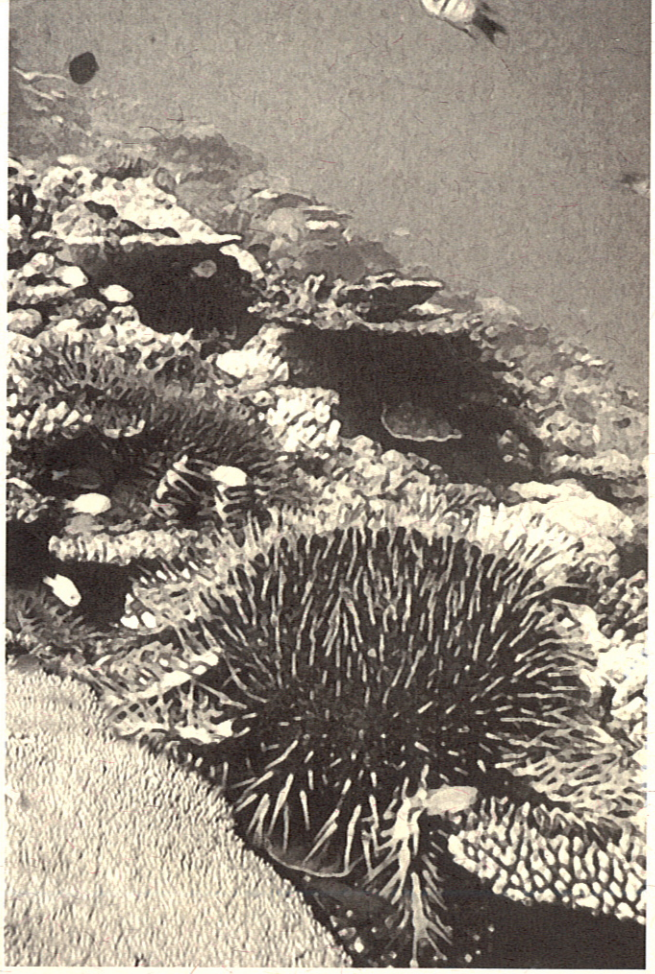

Long-term Monitoring of the Great Barrier Reef

Status Report
Number 5 2001

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In conjunction with the
CRC: Reef Research Centre

Australian Institute of Marine Science

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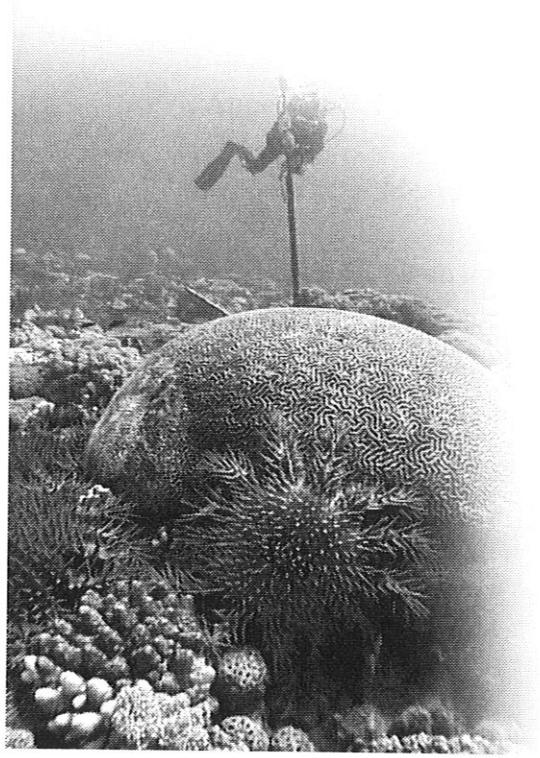

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The Great Barrier Reef World Heritage Area has immense aesthetic value and great economic importance, supporting tourism and fisheries worth more than $1 billion annually to the Australian economy. Inscription on the World Heritage List recognises the area's global significance and entails regular reporting on its status. Information on natural variability of populations is essential for informed management. The AIMS Long-term Monitoring Program is designed to provide information on population trends in key groups of organisms (particularly crown-of-thorns starfish, corals, algae, and reef fishes) on appropriate spatial scales over the length and breadth of the Great Barrier Reef World Heritage Area (GBRWHA). The results contained within this report are intended as a primary source of strategic information for the Great Barrier Reef Marine Park Authority (GBRMPA), the Commonwealth Government lead agency for matters concerning the care and development of the GBRWHA.

Broadscale manta tow surveys have now been carried out in 11 latitudinal sectors spanning the length of the GBR for a period of 15 years (1985-2000) and have played a significant role in our increased understanding of the crown-of-thorns-starfish (COTS) phenomenon. The perimeters of 98 reefs were surveyed using manta tows in 2000.

Intensive surveys on reefs in six sectors began in the 1993 field season. Coral and fish are surveyed annually on fixed sites within one habitat on each survey reef. Sites on 48 reefs were surveyed in 2000.

This report presents a synthesis of monitoring data collected over the last six years and includes unreported data from the 2000 field season.

Major results are:

Crown-of-thorns starfish

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A similar pattern is seen in the overall density of COTS on the GBR. The overall mean number of COTS per tow recorded in 2000 was 0.96. This has increased greatly from 1999 (when the mean was 0.15 COTS per tow) because of high densities of starfish in the Innisfail sector. For comparison, the highest overall mean number of COTS per tow on the GBR during the last major COTS outbreak was 1.17 in 1988.

Details of the current distribution of COTS are as follows:

- The abundance of COTS in the Cooktown / Lizard Is. sector decreased between 1999 and 2000.
- COTS numbers increased substantially in the Cairns, Innisfail and Townsville sectors. This is consistent with a southward drift and is compatible with the hypothesis that secondary outbreaks are caused by larvae being transported between reefs by the East Australian Current.
- COTS numbers in the Swain Reefs increased from 1999 values with greater numbers recorded on all three reefs with outbreaks.
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Coral Cover

The salient changes on the Great Barrier Reef over the six years to 2000 reflect the impact of cyclones and COTS on reef communities and their subsequent recovery from such disturbances. Key results were:

- The highest mean value for cover of living coral on the perimeters of reefs in 2000 (46%) occurred in the Capricorn / Bunker sector and on outer shelf reefs in the Pompey sector. This shows the extent that the coral on Capricorn / Bunker reefs has recovered from very low values after storm activity in 1988. Only one outer-shelf reef (Ben Reef) was surveyed in the Pompey sector.
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- Permanent survey sites on NE faces of reefs in 2000 showed that cover of hard coral was highest in the Capricorn / Bunker sector (62%), followed by reefs in the outer shelf region of the Cooktown / Lizard Is. sector (56%). These regions have been recovering from storm damage.
- Coral cover on permanent survey sites was lowest in the inshore region of the Cairns sector (7%) in 2000. These reefs have been affected by COTS, by coral bleaching and, in some cases, by cyclones.
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1. Introduction

Background

The Australian Institute of Marine Science set up a long-term monitoring program for the Great Barrier Reef (GBR) in 1992. The program is based on some previous monitoring initiatives on smaller scales and represents the first concerted attempt to assess a range of ecological variables across most of the GBR. In 1993 the Long-Term Monitoring Program (LTMP) became a task in the Cooperative Research Centre for Ecologically Sustainable Use of the Great Barrier Reef and subsequently Cooperative Research Centre for the GBR World Heritage Area.

Scope and limitations of the program

The objective of coral reef monitoring is to detect change. Coral reefs are always changing through natural processes such as recruitment, growth, mortality and disturbance by storms. A major function of the LTMP is to document status and to describe change in reef communities on the GBR. The GBR World Heritage Area (GBRWHA) includes the GBR Marine Park, administered by the Commonweath of Australia, and a small area owned by the State of Queensland. About 2% of the GBRWHA is not declared as Marine Park. The Great Barrier Reef Marine Park Authority (GBRMPA) is the lead agency for GBR World Heritage Area issues and principal adviser to the Commonwealth Government on care and development of the GBR Marine Park. Information from the AIMS LTMP contributes significantly to the GBRMPA's reporting on the status of the GBR World Heritage Area as required by the World Heritage Commission of UNESCO. It also allows park managers to place small scale, site-specific changes in the context of changes that are observed over much larger scales. This provides some perspective on the importance and significance of site-specific status and change.

The specific objectives of the Program are:

- to monitor the status and changes in distribution and abundance of reef biota on a large scale.
- to provide environmental managers with a context for assessing impacts of human activities within the GBR Marine Park and with a basis for managing the GBR for ecologically sustainable use.

The program addresses long-term regional change in benthic assemblages, reef fishes and crown-of-thorns starfish on coral reefs of the GBR. It does not address associated habitats: mangroves, seagrass beds and areas of soft substrate between reefs. Intensive sampling of benthic organisms and reef fishes is concentrated in one habitat, the NE face of each survey reef, but the perimeter of each reef is also surveyed by manta tow to give a reef-wide estimate of hard coral cover.

Structure of this report

This report describes changes on a large scale that includes most of the GBR (Section 3) and at regional scales organised by latitude (sector) and cross shelf position (Section 4). Although data are presented from 1993 to 2000, this report specifically examines trends over the six years to 2000. The period of six years was chosen because it included two surveys of broad-scale survey "Cycle" reefs (see Section 2). More generally, it represents a compromise between the biological need to look at periods longer than one year and the increasing complexity of statistical functions required to model variation over long periods.

Changes at the scale of individual reefs, as presented in a previous report (Sweatman et al. 1998) are now available on the Institute's web site:

http://www.aims.gov.au/reef-monitoring

Methods

Program design

The AIMS Long-term Monitoring Program is designed to detect changes over time in reef communities at a regional scale. In this context, reefs in a "region" are those that lie in one of three of three positions across the shelf (inshore, mid-shelf, outer shelf) within one band of latitude (a sector). Surveys by the Long-term Monitoring Program involve three "tasks": manta tow surveys for crown-of-thorns starfish (COTS) and reef-wide coral cover (broadscale surveys), surveys of sessile benthic organisms using video and visual counts of reef fishes. Broadscale surveys cover reefs in 11 sectors. Reefs in only six of the sectors are surveyed intensively. The data that are collected by each task are listed in Table 2.1.

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 (reefs in 11 sectors)	Crown-of-thorns starfish counts; estimates of cover of hard and soft coral, dead coral, other incidental observations (e.g. coral bleaching, Drupella, giant clams, reef aesthetics)
Benthic Organisms	Video transects at selected sites in one reef habitat (reefs in 6 sectors)	Percent cover of all identifiable sessile benthic organisms
Fishes	Visual surveys of fish at selected sites in one reef habitat (reefs in 6 sectors)	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 variation in the composition of coral and fish communities (Done 1982, Williams 1982), which are known to be greater across the GBR from the coast to the Coral Sea, than they are along its length.

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

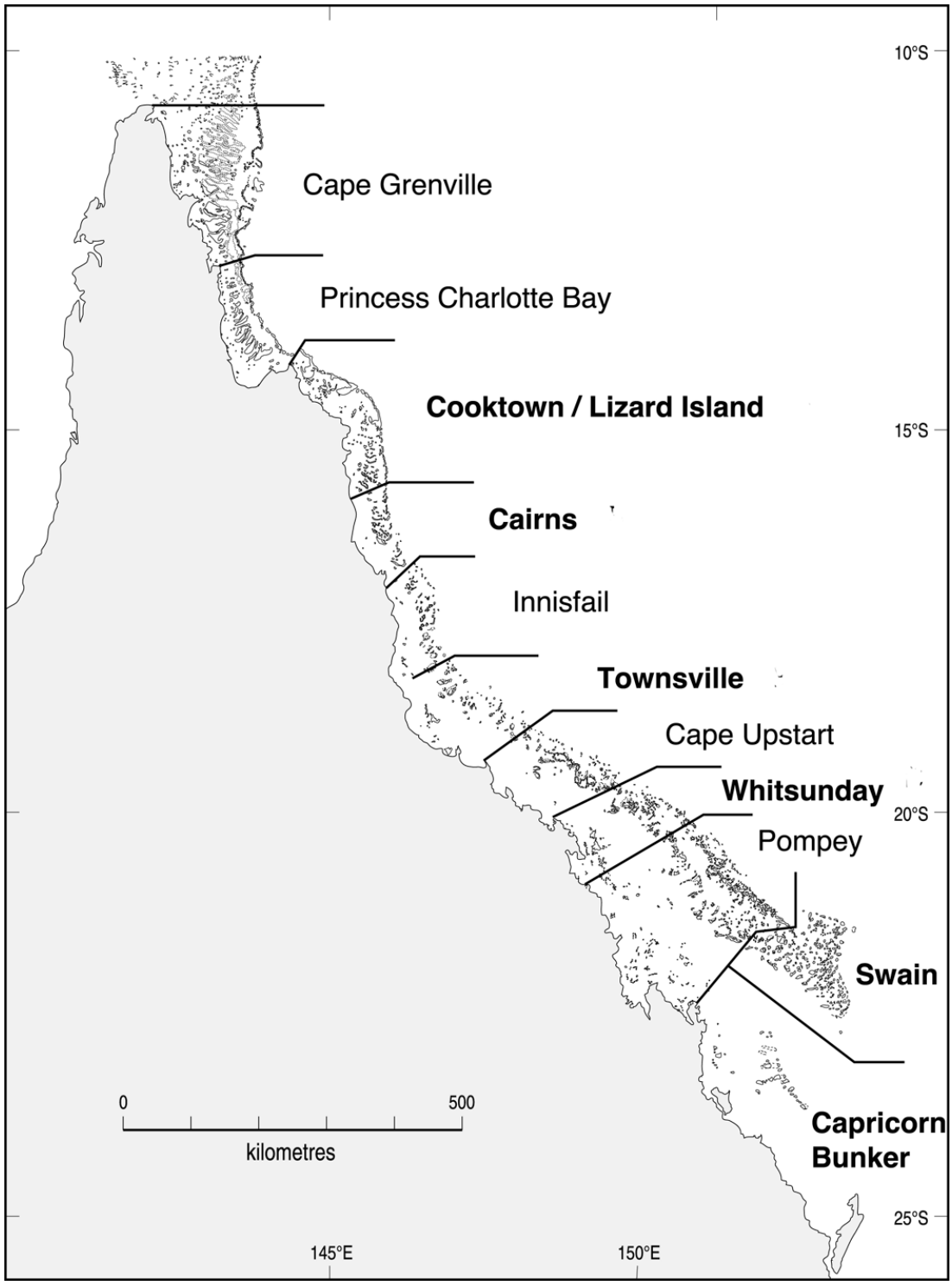


Figure 2.1 Map of the GBR showing the locations of latitudinal sectors. The six sectors where LTMP core survey reefs are located are shown in bold face type.

There are no inshore or mid-shelf reefs in the Capricorn-Bunker sector. Also, the innermost reefs in the Swains are more than 100 km from the mainland and so are not subject to coastal influences. These innermost Swains reefs have been grouped with mid-shelf reefs in this report.

The core survey reefs were chosen from the reefs within each region 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 since been reduced to 48 because some reefs could not be sampled reliably on a regular basis.

An additional 55 reefs from the 11 sectors are scheduled to be surveyed using manta tow only. Some of these reefs are surveyed every year (key reefs); others are surveyed every third year (cycle reefs). These manta tow reefs take second priority and the full set of surveys is rarely completed because of bad weather and limited ship time. Maps and a listing are given in Appendices A and B.

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 towards the front reef in a clockwise direction. The sites are usually situated on the north east flank of the reef (Fig. 2.2). Sites are separated by at least 250 m where possible.

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

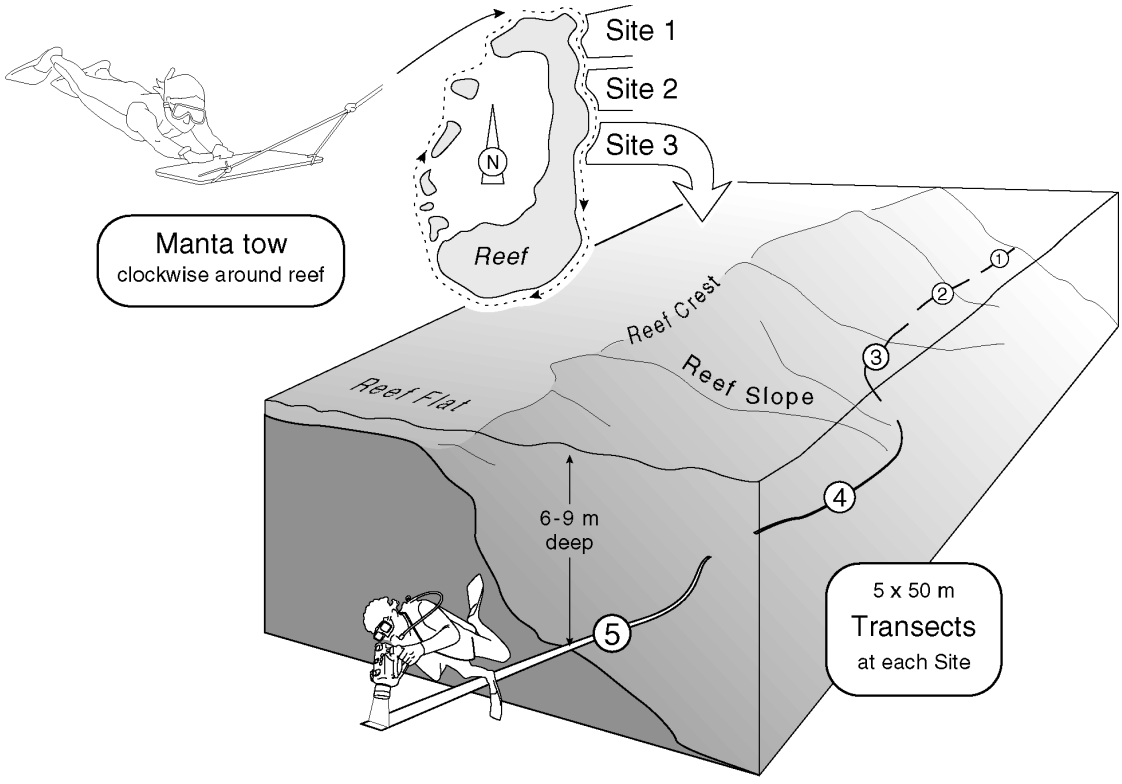


Figure 2.2: Schematic arrangement of sampling effort on a core survey reef.

Surveys are made between October of one year and June of the next year. The reefs in each sector are surveyed at about the same time each year in a series of five or six cruises that alternate to the north and the south of Townsville.

In this report, annual surveys are referred to by the year in which the field season ended: thus surveys made between October 1999 and June 2000 are referred to as 2000 surveys.

Forty-eight core reefs were sampled for fish and/or benthos in 2000 (Appendix B). Forty-three of these were also surveyed by manta tow; five inshore reefs could not be surveyed because of poor visibility. A further 55 reefs were surveyed by manta tow alone in 2000 (Appendix B).

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 Operational Procedures (SOPs, Table 2.2). These document 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/reef-monitoring).

Table 2.2: Titles of standard operational procedures. These are available in electronic form at www.aims.gov.au/reef-monitoring

Broadscale surveys	Bass DK and Miller IR (1996) Crown-of-thorns starfish and coral surveys using the manta tow and SCUBA search techniques. Standard Operational Procedure No. 1, AIMS, Townsville. 38 pp.
Fishes	Halford AR and Thompson AA (1996) Visual census surveys of reef fish. Standard Operational 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 Operational Procedure No. 2, AIMS, Townsville. 42 pp.
Data handling	Baker VJ and Coleman GJ (2000) A guide to the Reef Monitoring database. Standard Operational Procedure No. 5, AIMS, Townsville. 72 pp.

Data storage and access

Data are entered using a number of purpose-designed data entry and checking programs. All data are stored in an Oracle™ database at AIMS. The structure of the database is described in Baker and Coleman (2000).

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 COTS on the Great Barrier Reef. Manta tow surveys also include estimates of percent cover of soft corals, living soft coral and recently dead hard coral, allowing assessment of the impact of COTS outbreaks and other large-scale disturbances. This report presents coral cover and COTS data from 14 years of broadscale surveys on the GBR.

Sampling techniques

Broadscale surveys use the manta tow technique as described by Bass and Miller (1996) 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.

Quality control

Quality control is in two stages. First, all observers are trained before participating in the broadscale surveys (see Bass and Miller 1996). Secondly, on each sampling trip, some reefs are surveyed by two observers following the same towpath. This gives a measure of the variability between observers, which 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 hard and soft coral and dead hard 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). 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,

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 (11 categories)	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 = 12.1-18m
		4 = >18m

reefs with active outbreaks were those where >40 COTS were recorded over the whole reef perimeter and >30% of hard coral was dead. An 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" level.

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 (2000) 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.

Regional trends in coral cover and COTS populations were determined over a six-year period. Trends were only calculated for those regions where a minimum of three reefs was sampled in each of the six survey years. Simple (quadratic) curves were fitted to the annual estimates of mean reef-wide coral cover and mean number of COTS per tow from reefs in each region. Data were transformed using the empirical logit transformation (see Appendix I). For ease of interpretation these data have been back transformed on the provided plots.

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 I 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 30 cm wide swathe was recorded along each 50 m transect using a MiniDV 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).

Quality control

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

Table 2.4: Explanation of benthic categories.

Major Benthic Group	
Hard Corals	Order Scleractinia
Soft Corals	Subclass Alcyonaria
Algae	Macro-algae turf and coraline algae
Major Benthic Families	
Acroporidae	Family Acroporidae
Faviidae	Family Faviidae
Pocilloporidae	Family Pocilloporidae
Poritidae	Family Poritidae
Acroporidae Groups	
Montipora	Genus *Montipora*
Acropora tabulate	Genus *Acropora* tabulate life-form
Acropora other	Genus *Acropora,* non-tabulate life-forms

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 before analysis (see Appendix I). 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 (1) the overall trend (over the past six annual surveys) and (2) the current trend for each core survey reef. Previous reports (Sweatman et al. 1998, 2000) used a five year interval, but six years included two surveys of the "cycle" manta tow reefs.

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 I 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. 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 before 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, Sweatman et al. 1998, Sweatman et al. 2000), 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.

To look at trends in abundance of fishes on individual reefs, the 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 past six annual surveys) and current trend for each core survey reef. A taxon was considered too rare to test if it occurred at an average density of less than one per transect in any year.

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 I for a technical explanation. A taxon was considered too rare to test if it did not occur at an average density of 15 individuals or more (one per transect) on any reef in the region in any year.

Species richness refers to the mean number of species (from the prescribed list Appendix C) recorded on each reef in a region. The list in Appendix C includes most scarids, chaetodontids and pomacentrids, as well as surgeonfishes of the family Acanthuridae that occur on the GBR. Values are mainly useful for comparison with other regions within the program.

Reefs of the Great Barrier Reef: General Trends

The aim of this section is to summarise the broad pattern of changes throughout the GBR. Trends in numbers of organisms in regions of the GBR depend on the history of large-scale disturbances and the time that has been available for recovery. There were no large or persistent cyclones in the GBR province since the last set of surveys, so most of the declines are due to crown-of-thorns starfish activity.

The analyses (Section 2, Appendix I) of abundances of fishes and percent cover of benthic organisms on individual reefs identified two types of trends: average trends over the last six annual surveys, and current trends: those evident at the 2000 survey. Note that the analyses for current trends are less powerful than those for average trends (Appendix I). Trends for the GBR are summarised here by considering the proportions of core survey reefs in each sector that show increasing, decreasing, or no significant trends in cover of hard coral and abundance of reef fishes (see explanatory box below).

The crown-of-thorns starfish (COTS), *Acanthaster planci*, is an important cause of coral mortality when populations build up to outbreak levels. AIMS staff have been monitoring COTS populations since 1986. The results of these surveys are summarised in Fig. 3.1. Populations of the starfish decreased in the Cooktown / Lizard Is. sector, but continued to increase in the Cairns, Innisfail and Townsville sectors. This is consistent with observations of previous waves of outbreaks, where the incidence of reefs with new active outbreaks moved south over time. This is presumably involves southward transport of larvae by the East Australian Current. Three reefs in the Swains sector had active outbreaks and overall COTS numbers on Swain reefs had returned to levels at least as high as those recorded in 1998.

There was a general increase in hard coral cover in the Capricorn / Bunkers sector over the preceding six years (Fig. 3.2). Storms removed much of the coral from these reefs in 1988 (Fig. 3.1), but in 2000 the intensive survey sites had the highest coral cover values of any region. None of these reefs showed any current trend. Outer shelf reefs in the Cooktown / Lizard Is. sector showed a similar pattern though this was moderated by declines on midshelf reefs in the sector due to COTS. The general situation in the Swain was that coral cover had increased on average on the majority of reefs, though the dramatic declines in coral cover on two of the reefs with high COTS numbers neutralised trends in regional coral cover (Section 4). The substantial proportion of reefs where coral cover declined over the previous six years in Cairns sector was mainly made up of inshore reefs that were affected by bleaching in 1998. Subsequently there had been COTS activity and, in some cases, cyclone damage, leading to the declining current trend. Coral cover was currently declining on the majority of reefs in the Townsville sector, due to the build up of COTS.

The general increasing trend in families of larger, more mobile reef fishes in the Capricorn / Bunkers over the past six years was associated with the increasing coral cover. A number of families declined in abundance in the Townsville sector, principally on outer shelf reefs (Fig. 3.3). The families involved included herbivores and carnivores. No clear causes could be identified. Most reefs in most sectors showed no current trends in abundances of larger reef fishes.

Several genera of damselfishes increased in abundance over the last six years in the Capricorn / Bunker sector in the south and the Cairns and Cooktown / Lizard Is. sectors in the north (Fig. 3.4). The increases in the Capricorn / Bunkers were associated with the increase in coral cover. Several genera were increasing on inshore and outer-shelf reefs in the Cooktown / Lizard Is. sector. Coral cover increased on outer-shelf reefs, but there was no simple explanation for increases on inshore reefs. Several genera increased in abundance in each region of the Cairns sector. In the Swains sector, the damselfish genera that showed any trend all declined over the past six years in both regions. The genera that were declining were mainly found on the mid-shelf reefs, the region where COTS were active.

Explanation of summary plots

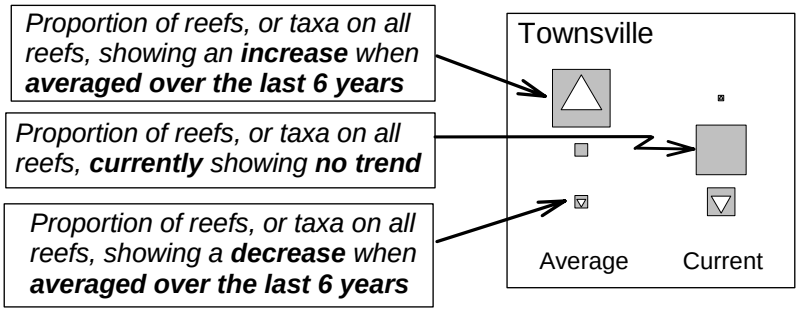
Trends in reef-wide cover of hard coral and in COTS estimated from broadscale surveys are represented by conventional line graphs and histograms (Fig. 3.1).

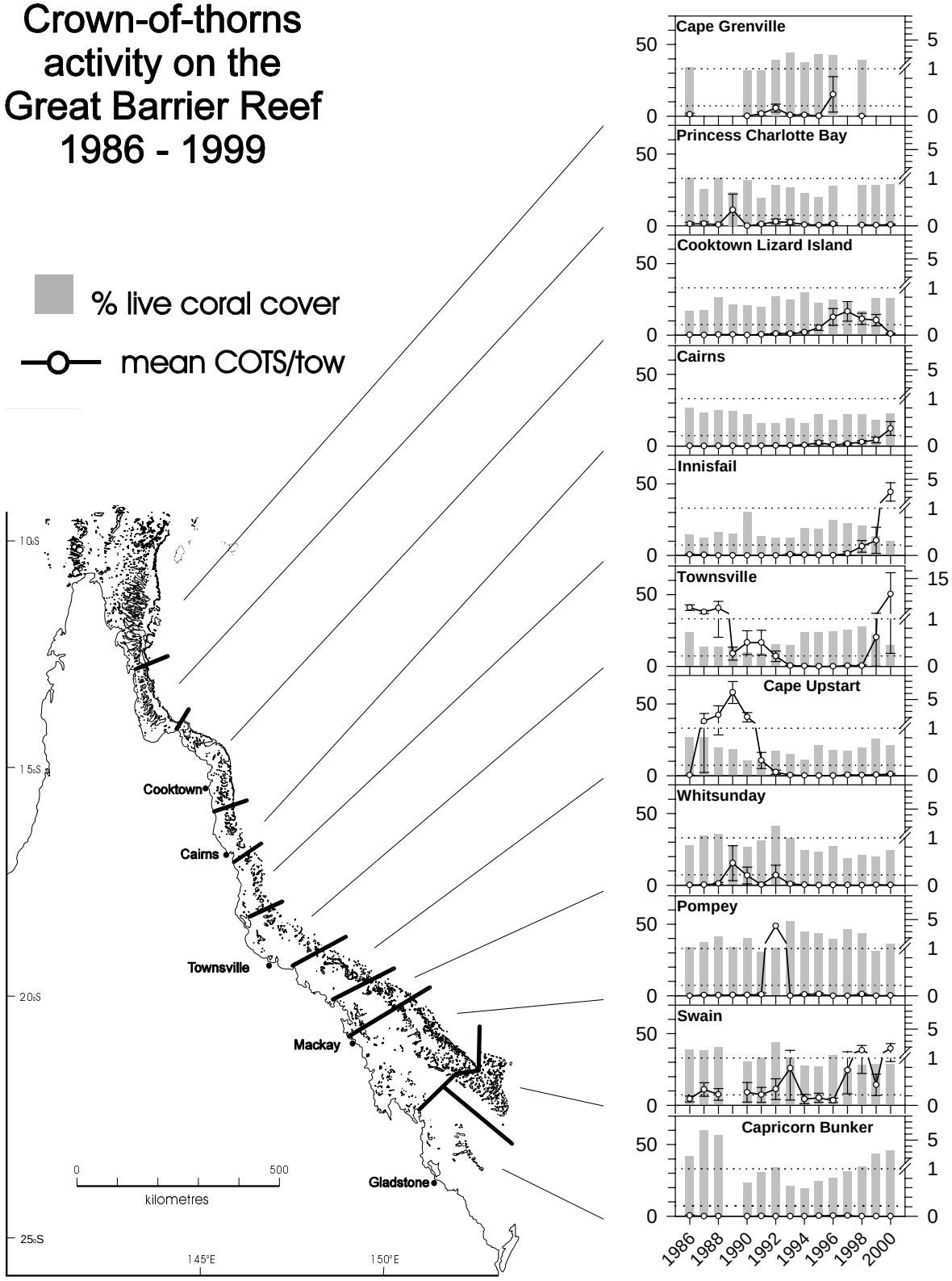
The trends in hard coral cover and in fishes from intensive survey sites on reefs in each sector are represented by two sets of plots. The left hand set of squares concerns the average trends over the past six years; right hand set concerns current trends. Dimensions of the three filled squares reflect the proportion of taxa on survey reefs in each sector showing significant ($p<0.1$) increasing trends, decreasing trends or no significant trend. Arrowheads within the squares indicate direction of trend.

