
2. Methods

Program design

The AIMS Long-term Monitoring Program is designed to detect changes over time in reef communities at a regional scale. Regions in this context refer to the combinations of three positions across the shelf (inshore, mid-shelf, outer shelf) at six latitudes (sectors). Surveys by the Long-term Monitoring Program involve three “tasks”: manta tow surveys for crown-of-thorns starfish (COTS) and reef-wide coral cover, surveys of sessile benthic organisms using video and visual counts of reef fishes. The data that are collected are listed in Table 2.1. A fourth task, routine water quality monitoring, was discontinued in 1995.

Table 2.1: Summary of Measurement Variables for each of the LTMP tasks

Task	Description	Variables Measured
Broadscale Surveys	Manta tow surveys around entire reef perimeter	Crown-of-thorns starfish counts; estimates of cover of hard and soft coral, dead coral, other incidental observations (e.g. coral bleaching, <i>Drupella</i> , giant clams, reef aesthetics)
Benthic Organisms	Video transects at selected sites in one reef habitat	Percent cover of all identifiable sessile benthic organisms
Fishes	Visual surveys of fish at selected sites in one reef habitat	Counts of most mobile and non-cryptic fish species (see Appendix C)

Selection of reefs

Initially, 52 “core” reefs were selected for annual survey. The reefs were widely distributed throughout the GBR and spanned variations in the composition of coral and fish communities (Done 1982, Williams 1982), which are known to be greater across the GBR than they are along its length.

The sample reefs were selected within six of the 11 cross-shelf sectors (Figure 2.1) that had been identified for manta-tow surveys for crown-of-thorns starfish (Bainbridge *et al.* 1994). Where possible, three or more reefs were selected in each of three zones of the continental shelf: inshore, mid-shelf and outer shelf, in each sector.

