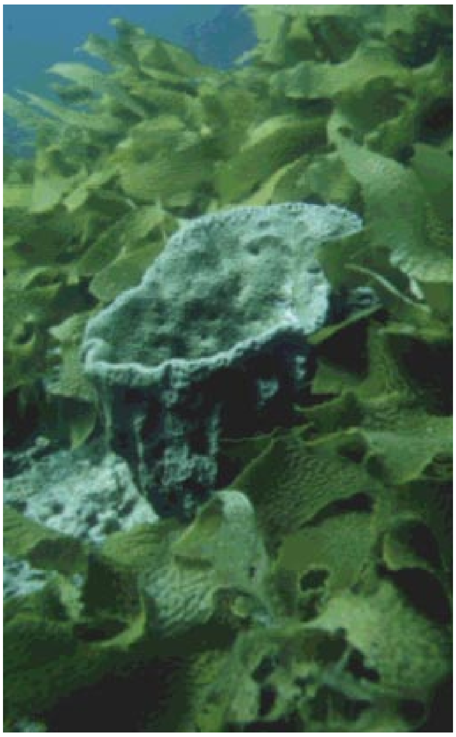

Plate 9: *Ecklonia radiata,* an example of BRFLAT

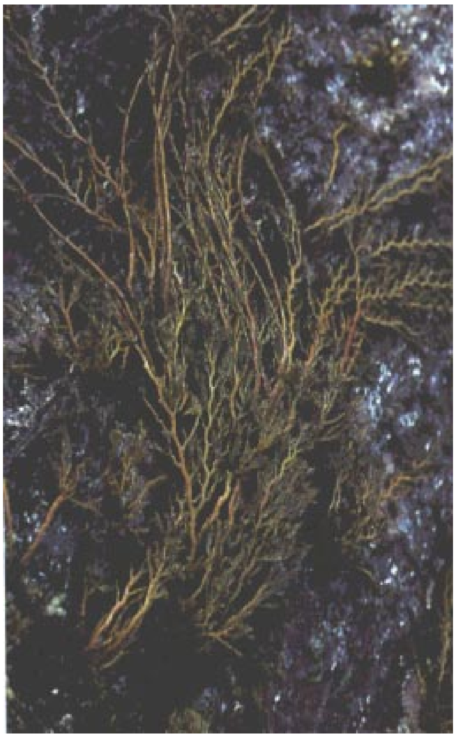

Plate 10: *Cystophora intermedia,* an example of BRBRANCH (Taken from Australian Marine Life, Edgar 1997)

Plate 11: *Codium sp.*, an example of GLUMP

9.8. Form LIT-1

Divers name =				Transect =	
Group/Club name =				Time of day=	
Date	Reef name or GPS coord=				
/ /	Aspect =	Horizontal	Vertical	45 degrees	Depth (m) =
	Exposure =	Seaward	Leeward		

Metre	Transition	Lifeform	Species	Metre	Transition	Lifeform	Species

10. Appendix B Methodology for using quadrat sampling for the survey of temperate rocky reefs

10.1. Abstract

The quadrat method provides one approach to the survey of marine benthic habitats. It is widely used in both terrestrial and marine ecosystems. This technique is simple to use and provides good data on the nature of sessile and sedentary communities on reefs. Importantly, the method is non-destructive and therefore suitable for surveys of ecologically sensitive habitats.

Data are collected by pairs of divers who lay out a line (rope or tape) across the seabed. Divers then place a quadrat of a particular size at random points along the line, and record abundances for sessile/sedentary biota.

This method compliments the line intercept transect (LIT) method which concerns mainly algal cover. It provides quantitative data that can be analysed or interpreted to develop our understanding about the status of the reef communities.

10.2. Background

The non-destructive quadrat sampling method described below is intended to compliment the LIT or line intercept transect method by providing a means of assessing invertebrate communities that may be associated with temperate reef systems. Survey methods using quadrat sampling are commonly used in both marine and terrestrial systems. The method is carried out by placing a quadrat of given size over the substratum. All unitary organisms within the area circumscribed by the quadrat are counted thus providing a quantitative measure of the abundance of each taxa/group within that area.

10.3. Advantages

- The quadrat sampling method is non-destructive.
- It is easy to implement and does not require expensive equipment.
- Quadrating provides quantitative abundance data which is a useful biological index.
- If broad level taxonomic categories are used, information about the major structural elements of the reef can be obtained by people with a limited amount of training in the identification of marine benthic organisms.