For hard coral cover (Fig. 3.2), the dimensions of the squares represent the proportion of reefs in each sector showing each trend (total = No. of reefs). For fishes (Fig. 3.3, 3.4), the dimensions of the squares represent the proportion of all taxa on all reefs in the sector that showed each trend (total = No. of fish taxa x No. of reefs).

Taxa that were too rare to allow a trend to be estimated were omitted.

An annotated example:




Crown-of-thorns activity on the Great Barrier Reef 1986 - 1999
% live coral cover
mean COTS/tow
Cape Grenville
Princess Charlotte Bay
Cooktown Lizard Island
Cairns
Innisfail
Townsville
Cape Upstart
Whitsunday
Pompey
Swain
Capricorn Bunker
50
0
5
1
15
1986
1988
1990
1992
1994
1996
1998
2000
10°S
15°S
20°S
25°S
145°E
150°E
Cooktown
Cairns
Townsville
Mackay
Gladstone
0
500
kilometres

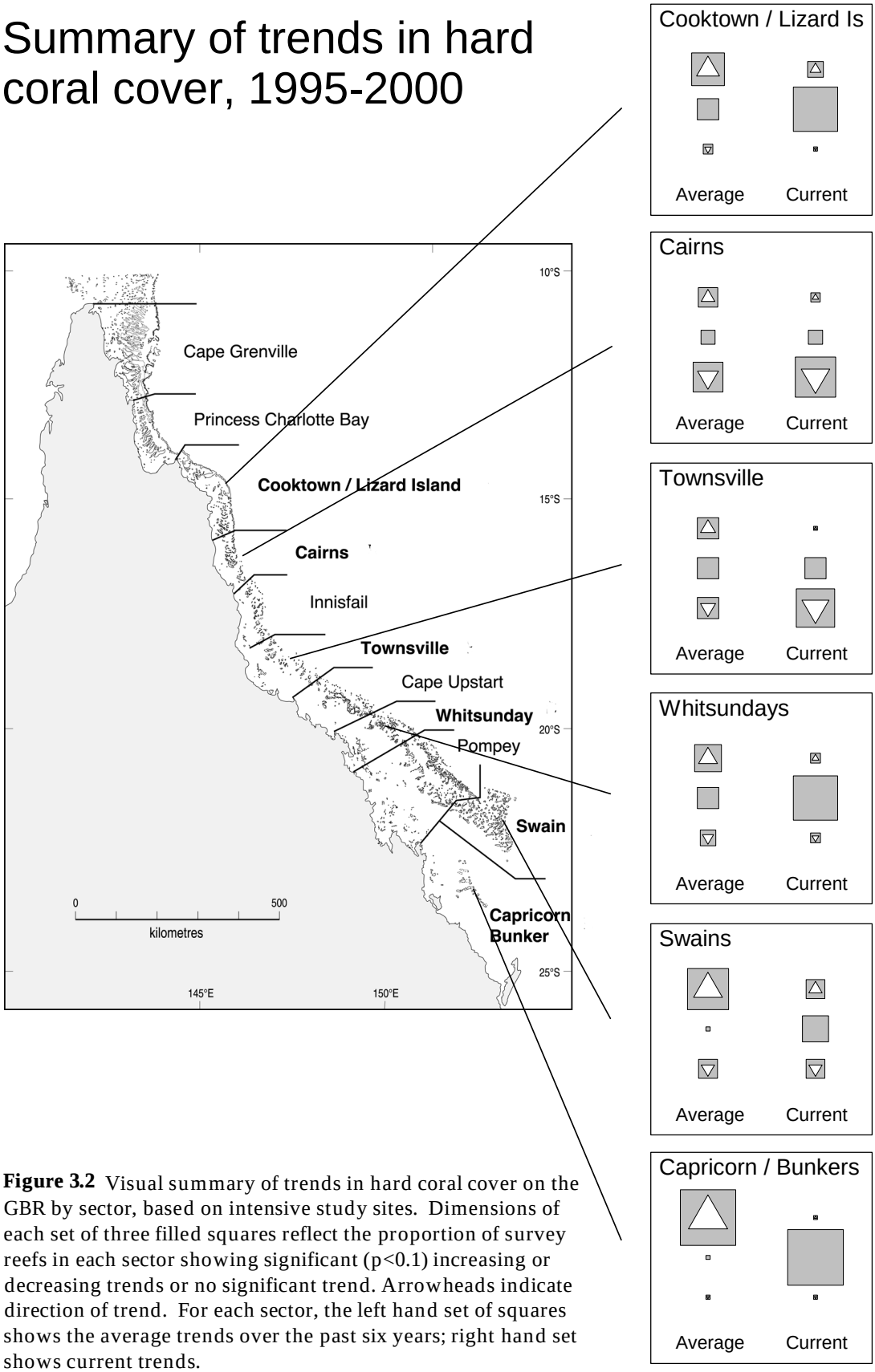
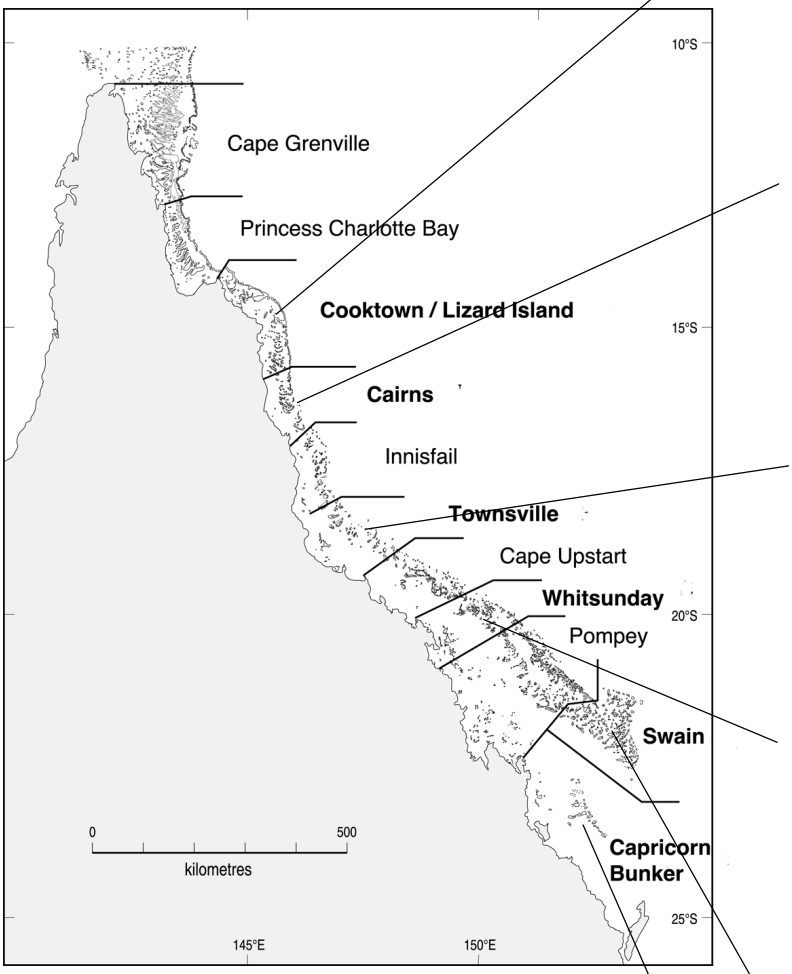
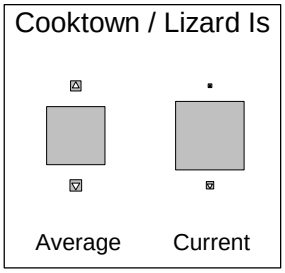
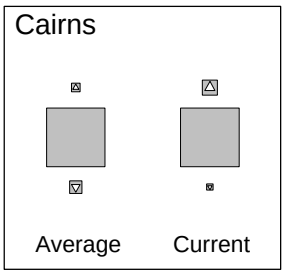


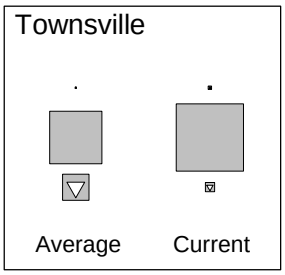
Figure 3.2 Visual summary of trends in hard coral cover on the GBR by sector, based on intensive study sites. Dimensions of each set of three filled squares reflect the proportion of survey reefs in each sector showing significant ($p<0.1$) increasing or decreasing trends or no significant trend. Arrowheads indicate direction of trend. For each sector, the left hand set of squares shows the average trends over the past six years; right hand set shows current trends.

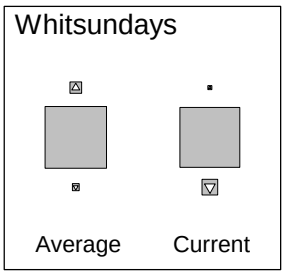
Summary of trends in abundance of larger fishes, 1995-2000

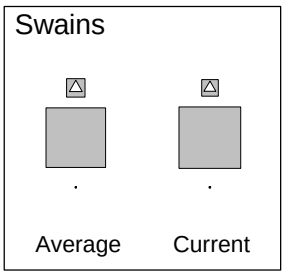












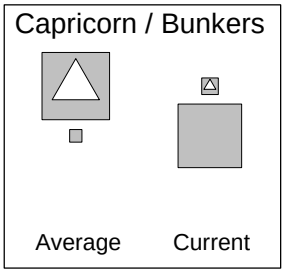
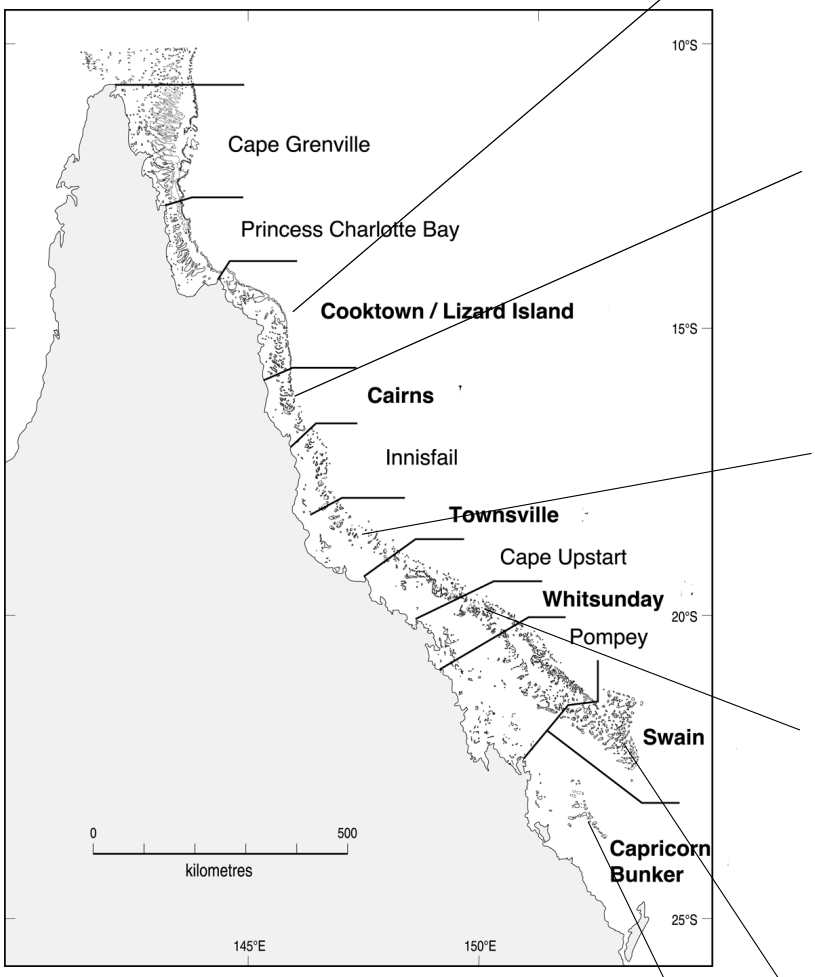
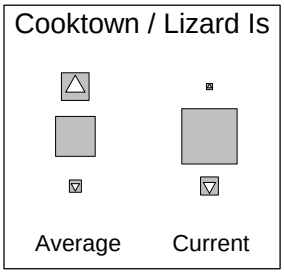
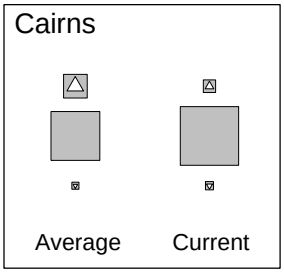


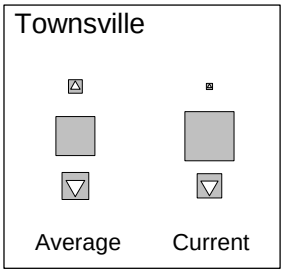
Figure 3.3 Visual summary of trends in abundance of larger reef fishes on the GBR by sector. Dimensions of each set of three filled squares reflect the number of families of larger fishes showing significant ($p<0.1$) increasing or decreasing trends or no significant trend on each reef, summed over all survey reefs in each sector and expressed as a proportion. Arrowheads indicate direction of trend. For each sector, the left hand set shows the average trends over the past six years; right hand set shows current trends. Families that were too rare to test have been omitted.

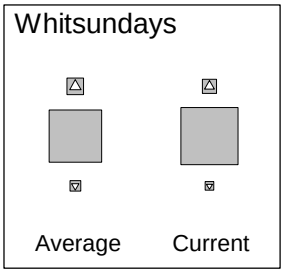
Summary of trends in abundance of damselfishes, 1995-2000

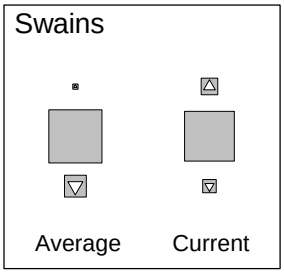












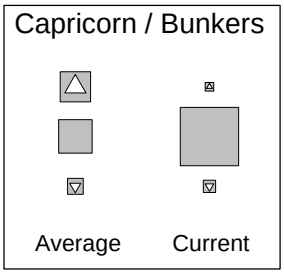


Figure 3.4 Visual summary of trends in abundance of damselfishes on the GBR by sector. Dimensions of each set of three filled squares reflect the number of damselfish genera showing significant ($p<0.1$) increasing or decreasing trends or no significant trend on each reef, summed over all survey reefs in each sector and expressed as a proportion. Arrowheads indicate direction of trend. For each sector, the left hand set shows the average trends over the past six years; right hand set shows current trends. Genera that were too rare to test have been omitted.

Reefs of the Great Barrier Reef: regional status and trends

Introduction

The AIMS Long-term Monitoring Program is designed to provide estimates of regional status of reefs, where the term "region" refers to a position on the continental shelf (inshore, mid-shelf, outer shelf) within a sector.

This section of the report considers status in terms of mean abundances or cover values for major groups of organisms, as well as the past and current trends in those values. These are presented sector by sector from north to south. Mean values for regions are given in Appendices E and F. Similar information about each survey reef is available on the AIMS website.

Analyses and their interpretation have been described in Section 2 and are given in detail in Appendix I.

Several facts need to be born in mind when reading the regional summaries:

1. The summaries draw on the three components of the LTMP and these differ in the areas of the individual reefs that are sampled and in the length of the time since surveys were started:
   - Fishes and benthic organisms have been sampled on permanent sites on the NE faces of all the core sample reefs since 1995. Earlier surveys did not include all core reefs in each year.
   - The entire perimeters of most of the core reefs and of a large number of additional reefs have been surveyed using manta tows at varying intervals since the mid-1980s. Manta tows provide information on coral cover and population densities of crown-of-thorns starfish, *Acanthaster planci,* (COTS).
2. The statistical model (Appendix I) requires a sequence of observations from several reefs in each region; this condition was not always fulfilled. Some reefs that have been surveyed were not included because they have not been sampled frequently enough to allow trends to be estimated. Similarly, some regions have been omitted because too few reefs within them had been surveyed adequately. The reefs that were included in the analyses are indicated in Appendix B, with a few exceptions that are mentioned in the text.
3. Estimates of the magnitude of changes that would have been detected - the statistical power of the tests - are given in Appendix I.
4. Percent cover refers to the absolute value: the percent of the total substrate that is covered by a certain taxon.

Explanation of the sector status pages

This section of the report summarises data on each latitudinal sector and, within these sectors, each region (inshore, mid-shelf and outer shelf) that was surveyed in the 2000 field season. All sectors have information concerning reef-wide hard coral cover and crown-of-thorns starfish populations collected by manta tow from at least one region. Core sectors also have fish abundance and benthic cover information collected from fixed transects on core survey reefs in each region.

The symbols on the first page (sectors surveyed by manta tow only) or first page spread (core sectors) for each sector summarise the regional trends for the variables over the past six years. For interpretation, the steepness and direction of slope of the line to the left of the vertical tick mark indicates the strength and direction (respectively) of the **average trend** on reefs in a region over the past six years. The line to the right of the vertical tick mark represents the strength and direction of the **current trend** at the 2000 survey, based on the past six years. Marginally significant trends ($0.1 > p > 0.01$) are indicated by broken lines. When neither the average trend nor the current trend was even marginally significant, the cell was left blank. A star (★) indicates that the data were insufficient to detect a trend with any certainty.

Roman numerals identify summaries of **trends** in the following variables:

(i) Reef-wide hard coral cover and crown-of-thorns starfish populations collected via manta tow surveys.

(ii) Benthic cover of the main groups of benthic organisms, principal families of hard corals and three groups within the family Acroporidae.

(iii) Fish abundances (mean number per site) of eight families of larger, more mobile species and of eight genera of site-attached damselfishes.

(iv) Fish species richness for selected taxa based on numbers of species per reef.

The plots on subsequent pages show the **distribution** of the variables described below and the fitted trend line for each region . In each case, all of the available time-series for each region is shown, while the trend line is only fitted to the past six years. Plots, identified by letters, summarise the following variables:

A Reef-wide hard coral cover and crown-of-thorns starfish populations collected by manta tow surveys.

B Percent cover of the main groups of benthic organisms.

C Percent cover of the principal families of hard corals.

D Percent cover of three groups within the family Acroporidae.

E, F Abundances of fish belonging to eight families of larger, more mobile species (mean number per site).

G, H Abundances of fish belonging to eight genera of site-attached damselfishes (mean number per site).

The legends for plots of means and fitted trend lines include information on the significance and direction of the trends. Where the six-year average or the current trend is significant,

this is coded in symbols beside the variable names in the figure legends. The symbol before the slash mark (/) gives the direction of the average trend over the past six years; the symbol after the slash mark gives the current trend. A plus sign (+) indicates a significant increasing trend, a minus sign (-) indicates a significant decreasing trend and a dot (.) indicates no significant trend. Thus "+/." would indicate that the abundance or cover has increased significantly over the past six years but there is currently no significant trend. "-/-" would indicate that the abundance or cover has decreased significantly over the past six years and is currently decreasing.

Summaries by sector and region

Cape Grenville

No reefs in the Cape Grenville sector were surveyed in 2000.

Princess Charlotte Bay Sector

This sector was last surveyed in October 1999.

Summary

The limited information from this sector does not reveal any notable changes in coral cover or significant populations of COTS in 2000 or the preceding 6 years.

Geography

The outer reefs in this sector form a substantial wall against the influences of the Coral Sea. The mid-shelf reefs are very large.

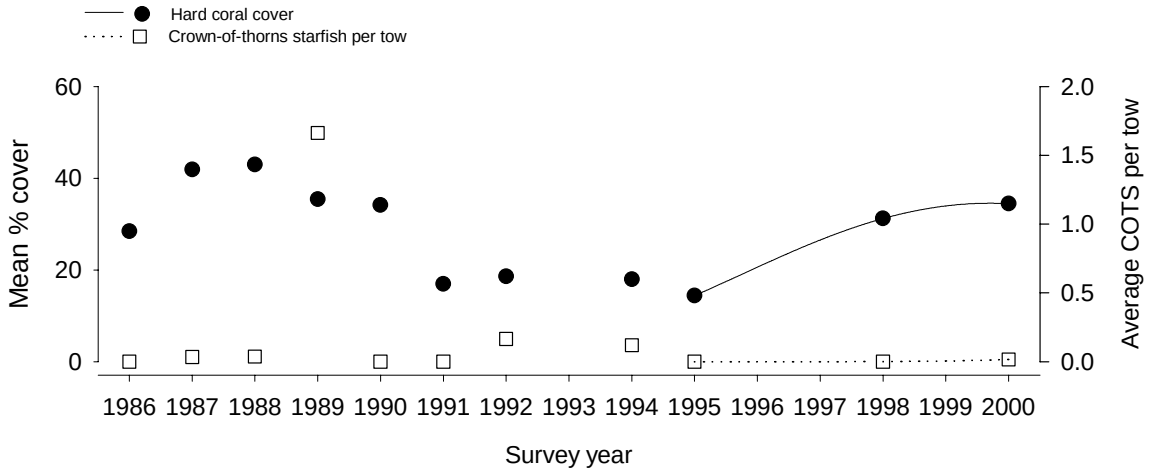
Figure 4.1(i) Summary of trends in reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the Sector.

	Inner	Mid	Outer
Crown-of-thorns starfish	*	*	
Hard Coral	*	*	

Princess Charlotte Bay Sector Inshore Reefs

Too few reefs have been surveyed in recent years to estimate trends for the region reliably. This year only one inshore shelf reef was manta tow surveyed and an increase in coral cover was detected. In previous surveys a low level of COTS activity has been recorded within the region. An exception occurred in 1989 when a COTS outbreak on Clack Reef resulted in a dramatic increase in COTS totals for this region. A decline in coral cover between 1990 and 1991 was most likely due to the effect of Cyclone Ivor which passed through the region in March 1990. Reef-wide coral cover remained low between 1991 and 1995 before steadily recovering from 1995 to the moderate levels (35%) recorded in 2000. Bleaching was recorded in this region but at insufficient levels to impact on overall coral cover.

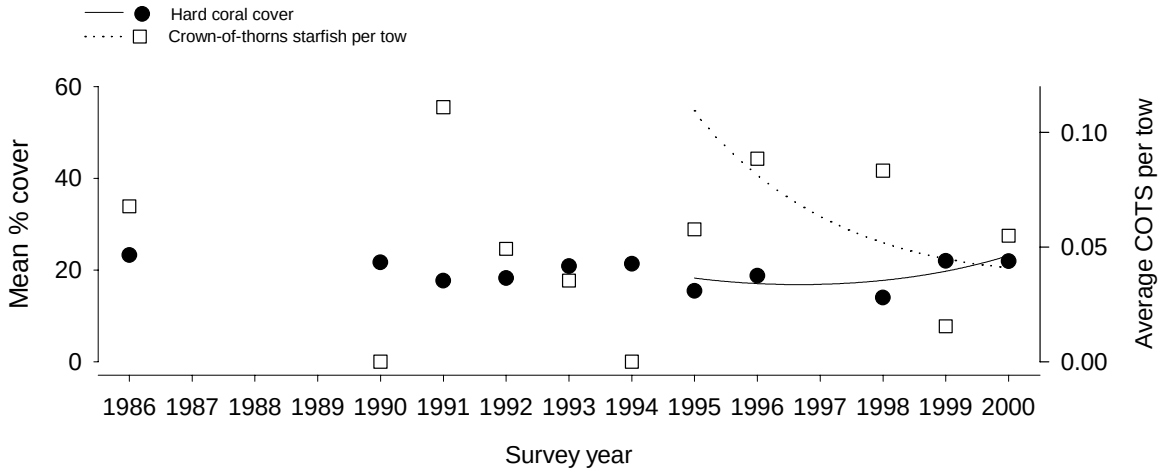
Figure 4.2(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.



Princess Charlotte Bay Sector Mid-Shelf Reefs

Two mid-shelf reefs were surveyed by manta tow in 2000. Mean coral cover has remained moderate at 22%. COTS have been recorded consistently on these reefs in past surveys but too few reefs have been surveyed in recent years to estimate trends for the region reliably. The abundance of 0.055 COTS per tow is considered well below outbreak levels and too low to have an overall effect on reef-wide coral cover. Bleaching was recorded in this region but also at levels too low to impact on overall coral cover.

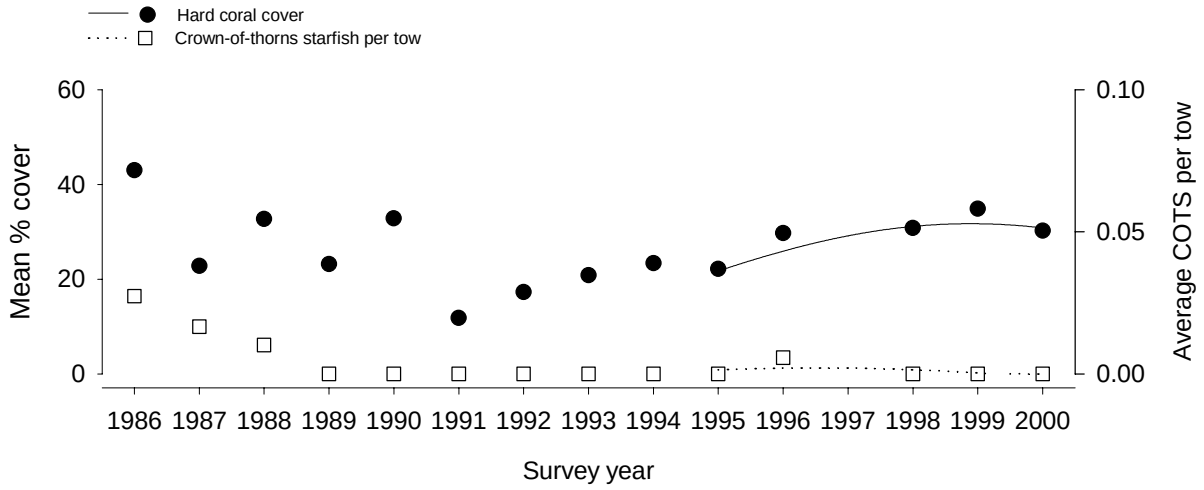
Figure 4.3(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.



Princess Charlotte Bay Sector Outer Shelf Reefs

In 2000 three outer shelf reefs were surveyed by manta tow. Overall reef-wide coral cover was moderate (30%). There has been a consistent trend of increasing coral cover observed for the region since 1990 when coral cover was low following Cyclone Ivor. This trend is not significant over the past six years. No COTS were observed in 2000. Few COTS have been observed in this region since the late 1980s.

Figure 4.4(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.



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Cooktown / Lizard Island Sector

This sector was last surveyed in October 1999.

Summary

Surveys in 2000 showed that the COTS populations present on many inner-shelf and mid-shelf reefs through the mid to late 1990's have declined or disappeared. This recent episode of COTS activity has had little effect on the reef-wide coral cover on inner-shelf reefs. In contrast, coral cover on the mid-shelf reefs declined significantly. Slight current increases in coral cover indicated that these mid-shelf reefs were beginning to recover. The contrasting changes in coral cover on the inner-shelf and mid-shelf may be reflected in the reef fish assemblages: the few groups which changed significantly tended to increase on inshore reefs but decreased on the mid-shelf reefs. Coral communities on several of the outer shelf reef fronts were severely damaged by Cyclone Ivor in 1990. The increases in coral cover both reef-wide and in the intensive study sites reflect recovery from this disturbance. The increase in coral cover is mainly due to Acroporidae, in particular tabulate forms, in the front reef zone. The marked trends in the outer shelf fish assemblages reflect the response of fishes to the recovering coral habitat. The most marked trends over the last six years have seen the abundance of herbivorous surgeonfishes halved, while some genera of damselfishes more than tripled in abundance.

Geography

The offshore reefs in this sector form a wall and represent a substantial barrier to influences from the Coral Sea, both in terms of wave energy and exchange of water.

Figure 4.5(i) Summary of trends in reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the Sector.

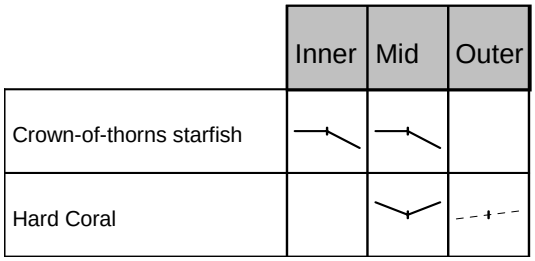


Figure 4.5(ii) Summary of trends in benthic cover on intensive survey sites in the Sector.

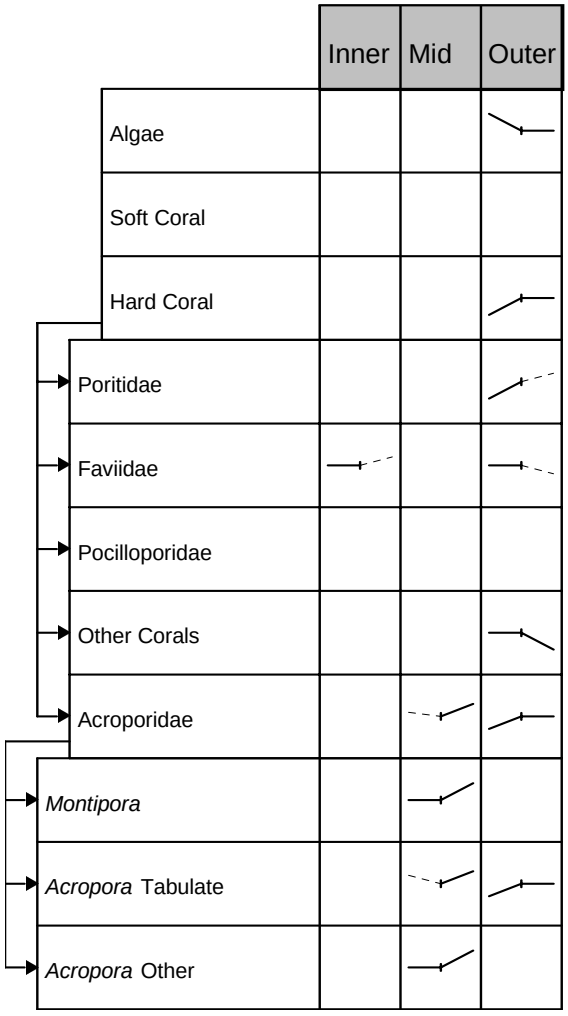


Figure 4.5(iii) Summary of trends in fish abundance in the Sector.