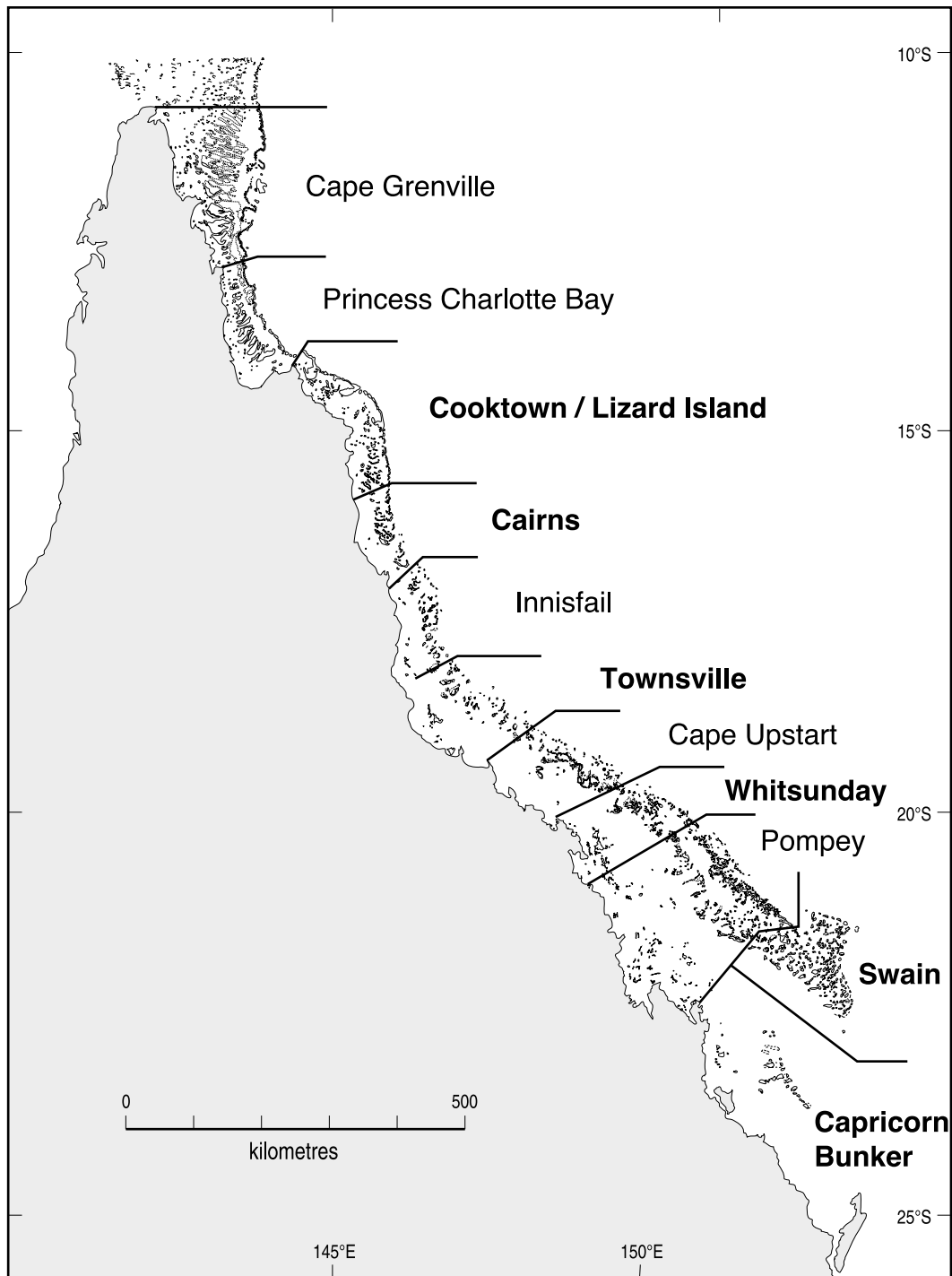


Figure 2.1 Map of the GBR showing the locations of latitudinal sectors. The six sectors where LTMP sites are located are shown in bold face type.

There are no inshore or mid-shelf reefs in the Capricorn/Bunker sector. The core survey reefs were chosen from the reefs within each shelf position for logistical and historical reasons. Because of the non-biological nature of the selection criteria, the survey reefs are likely to be representative of the reefs in each of the regions. The

number of core survey reefs has been reduced subsequently to 49 because some reefs could not be sampled reliably on a regular basis.

An additional 35 reefs from the 11 sectors are surveyed annually using manta tow only. Some of these reefs are surveyed every year (key reefs); others are surveyed every three years (cycle reefs). Maps and a full listing are given in Appendices A and B.

In addition to data from the LTMP, staff of the Cairns region of the Queensland Department of Environment and Heritage made video surveys of sites on the LTMP key manta tow reefs in the far northern GBR. These data are included in Section 6.

Sampling methods

The core survey reefs are sampled in two stages (Fig. 2.2). The entire perimeter of each reef is surveyed using manta tows. Fishes and benthic organisms are surveyed intensively at three sites in a habitat that is standardised across reefs. The sites are located in the first stretch of continuous reef (excluding vertical drop-offs) to be encountered when following the perimeter from the back reef zone in a clockwise direction towards the front reef. The sites are usually situated on the north east flank of the reef (Figure 2.2). Sites are separated by at least 50 m where possible. On small reefs, the sites may extend around the reef as far as the east or south east flanks.

There are five 50 m transects within each site. These are permanently marked with a star picket at each end and lengths of reinforcing rod at 10 m intervals. Transects run parallel to the reef crest at about 6-9 m depth (Fig. 2.2). Transects were initially laid in a haphazard manner with 10 - 40 m between transects.

Surveys are made each year between September and May. In this report, annual surveys are referred to by the year in which the field season ended: thus surveys made between October 1997 and May 1998 are referred to as 1998 surveys.

Fifty-one core reefs were sampled for fish and benthos in 1995-96, 45 reefs in 1996-97 and 48 in 1997-98 (Appendix B). In addition to the core reefs, 59 reefs were surveyed by manta tow alone in 1995-96, 29 in 1996-97, and 60 in 1997-98 (Appendix B).