10.4. Disadvantages

- The use of broad level taxonomic categories provides little taxonomic resolution and therefore cannot be used in broad based biodiversity assessments.
- Quadrat counts do not provide a consistent proxy for other indices such as standing biomass or cover.

10.5. Logistics

10.5.1. Personnel

- A team of at least 3 people is required comprising 2 divers (working together) and a surface support person.

- Divers need to undertake training in the identification of the organisms. Ideally training should be carried out in the field (see below) and is undertaken to ensure consistency in the information recorded by different people.
- Divers need to be aware of the need to carefully monitor their bottom times. It is easy to lose track of time when making detailed observations.

10.5.2.Equipment

- Except in very shallow water the method requires divers to operate on SCUBA or hookah.
- Each dive team requires 1 fibreglass surveying tape or non-buoyant rope marked at 1 m intervals. This line should be 20 m in length and have a hook and/or light line at each end so that it can be attached to the seabed either by tying off to reef protuberances or to weights.
- Each diver requires a 25 cm^2 quadrat. The quadrat needs to be made from a material that will allow it to sink and rest firmly on the bottom (heavy gauge wire is recommended). The quadrat should be marked in a way to make it highly visible underwater either by colouring it or marking it with fluorescent flagging tape.
- Each diver requires an underwater slate (A4 underwater paper is recommended) and pencils (tied to the slate, sharpened at both ends). Each diver will record data onto this sheet which should be pre-printed using waterproof ink (**do not print using an ink-jet or bubble-jet printer**) or manually ruled up using a pencil**.** The easiest approach is to photocopy the data sheet labelled "Quadrat sample data" at the end of this appendix onto architectural drafting film or permanent paper (waterproof).

10.5.3.Maintenance

- All equipment should be washed in freshwater immediately after use. The data sheets should be washed in freshwater to get rid of salt and then pegged onto a line to dry.

10.6. Site selection

To undertake a complete assessment of any reef it is necessary to determine the range of sites present on the reef. This requires a consideration of a number of issues including the overall size of the reef system. Importantly, however rather than trying to cover the whole reef with a number of *ad-hoc* surveys it is better to obtain replicate transects from one or more specific sites on the reef. In order to make a quantitative assessment it is better to have 5 replicate transects from one site rather than a single transect from each of five sites.

- A site is defined as a place on the reef which has a generally consistent physical environment. This should include a consideration of:
    1. **Substrate type** - preferably a rocky habitat with little or no sand.
    2. **Depth** - all transects should be run at around the same depth. Depth should be constant across the length of a transect. Ideally surveys should only be conducted at depths representing multiples of 5 m (5m, 10m 15m etc). Depth is defined as depth below mean low water.
    3. **Aspect** - all transects should be run across a surface with a relatively consistent aspect (vertical surface, horizontal surface, 45 degree angle surface).
    4. **Exposure** - all transects for a given site should have similar exposure to prevailing wave or tidal flows (ie either on the exposed or leeward side of the reef).

It needs to be recognised that no two areas where a transect can be run are identical so this requires a degree of judgement. Problems from inconsistencies between transects can be addressed by carefully recording relevant data about the transects on the data sheets.

- If it is intended to repeatedly monitor a given site then it is important to mark the site in such a way that it can be relocated at a future date. Star pickets may be wedged into crevices on the reef and will survive for a few years. Plastic cattle ear tags can be attached to the picket to provide a label if required.

10.7. General procedure

The general approach involves laying out quadrats in a stratified random procedure. This can be achieved by laying a 20 m transect line across the substratum and then assigning the placement of quadrats according to random distances along that line. All sedentary organisms within quadrats are identified and counted.

- Before commencing a days work a series of random numbers (between 0 and 10) need to be generated. Before each dive, both divers will need to record on their slates four random numbers which indicate the distance along the tape at which they will sample.
- The twenty metre guide-tape/rope is placed over the substratum and secured at either end to minimize movement. When laying out the transect rope or tape, care should be taken not to disturb the area, particularly with fins.
- One diver then moves to the start of the line the other to the 10 m mark on the line.
- The divers move along the transect the distance shown by the first of their random numbers and record that distance in the first column of their data record sheets (Form QUAD-1 at the end of this section).
- They then place their quadrat with the bottom side in contact with the transect line and the left side in line with the sampling distance (random no.). Care should be taken to maintain topographical consistency in sampling quadrats. The quadrat should be placed on surfaces with an inclination of no more than forty five degrees. If it is found that the point to be sampled is predominantly more vertical than this, then the quadrat should be placed on the nearest surface that meets this requirement.
- The diver then writes down in the second column of their data sheet (labelled Fieldcode) the name of each taxa present in the quadrat (eg OASC, TUBPOL and GAST). They then proceed to count each of the taxa and record their abundances in the third column (labelled Abundance).
- The diver looks for the next sampling point and records taxa present and their abundances for that quadrat. This process is repeated until the four quadrats have been completed. An example of a typical set of quadrats is shown in Table 5.