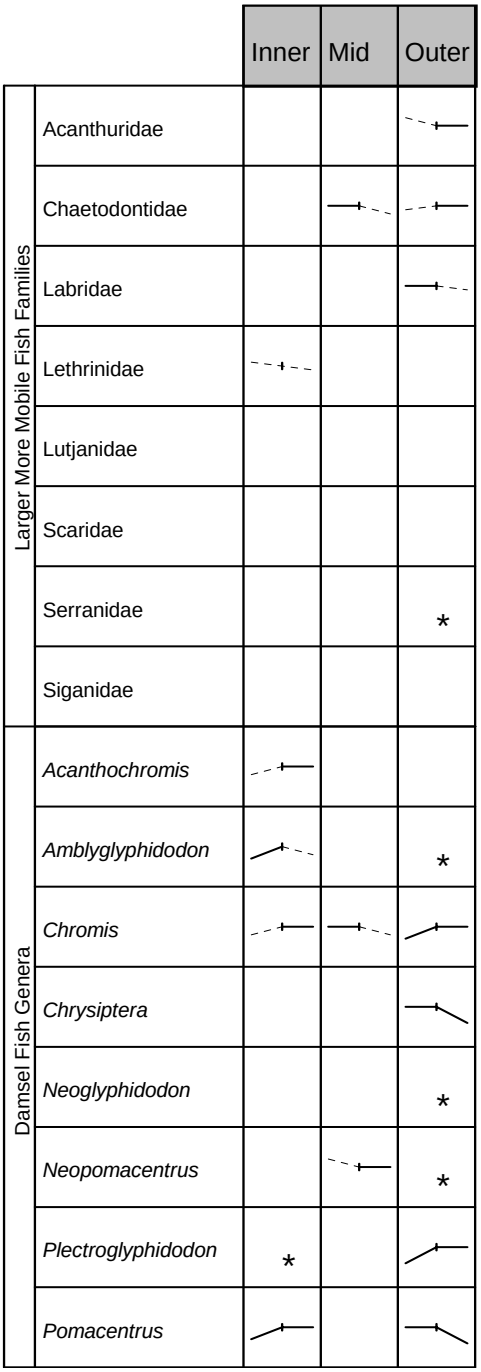
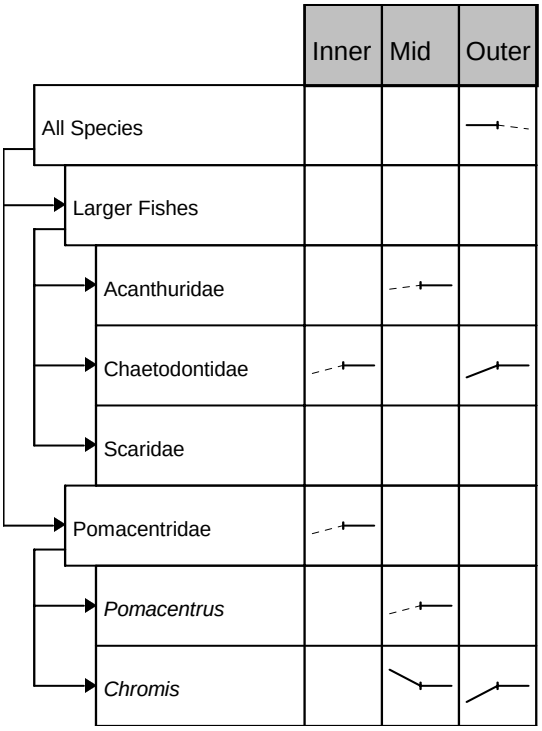


Figure 4.5(iv) Summary of trends in fish species richness in the Sector.



Cooktown / Lizard Island Sector Inshore Reefs

COTS numbers have declined significantly from the peak recorded in 1998 (Fig. 4.5(i), Fig. 4.6A). COTS were recorded on only two of five inshore reefs surveyed in 2000 (Boulder and Martin). In both cases numbers were too low to cause significant reef-wide coral mortality. Two reefs (Boulder and Three Isles) were classified as Recovering from prior COTS activity, ending in 1999 and 1997 respectively. The other three reefs (Linnet, Martin and Turtle B) were classified as No Outbreak, although Martin and Linnet Reefs had Incipient Outbreaks in 1999. There has been no overall trend in reef-wide hard coral cover which has remained at moderate levels (20-30%) over the last six years (Fig. 4.5(i))

Cover of hard coral, soft coral and algae has remained relatively stable on intensive study sites (Fig. 4.5(ii), Fig. 4.6B). These major benthos groups averaged 30%, 4% and 44% respectively in the 2000 survey. There have been no major changes in the cover among any hard coral families (Fig. 4.5(ii)).

Within fish assemblages, most taxa showing trends had increased in abundance (Fig. 4.5(iii)). Numbers of large mobile fishes have remained stable since 1995, with the exception of the emperors (Lethrinidae), which continued to decline (Fig. 4.6F). This decline followed abnormally high counts of three emperor species recorded in 1997 and 1998. As abundances were low, the transitory presence of one large school can overly influence the mean values. This trend may not reflect actual population declines.

Numbers of a number of genera of damselfishes (Pomacentridae) increased over time (Fig. 4.5(iii)). A number of species contributed to trends in *Chromis* and *Pomacentrus* (Fig. 4.6G). Numbers of spiny Chromis (*Acanthochromis polyacanthus*) remained high (Fig. 4.6H); the numbers at Linnet Reef were the highest recorded on any survey reef on the GBR in 2000. The decline in abundance of the genus *Amblyglyphidodon*, influenced mostly by the staghorn damsel (*A. curacao*), was minimal and numbers remained high in 2000 (Fig. 4.6H).

Species richness of reef fishes has been stable (Fig. 4.5(iv). A slight increase for the butterflyfishes (Chaetodontidae) is difficult to interpret as species richness has a range of only 12 to 14 over the past six years. The increase noted for damselfish showed an increase from 27 species in 1995 to 34 in 2000 and reflects the more regular inclusion of rare species through time, rather than the appearance of new species.

Figure 4.6(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.

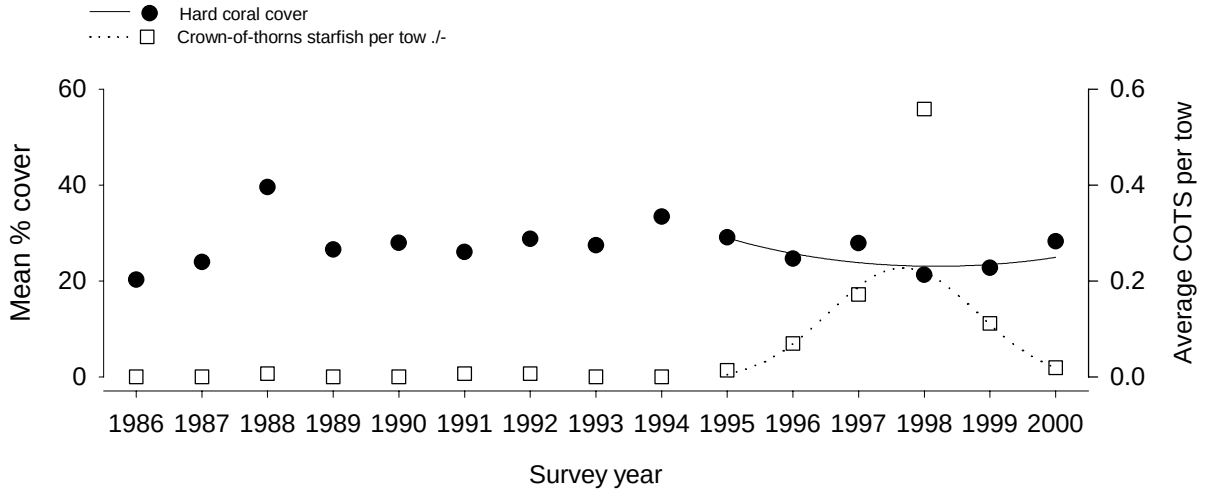
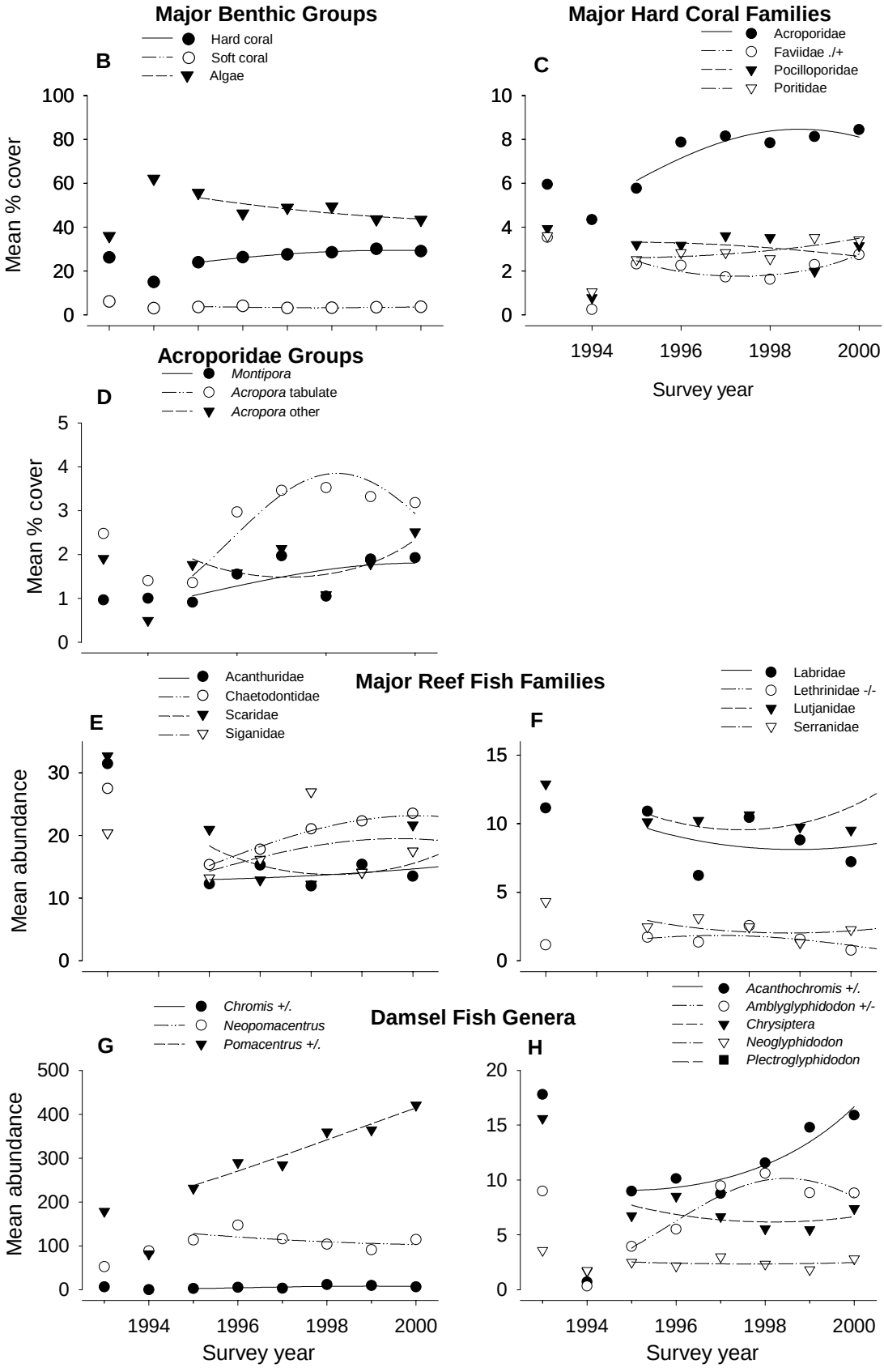


Figure 4.6 cont. Plots showing distribution of regional means and the fitted trend lines for: (B,C,D) percent cover of benthic groups on fixed sites, (E,F,G,H) fish abundance on fixed sites.



Cooktown / Lizard Island Sector Mid-Shelf Reefs

COTS populations peaked at an average 0.36 COTS / tow in 1997 and numbers have declined steadily since (Fig. 4.5(i), Fig. 4.7A). In 2000, COTS were observed on five of the nine mid-shelf reefs. In each case, numbers were well below levels that would cause significant reef-wide coral mortality. No reefs were classified as having Active Outbreaks in 2000. Four reefs (Forrester, Lizard Island, MacGillivray and North Direction Island) were classified as Recovering from previous COTS activity, while the remainder had No Outbreaks.The effects of COTS activity is reflected in changes in reef-wide coral cover which has declined significantly over the six years from 1995 (Fig. 4.5(i), Fig. 4.7A). Results form the 2000 survey indicated an overall recovery in reef-wide coral cover on reefs in the region to a moderate level (18.9%) in the absence of large scale COTS feeding activity.

Intensive surveys found that the cover of hard coral, soft coral and algae have not changed significantly during the past six years (Fig. 4.5(ii)). Algae are the dominant benthic group covering 59% of the substratum while cover of hard corals and soft corals are low, averaging 16% and 7% respectively in 2000 (Fig. 4.7B). While Poritidae are the dominant family of hard coral (average 7%) the Acroporidae were the only hard coral family which showed a statistically significant trend in cover, having decreased from 3% in 1993 to just 0.2% in 1999 (corresponding to elevated COTS numbers) before a slight recovery in 2000 (Fig. 4.7C).

In contrast to 1999, when ten of the 18 reef fish taxa showed declining trends, abundance of fish taxa tended to stabilise in 2000 with only three taxa declining (Fig. 4.5(iii)). A number of species of butterflyfishes (Chaetodontidae) declined in abundance (Fig. 4.7E). Numbers of two species in particular, the redfin butterflyfish (*Chaetodon trifasciatus*) and Klein's butterflyfish (*C. kleinii*), have decreased dramatically since 1996. Numbers of the damselfish genus *Chromis* were decreasing in 2000 (Fig. 4.7G), however this followed inclusion of unusually large school of Weber's chromis (*C. weberi*) at Lizard Island in 1998. The general decline in the genus *Neopomacentrus*, particularly the yellowtail demoiselle (*Neopomacentrus azysron*) has stabilised (Fig. 4.7G).

Species richness of reef fishes has been relatively stable (Fig. 4.5(iv)). There have been slight general increases in both the surgeonfishes (Acanthuridae) and the damselfish genus *Pomacentrus* (Fig. 4.5(iv), ranging from 9 to 13 species and 9 to 11 species respectively over six years. Species richness of the damselfish genus *Chromis* has declined: three of the nine species commonly encountered prior to 1997 were absent in later surveys.

Figure 4.7(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.

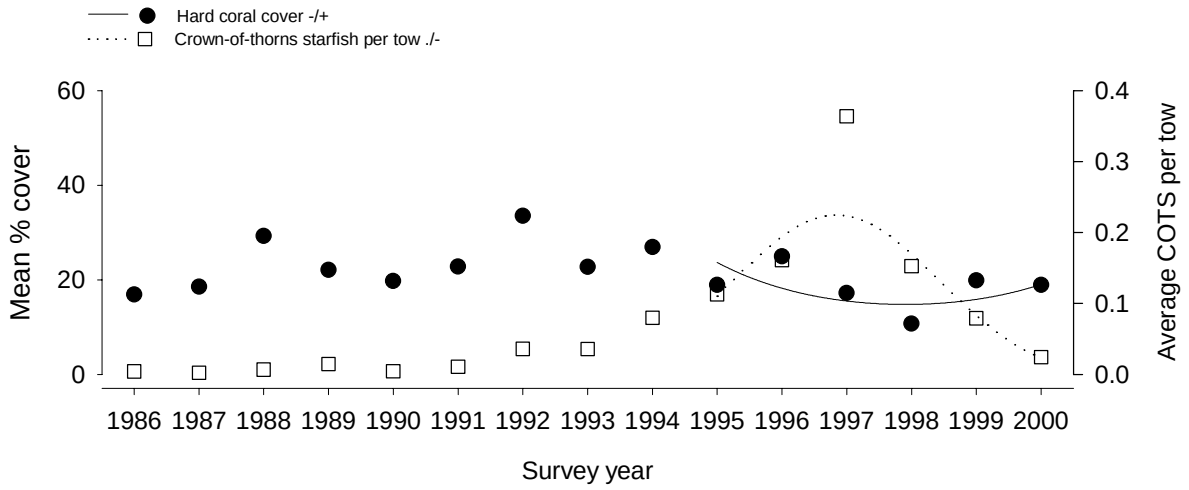
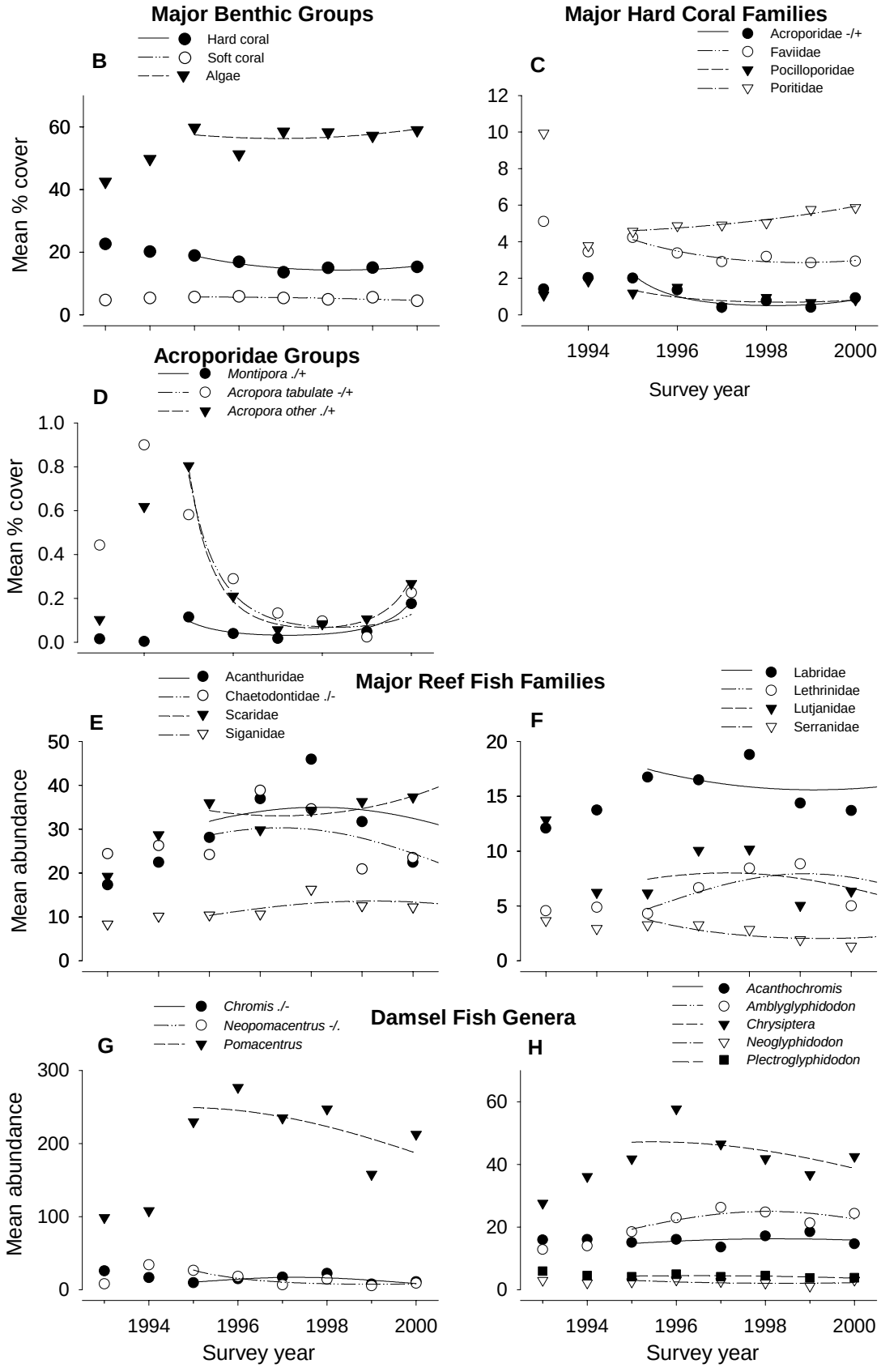


Figure 4.7 cont. Plots showing distribution of regional means and the fitted trend lines for: (B,C,D) percent cover of benthic groups on fixed sites, (E,F,G,H) fish abundance on fixed sites.



Cooktown / Lizard Island Sector Outer Shelf Reefs

Only a few COTS have been observed in this region since surveys began in 1986 and none was observed on the seven reefs surveyed in 2000 (Fig. 4.8A). Reef-wide coral cover had increased over the past six years to high value (31.9%, Fig. 4.5(i), Fig. 4.8A).

Cover of hard corals increased rapidly in intensive survey sites, from 12% in 1993 to 56% in 2000 (Fig. 4.5(ii), Fig. 4.8B). Much of the increase in hard corals has been due to rapid growth of tabulate *Acropora* spp. These corals were virtually absent in 1993 but accounted for over half of the hard coral cover in 1999 (average 31%, Fig. 4.8D). There has been a general increase in cover of Poritidae (Fig. 4.5(ii)), but cover still averaged less than 3% in 2000 (Fig. 4.8C). The cover of algae showed the complementary pattern, falling to around 34% in 2000 (Fig 4.5(ii), Fig. 4.8B). Cover of soft corals did not change significantly in the preceding six years (average 6%).

Trends in abundance of reef fishes have varied considerably among taxa over a period in which hard coral cover has dramatically increased and cover of algae has declined (Fig. 4.5(iii), Fig. 4.8E-H). Some of the changes appear related to these habitat changes: surgeonfishes (Acanthuridae) have declined in abundance since surveys began, although in 2000 numbers showed no trend (Fig. 4.8E). Much of the decline in total surgeonfish numbers is due to the algal feeding brown surgeonfish (*Acanthurus nigrofuscus*) and bristletooth species (*ctenochaetus* spp.), which feed on detritus trapped in turf algae. The opposite trend for increasing abundance in the butterflyfishes (Chaetodontidae) (Fig.4.8E) predominantly reflect an increase in the chevroned butterflyfish (*Chaetodon trifascialis*), an obligate coralivore, usually associated with tabulate *Acropora* corals. Declines since 1998 in numbers of wrasse (Labridae) (Fig. 4.8F) are due to the slingjaw (*Epibulus insidiator*) and the barred thicklip (*Hemigymnus fasciatus*). The decreases in abundance of the damselfish genera, *Chrysiptera* and *Pomacentrus* in 2000 follow high counts of single species (Fig. 4.8G, H): the king demoiselle (*C. rex*) and the scaly damsel (*P. lepidogenys*) in 1998. The genus *Chromis* showed no trend after a general increase due to a number of species (Fig. 4.8G). The genus *Plectroglyphidodon* showed no trend (Fig. 4.8H) after large increases in abundance of two species: Johnston's damsel (*P. johnstonianus*) and Dick's damsel (*P. dickii*), both of which live among hard corals. Interestingly the jewel damsel (*P. lacrymatus*), which farms and feeds exclusively on algal turf, has not increased in abundance.

Overall species richness of reef fishes initially tracked the increasing coral cover with numbers of species increasing steadily from 1995 to 1998. This trend reversed with species richness in 2000 at 95 compared to the high of 105 in 1998. This decline was not confined to any one taxon, rare species from a number of families and genera were not present in later surveys. This was not true for the butterflyfishes (Chaetodontidae) and *Chromis*, both of which showed a general increase in species richness over the last six years (Fig. 4.5(iv). The increase in butterflyfish species reflected the increase in abundance of the family. Species richness *Chromis* spp. has been relatively stable from 1997 to 2000, with surveys in 1995-96 omitting two or three rare species.

Figure 4.8(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.

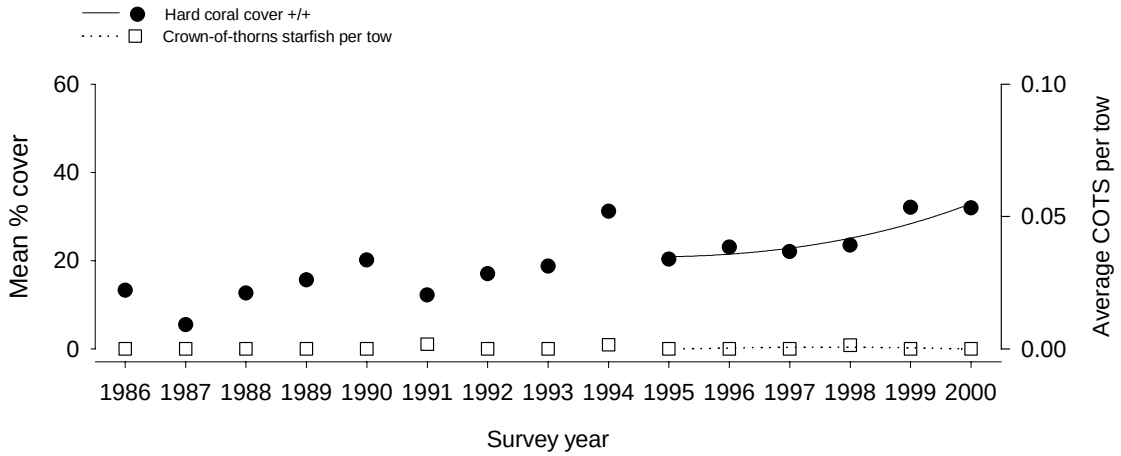
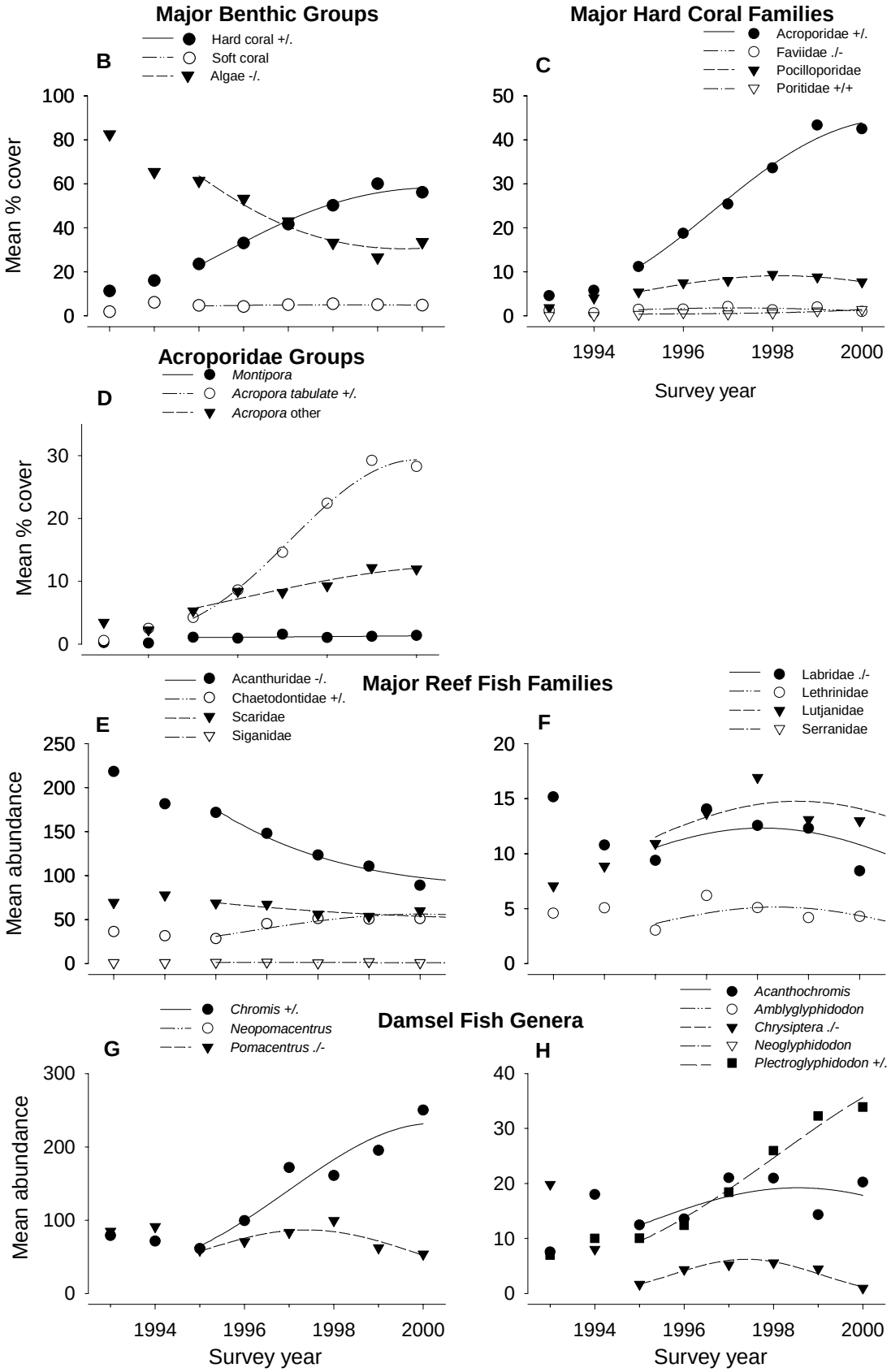


Figure 4.8 cont. Plots showing distribution of regional means and the fitted trend lines for: (B,C,D) percent cover of benthic groups on fixed sites, (E,F,G,H) fish abundance on fixed sites.



Cairns Sector

This sector was last surveyed in February 2000.

Summary

The abundance of COTS has increased steadily throughout this sector. Cover of hard corals has decreased on inshore reefs due to the combined effects of coral bleaching and COTS. Declines in cover of hard coral (mainly Acropora spp.) on intensive survey sites on mid-and outer shelf reefs can be attributed to increasing numbers of COTS. Trends in fish abundance vary both among reefs and taxa. Increases in some herbivorous fish (Siganidae and Pomacentridae) on inshore reefs may be related to increases in cover of turfing algae, while the abundance of surgeonfishes (Acanthuridae) has declined on outer shelf reefs.

Geography

Unlike the Cooktown / Lizard Is. sector to the north, the outer reefs of this sector form less of a barrier, so mid-shelf reefs are likely to be exposed to more wave action and to more oceanic water from the Coral Sea. The coastal hinterland falls within the Wet Tropics and several large rivers drain into this sector.

Figure 4.9(i) Summary of trends in reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the Sector.

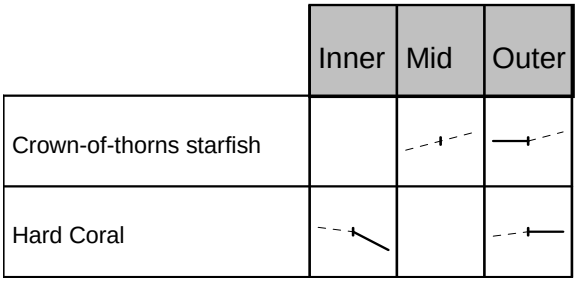


Figure 4.9(ii) Summary of trends in benthic cover on intensive survey sites in the Sector.