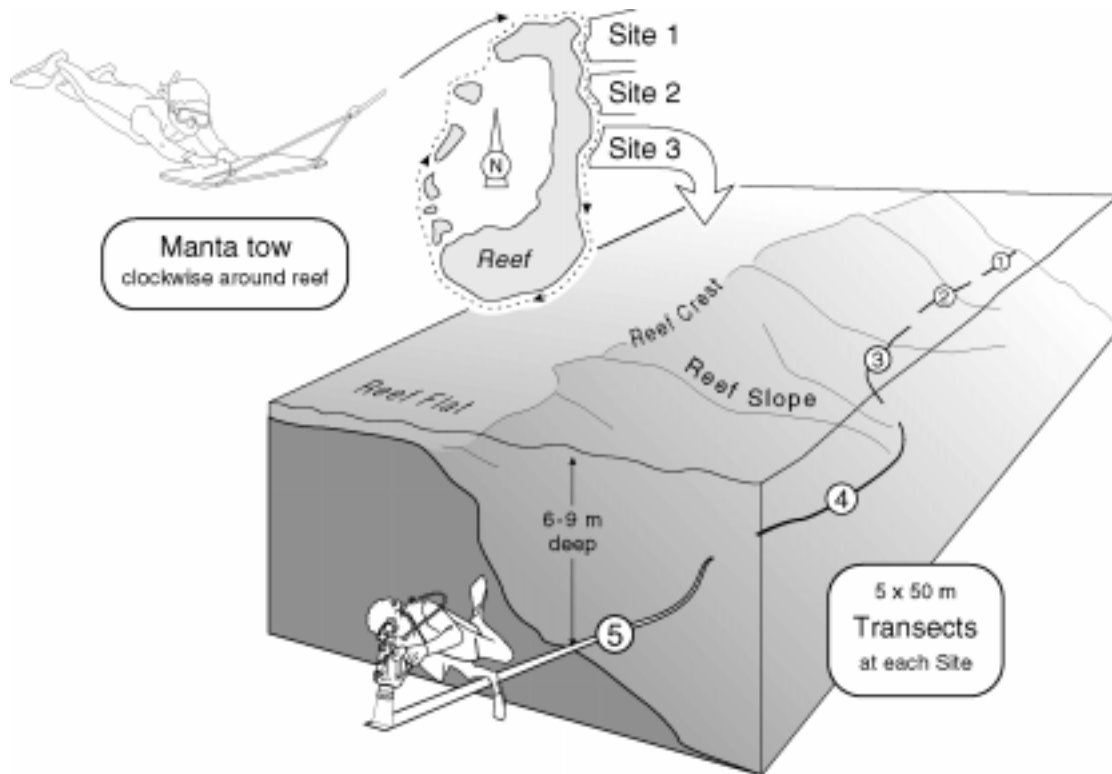


Figure 2.2: Schematic arrangement of sampling effort on a core survey reef

Quality control

It is important to maintain consistency in the way data are collected and processed, so that differences that appear over time reflect differences in the populations of reef organisms rather than changes in sampling. Each part of the program has quality control measures in place, but one general approach has been to produce a series of Standard Operating Procedures (SOPs, Table 2.2). These document the current methods of data collection and processing in considerable detail. They are reviewed at least every two years and updated as necessary. Current SOPs are available in electronic form via the AIMS web page (www.aims.gov.au).

Data storage and access

Data are entered using a number of purpose-designed data entry and checking programs. All data are held in an Oracle™ database at AIMS. The structure of the database is described in Baker and Coleman (in press).

Table 2.2: Titles of standard operating procedures and related documents

Broadscale surveys	Bass DK and Miller IR (1996) Crown-of-thorns starfish and coral surveys using the manta tow and SCUBA search techniques. Standard Operating Procedure No. 1, AIMS, Townsville. 38 pp.
Fishes	Halford AR and Thompson AA (1996) Visual census surveys of reef fish. Standard Operating Procedure No. 3, AIMS, Townsville. 24 pp.
Benthos	Christie CA, Bass DK, Neale SJ, Osborne K and Oxley WG (1996) Surveys of sessile benthic communities using the video technique. Standard Operating Procedure No. 2, AIMS, Townsville. 42 pp.
Data handling	Baker VJ and Coleman G (in press) A guide to the Reef Monitoring database. Standard Operating Procedure No. 6, AIMS, Townsville.

Methods for individual tasks

Broadscale surveys

AIMS began broadscale surveys of the Great Barrier Reef in the mid-1980s. These surveys were incorporated into the LTMP in 1992. The primary objective of the broadscale surveys is to detect and monitor populations of crown-of-thorns starfish (COTS) on the Great Barrier Reef. Manta tow surveys also provide estimates of percent cover of soft corals and living and dead coral, allowing assessment of the impact of COTS outbreaks and other large-scale disturbances. This report presents coral cover and crown-of-thorns starfish data from 13 years of broadscale surveys on the GBR.