Table 5 - Example of data recorded from quadrat sampling.

Distance (m)	Fieldcode	Abundance
2.5	URCHIN	2
	POL	1
	TUBPOL	10
4	GAST	3
	OASC	4
	AMOSP	1
6	BIV	4
	GAST	2
	STASC	3
8.5	DISP	2
	COLASC	2
	TUBPOL	5

10.7.1. Diver training

10.7.1.1. Overview

It is important to ensure that different divers record the same information about the benthos. In order to ensure that this happens divers should be trained in the methodology. Diver training should consist of instruction in the use of the technique followed by field training including calibration. Divers need to become familiar with the quadrat method, the terminology used to distinguish various taxa and the taxa themselves. Training should involve the following steps:

- Introduction to the method including an explanation of the importance of obtaining repeatable quantitative measurements.
- Introduction to the terminology to ensure a common understanding of terms and concepts.
- Introduction to the biota likely to be encountered including a general consideration of their basic biology.
- Simulated transects on land to familiarise divers with the method and equipment.
- Practice sessions in identification of common taxa from pictures. Table 6 shows field codes used for various taxa likely to be encountered on reefs in the Gulf St Vincent. "Australian Marine Life" (Edgar, 1997) contains good photographic illustration of most organisms that are likely to be encountered.
- Field identification of taxa. Field based exercises to introduce divers to the taxa and to develop skills in assigning different organisms to the various taxa categories.
- Field practice and calibration of divers. Field calibration of divers should be carried out in a location which has a variety of biota, but is relatively simple for diving (ie good conditions with little or no surge/wave action). This allows divers to become familiar with the use of the technique underwater.

Table 6. Taxa and field codes for the quadrat sampling technique

Broad category	Field code	Representative taxa
Sponges	AMOSP	Amorphous sponges
	DISP	Discreet sponges
Molluscs	GAST	Gastropods
	BIV	Bivalves
	OPIS	Opisthobranchs
Ascidians	COLASC	Colonial ascidians
	STASC	Stalked ascidians
	OASC	Other ascidians
Echinoderms	URCHIN	Urchins
	COSC	Coscinastarias starfish
	CRIN	Crinoids
	STAR	Starfish (all other types)
Worms	TUBPOL	Tube polychaetes
	POL	Other polychaetes
	SABEL	Sabellid worms
	HOLO	Holothurians
Hydriods	HYD	Hydriods
Anemones	ANEM	Anemones
Coral	CORAL	Corals
Crustaceans	CRAB	Crabs
	GOOS	Goose barnacles
	CRUS	Other crustaceans

10.7.1.2.In water diver training and calibration

- One or more training transects should be set up for the training and calibration of divers. Initially these should be relatively short (3-5 m). Divers should initially swim the transect in pairs taking turns in identifying the taxa that they encounter. With each new taxa divers should check the identifications with their buddy. This exercise should proceed until both divers are satisfied that they know and agree on most taxa along the transect.
- Divers should then lay down their quadrats and record taxa and abundances present.
- Without moving the quadrats the divers should then swap, re-sample then compare results and reconcile any differences.
- This process should be repeated several times until the identifications and counts are reasonably consistent between divers. With groups of divers it is preferable to mix diver pairs to ensure consistency between the whole group. Additional training transects should be laid out if required for divers to use in developing their skills.

Data from these training transects should be kept as originally recorded as it can provide important information about sampling variability and the effectiveness of training. Training dives also serve as valuable familiarisation time for divers to become competent at working underwater.

10.7.2.Data recording

- Before each dive, the name of the diver and their buddy should be written on each data sheet. Details about the site and transect location should also be recorded along with relevant data on ambient water/weather conditions.
- Once in the water one diver lays out the transect line. The second diver should record details for the transect. This will include depth, visibility and comments about the general appearance of the site.
- Divers should then proceed to record data for their respective sections of transect in the manner described above. If unsure of an identification a best guess should be recorded along with some notes about the appearance of the organism in question. Once the transect has been completed buddies can help resolve uncertainties for one another.