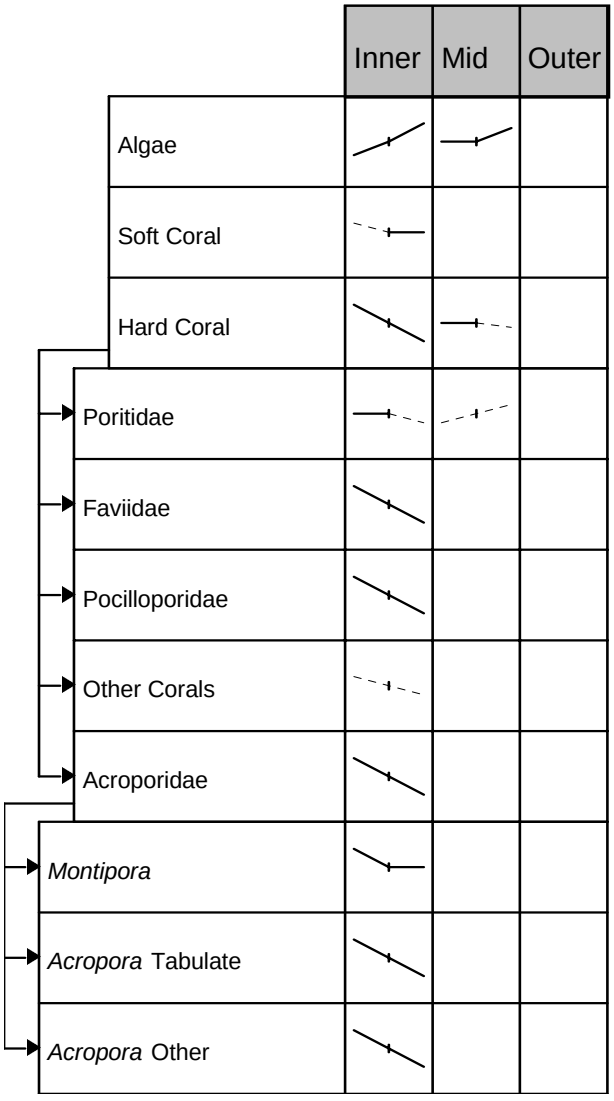


Figure 4.9(iii) Summary of trends in fish abundance in the Sector.

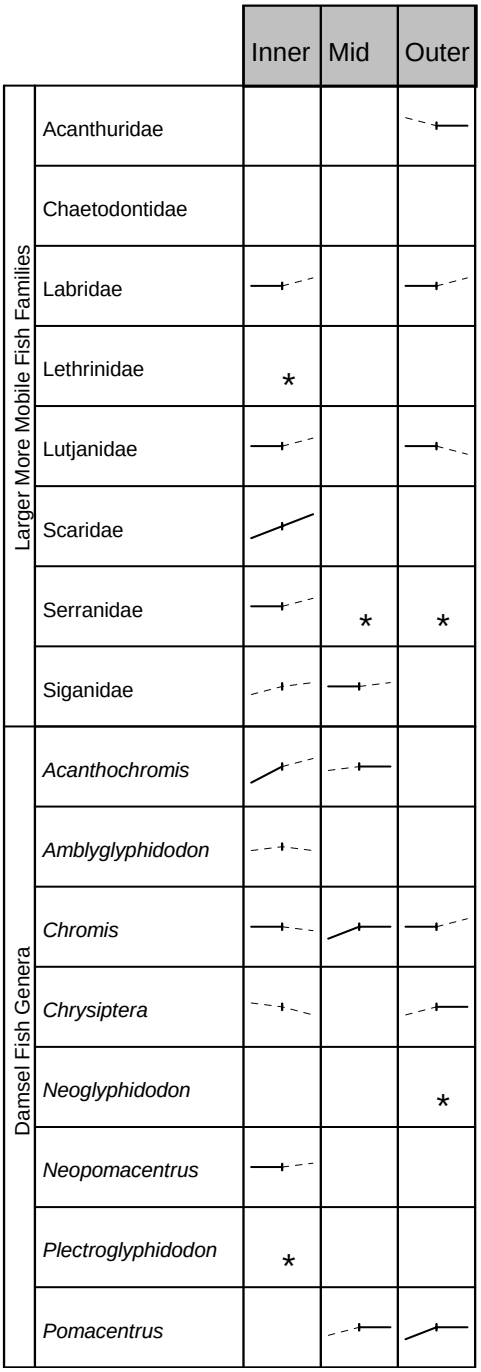
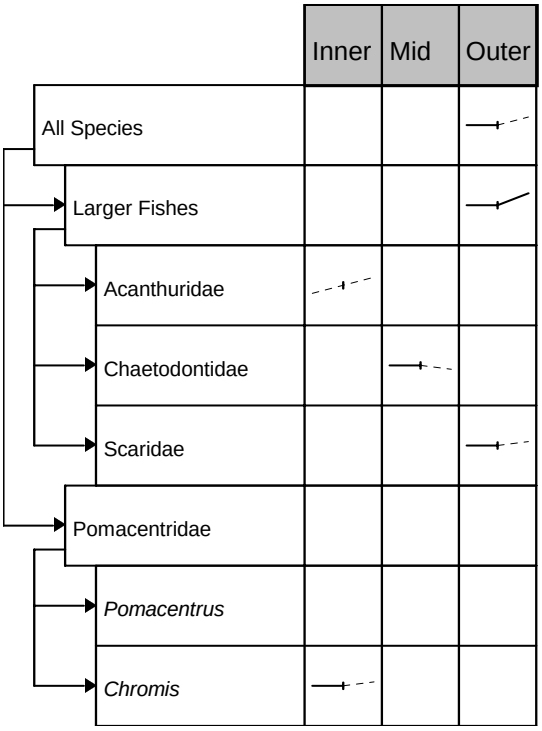


Figure 4.9(iv) Summary of trends in fish species richness in the Sector.



Cairns Sector Inshore Reefs

Due to poor visibility, reef-wide coral cover could only be surveyed at Low Isles in 2000, so regional trends in reef-wide coral cover and COTS could not be estimated. SCUBA searches revealed an Active Outbreak of COTS at Fitzroy Island. While no COTS were observed at Low Isles, reef-wide coral cover had decreased to the lowest level in 11 years of survey. This decline is likely to have been caused by a combination of COTS, coral bleaching and Cyclone Rona.

Cover of hard coral decreased in all intensive survey sites (Fig. 4.9(ii), Fig. 4.10B)) reaching very low levels. Average cover of hard coral ranged from 4% at Green Island to 8% at Low Isles, the lowest average cover of any region. All major families of hard coral declined. Cover of soft corals declined slightly on two of the three survey reefs. Cover of algae increased on all reefs, averaging approximately 70% in 2000 (Fig. 4.10B).

Increased cover of turfing algae may be reflected in the numbers of herbivorous parrotfishes (Scaridae) and rabbitfishes (Siganidae) (Fig. 4.9(iii), Fig.4.10E,F). The increase in *Acanthochromis* between 1998 and 1999 (Fig. 4.10H) could not be explained by changes in habitat. Of the current trends (Fig. 4.9(iii)), decreases in *Chrysiptera* (specifically Rolland's demoiselle, *C. rollandi*) and *Chromis* resulted in the lowest abundance observed (Fig. 4.10G,H). The increase in abundances of snappers (Lutjanidae) (Fig. 4.10F) was caused by increases in several species. Other current trends could simply be variation within the natural range.

Reef fish species richness has remained stable (Fig. 4.9(iv)) with indicated trends in surgeonfish (Acanthuridae) and *Chromis* resulting from sporadic inclusion of a few rare species.

Figure 4.10(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.

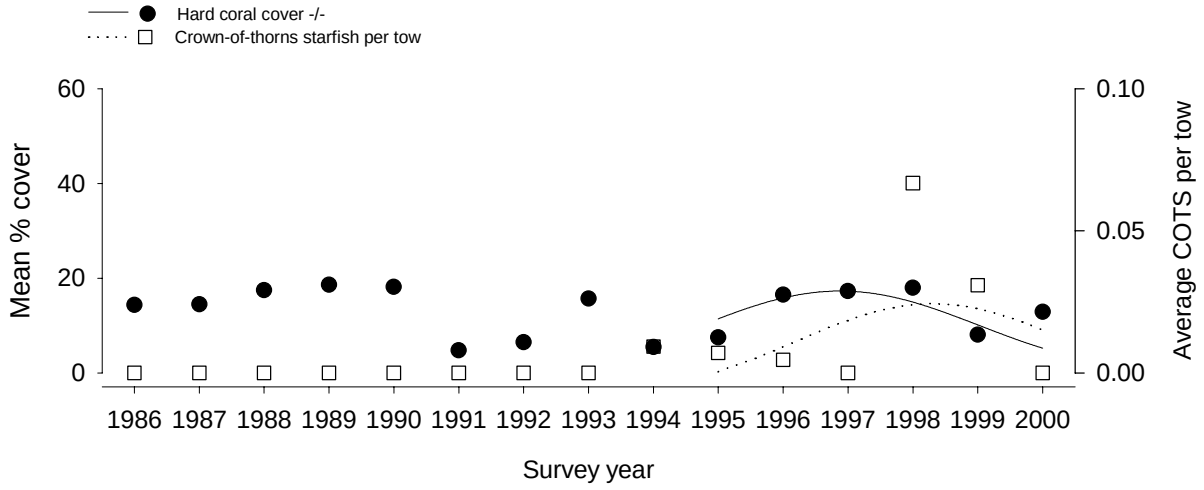
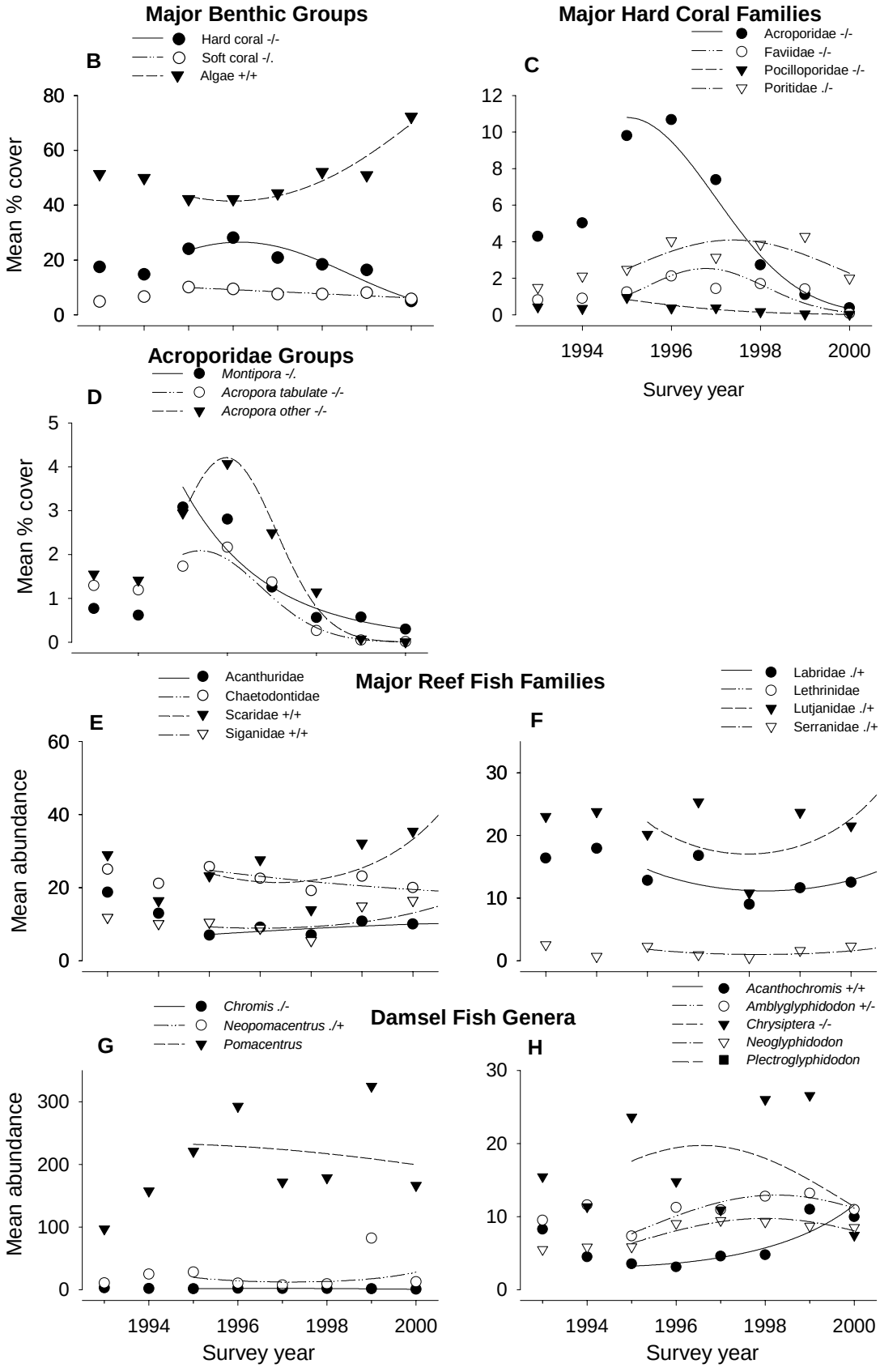


Figure 4.10 cont. Plots showing distribution of regional means and the fitted trend lines for: (B,C,D) percent cover of benthic groups on fixed sites, (E,F,G,H) fish abundance on fixed sites.



Cairns Sector Mid-Shelf Reefs

Numbers of COTS increased over the past six years and the trend continued in 2000 (Fig. 4.9(i), Fig. 4.11A). COTS were observed on seven of the eight survey reefs, with Reef 16-017 and Middle Cay B having Active Outbreaks and Hastings and Thetford having Incipient Outbreaks. Overall, COTS numbers were slightly below outbreak levels (Fig. 4.11A). While average reef-wide coral cover remained moderate (10-20%) over the past six years, the increased densities of COTS in 2000 indicate that coral cover will decline.

The benthic communities in intensive survey sites on three reefs (Hastings, Michaelmas and Thetford) were dominated by soft corals and hard corals in the family Acroporidae (Fig 4.11B,C). The dynamics of hard corals on these reefs follow COTS activity. Cover of Acroporidae generally increased between 1993 and 1999, then declined. This decline coincided with a sharp increase in numbers of COTS in the region (Fig. 4.11A). Cover of algae showed a positive trend after a slight decline from 1995 to 1999 (Fig. 4.9(ii), Fig. 4.11B) and averaged approximately 55% in 2000. Cover of soft coral has remained stable over the past six years (Fig. 4.9(ii), Fig 4.11B).

Reef fish populations have been relatively stable in this region. Abundance of the damselfish genus *Pomacentrus* increased over the past six years (Fig. 4.9(iii), Fig. 4.11G) due to the scaly damsel (*P. lepidogenys*). Increases in rabbitfishes (Siganidae) and *Chromis* were due to relatively large increases in abundance of several species in 1999 (Fig. 4.9(iii), Fig. 4.11E,G,H).

Reef fish species richness was generally stable over the past six years (Fig. 4.9(iv)).

Figure 4.11(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.

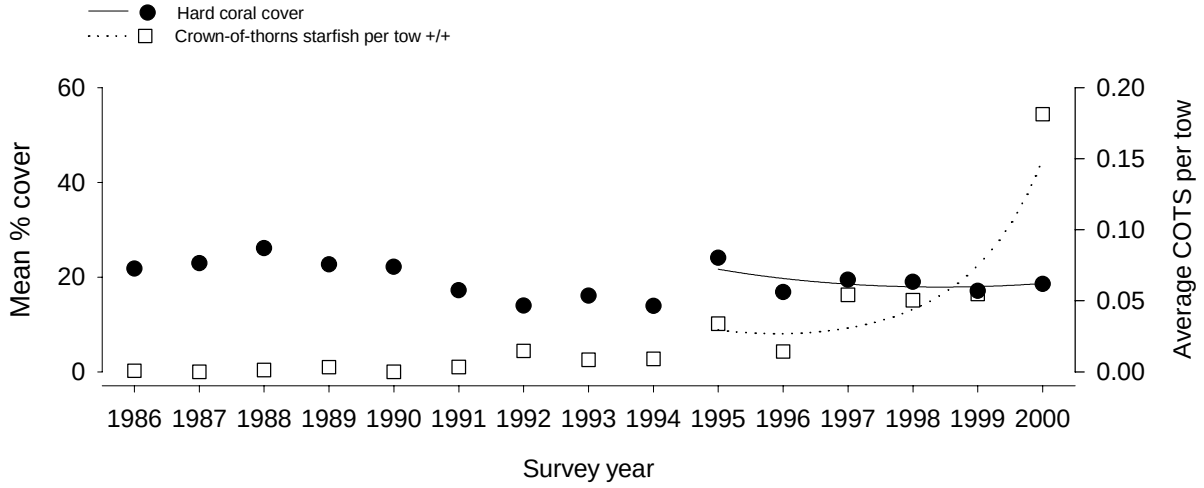
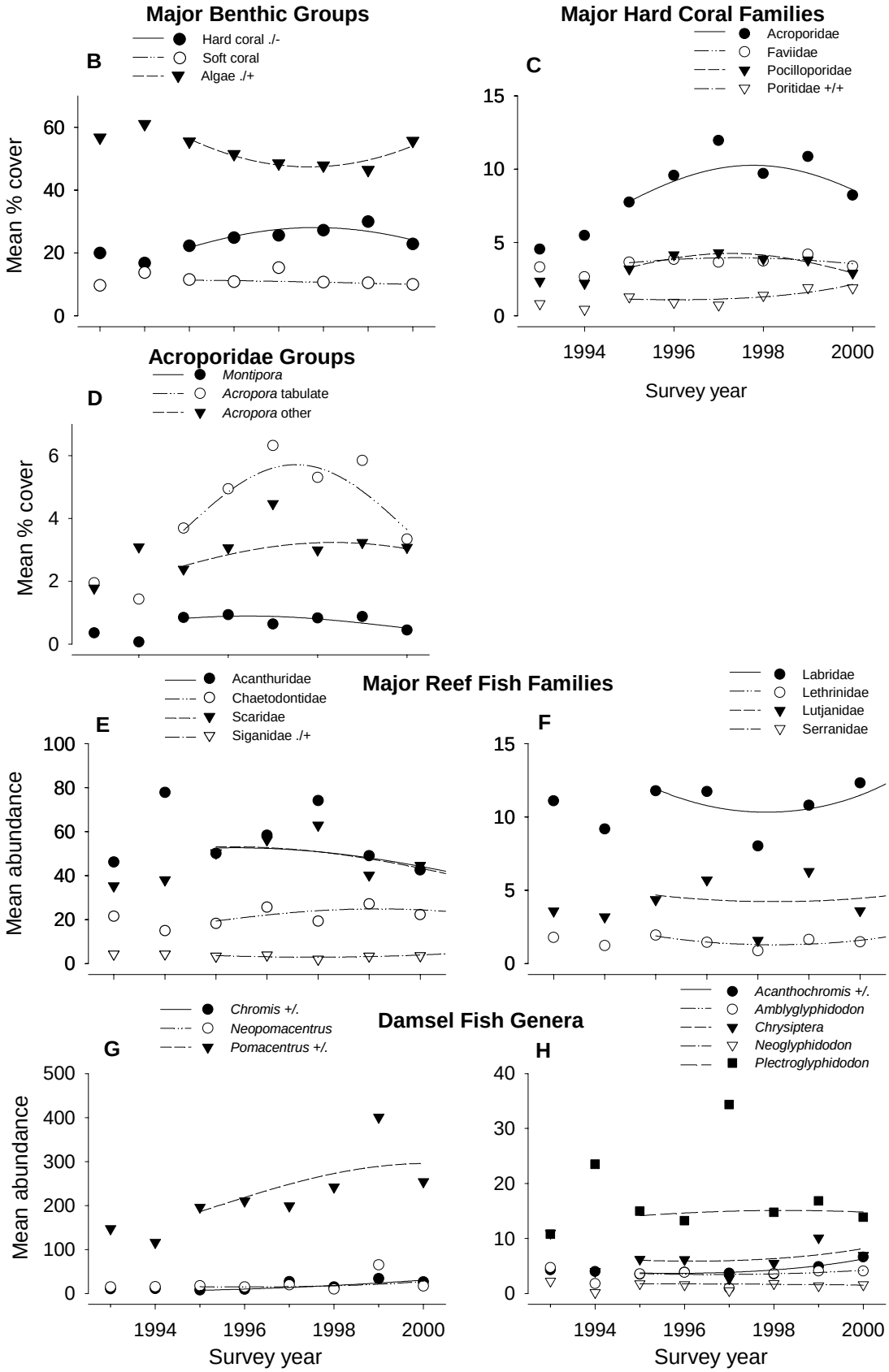


Figure 4.11 cont. Plots showing distribution of regional means and the fitted trend lines for: (B,C,D) percent cover of benthic groups on fixed sites, (E,F,G,H) fish abundance on fixed sites.



Cairns Sector Outer Shelf Reefs

Cots activity increased in 2000, with populations at Opal Reef (Active Outbreak) and Agincourt #3 Reef (Incipient Outbreak) (Fig. 4.9(i), Fig. 4.12A). No impact on reef-wide coral cover was evident yet. Cover of hard corals increased over the past six years to moderate levels (27%, Fig. 4.9(i), Fig.4.12A).

Trends in cover of hard coral on intensive survey sites varied among reefs and differences in dynamics can largely be attributed to variation in COTS feeding activity within this region. Benthic assemblages on reef fronts in this region are dominated by soft corals in the family Xeniidae and hard corals in the family Acroporidae. Cover of hard coral increased at Agincourt Reef (where no COTS were detected) and remained stable on St Crispin and Opal where COTS were present. Cover of soft corals and algae remained stable, maintaining an average cover of 31% and 38% respectively in 2000 (Fig. 4.9(ii), Fig. 4.12B). Cover of soft corals on Opal Reef has been decreasing since surveys began in 1994; the cause is unclear. Although declining, cover of soft corals was relatively high on this reef, averaging 30% in 2000.

The majority of larger reef fish families in the region did not show strong trends in abundance (Fig. 4.9(iii)). The recent increase in wrasses (Labridae) was within the bounds of previous interannual change. The decrease in snappers (Lutjanidae) (Fig. 4.12F) was due to changes in counts of paddletail, *Lutjanus gibbus* which occurs in schools. An exception was the long term decline in the surgeonfishes (Acanthuridae, Fig. 4.9(iii), Fig.4.12E). The rate of decline is slowing because the abundance of bristletooths (Ctenocheatus spp.) changed little in the previous year, several other relatively common species of surgeonfish (*Acanthurus*) and tang (*Zebrasoma*) continued to decline. Damselfishes that showed trends all increased in abundance (Fig. 4.9(iii)). The genus *Chromis* showed a current increase (Fig. 4.12G) due to the recovery in numbers of the common black-axil chromis (*C. atripectoralis*) and bicolour chromis (*C. margaritifer*) which dropped in abundance in the mid 1990*S*. Abundance of several *Pomacentrus* spp. and the king demoiselle, *Chrysiptera rex* increased after the mid 1990s (Fig. 4.12G,H).

Species richness, primarily of the larger fishes, increased (Fig. 4.9(iv)), returning to former levels after a decline in the late 1990s.

Figure 4.12(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.

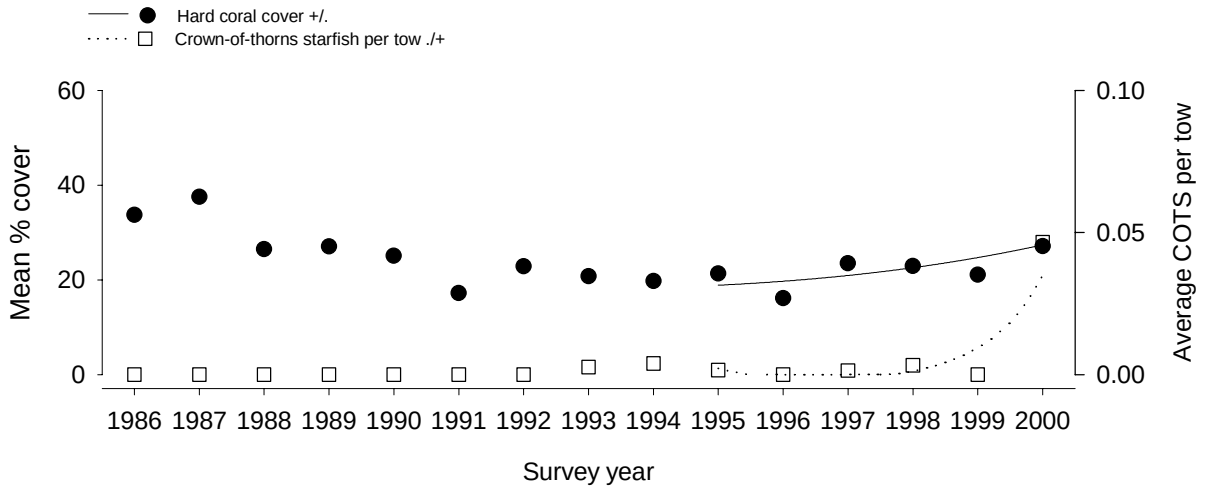
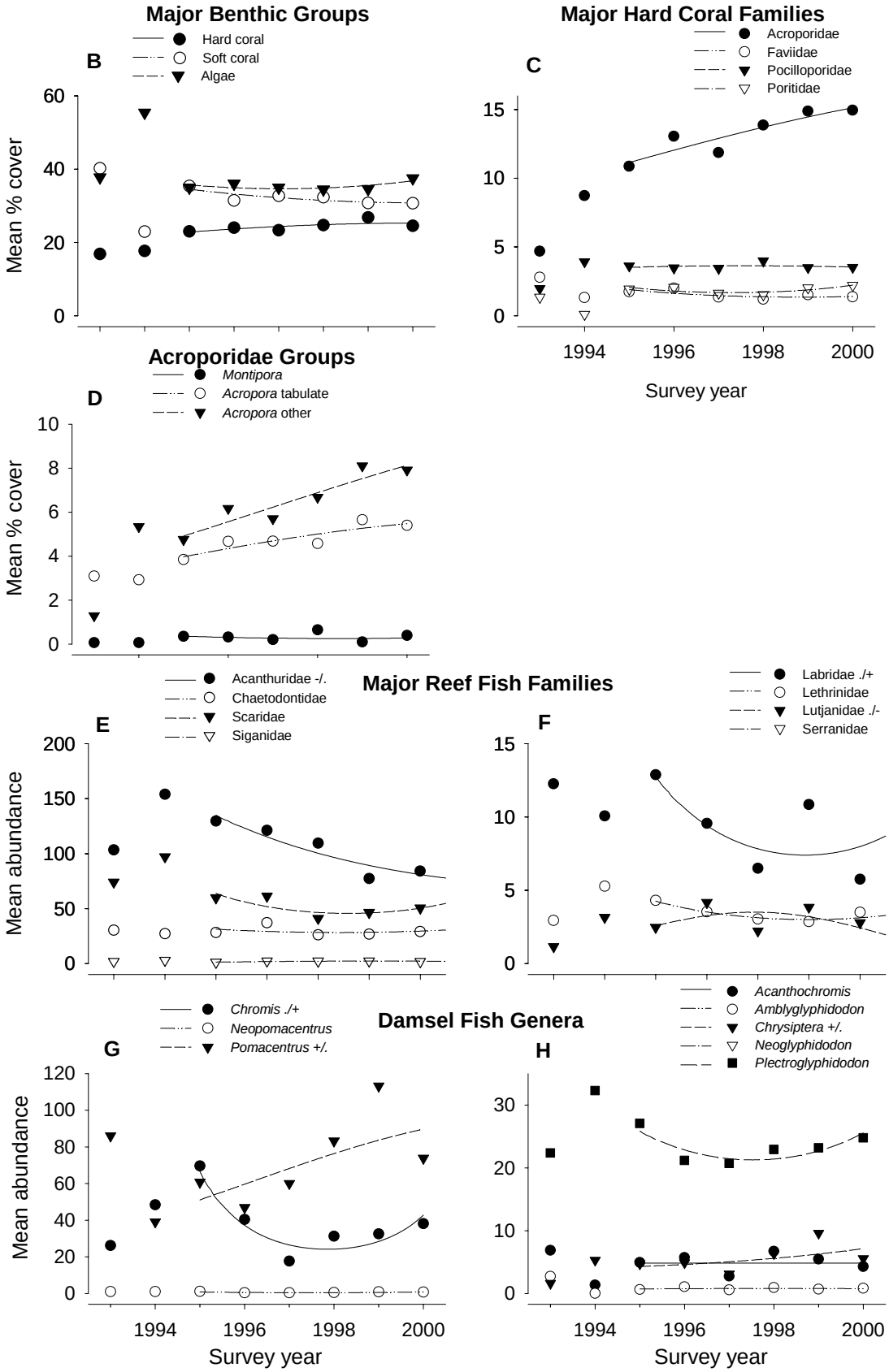


Figure 4.12 cont. Plots showing distribution of regional means and the fitted trend lines for: (B,C,D) percent cover of benthic groups on fixed sites, (E,F,G,H) fish abundance on fixed sites.



Innisfail Sector

This sector was last surveyed in June 2000.

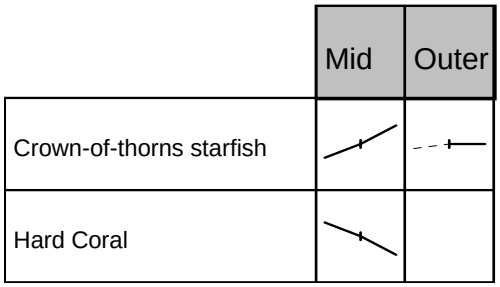
Summary

Because of the threat of increased COTS activity, twelve reefs were surveyed in 2000. COTS numbers increased significantly in this sector over the past six years. COTS numbers continued to increase significantly in 2000. Overall reef-wide coral decreased over the past six years and continued to do so in 2000. The majority of COTS were found on mid-shelf reefs, though one of the four outer shelf reefs surveyed had an Active Outbreak. Bad weather and poor visibility precluded regular sampling inshore in recent years, so the impact of COTS on these reefs is unknown.

Geography

This sector resembles the Cairns sector in that the outer-shelf reefs do not form an impermeable barrier to oceanic influences and the adjacent coast receives a lot of rainfall.

Figure 4.13(i) Summary of trends in reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the Sector.