Sampling techniques

Broadscale surveys use the manta tow technique as described by Bass and Miller (1995) and English *et al.* (1997). At each reef, two teams work in opposite directions around the reef to survey about half the perimeter each. A team consists of a boat driver and an observer who is towed behind the boat on a manta board. At two-minute intervals the boat stops, allowing the observer to record the data for that tow (Table 2.3). Current practice differs from the documented method in that cover of soft coral is estimated in place of sand and rubble. This was instigated in the 1998 field season.

Table 2.3: Primary variables recorded every 2 minutes during a manta tow survey. See Bass and Miller (1996) for more details.

Variable	Data recorded	Categories
Number of COTS	number observed	actual counts
Size class of COTS	size class	A = juvenile (<25cm) B = adult (>25cm)
Presence of feeding scars	abundance categories	A = absent (0) P = present (1-10) C = common (>10)
Live coral	estimated cover categories (scale of 0-5)	0 = 0%
Dead coral		1- = >0-5%
Soft coral		1+ = >5-10%
		2- = >10-20%
		2+ = >20-30%
		3- = >30-40%
		3+ = >40-50%
		4- = >50-62.5%
		4+ = >62.5-75%
		5- = >75-87.5%
		5+ = >87.5-100%
Visibility	distance categories (scale of 1-4)	1 = <6m 2 = 6-12m 3 = 12-18m 4 = >18m

Quality control

Quality control is in two stages. First, all observers are trained before participating in the broadscale surveys (see Bass and Miller 1995). Secondly, on each sampling trip, some reefs are surveyed by two observers following the same tow path to give a measure of the variability between observers. This is necessary because the precision

of observers varies continually (Moran and De'ath 1992). When observers show signs of bias (Miller and Müller 1997) they are retrained.

Data handling and analysis

Percent cover of living coral, dead coral and soft coral is calculated from the manta tow results by representing each cover category by the mid-point of its range. Coral cover, the number of COTS per reef and the average number of COTS per tow are used to assess the outbreak status of each reef (Fernandes 1991; Moran and De'ath 1992). There are four categories: Active Outbreak (AO); Incipient Outbreak (IO), Recovering (RE); or No recent Outbreak (NO). In concept, an Active Outbreak occurs when starfish densities reach levels where loss of coral tissue through starfish feeding is estimated to be faster than the growth of the coral. Definitions of outbreaks have evolved over the time that surveys have been made. Initially, reefs with active outbreaks were those where >40 COTS were recorded over the whole reef and >30% of coral was dead. Examination of manta tow data from reefs of all categories found that 90% of reefs with active outbreaks by these criteria supported >1500 COTS km⁻² (Moran and De'ath 1992). This is approximately 0.22 COTS per two-minute tow. After consideration of the relative costs of Type I and Type II errors, the criterion for an Active Outbreak was revised upwards to 1.0 COTS per tow (Lassig and Engelhardt 1995, Engelhardt *et al.* 1997). This represents a starfish density that is highly likely to cause net decline in corals. In this report the criterion of 0.22 COTS per tow is referred to as "Incipient outbreak".

Reefs which fit the following criteria were chosen to estimate the regional trends:

- reefs must have been surveyed at least four times
- reefs must also have been surveyed within three years of both the start (1986) and the end (1998) of the surveys.

An exception was made in the case of the inshore region of the Cape Grenville sector where one reef which had only been surveyed three times was included to provide an adequate sample. At least three reefs from each region were required for the analysis.

Linear models were used to fit simple (quadratic) curves to the sequence of observations of median coral cover (reef-wide coral cover) and mean numbers of COTS per tow from each reef. The fitted values from these curves for individual reefs were then used to estimate regional means. A similar linear model was fitted to the regional means and then used to estimate the overall trend over time and the current trend for each region. See Appendix K for a more technical explanation.