- Upon completion data sheets and slates should be placed in a catchbag, transect line/tape retrieved and divers should ascend as per normal.
- Immediately upon completion of the dive the divers should swap slates for checking (or have a dive supervisor check them). Slates should be checked for readability and proper recording of taxa codes. Any problems encountered should be discussed at this time while they are still fresh in the diver's memory.

10.7.3.Data Processing

Details of the day's diving should be recorded in a diary, and data should be entered into a database. Records should be entered into a data table, each with a unique sample identifier, taxa and abundance count (eg Table 7). All data entered should be checked and verified by a second person after entry, and data should always be backed up.

Table 7. Data table for quadrat data.

Transect	Distance (m)	Fieldcode	Taxa	Abundance
2	2.5	URCHIN	Urchin	2
2	2.5	POL	Polychaete	1
2	2.5	TUBPOL	Tube polychaetes	10
2	4	GAST	Gastropod	3
2	4	OASC	Asidian	4
2	4	AMOSP	Amorphous sponge	1
2	6	BIV	Bivalve	4
2	6	GAST	Gastropod	2
2	6	STASC	Stalked ascidian	3
2	8.5	DISP	Discreete sponge	2
2	8.5	COLASC	Colonial ascidian	2
2	8.5	TUBPOL	Tube polychaetes	5

10.8. Form Quad - 1

Divers name =				Transect =	
Group/Club name =				Time of day=	
Date	Reef name or GPS coord=				
/ /	Aspect =	Horizontal	Vertical	45 degrees	Depth (m) =
	Exposure =	Seaward	Leeward		

Distance.	Fieldcode	Abundance	Species or comment	Distance.	Fieldcode	Abundance	Species or comment

11. Appendix C: Methodology for using fish visual census sampling for the survey of temperate rocky reefs

11.1. Abstract

Fish visual census is a method of assessing fish communities. It is a commonly used method which produces data which can be used to assess spatial or temporal changes in reef fish assemblages.

Data are collected by pairs of divers swimming 50 metre transects recording fish taxa present within a 3 metre radius and their abundances. This effectively gives an estimate of the fish community within a 50 metre by 3 metre radius tunnel. It provides quantitative data that can be analysed or interpreted to develop our understanding about the status of the reef communities.

11.2. Background

The fish visual census method described below is a widely used method adapted for use in conjunction with the line intercept transect (LIT) and non destructive quadrat sampling methods developed for this study. It represents one method for the quantitative assessment of temperate reef communities. As a complement to the LIT and quadrat sampling methods described in this study it is a valuable tool for consolidating knowledge of temperate reef systems.

The method described below involves divers recording fish taxa and abundances along a 50 m transect within a 3 m radius of the diver. This method can quickly and easily supply quantitative information about a range of fish taxa which can be used in the management of temperate reef systems. Information can be collected at a variety of taxonomic levels, however, collection at the level of the common names of fish in a particular region makes the method more easily adapted for use by community groups.

11.3. Advantages

- It is easy to implement and does not require expensive equipment.
- It provides quantitative abundance data which is a useful biological index.
- The use taxonomic categories familiar to the average diver enables information about the fish community of a reef to be obtained by people with a limited amount of training in the identification of marine organisms.

11.4. Disadvantages

- The use of broad level taxonomic categories provides little taxonomic resolution and therefore cannot be used in broad-based biodiversity assessments.
- Fish may be attracted or repelled by the presence of a diver (English *et al.* 1994).
- Potential for error in abundance estimates with highly mobile and/or numerous fish.

11.5. Logistics

11.5.1. Personnel

- A team of at least 3 people is required comprising 2 divers (working together) and a surface support person.

- Divers need to undertake training in the identification of the organisms. Training should be carried out in the field (see below) and through use of pictures to ensure consistency in the information recorded by different people.
- Divers need to be aware of the need to carefully monitor their bottom times. It is easy to lose track of time when making detailed observations.

11.5.2. Equipment

- Except in very shallow water the method requires divers to operate on SCUBA or hookah.
- Each dive team requires 1 fibreglass surveying tape or non-buoyant rope. This line should be 50 m in length and have a hook and/or light line at each end so that it can be attached to the seabed either by tying off to reef protuberances or to weights.
- One diver requires an underwater slate (A4 underwater paper is recommended) and pencil (tied to the slate, sharpened at both ends). This diver will record data onto the sheet which should be pre-printed using waterproof ink (**do not print using an ink-jet or bubble-jet printer**) or manually ruled up using a pencil**.** The easiest approach is to photocopy the data sheet labelled "Fish visual census data" at the end of this section onto architectural drafting film or permanent paper (waterproof).