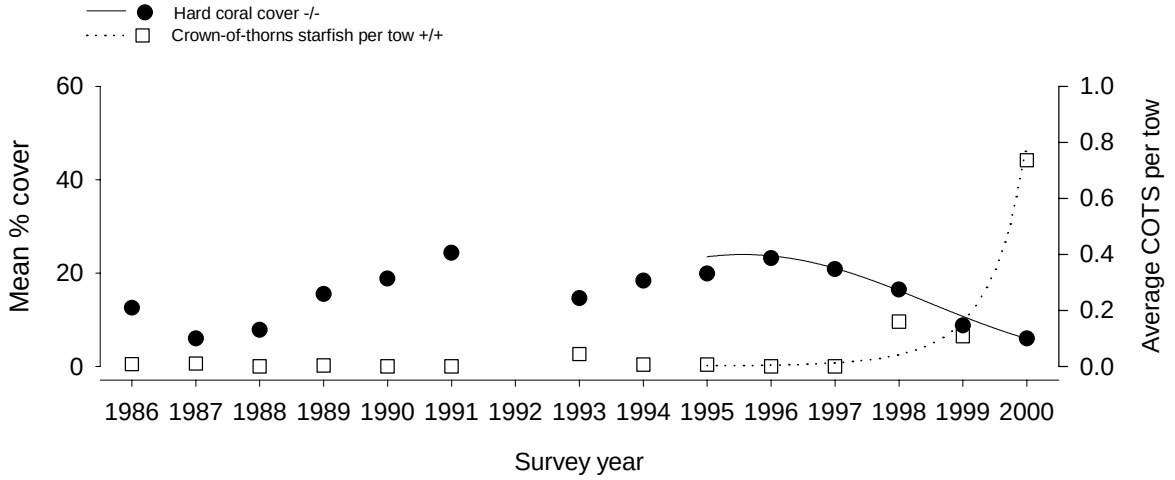
Innisfail Sector Inshore Reefs

No reefs were surveyed in this region in 2000.

Innisfail Sector Mid-Shelf Reefs

Eight reefs were surveyed in 2000; COTS were observed on all but two (Flora and Coates). Four (Beaver, Ellison, Feather, Taylor) were classified as Active Outbreak while two (Coates, Flora) are classified as Recovering from prior COTS activity. COTS densities had increased over the past six years and the trend continued (Fig. 4.13(i), Fig. 4.14A). Reef-wide coral cover decreased correspondingly over the past six years and continue to do so (Fig. 4.13(i)). Overall reef-wide coral cover was low at about 6% (Fig. 4.14A).

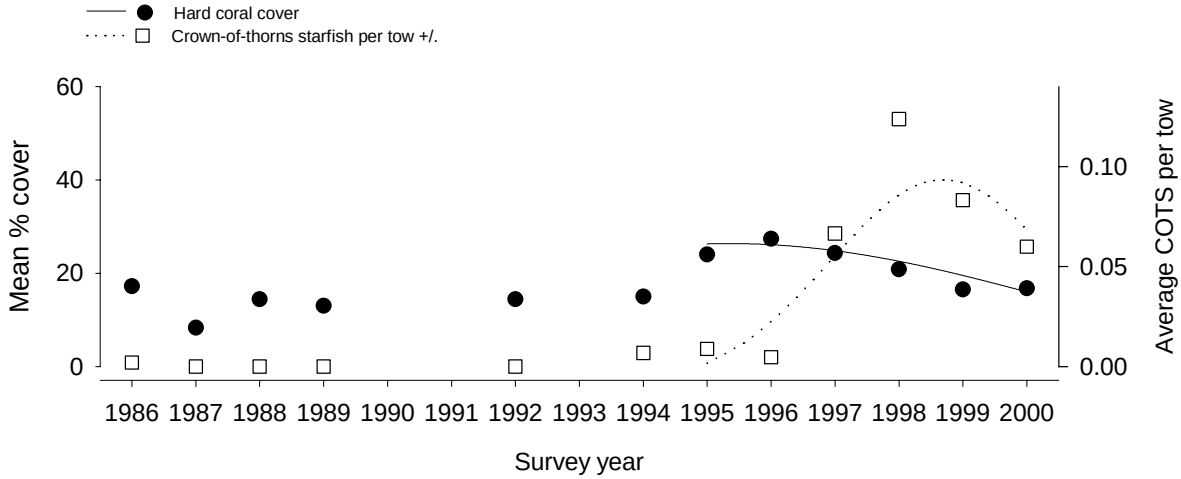
Figure 4.14(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.



Innisfail Sector Outer Shelf Reefs

Four reefs were surveyed in 2000. COTS were observed on two of these: Potter (A) (Active Outbreak) and Wardle (Recovering from prior COTS activity). COTS numbers increased and peaked in 1998 then declined (Fig. 4.15A), resulting in no average trend. COTS numbers also showed no current trend, the mean of 0.06 COTS per tow was below levels that would be expected to cause an overall significant decline in coral cover. Reef-wide coral cover also showed no trend over the previous six years and is currently moderate (16%, Fig. 4.15A)

Figure 4.15(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.



Townsville Sector

This sector was last surveyed in June 2000.

Summary

Overall there was a significant recent decrease in reef-wide live coral cover on reefs in this sector in 2000, particularly on inner and mid-shelf reefs. Inner shelf reefs showed the effects of the 1998 bleaching event (Fig.4.17A), mid-shelf reefs had been affected by COTS (Fig. 4.18A). COTS continue to increase in this sector (Fig. 4.16(i)). While declines in coral cover were evident on outer shelf reefs affected by COTS, detailed benthic video indicated little change in live coral cover on those reefs that were unaffected by COTS (Fig 4.19A,B).
A reduction in coral cover on inner-shelf reefs saw a corresponding decline in Butterflyfishes. On mid-shelf reefs there were few clear trends in reef fish taxa. There was a general trend of decline in both number of individuals counted and species richness on outer shelf reefs. The causes are not known.

Geography

The outer-shelf reefs in this sector do not exclude oceanic influences, but the GBR lagoon is wider near Townsville than it is further north. The Herbert River drains into the northern part of this sector, and the mouth of the Burdekin is just to the south. River plumes tend to be transported northwards by the prevailing winds.

Figure 4.16(i) Summary of trends in reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the Sector.

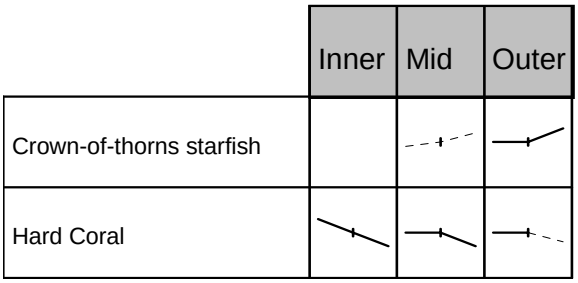


Figure 4.16(ii) Summary of trends in benthic cover on intensive survey sites in the Sector.

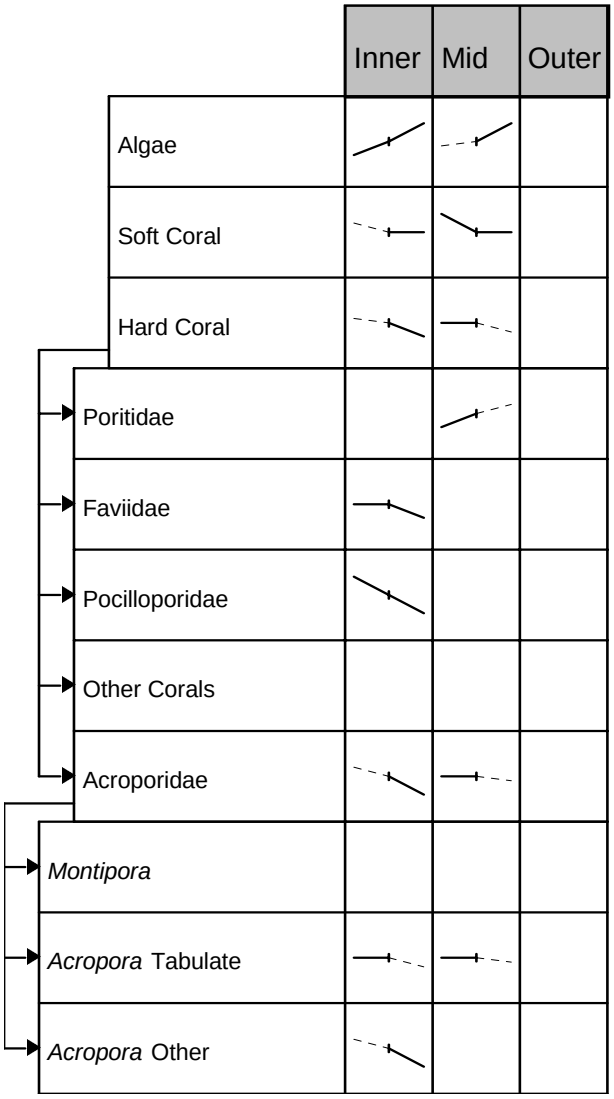


Figure 4.16(iii) Summary of trends in fish abundance in the Sector.

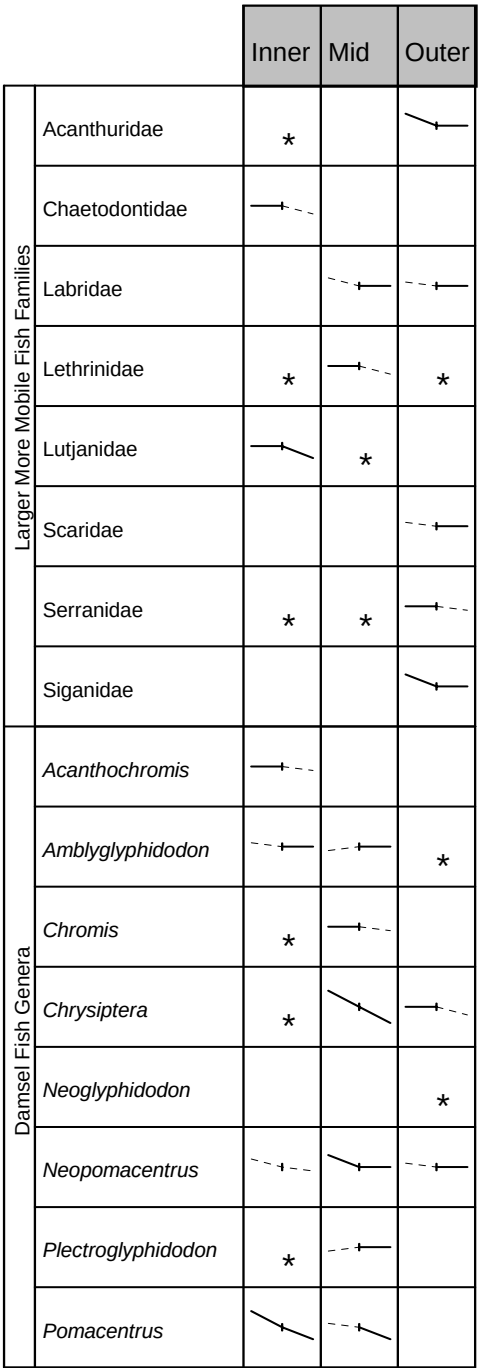
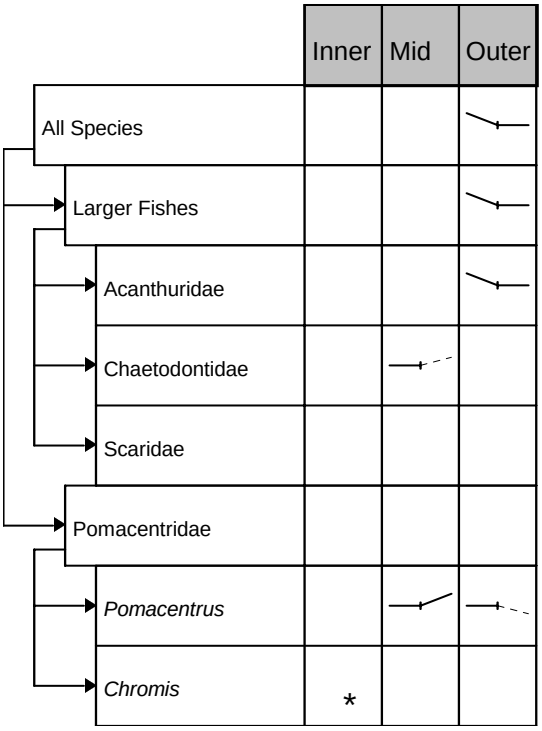


Figure 4.16(iv) Summary of trends in fish species richness in the Sector.



Townsville Sector Inshore Reefs

Only two reefs in this region, Havannah Is. and Fantome Is., were surveyed by manta tow in 2000. Both these reefs suffered severe bleaching early in 1998, which contributed to a regional decline in reef-wide coral cover (Fig. 4.17A). Coral cover at Havannah Is. declined further in 1999 and remained low (5-10%) in 2000. No COTS were observed on either reef. Too few inshore reefs have been sampled over recent years to estimate regional trends.

Hard coral cover decreased in the intensive survey sites over the previous six years due to the bleaching event (Fig. 4.16(ii), Fig. 4.17B). Bleaching mainly affected the Acroporidae and reefs that formerly had high cover of Acroporidae tended to show the largest declines in coral cover. Cover of hard coral decreased at Havannah Is. (43% in 1997 to 11% in 2000) and Pandora Reef (58% in 1997 to 42% in 2000) but increased at Middle Reef. The apparent decline in cover of the family Poritidae between 1996 and 1997 is due to the inclusion of Havannah Is as a survey reef in 1997. First surveyed in 1997, Havannah Is. had a lower cover of Poritidae (1%) than either Middle Reef (17%) and Pandora Reef (23%). Declines in cover of hard coral have been matched by increases in algal cover from 19% in 1994 to 48% in 2000 (Fig. 4.16(ii), Fig.4.17B). Cover of soft corals has shown a slight decline over the last three years (Fig. 4.17B).

Larger fishes have often not been counted because of the poor visibility on these inshore reefs, so estimated regional trends should be treated with caution (Fig. 4.16(iii), Fig. 4.17E,F). Data from individual reefs confirmed that abundance of butterflyfishes (Chaetodontidae) had declined since early 1998 when bleaching occurred (Fig. 4.17E). Declines in abundance of the genus *Pomacentrus* may also have been due to bleaching (Fig. 4.16(iii), Fig. 4.17G). *Neopomacentrus* numbers declined on all reefs over the last 3 to 4 years (Fig. 4.16(iii), Fig. 4.17G). *Amblyglyphidodon* and *Acanthochromis* showed a slight decline in previous surveys (Fig. 4.16(iii), Fig. 4.17H).

There has been no discernible change in reef fish species richness over the last six years (Fig. 4.16(iv)).

Figure 4.17(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.

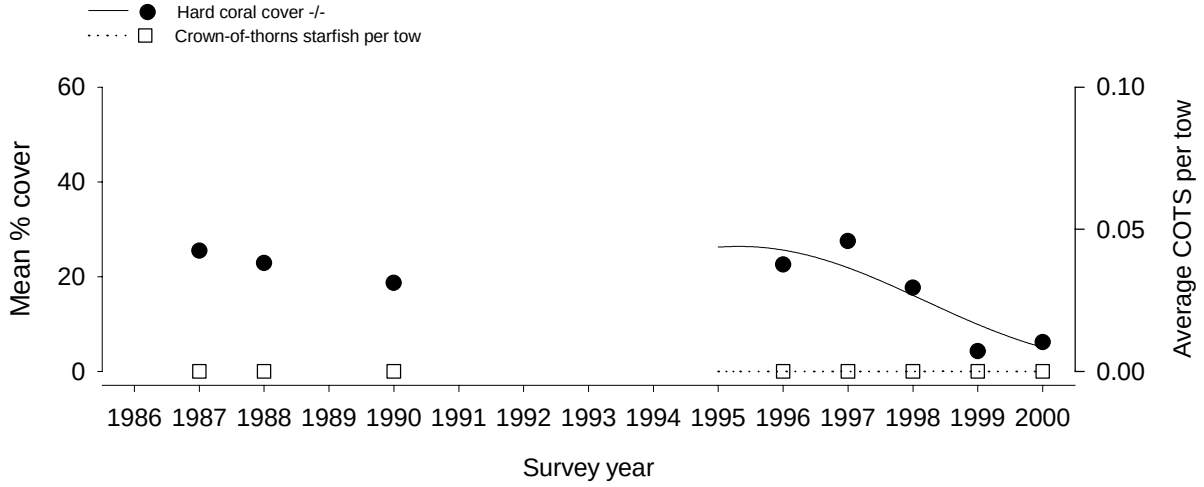
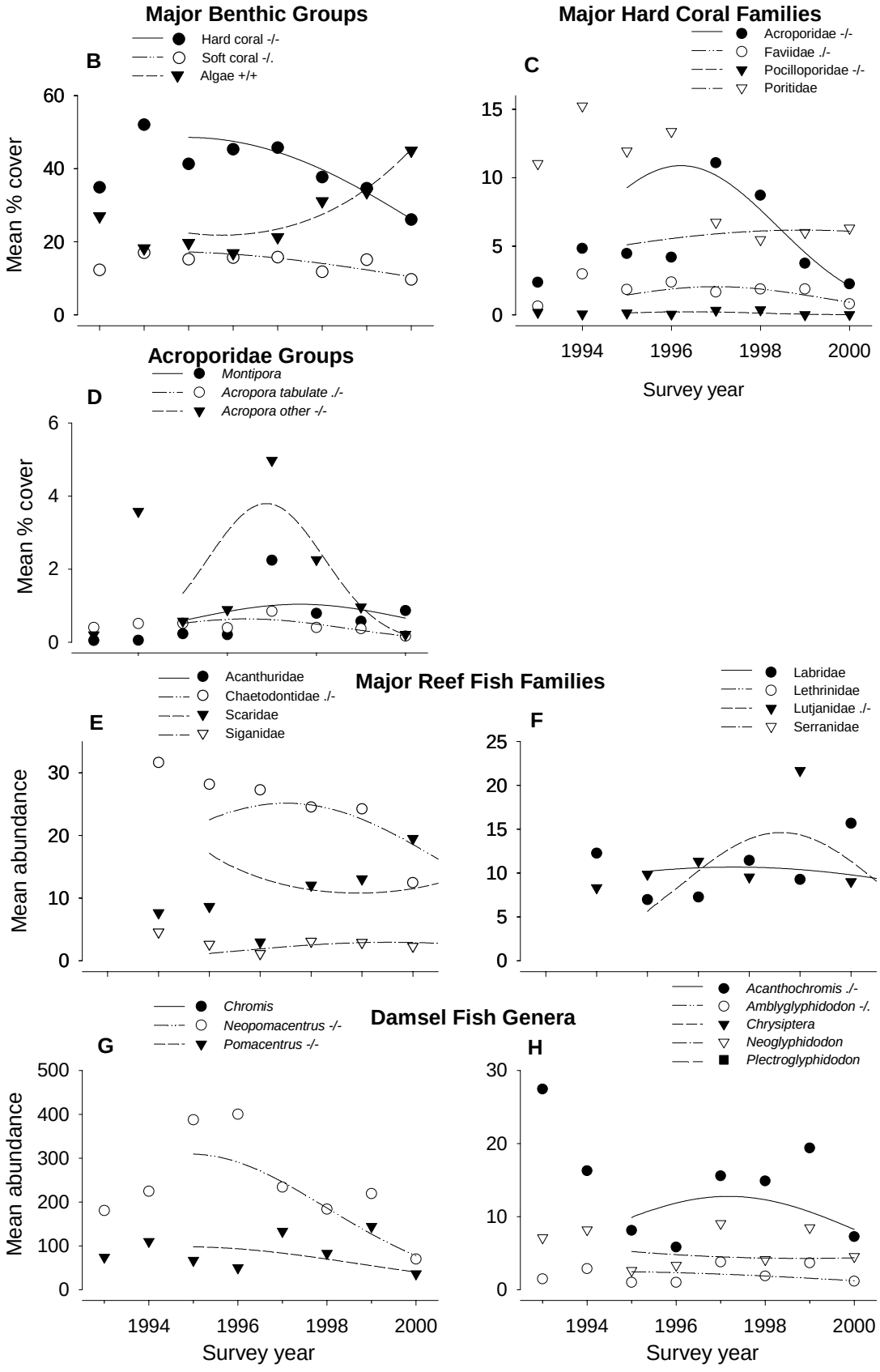


Figure 4.17 cont. Plots showing distribution of regional means and the fitted trend lines for: (B,C,D) percent cover of benthic groups on fixed sites, (E,F,G,H) fish abundance on fixed sites.



Townsville Sector Mid-Shelf Reefs

Four reefs were surveyed in 2000. COTS were recorded on three of these (Bramble Reef - Incipient Outbreak; Rib Reef - Active Outbreak and John Brewer Reef - Recovering). No COTS were recorded on Davies Reef, which was classified as Recovering from COTS activity prior to 1991. COTS numbers increased over the past six years with numbers increasing further in 2000 (Fig 4.16(i)). Reef-wide coral cover has been decreasing over the last six years and decreased further in 2000. Reef-wide coral cover is moderate (10-20%) across the region.

Cover of hard corals on the intensive survey sites had shown no net trends up until the year 2000 (Fig. 4.16(ii)). Hard coral cover declined from 38% in 1999 to 28% in 2000 (Fig. 4.18B). The decline in hard coral cover was greatest at Rib Reef although all three reefs experienced declines. The decline in hard coral cover was largely due to tabulate *Acropora* spp. (Fig. 4.18D). Cover of encrusting *Porites* increased (Fig. 4.18C) but the family accounted for less than 3% cover. Cover of soft coral shows a general decline from 1995 which has stabilised (Fig. 4.16(ii), Fig. 4.18B) and averaged 2% in 2000. Since 1996 algal cover has increased from 18% to 28% (Fig. 4.16(ii), Fig. 4.18B).

The few reef fish taxa that showed a trend decreased in abundance (Fig. 4.16(iii)). Exceptions were the staghorn damsel (*Amblyglyphidodon curacao*) and the jewel damsel (*Plectroglyphidodon lacrymatus*) which increased slightly (Fig. 4.16(iii), Fig. 4.18H). Among the larger fishes, the wrasses (Labridae) decreased in abundance from 1995 through 1997 then stabilised (Fig. 4.18F). There was a peak in abundance of red-throat emperor (Lethrinidae) following Cyclone Justin in 1997 (Fig. 4.18F). This increase was not sustained and possibly resulted from movement of fish rather than net population changes. Decline in numbers of the yellowtail demoiselle (*Neopomacentrus azysron*) and several abundant members of the genera *Chrysiptera* and *Pomacentrus* began in the 1996 (Fig. 4.18G,H). The current decline in *Chromis* was due to a large drop in abundance at Davies Reef.

Reef fish species richness was stable (Fig. 4.16(iv)). The increase for the genus *Pomacentrus* was due to the inclusion of single individuals of two species not recorded in the previous four years. The slight current increase in the butterflyfishes (Chaetodontidae) reflected several rare species observed in the 1999 and 2000 surveys.

Figure 4.18(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.

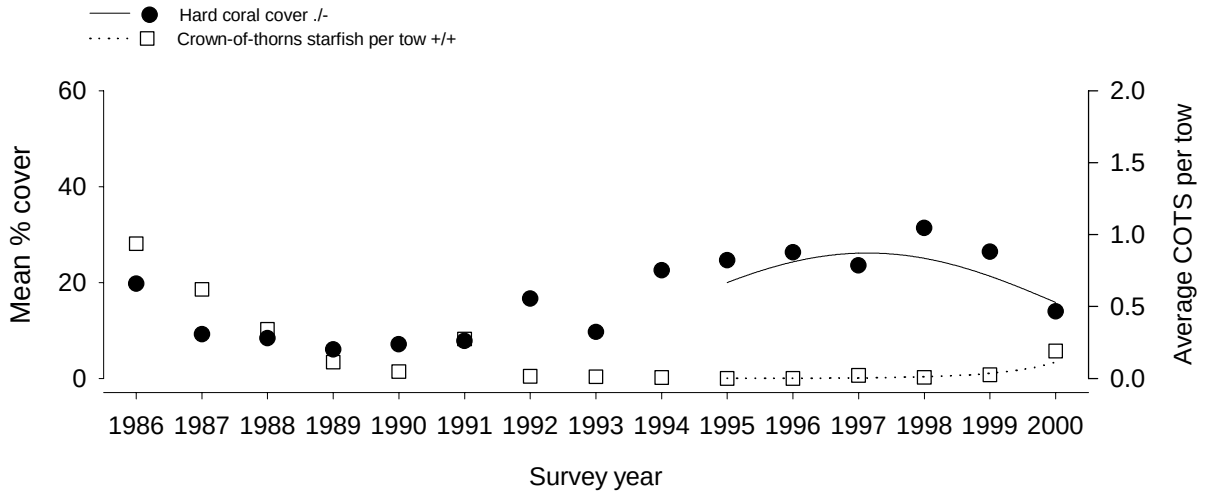
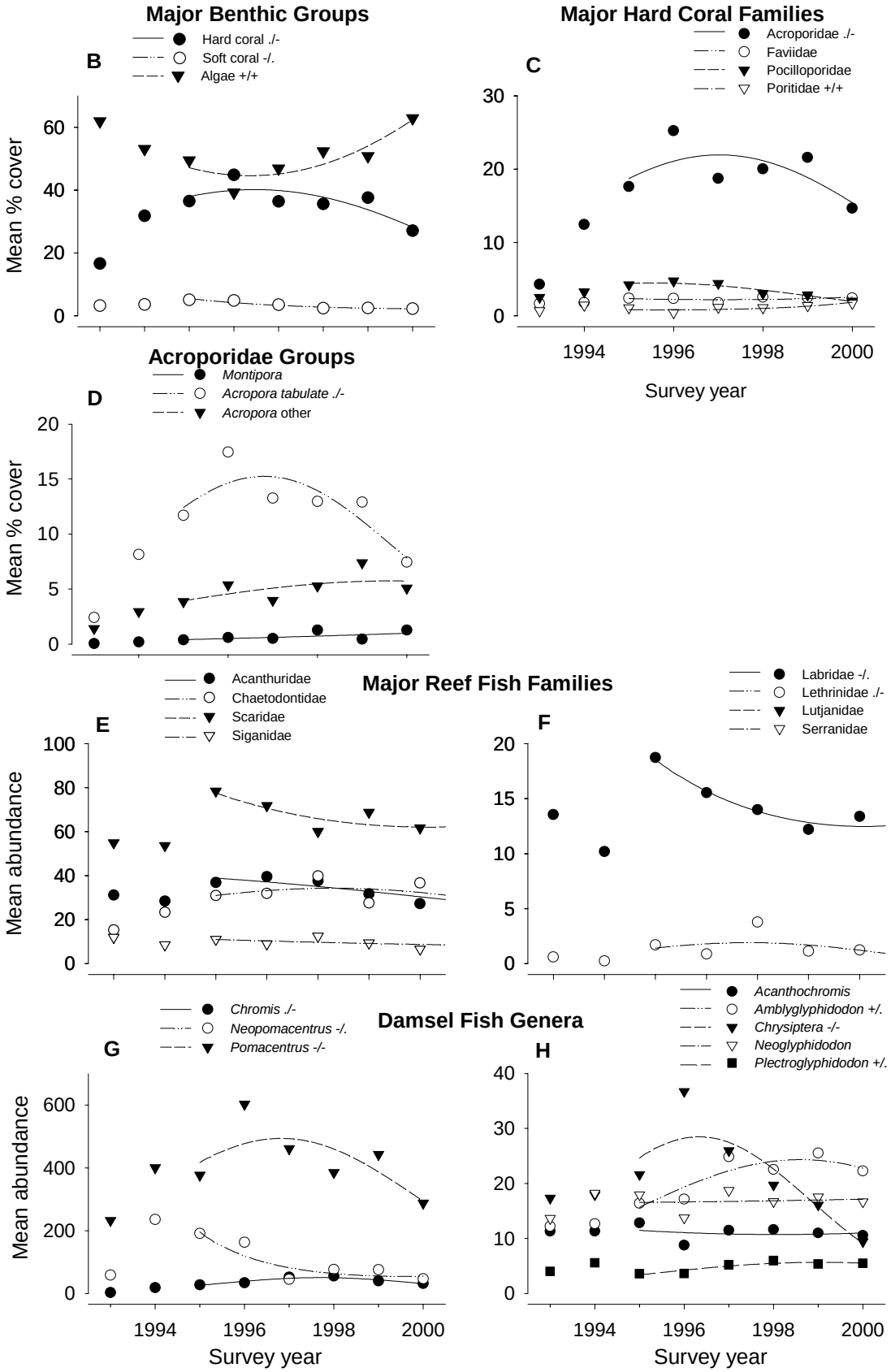


Figure 4.18 cont. Plots showing distribution of regional means and the fitted trend lines for: (B,C,D) percent cover of benthic groups on fixed sites, (E,F,G,H) fish abundance on fixed sites.



Townsville Sector Outer Shelf Reefs

Four reefs were surveyed in 2000. COTS were observed on two (Reef 18-023 and Chicken). Extremely high densities of COTS were observed on Reef 18-023, boosting the regional average (Fig. 4.16(i), Fig. 4.19A). Reef-wide coral cover had been generally stable over the last six years (Fig. 4.16(i), Fig.4.19A) but the low value at 18-023 in 2000 reduced regional coral cover to a moderate (15%).

Intensive surveys showed no significant changes in the cover of major benthic groups or hard coral families (Fig. 4.16(ii), Fig. 4.19B,C,D). Hard coral cover averaged 32% in 2000; cover of soft corals and algae averaged 14% and 48% respectively. Acroporidae is the dominant family of hard corals on these reefs but the communities are relatively diverse.

All reef fish taxa that showed trends in abundance declined (Fig. 4.16(iii)). parrotfish (Scaridae), wrasse (Labridae) and rabbitfish (Siganidae) showed marginal decreases over time (Fig. 4.19E,F). Counts of surgeonfish (Acanthuridae) were variable (Fig. 4.19E) however bristletooth species (*Ctenochaetus* spp.) and the brown surgeonfish (*Acanthurus nigrofuscus*) declined sharply in the 1999 and 2000 survey. Abundance of the common coral trout (*Plectropomus leopardus*) declined from a peak in 1997. The king demoiselle (*Chrysiptera rex*) showed a similar trend. Abundance of the yellowtail demoiselle (*Neopomacentrus azysron*) was high in 1996 and to a lesser extent in 1999 (Fig. 4.19G,H).

Species richness of reef fishes showed a general decline over the past six years (Fig. 4.16(iv)). This was most evident in the larger reef fishes. Within the Acanthuridae the blackstreak surgeon (*Acanthurus nigricauda*) and the convict surgeon (*A. triostegus*) were absent in the last survey. Within the genus *Pomacentrus* both the lemon damsel (*P. moluccensis*) and ward's damsel (*P. wardi*) had been present in most years up to 2000 but were absent in 2000. This caused the current decline (Fig.4.16(iv)).

Figure 4.19(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.