Sessile benthos

Sampling Techniques

Benthic organisms were surveyed on the five marked transects within each site on the core reefs. A 25 cm wide swathe was recorded along each 50 m transect using a Hi-8 video camera held 25-30 cm above the substrate. Percent cover of corals and other benthic categories were estimated using a point sampling technique, in which approximately 200 systematically-dispersed points were sampled from each video transect. Details of the video survey and sampling techniques can be found in the SOP (Christie *et al.* 1996). Corals were identified to the greatest taxonomic detail achievable, but aggregated for analysis. Analysis concentrated on three major components of the benthic community: hard corals, soft corals and algae. The hard corals were then divided into the dominant families: Acroporidae, Faviidae, Pocilloporidae and Poritidae. The Acroporidae were further subdivided into *Montipora* spp., tabulate *Acropora* spp. and other *Acropora* spp. (see Table 2.4).

Table 2.4: Explanation of benthic categories

Major Benthic Group

Hard Corals	Order Scleractinia
Soft Corals	Subclass Alcyonaria
Algae	Macro-algae and turf algae

Major Benthic Families

Acroporidae	Family Acroporidae
Faviidae	Family Faviidae
Pocilloporidae	Family Pocilloporidae
Poritidae	Family Poritiidae

Acroporidae Groups

<i>Montipora</i>	Genus <i>Montipora</i>
<i>Acropora</i> tabulate	Genus <i>Acropora</i> tabulate life-form
<i>Acropora</i> other	Genus <i>Acropora</i> , non-tabulate life-forms

Quality control

Quality control involves training new observers to use the video camera effectively in the field followed by initial training and an on-going program monitoring agreement between all observers when identifying organisms in the recordings. A

second on-going program checks field identifications against identifications in the recordings.

Data handling and analysis

For each category of benthic organisms, the mean values (based on the five transects) for percent cover at each site in each year were used to estimate temporal trends in cover of benthic organisms at each reef. Annual cover values were transformed using the empirical logit transformation prior to analysis (see Appendix K). A linear model was then used to fit a simple (quadratic) curve to the transformed annual values for percent cover. This model was then used to estimate the overall trend (over the six annual surveys) and current trend for each core survey reef.

Regional trends in percent cover over time were estimated using a similar procedure except that the linear model was fitted to transformed annual estimates of overall mean cover on each reef in the region. See Appendix K for a more technical explanation.

Reef fishes

Sampling technique

Fishes of 191 species (Appendix C) were counted on the five 50 m transects at three sites on each reef. Because the surveys span the annual recruitment season, 0+ individuals are excluded from counts. Initially, larger more mobile species were counted using transects 10 m wide and pomacentrids were counted using transects 2 m wide. These dimensions were too wide to give accurate counts in the low visibility that is often encountered at inshore reefs. Sampling time also became very long when large schools of planktivorous fishes were encountered which resulted in problems with dive times. Transect widths were reduced to 5 m and 1 m respectively prior to the third year of sampling (1995). A correction factor for change in transect dimensions was incorporated into the analysis (see Appendix K). Full details of the sampling method are given in the SOP (Halford and Thompson 1996).

Quality control

All observers cross calibrate their counts each year during training prior to the field season. Estimating the cut point for 0+ individuals is particularly important.

Counts are entered into a database at the end of each day's diving using specially written programs that trap simple errors. When data for all the transects on a reef have been entered, the new data are compared with counts from previous years using a linear model to check for unlikely values. This allows observers to check for misidentifications.

Data handling and analyses

Counts have been summed over the five transects, giving estimates of abundance from three sites in the one area of each reef. As in previous Status Reports (Oliver *et al.* 1995, Sweatman 1997), larger species have been grouped into families and pomacentrid fishes have been grouped into genera. This increases the power of the analyses, but complicates interpretation.

Abundances required correction to account for the change in transect width after two annual surveys. A correction factor, based on the change in intercepts of regression lines for data collected before and after the change in transect width, was incorporated into the analysis (see Appendix K).

Three reefs (Fitzroy, Reef 21-583 and Havannah Is.) were only sampled twice and were not included in temporal analyses.

To look at trends in abundance of fishes on individual reefs, the corrected abundances for the five transects in each site were summed and log transformed [$\ln(x + 1)$] to reduce the influence of abundant taxa. A linear model was then used to fit a simple (quadratic) curve to the transformed annual estimates of abundance. This model was then used to estimate the overall trend (over the six annual surveys) and current trend for each core survey reef.

Regional trends in abundance over time were estimated using a similar procedure except that the linear model was fitted to transformed annual estimates of mean abundance per site for each reef in the region. See Appendix K for a technical explanation.