11.5.3. Maintenance

- All equipment should be washed in freshwater immediately after use. The data sheets should be washed in freshwater to get rid of salt and then pegged onto a line to dry.

11.6. Site selection

To undertake a complete assessment of any reef it is necessary to determine the range of sites present on the reef. This requires a consideration of a number of issues including the overall size of the reef system. Importantly, however rather than trying to cover the whole reef with a number of *ad-hoc* surveys it is better to obtain replicate transects from one or more specific sites on the reef. In order to make a quantitative assessment it is better to have 5 replicate transects from one site rather than a single transect from each of five sites.

- A site is defined as a place on the reef which has a generally consistent physical environment. This should include a consideration of:

  1. **Substrate type** - preferably a rocky habitat with little or no sand.
  2. **Depth** - all transects should be run at around the same depth. Depth should be constant across the length of a transect. Ideally surveys should only be conducted at depths representing multiples of 5 m (5m, 10m 15m etc). Depth is defined as depth below mean low water.
  3. **Aspect** - all transects should be run across a surface with a relatively consistent aspect (vertical surface, horizontal surface, 45 degree angle surface).
  4. **Exposure** - all transects for a given site should have similar exposure to prevailing wave or tidal flows (ie either on the exposed or leeward side of the reef).

  It needs to be recognised that no two areas where a transect can be run are identical so this requires a degree of judgement. Problems from inconsistencies between transects can be addressed by carefully recording relevant data about the transects on the data sheets.

- If it is intended to repeatedly monitor a given site then it is important to mark the site in such a way that it can be relocated at a future date. Star pickets may be wedged into crevices on the reef and will survive for a few years. Plastic cattle ear tags can be attached to the picket to provide a label if required.

11.7. General procedure

The general approach involves a pair of divers swimming along a transect, one counting and recording fish abundances, and the other measuring distance.

- Divers should carry out fish visual censuses before any other activity to avoid influencing consequent counts.
- Upon reaching the bottom divers should attach the fifty metre guide-tape/rope to the substrate or weight. Divers then swim off in a predetermined direction being careful to maintain a consistent depth.
- The leading diver identifies and counts any fish encountered within a 3 m radius, recording the information on the fish visual census data-sheet as shown in Table 8. The second diver lays out the measuring line/tape ideally staying behind and below the diver doing the recording. Care should be taken to maintain a slow but constant speed throughout the transect.
- Once fifty metres have been covered the second diver notifies the first to stop recording. The transect line can then be retrieved. If a second transect is to be done, divers should be careful not to cover the same area unless sufficient time has past (several hours).

Table 8 - Example of data recorded from Fish census.

Transect	Taxa	Abundance
1	Leather jacket	2 + 1 + 3
	Silver drummer	1 + 2 + 1 + 4
	Bullseye	10 + 6 + 8
	Cowfish	3
	Old Wife	24 + 10
	Dusky Morwong	2
2	Cowfish	1
	Silver drummer	2 + 1
	Weedy whiting	8
	Dusky Morwong	1 + 1 + 1
	Magpie Perch	4
	Leather jacket	1 + 5

11.7.1. Diver training

11.7.1.1. Overview

It is important to ensure that information collected is consistent between divers. In order to ensure that this happens divers should be trained in the methodology. Diver training should consist of instruction in the use of the technique followed by field training including calibration. Divers need to become familiar with the fish visual census method and the fish taxa likely to be encountered (Table 9). Training should involve the following steps:

- Introduction to the method including an explanation of the importance of obtaining repeatable quantitative measurements.
- Introduction to the terminology to ensure a common understanding of terms and concepts.
- Introduction to the biota likely to be encountered including a general consideration of their basic biology.
- Familiarisation with the features and terminology used in identifying fish.

- Identification of taxa from texts ("Sea fishes of Southern Australia" by Hutchins and Swainston, 1986 provides graphics of most fish likely to be encountered with both common and scientific names).
- Field identification of taxa. Field based exercises to further improve divers knowledge of the fish taxa.
- Field practice and calibration of divers. Field calibration of divers should be carried out in a location which has a variety of biota, but is relatively simple for diving (ie good conditions with little or no surge/wave action). This allows divers to become familiar with the use of the technique underwater.