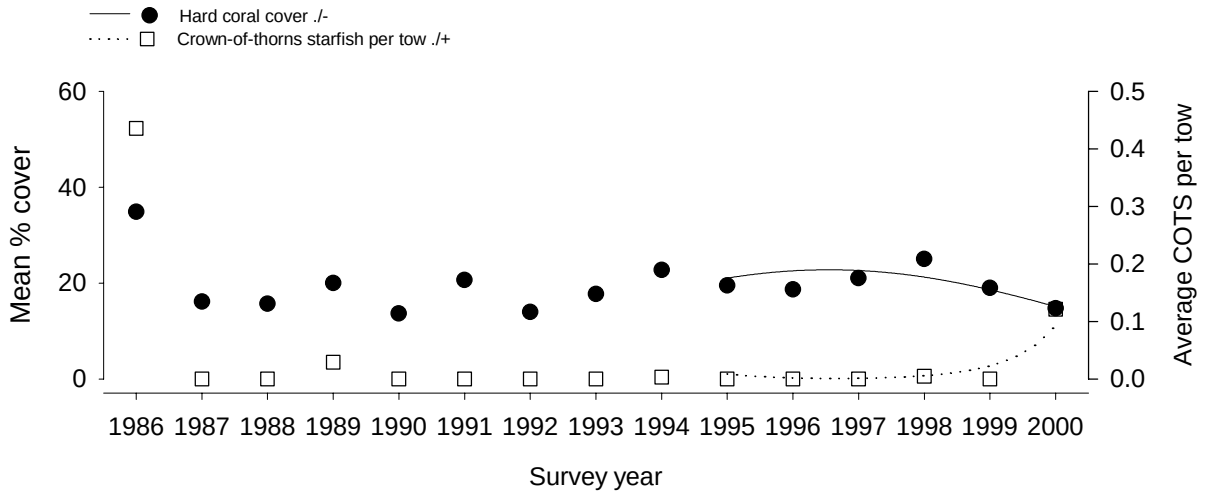
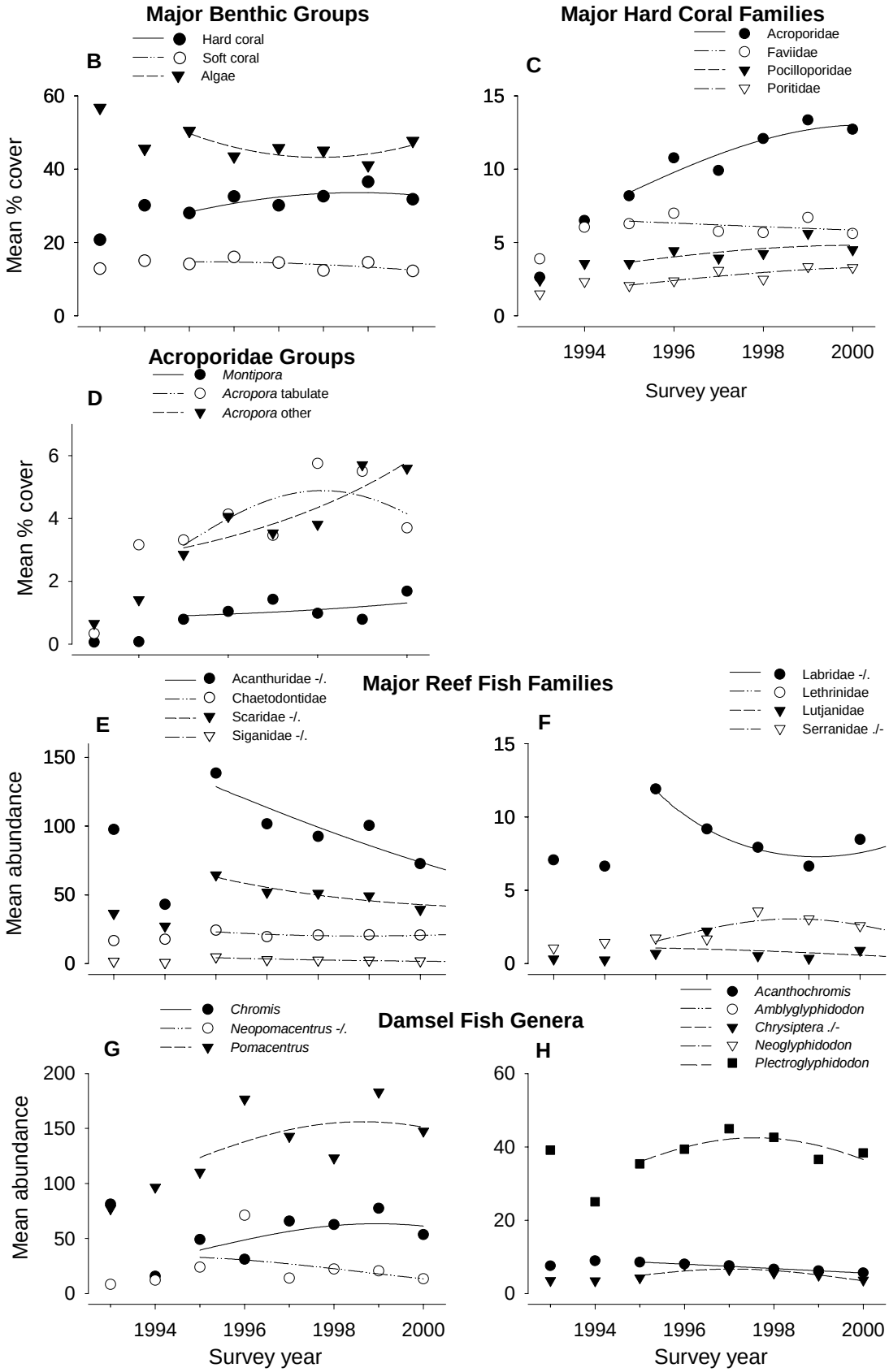


Figure 4.19 cont. Plots showing distribution of regional means and the fitted trend lines for: (B,C,D) percent cover of benthic groups on fixed sites, (E,F,G,H) fish abundance on fixed sites.



Cape Upstart Sector

This sector was last surveyed in May 2000.

Summary

No active COTS outbreaks were recorded on any of the survey reefs. Reef-wide cover of live coral showed little change from the previous survey. The reefs in this sector are surveyed by manta tow only, often at intervals of more than a year. No inshore or outer shelf reefs were surveyed in this sector in 2000.

Geography

The reefs in the Cape Upstart sector do not form a significant barrier to oceanic influences and the tidal range is higher than in the sectors to the north.

Figure 4.20(i) Summary of trends in reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the Sector.

	Mid
Crown-of-thorns starfish	
Hard Coral	

Cape Upstart Sector Inshore Reefs

No reefs were surveyed in this region in 2000.

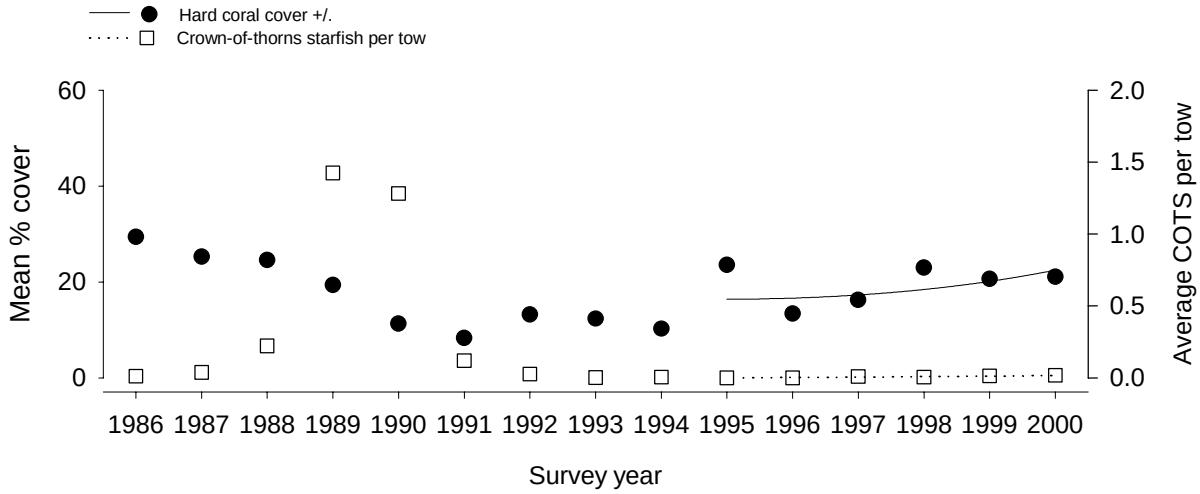
Cape Upstart Sector Outer Shelf Reefs

No reefs were surveyed in this region in 2000.

Cape Upstart Sector Mid-Shelf Reefs

Six mid-shelf reefs were surveyed in 2000. Three reefs had COTS present but at densities too low to affect reef-wide coral cover. Reef-wide cover of hard coral has increased over the last six years (Fig. 4.20(i)). Reef-wide coral cover is currently at a moderate level (21%, Fig. 4.21A). This area is still considered to be recovering from widespread COTS activity in the early 1990s

Figure 4.21(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.



Whitsunday Sector

This sector was last surveyed in March 2000.

Summary

No active COTS outbreaks were recorded in this sector and COTS were only recorded in low numbers on one outer shelf reef (19-159). Cover of the major benthic groups has remained stable over the last six years despite significant changes in some families and groups of hard corals (Fig. 4.22(ii)). The abundances of many reef fish taxa have changed (Fig. 4.22(iii)). Some of these changes may relate to past declines in coral cover due to Cyclone Justin; others are unexplained.

Geography

The tidal range is high in this sector causing strong currents particularly at the southern outer reefs. Inshore reefs are associated with large continental islands and there are some very sheltered areas. The area is subject to plumes from the Fitzroy River to the south.

Figure 4.22(i) Summary of trends in reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the Sector.

Figure 4.22(ii) Summary of trends in benthic cover on intensive survey sites in the Sector.

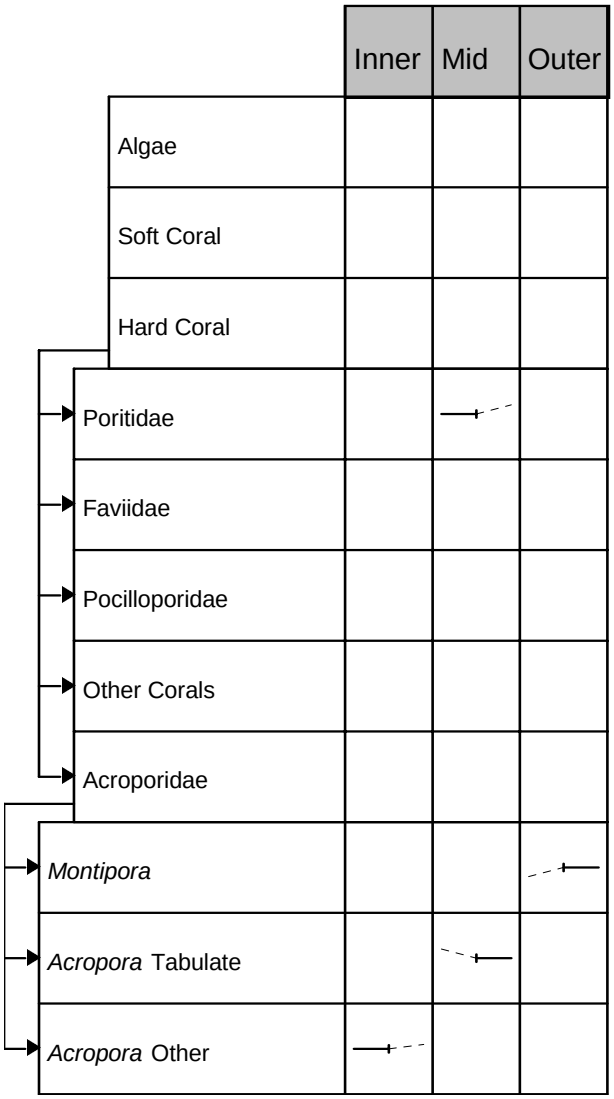


Figure 4.22(iii) Summary of trends in fish abundance in the Sector.

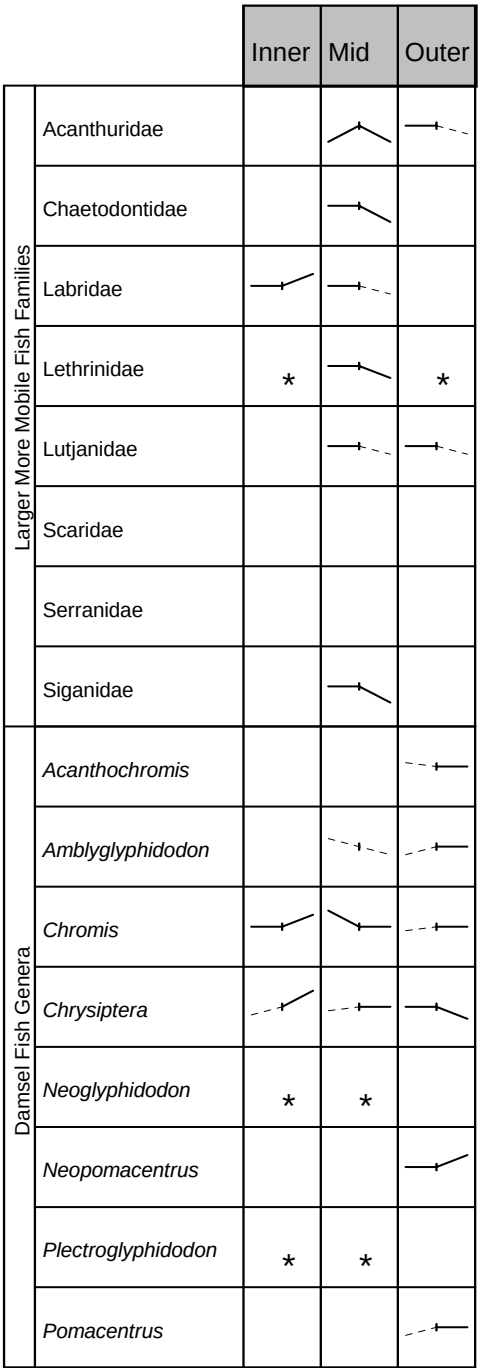
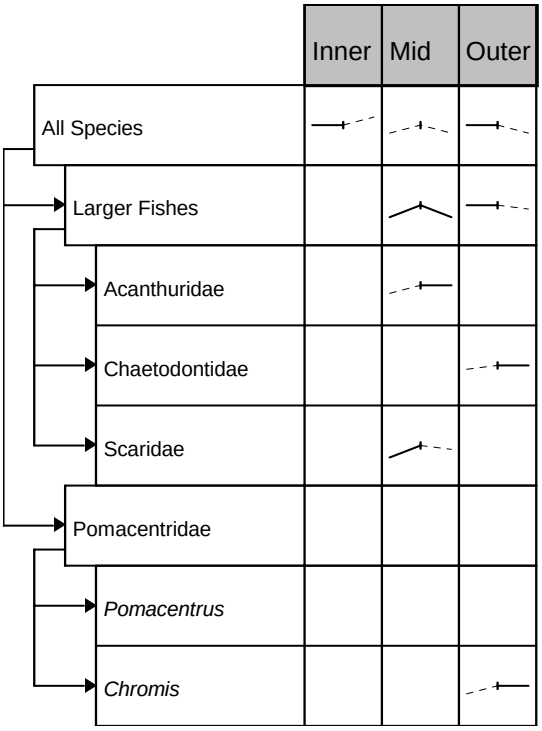


Figure 4.22(iv) Summary of trends in fish species richness in the Sector.



Whitsunday Sector Inshore Reefs

Three reefs were surveyed in 2000. Reef-wide coral cover increased only slightly over the past few years and was moderate at 21% (Fig. 4.23A). No COTS were observed on these reefs.

Cover of hard coral, algae and soft corals has changed little in recent years at the intensive study sites (Fig.4.23B), averaging about 29%, 28% and 23% respectively. Among hard corals, only cover of "Other" *Acropora* corals showed a trend over the past six years (Fig. 4.22 (ii)): a slight increase but remaining at less than 3%. The benthic communities in this region vary markedly from each other: Border Is. Reef has high cover (18%) of corals in the Poritidae family (mainly *Goniopora* spp.). Langford and Bird Is. Reef is also dominated by Poritidae, in particular massive *Porites* and *Goniopora* spp. Hayman Is. Reef has a high cover of *Montipora* spp. and branching and bottlebrush *Acropora* spp.

The majority of fish taxa showed no clear trends in abundance (Fig. 4.22(iii)). A number of wrasse species (Labridae) increased in abundance since 1998 (Fig. 4.23F). Increases in abundance of *Chromis* spp. (Fig. 4.23G) were due to large numbers of the Barrier Reef *Chromis* (*C. nitida*) recorded at Border Island and Langford and Bird Islands in 2000. The increase in abundance of *Chrysiptera* (Fig. 4.23H) resulted from an increase in Rolland's demoiselle (*C. rollandi*) in 1999. Numbers of this species had declined in 2000.

Species richness of reef fishes has been variable. The slight overall increase in 2000 (Fig. 4.22(iv)) was real, but the total of 65 spp. was within the range of 52 to 69 spp. observed over the last six years.

Figure 4.23(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.

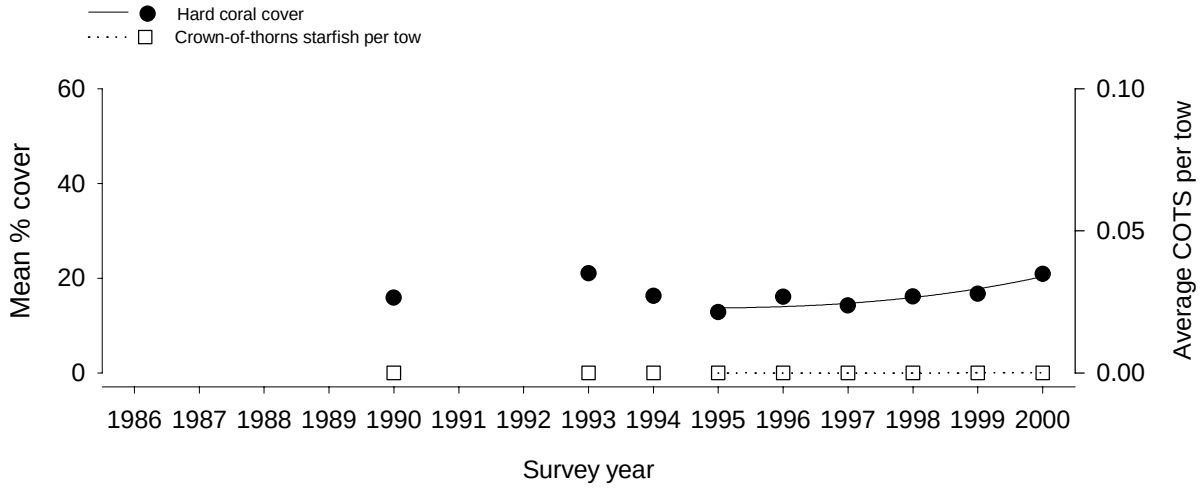
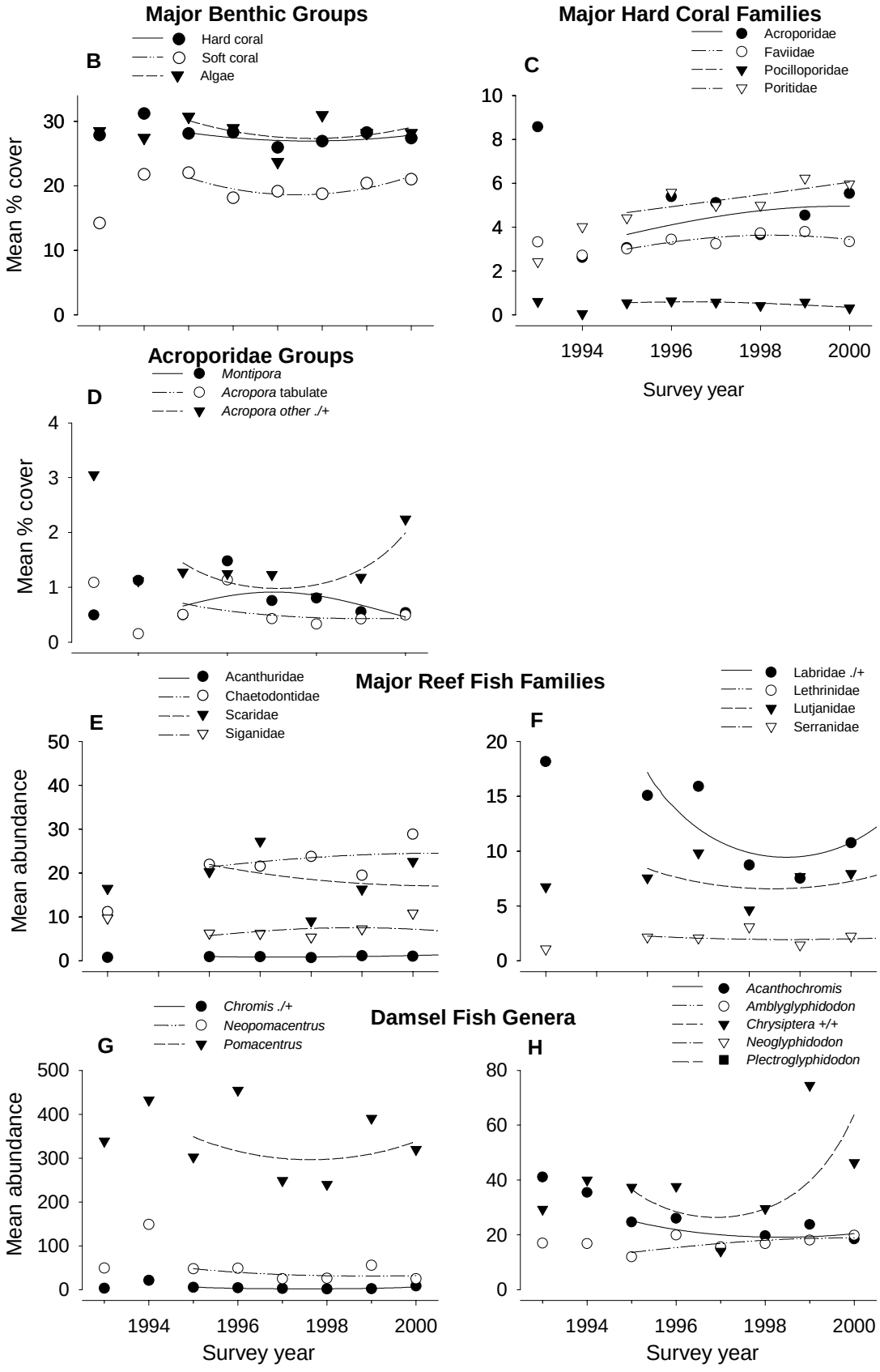


Figure 4.23 cont. Plots showing distribution of regional means and the fitted trend lines for: (B,C,D) percent cover of benthic groups on fixed sites, (E,F,G,H) fish abundance on fixed sites.



Whitsunday Sector Mid-Shelf Reefs

Four reefs were surveyed during 2000; no COTS were recorded. Reef-wide coral cover declined sharply due to Cyclone Justin in March 1997 giving an average decrease over the past six years (Fig. 4.22(i), Fig. 4.24(A). Average reef-wide coral cover in 2000 was moderate at 21%.

At the intensive survey sites hard coral cover increased 40% in 1996 then declined to 24% by 1997 (Fig. 4.24B) due to Cyclone Justin. Hard coral cover had not recovered in 2000, averaging 23%. Cover of most groups of hard corals show declines associated with Cyclone Justin (Fig. 4.24B,C,D). This decline was significant in the Acroporidae, due to large decreases in the cover of tabulate *Acropora* spp. (Fig. 4.22(ii), Fig. 4.24D). Cover of this group has now stabilised. Cover of algae showed a complementary increase between 1996 and 1997 (Fig. 4.24B). Cover of algae remained stable since 1997 averaging 65% in 2000. Cover of soft coral has remained less than 2% for the duration of this study.

Seven fish taxa were declining in abundance in 2000 (Fig. 4.22(iii)). The general increase in the abundance of the surgeonfishes (Acanthuridae) up until 1998 was followed by a marked decline (Fig. 4.22(iii), Fig. 4.24E), driven by at least three species. The current decline in numbers of butterflyfishes (Chaetodontidae) (Fig. 4.22(iii)) is driven by several species. This decline started in 1997 following the loss of hard coral cover due to Cyclone Justin (Fig. 4.24B,E). Decreasing abundances of both rabbitfishes (Siganidae) and wrasse (Labridae) in 2000 were due to major declines in several species from 1999 (Fig. 4.24 E,F). Declines in the abundance of emperors (Lethrinidae) and snappers (Lutjanidae) (Fig. 4.22(iii)) were driven by changes in the yellow-tailed emperor (*Lethrinus atkinsoni*), spangled emperor (*Lethrinus nebulosus*), spanish flag (*Lutjanus carponotatus*) and black-spot snapper (*Lutjanus fulviflamma*). However, in 2000 numbers of all four species were still within the range of previous records (Fig. 4.24E,F). Among damselfishes, *Chromis* spp. declined from a peak in 1996 (Fig. 4.22(iii), Fig. 4.24G). This was largely due to the Barrier Reef chromis (*C. nitida*) and the black-axil chromis (*C. atripectoralis*), both of which occurred in low numbers in 2000. Numbers of *Amblyglyphidodon* declined consistently since 1996 (Fig.4.22(iii), 4.24H).

Several groups of reef fishes showed general increases in species richness from low values in 1995 (Fig. 4.22(iv)). Changes in most groups were due to rare and occasionally represented species. The scaridae were an exception: several species were not observed in 1995 but were common subsequently.. The over all decline (Fig. 4.22(iv) in 2000 was mainly due to the larger fish but this value was within the range of previous observations..

Figure 4.24(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.

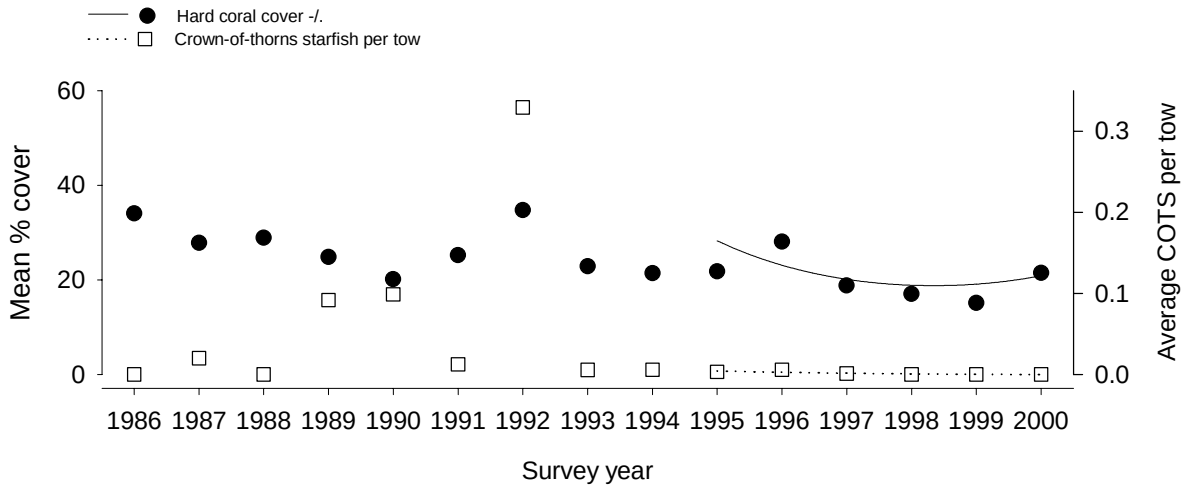
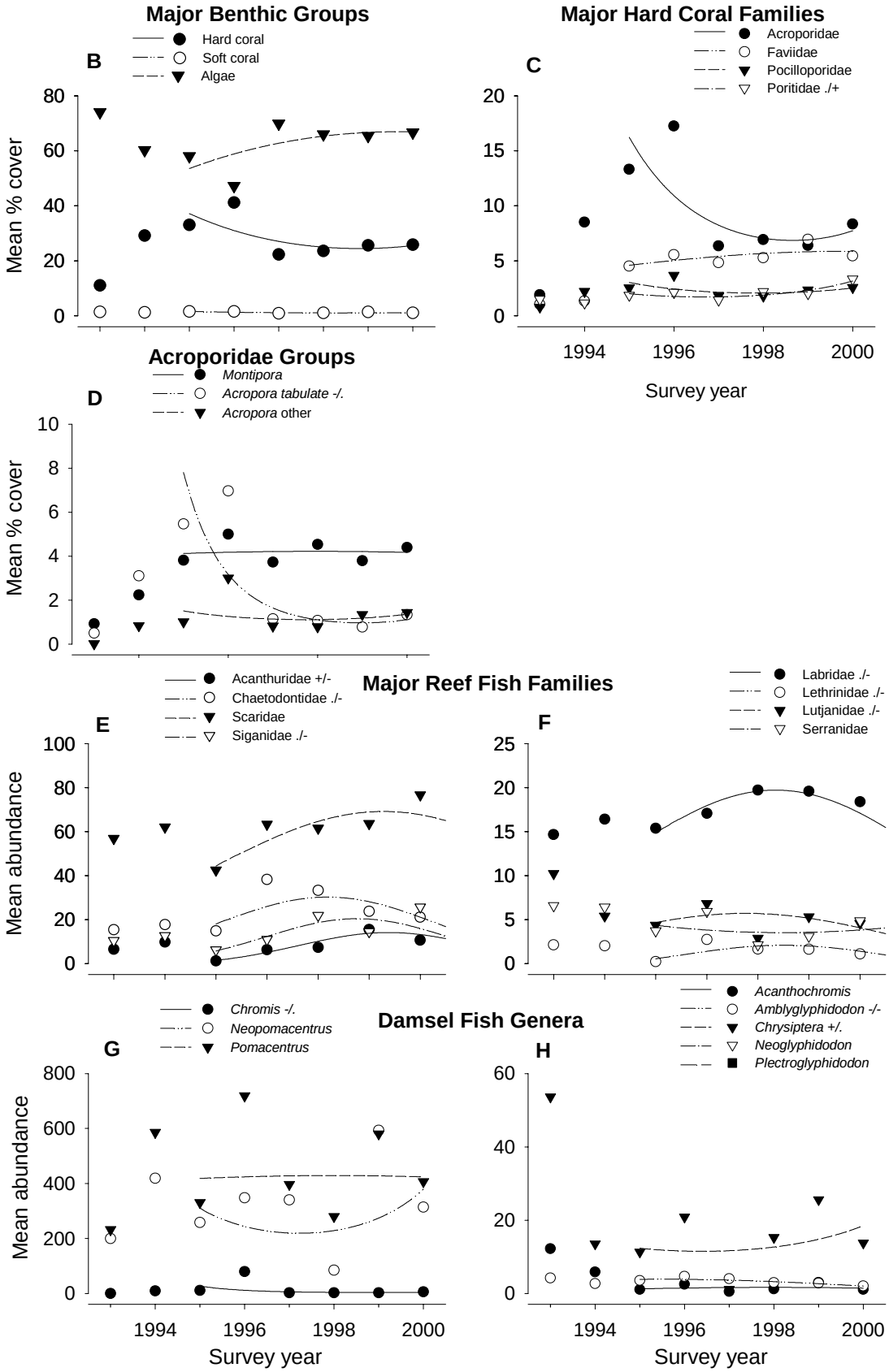


Figure 4.24 cont. Plots showing distribution of regional means and the fitted trend lines for: (B,C,D) percent cover of benthic groups on fixed sites, (E,F,G,H) fish abundance on fixed sites.



Whitsunday Sector Outer Shelf Reefs

Reef-wide coral cover changed little over the last six years and was high at 31% in 2000 (Fig. 4.25(A). Low numbers of COTS were recorded in 2000, densities were well below those considered to cause significant damage to the coral community. All reefs are classified as No Outbreak.

Cover of hard coral, algae and soft coral at the intensive study sites remained relatively stable over the past six years (Fig. 4.25B) averaging 27%, 24% and 35% respectively. Soft corals were an important component of the benthic communities on both Rebe and Hyde Reefs averaging 39% and 43% respectively. In contrast hard corals dominated Reef 19-159 (37% cover), soft corals averaged only 20%. The hard coral community of Reef 19-159 was dominated by *Acropora* spp. while no particular taxa dominated Rebe or Hyde Reefs.

Among larger reef fishes, only the Snappers (Lutjanidae) and Surgeonfishes (Acanthuridae) showed significant trends (Fig. 422(iii), Fig. 4.25E,F). Numbers of Snapper (Lutjanidae) have been consistently low but appeared to be declining (Fig. 4.25F) due to numbers of Sea Perch (*Macolor* spp.) that were only observed in 1997 and a gradual decline of Spanish Flag (*Lutjanus carponotatus*) since 1997. The variable nature of counts of Surgeonfishes (Acanthuridae) are not well represented by a quadratic function (Fig. 4.25E); in fact Surgeonfish numbers increased in 2000 after a period of decline. The apparent decreases in their abundance (Fig. 4.22(iii)) in 2000 should be disregarded. Among damselfishes (Pomacentridae) general increases in abundance of *Chromis* spp. (Fig. 4.22 (iii), Fig, 4.25G) were due largely to the Black-axil *Chromis* (*C. atripectoralis*) which peaked at high numbers in 1999. *Amblyglyphidodon* (mainly the Staghorn Damsel, *A. curacao*) increased in abundance until 1999 then stabilised (Fig. 4.25H). Increase in *Pomacentrus* spp. (Fig. 4.22(iii), Fig.4.25G) was due to a very large increase (>200%) in abundance of the Scaly Damsel (*P. lepidogenys*) in 1999 which had moderated by 2000. The Yellowtail Demoiselle (*Neopomacentrus azysron*) increased in abundance from a low in 1998 (Fig. 4.25G). The general decline of Spiny *Chromis* (*Acanthochromis polyacanthus*) appears to have stabilised while several *Chrysiptera* spp. were declining in abundance in 2000 (Fig.4.22(iii), Fig. 4.25H).

The current decline in overall fish species richness (Fig. 4.22(iv)) reflects the lowest value recorded in the period 1995 to 2000. There were 94 species recorded in the latest survey compared to between 97 and 108 previously. No particular family or genera stands out as having obviously reduced richness, rather, the low point represents the simultaneous omission of a range of rare species that had been present sporadically. The increases in species richness of Chaetodontidae and *Chromis* (Fig. 4.22(iv)) both reflect lower estimates in 1995 compared with subsequent years.

Figure 4.25(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.

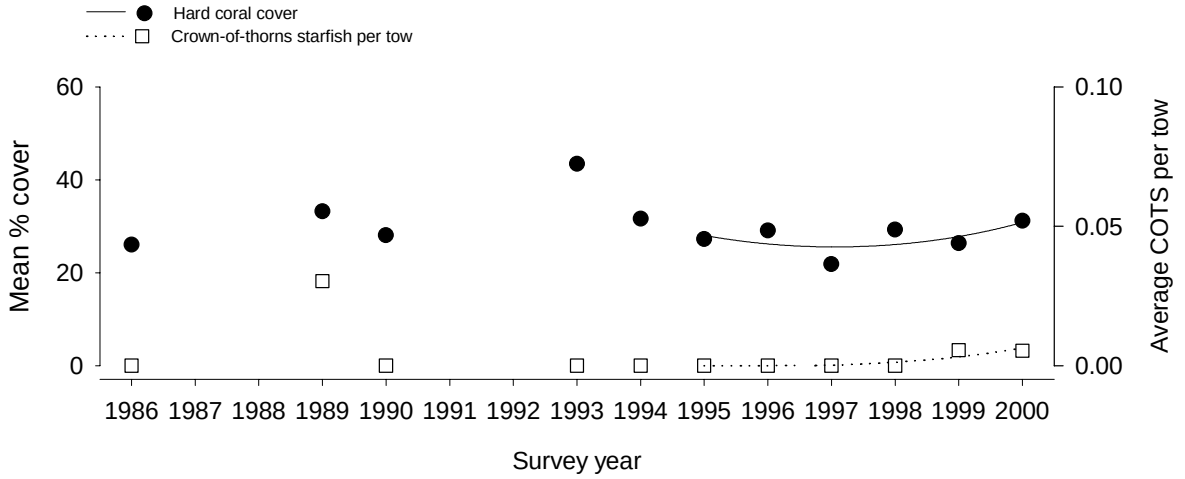
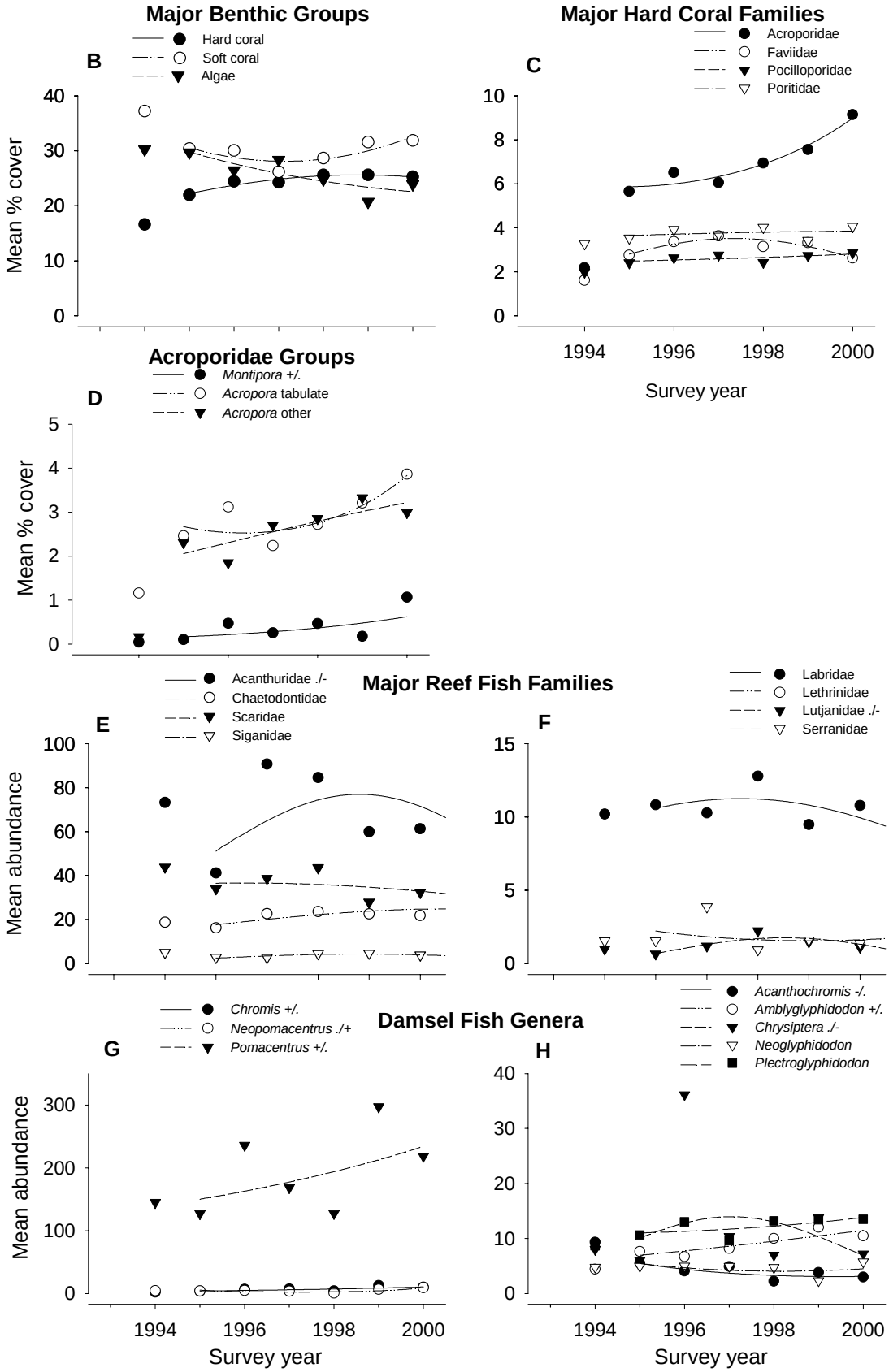


Figure 4.25 cont. Plots showing distribution of regional means and the fitted trend lines for: (B,C,D) percent cover of benthic groups on fixed sites, (E,F,G,H) fish abundance on fixed sites.



Pompey Sector

This sector was last surveyed in March 2000.

Summary

The reefs in this sector are surveyed by manta tow only, often at intervals of more than a year. No inshore reefs and only one outer shelf reef was surveyed in 2000, so trends have not been estimated for this region. COTS were observed in low numbers on one reef (Credlin). All reefs were classified as No Outbreak.

Geography

The reefs in this sector are sheltered from oceanic swells by the Hard Line reefs that form a wall. The tidal range in this sector is large.

Figure 4.26(i) Summary of trends in reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the Sector.

	Mid	Outer
Crown-of-thorns starfish		*
Hard Coral		*

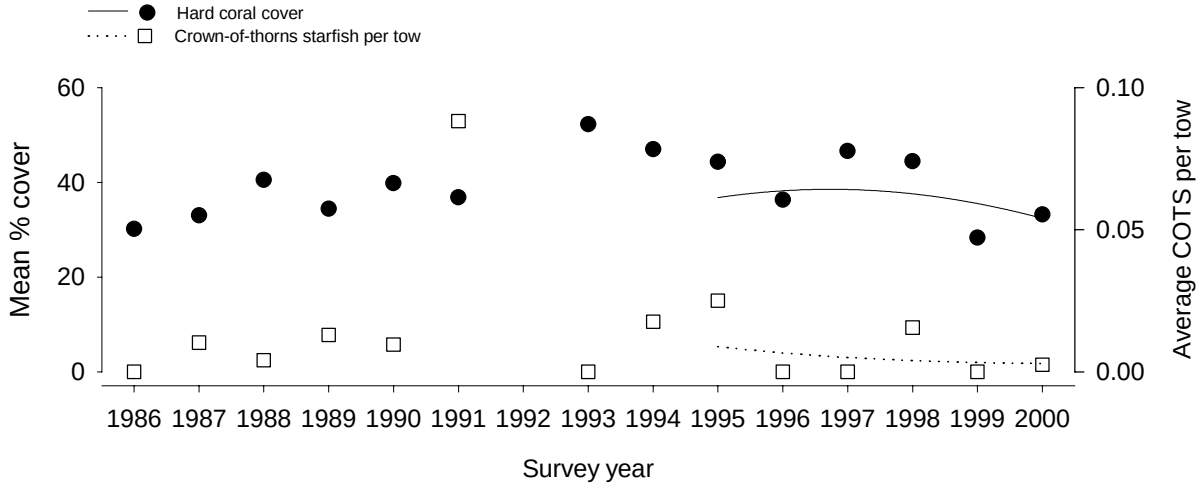
Pompey Sector Inshore Reefs

No reefs were surveyed in this region in 2000.

Pompey Sector Mid-Shelf Reefs

Five reefs were surveyed and COTS were only seen at Credlin Reef, though densities were too low to cause significant reef-wide coral mortality. Reef-wide coral cover has remained high (30-45%) over the past six years (Fig. 4.27A)

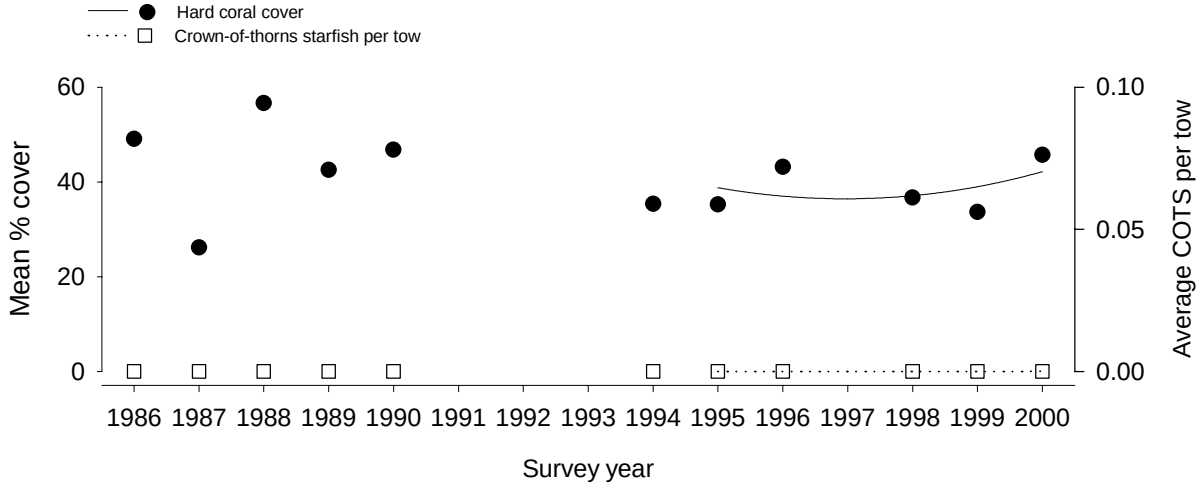
Figure 4.27(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.



Pompey Sector Outer Shelf Reefs

Only one reef in this region was surveyed in 2000, no COTS were seen and reef-wide coral cover was high (46%)(Fig 4.28A)

Figure 4.28(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.



Swain Sector

This sector was last surveyed in December 1999.

Summary

COTS were active in this sector with three of the seven survey reefs having Active Outbreaks in 2000. Divergent trends on reefs with and without high COTS numbers have produced no overall regional trend in hard and soft coral cover. Between 1999 and 2000 cover of algae increased on mid-shelf reefs. Fish taxa have varied in abundance over time but tended to stabilise or increase in 2000. NB: More recent surveys have shown that COTS numbers have risen to highest average numbers from any sector since surveys began in 1985 and four of the seven survey reefs supported active outbreaks (see Regional Surveys in www/aims.gov.au/reef monitoring).

Geography

Reefs in the Swain sector differ from other regions in that they are remote from the coast, so that inner Swains reefs are removed from coastal influence. Because of the prevailing SE wind direction, the inner Swain reefs are subject to more wave action than the mid-shelf reefs. This is also an area of large tides and strong currents.

Figure 4.29(i) Summary of trends in reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the Sector.

Figure 4.29(ii) Summary of trends in benthic cover on intensive survey sites in the Sector.

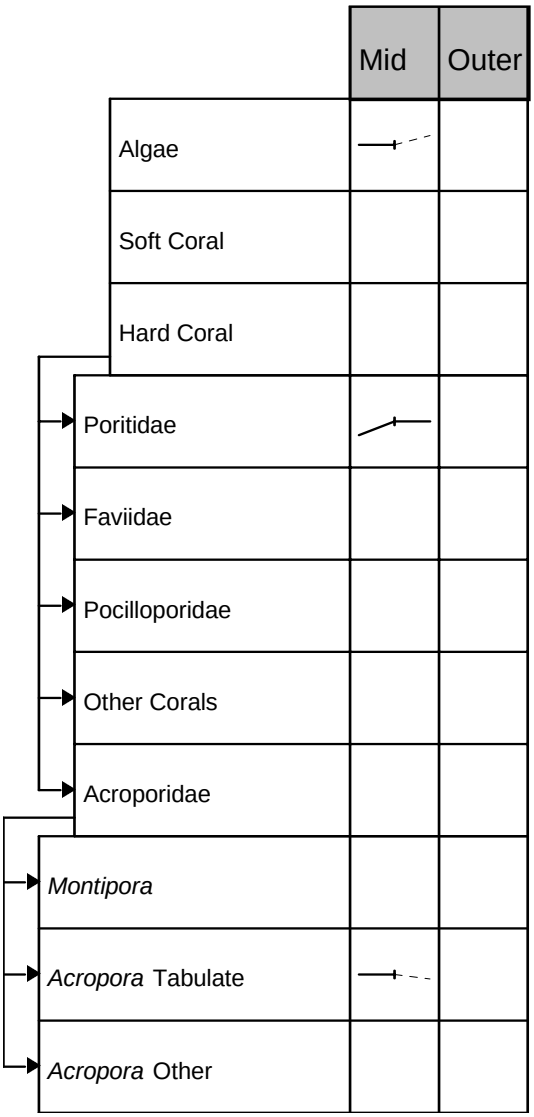


Figure 4.29(iii) Summary of trends in fish abundance in the Sector.

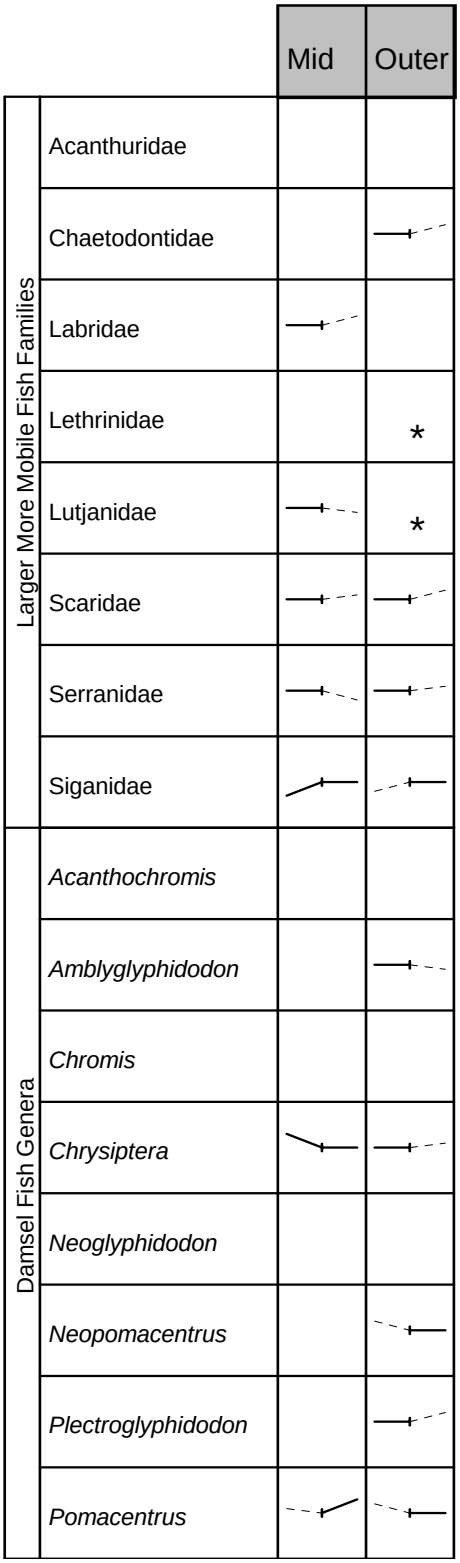
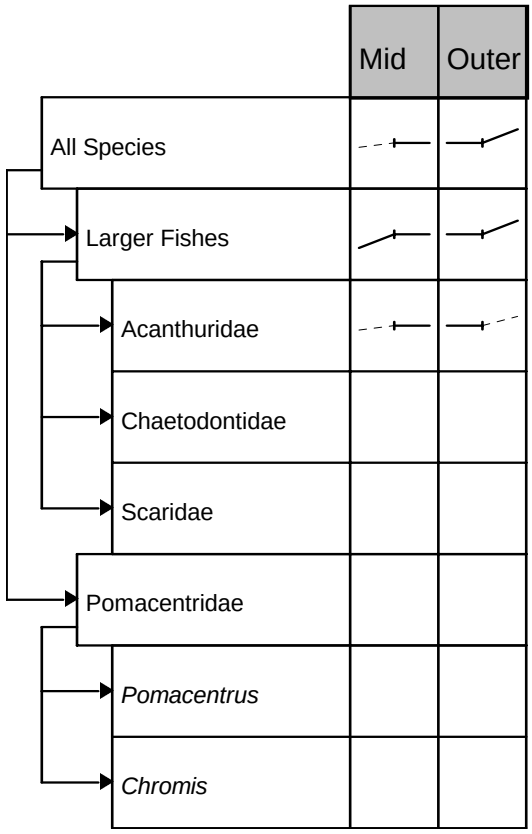


Figure 4.29(iv) Summary of trends in fish species richness in the Sector.



Swain Sector Mid-Shelf Reefs

Five reefs were surveyed in 2000. Three reefs, Gannet Cay, Horseshoe and Chinaman had Active Outbreaks. Reef 21-529 was classified as No Outbreak while Reef 22-088 has been Recovering from a COTS outbreak which was present up untill 1996. Overall, COTS density was at Incipient Outbreak levels (0.36 COTS per tow). There was no regional trend in reef-wide hard coral cover (Fig. 4.29 (i), Fig. 4.30A). This is because declines in coral cover on reefs affected by COTS either were marginal or were balanced by increases on unaffected reefs. Average reef-wide coral cover was moderate (24%).

Cover of algae increased at intensive survey sites between 1999 and 2000 (Fig. 4.29(ii), Fig. 4.30B), predominantly due to increases at Gannet Cay and Horseshoe Reef. There was no regional trend in hard coral cover (Fig.4.29(ii), Fig. 4.30B), though individual reefs showed divergent patterns. Regional hard coral cover averaged 33%, with individual reefs varying from 17% at Gannet Cay to 50% at Reef 21-529. Cover of soft corals was unchanged, averaging 8% (Fig. 4.30B).

The significant trends in abundance rabbitfishes (Siganidae), wrasses (Labridae), snappers (Lutjanidae) and coral trout (Serranidae) are hard to interpret due to high temporal variability (Fig. 4.29 (iii), Fig. 4.30E,F). Although abundance of each of these taxa had changed, abundances in 2000 were within the range of previous observations. The one exception may be the parrotfishes (Scaridae) with several species increasing in abundance to the highest observed levels in 2000 (Fig. 4.30E). abundance of *Pomacentrus* spp. have returned to previous levels after declines in 1999 (Fig. 4.30G,H). Declines in numbers of *Chrysiptera* did not continue in 2000.

The increase in species richness of the fish assemblage (Fig. 4.29 (iv)) involved the addition of only two species.

Figure 4.30(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.

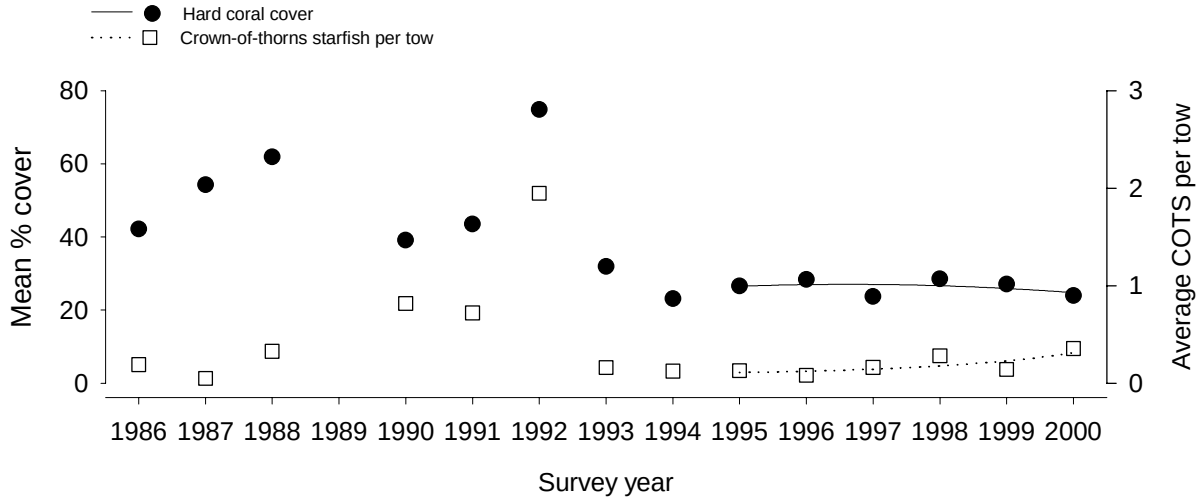
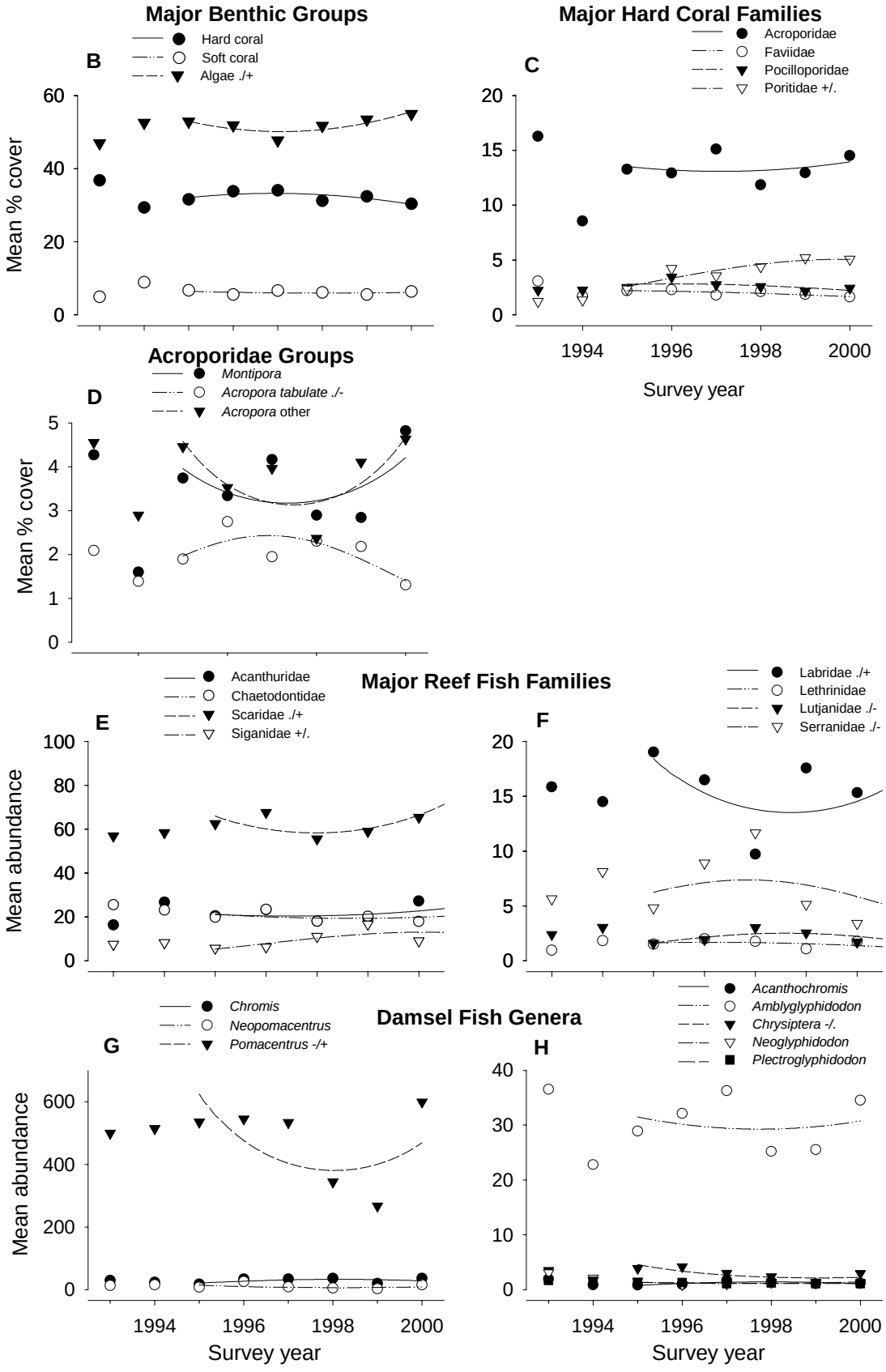


Figure 4.30 cont. Plots showing distribution of regional means and the fitted trend lines for: (B,C,D) percent cover of benthic groups on fixed sites, (E,F,G,H) fish abundance on fixed sites.



Swain Sector Outer Shelf Reefs

COTS were recorded on both survey reefs in this region, but at densities too low to impact on live coral cover (Fig. 4.29(i), Fig. 4.31A). Reef-wide coral cover increased in 2000 to a high value of 38% (Fig. 4.29 (i), Fig. 4.31A).

Cover of hard coral averaged about 26% at intensive survey sites and remained steady (Fig. 4.29 (ii), Fig. 4.31B). Cover of algae (mean of 37%) and soft corals (mean of 30%) had not changed significantly between 1995 and 2000 (Fig. 4.29 (ii), Fig. 4.31B). There were no significant trends in cover of the main families of coral over the same period.

All the larger reef fishes that showed trends in abundance were increasing (Fig. 4.29 (iii). The 1999 and 2000 increases in the butterflyfish (Chaetodontidae), parrotfish (Scaridae) and rabbitfish (Siganidae) (Fig. 4.31B,C) reflect increased abundance of a number of species in each case. The highest observed abundance of common coral trout (*Plectropomus leopardus* (Serranidae)) was recorded in the 2000 survey. Long term declines in abundance had been evident in the genera *Chrysiptera* and *Pomacentrus*. While abundances of these genera remained low in 2000 they increased and were steady respectively (Fig. 4.29 (iii), Fig. 4.31G,H). Numbers of *Neopomacentrus* were still very low (Fig. 4.31G). Abundance of *Plectroglyphidodon* spp. increased but remained within the previously observed range for the genus (Fig. 4.29 (iii), Fig. 4.31H). Numbers of *Amblyglyphidodon* (due solely to *A. curacao*) declined to the lowest level recorded in this region following peak values in 1998.

Species richness of fishes increased (Fig. 4.29 (iv)). This was due in part to the larger reef fishes, particularly the surgeonfishes (Acanthuridae) with five rarely-encountered species present in the 2000 survey.

Figure 4.31(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.