Table 9. Fish commonly encountered in the Adelaide metropolitan region.

Fish field names	Fish taxa
Blenny	Blennidae
Blue Devil	Paraplesiops meleagris
Bullseye	Pempheris spp
Cowfish	Aracana spp
Crab	Portunidae
Cuttlefish	Sepia
Dragonet	Bovichthys variegatus
Dusky Morwong	Dactylophora nigricans
Fry	Fry
Goatfish	Upeniechthys vlamingii
Goby	Gobidae
Herring Cale	Odax cyanomelas
Hula Fish	Trachinops spp.
Leather Jacket	Meuschenia spp.
Long Finned Pike	Dinolestes lewini
Magpie Perch	Cheilodactylus nigripes
Moonlighter	Tilodon sexfasciatum
Mullet	Aldrichetta forsteri
Old Wife	Enoplosus armatus
Salmon trout	Arripis truttaceus
Silver Drummer	Kyphosus sydneyanus
Squid	Sepioteuthus australis
Stingray	Myliobatis australis
Sweep	Scorpis spp
Talma	Chelmonops spp
Three fin	Norfolkia clarkei
Toadfish	Tetradontidae
unknown	Unidentified
Victorian Scalyfin	Parma victoriae
Weedfish	Clinidae
Weedy Whiting	Siphonognathus spp, Neoodax balteatus & Haletta semifasciata
Whiting	Sillaginidae
Wrasse	Thalossoma spp.
Yellowtail Scad	Trachurus novaezelandiae
Zebra Fish	Girella zebra
Silver Belly	Parequula melbournensis

11.7.1.2. Identification of taxa

Divers need to memorise the different fish taxa they are likely to encounter. It is recommended that common names are used to make this process simpler. Best results are achieved by divers taking a text with good pictures of each of the fish likely to be encountered, and testing one another on a small number of pictures at a time until most taxa likely to be encountered are easily recognised (Table 9). This is easily achieved since most divers already have some knowledge of fish species.

11.7.1.3.In water diver training and calibration

- Due to the highly mobile nature of fish, calibration can only be done by divers simultaneously looking at the same area.
- Initially divers should swim along together pointing out different taxa and checking that both agree on the identification.
- Once confident divers should then swim sections of reef side by side recording data separately, periodically stopping to compare results and resolve differences.

Data from these training transects should be kept as originally recorded as it can provide important information about sampling variability and the effectiveness of training. Training dives also serve as valuable familiarisation time for divers to become competent at working underwater.

11.7.2.Data recording

- Before the dive details of the transect such as location, depth, conditions and the name of diver and buddy should be recorded on the data sheet.
- At the start of each transect the first diver writes the transect number in the first column of the data sheet (Fish Visual Census)
- Divers swim each transect with the person recording data at the front. They should remain close to the bottom to reduce the effect of their presence on the fish. The pace should be slow but constant.
- Divers need to be particularly wary of counting the same individual fish more than once.
- If a diver is uncertain of an identification they should record a description and best guess, and bring it to the attention of their dive buddy so they can discuss it upon surfacing.

11.7.3.Data Processing

Details of the days diving should be recorded in a diary, and data should be entered into a database. Records should be entered into a data table, each with a unique sample identifier, taxa and abundance count (Table 10). All data entered should be checked and verified by a second person after entry, and data should always be backed up.

Table 10. Fish census data table.

Transect	Field name	Taxa	Total abundance
1	Leather jacket	Meuschenia spp	6
1	Silver drummer	Kyphosus sydneyanus	8
1	Bullseye	Pempheris spp	24
1	Cowfish	Aracana spp	3
1	Old Wife	Enoplosus armatus	34
1	Dusky Morwong	Dactylophora nigricans	2
2	Cowfish	Aracana spp	1
2	Silver drummer	Kyphosus sydneyanus	3
2	Weedy whiting	Siphonognathus spp	8
2	Dusky Morwong	Dactylophora nigricans	3
2	Magpie Perch	Cheilodactylus nigripes	4
2	Leather jacket	Meuschenia spp	6

11.8. Fish visual census data-sheet

Divers name =					
Group/Club name =				Time of day=	
Date	Reef name or GPS coord=				
/ /	Aspect =	Horizontal	Vertical	45 degrees	Depth (m) =
	Exposure =	Seaward	Leeward		

Transect	Fish fieldname	Abundance	Transect	Fish fieldname	Abundance