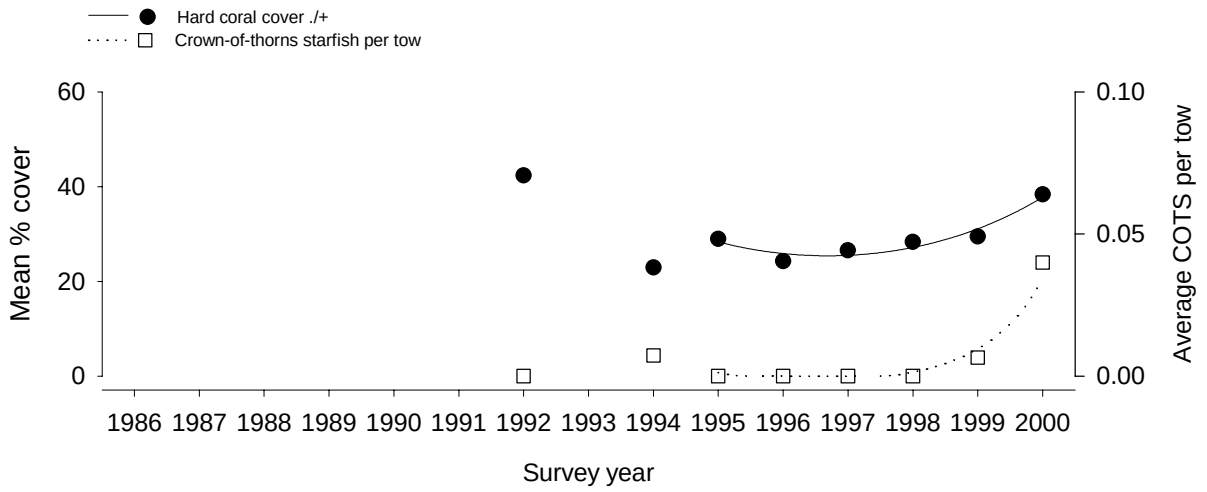
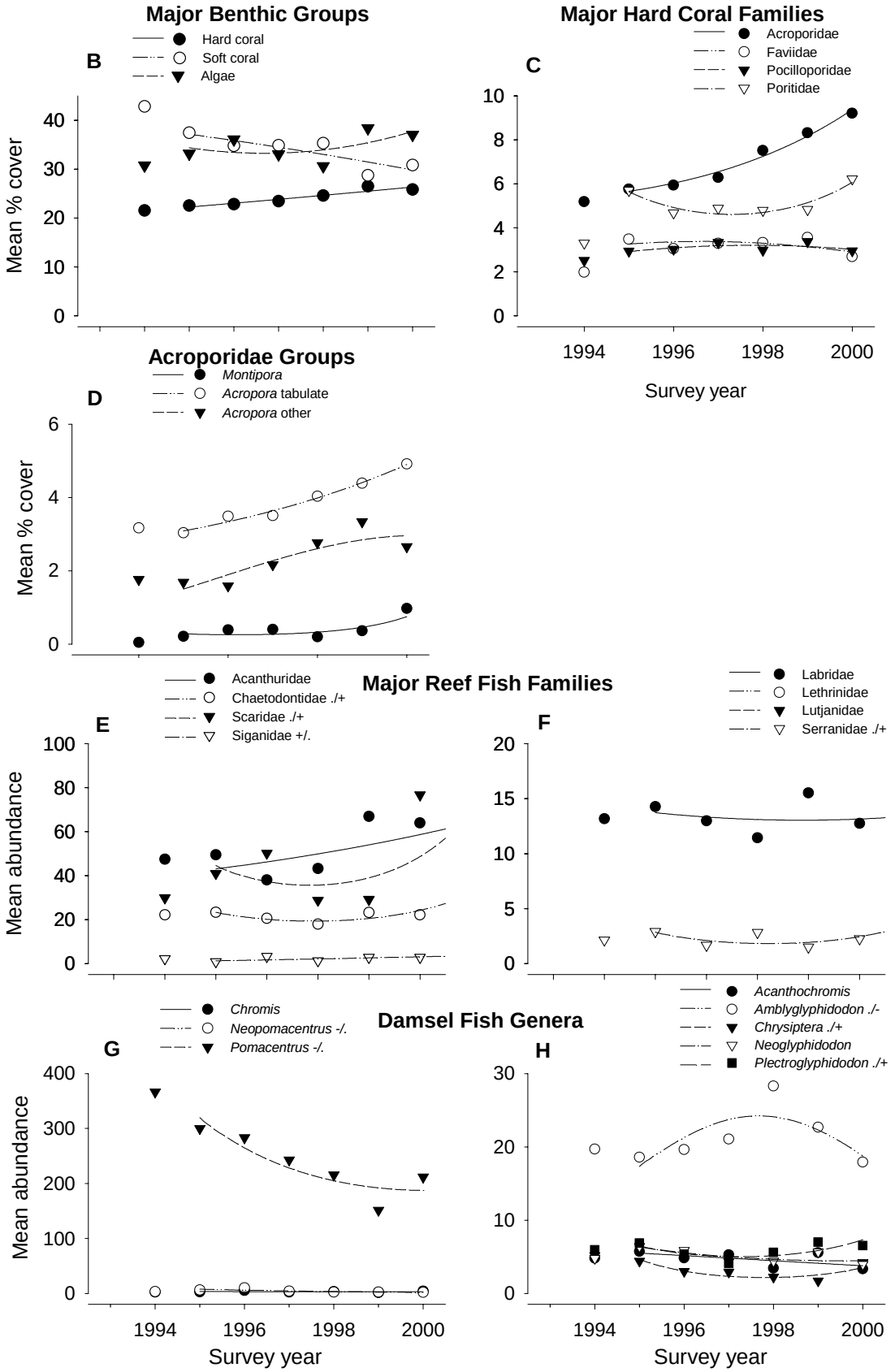


Figure 4.31 cont. Plots showing distribution of regional means and the fitted trend lines for: (B,C,D) percent cover of benthic groups on fixed sites, (E,F,G,H) fish abundance on fixed sites.



Capricorn Bunker Sector

This sector was last surveyed in December 1999.

Summary

No COTS were observed in this sector. In the absence of COTS activity and other major disturbances, hard coral cover has continued to increase. Much of this cover is tabulate *Acropora* spp. Several groups of reef fishes increased in abundance or had stabilised after large increases. Fish species richness continued to increase.

Geography

The survey reefs in the Capricorn-Bunker sector are outer-shelf reefs that are exposed to the influence of the Coral Sea. The low density of reefs means that there is little gradient in exposure. The reefs receive little terrestrial influence in the form of runoff.

Figure 4.32(i) Summary of trends in reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the Sector.

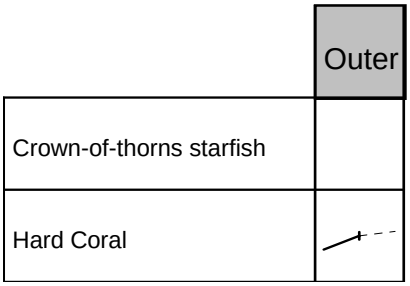


Figure 4.32(ii) Summary of trends in benthic cover on intensive survey sites in the Sector.

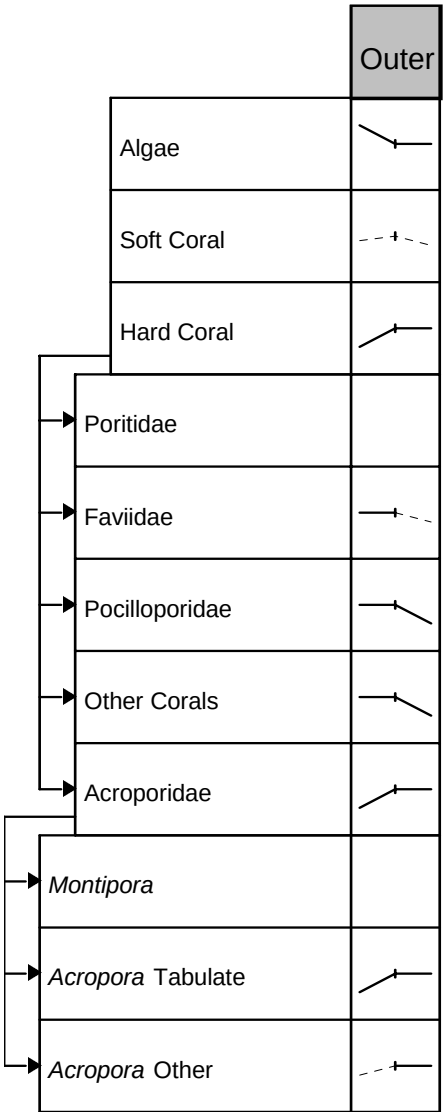


Figure 4.32(iii) Summary of trends in fish abundance in the Sector.

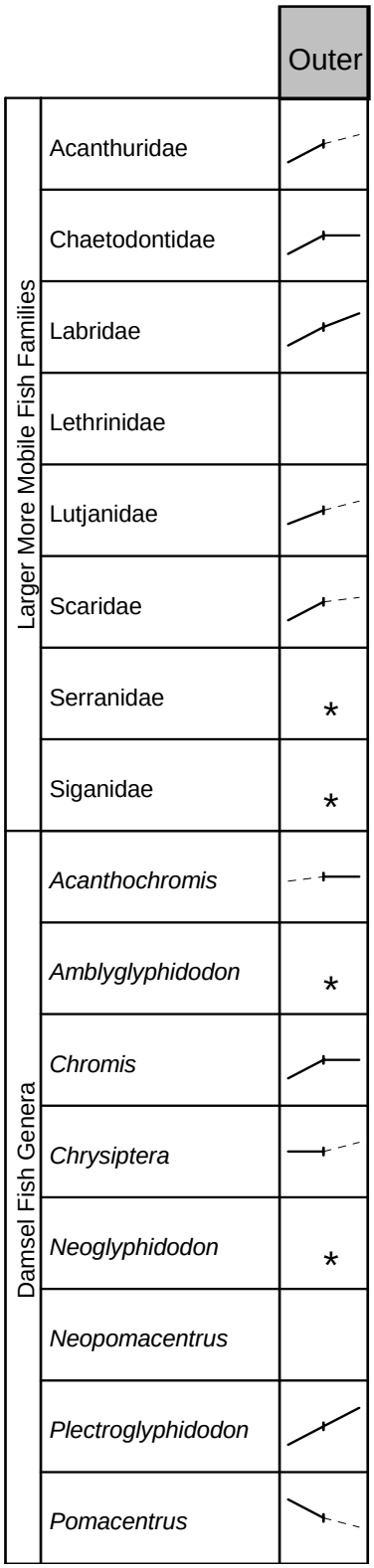
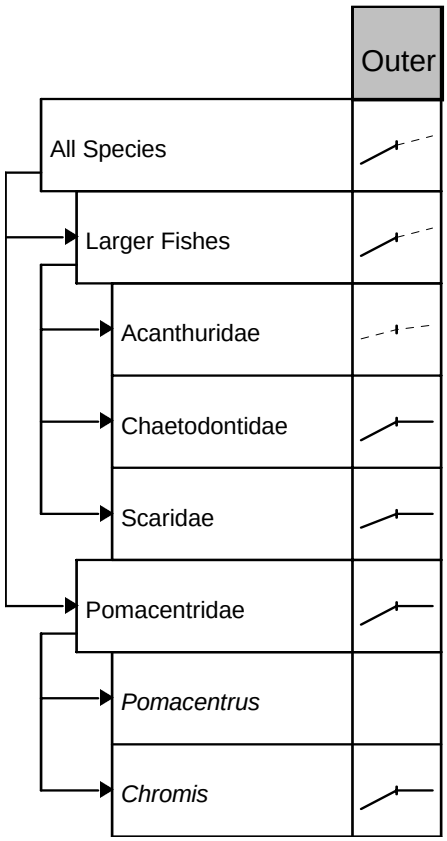


Figure 4.32(iv) Summary of trends in fish species richness in the Sector.



Capricorn Bunker Sector Outer Shelf Reefs

COTS have only ever been observed intermittently and in low numbers (Fig. 4.33A). No COTS were observed in surveys in 2000. Reef-wide coral cover increased between 1995 and 2000 (Fig4.32(i), Fig. 4.33A). Overall reef-wide coral cover was high in 2000 (46%) and still increasing.

Cover of hard corals has increased from an average of about 8% in 1993 to 63% in 2000 (Fig. 4.32 (ii), Fig. 4.33B). This rapid increase in coral cover is mainly due to tabulate *Acropora* spp. which increased from 1% in 1993 to 58% in 2000 (Fig. 4.33D). There has been a corresponding decrease in cover of algae from 85% in 1993 to 31% in 2000 (Fig.4.32 (ii), Fig. 4.33B). Cover of soft corals has varied over the period, but has remained below 3% (Fig. 4.33B).

Many taxa of reef fishes increased in both abundance and species richness as the coral cover increased (Fig. 4.32(iii,iv). This pattern held for a number of species within most taxa. The notable exception was the decline in *Pomacentrus* spp. (Fig. 4.33G), which was due to two species: the neon damsel (*P. coelestis*), which settled in huge numbers in 1994, but has since declined and the australian damsel (*P. australis*) which peaked in abundance in 1996 and declined subsequently . These decreases are presumably due to mortality of a large cohort without substantial replenishment. A number of less abundant *Pomacentrus* spp. increased in abundance over the past five years. Trends in abundance of the genus *Chrysiptera* (essentially the king demoiselle, *Chrysiptera rex*) were inconsistent, declining in abundance from 1996 then increasing significantly in 2000 (Fig. 4.33H).

Fish species richness generally increased with the exception of the damselfish genus *Pomacentrus* (Fig. 4.32 (iv). The total increase from 76 species in 1995 to 92 in 2000 is the greatest change in overall species richness recorded in any sector.

Figure 4.33(A) Plots showing distribution of regional means and the fitted trend lines for reef-wide hard coral cover and crown-of-thorns starfish abundance from manta tow surveys in the region.

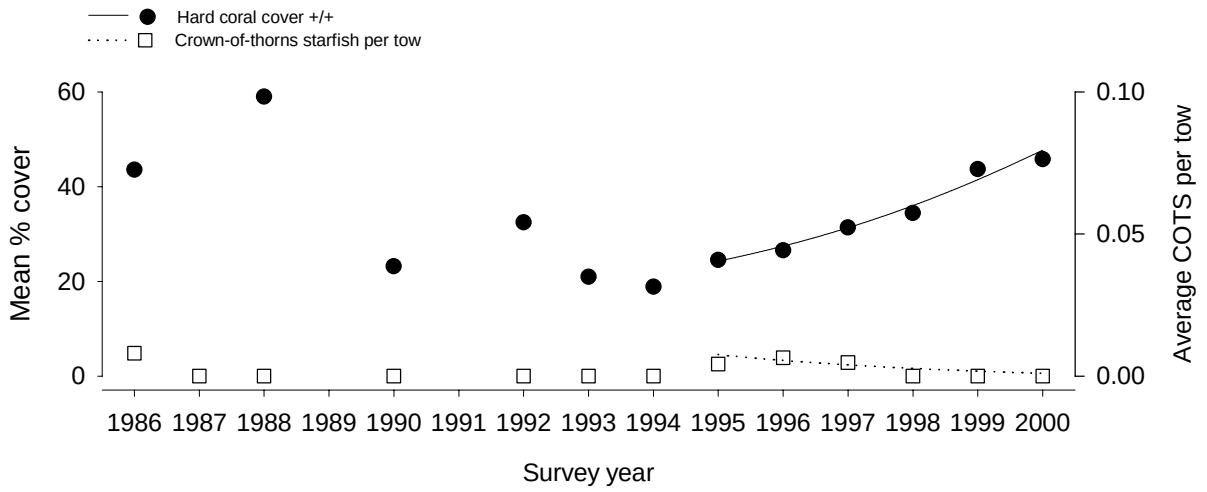
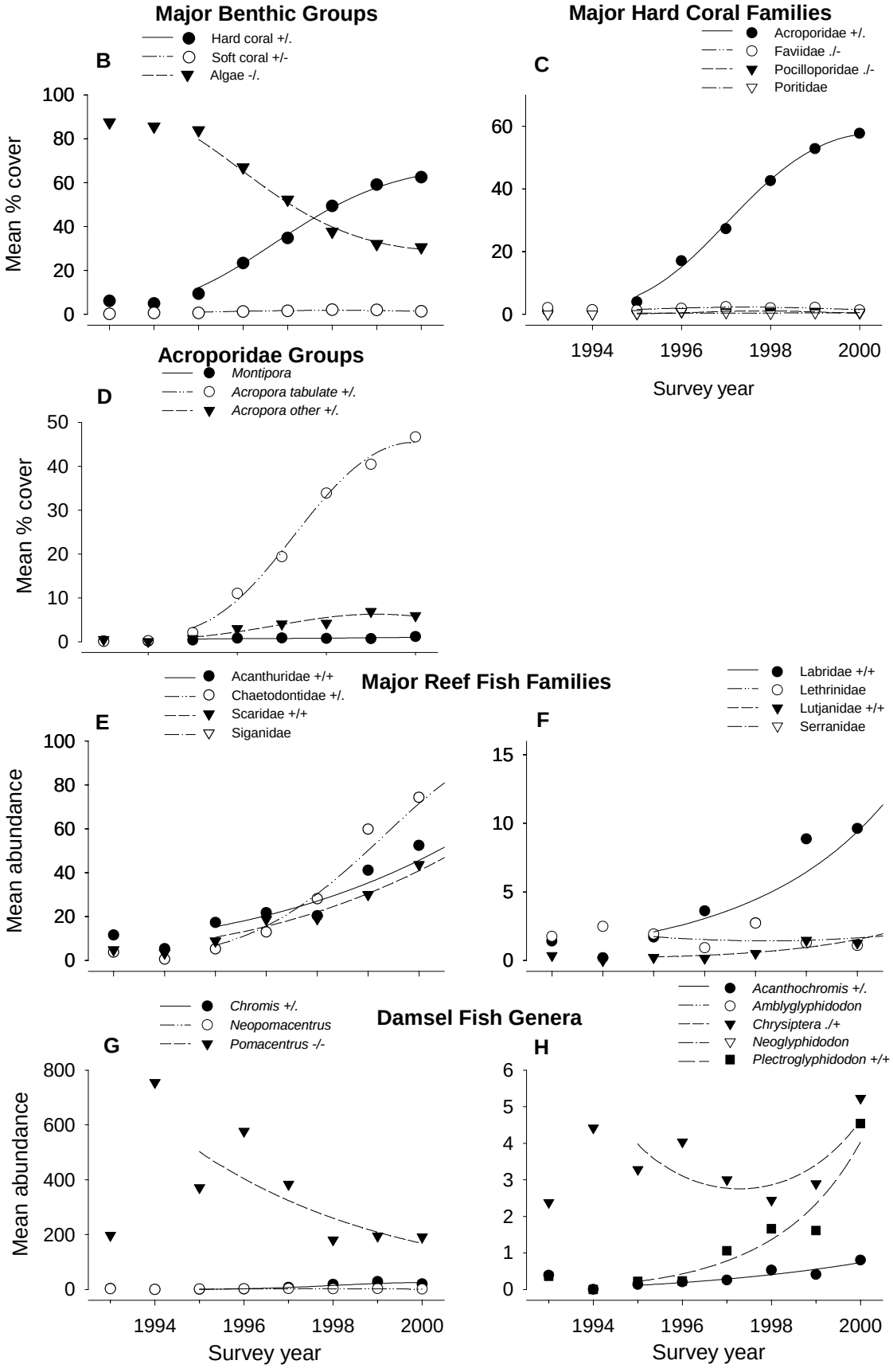


Figure 4.33 cont. Plots showing distribution of regional means and the fitted trend lines for: (B,C,D) percent cover of benthic groups on fixed sites, (E,F,G,H) fish abundance on fixed sites.



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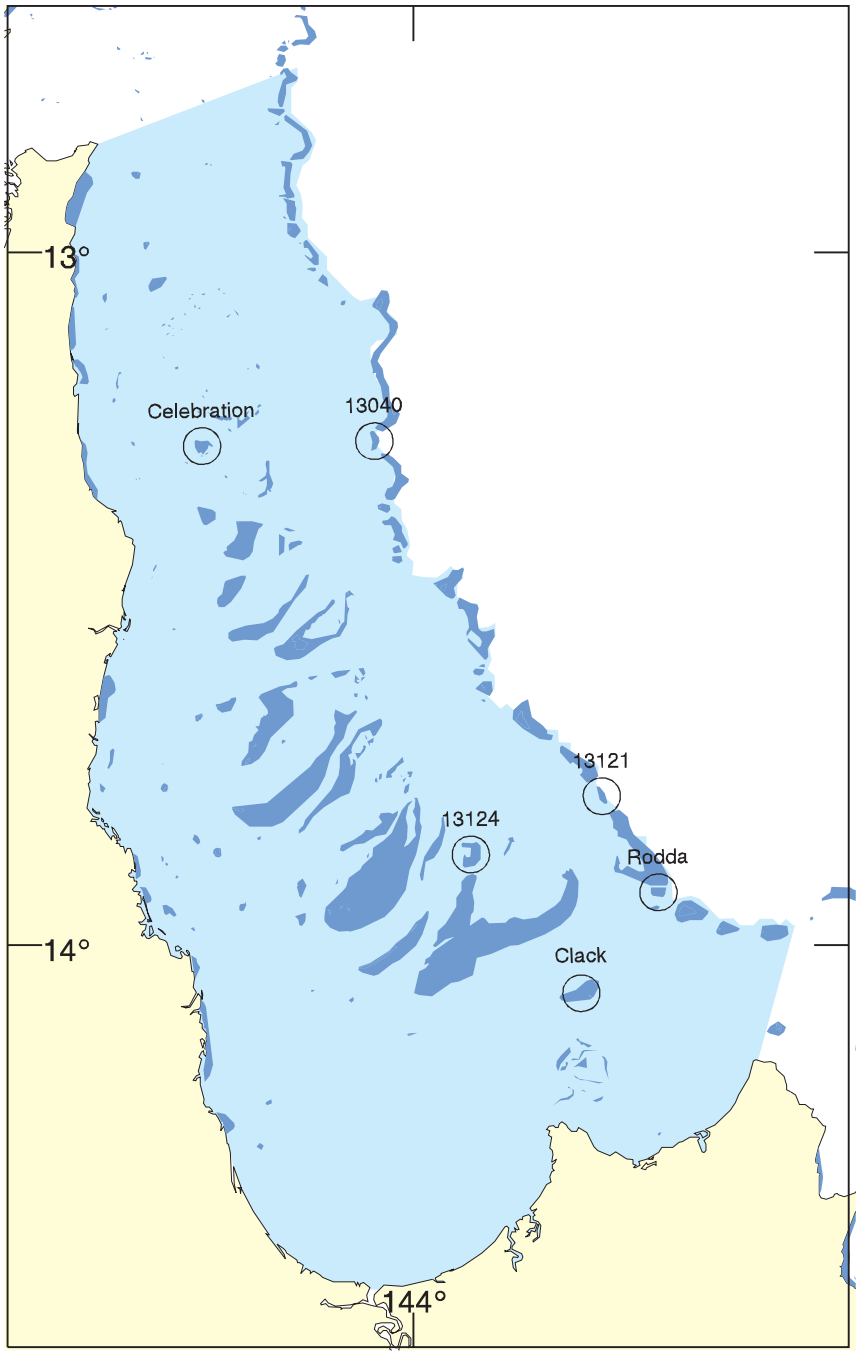
7. Appendices

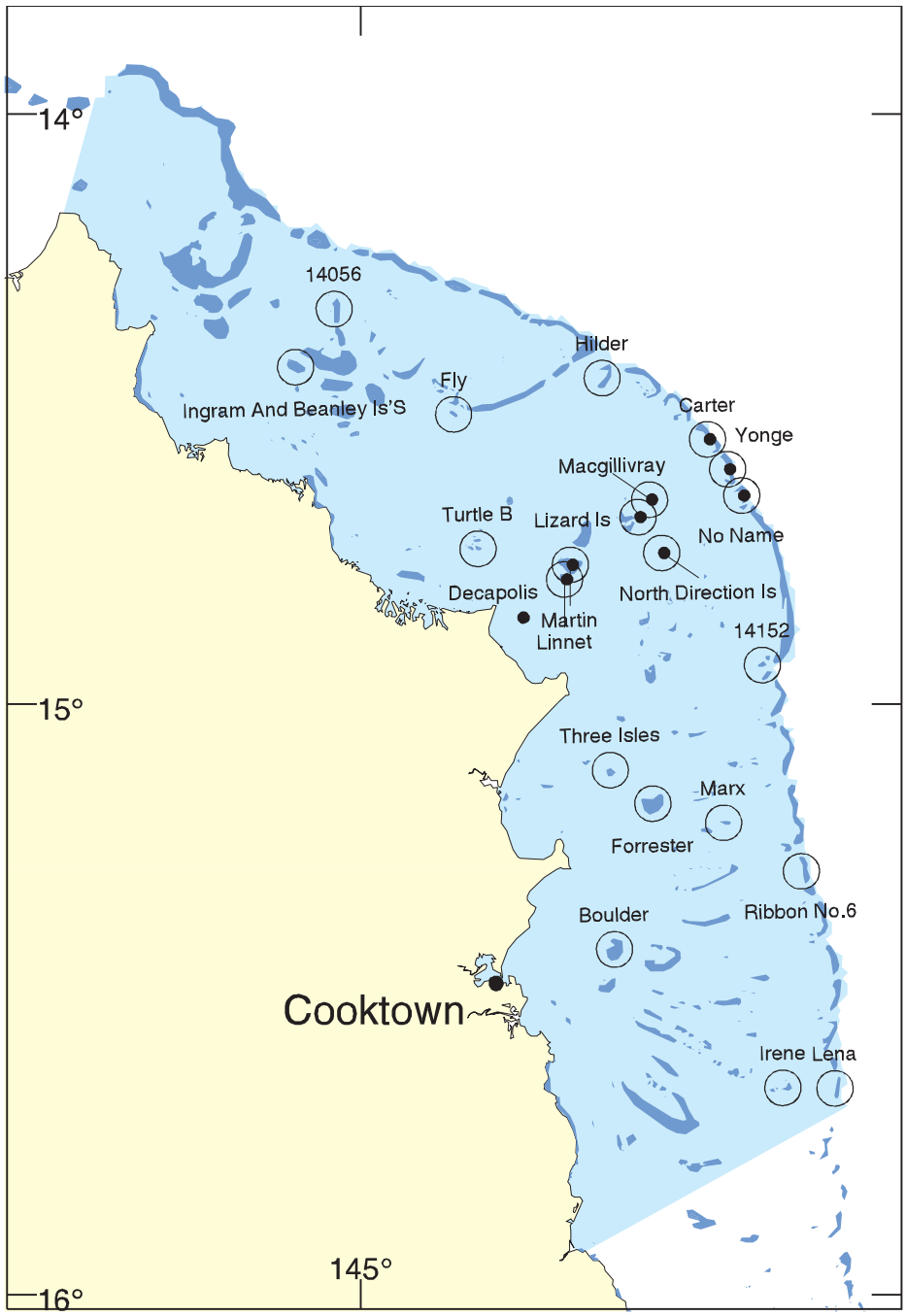
Appendix A

Location of reefs surveyed in 2000 and the types of surveys taken

Princess Charlotte Bay Sector



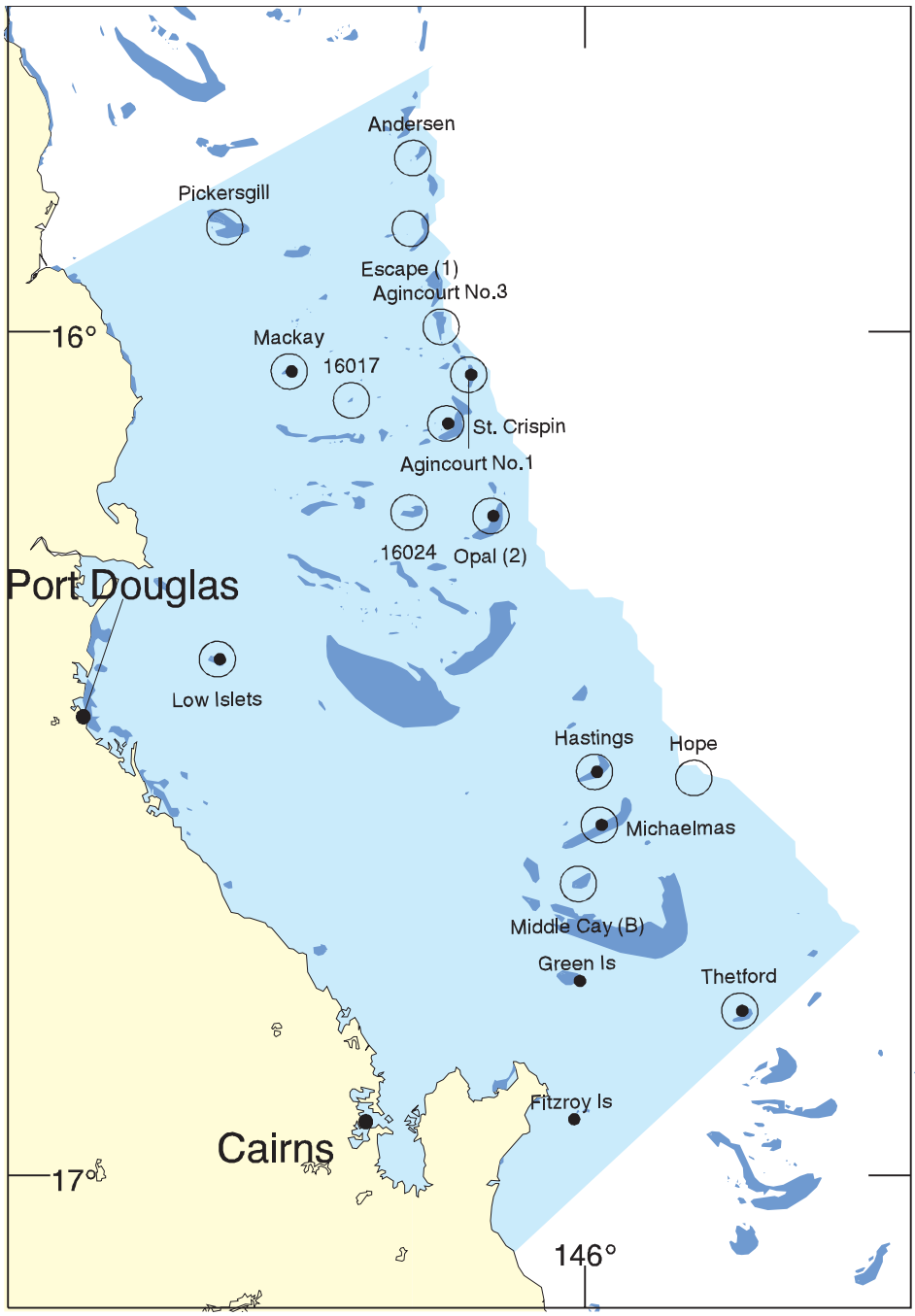
Cooktown / Lizard Island Sector



• Fish and Benthos

○ Manta Tow

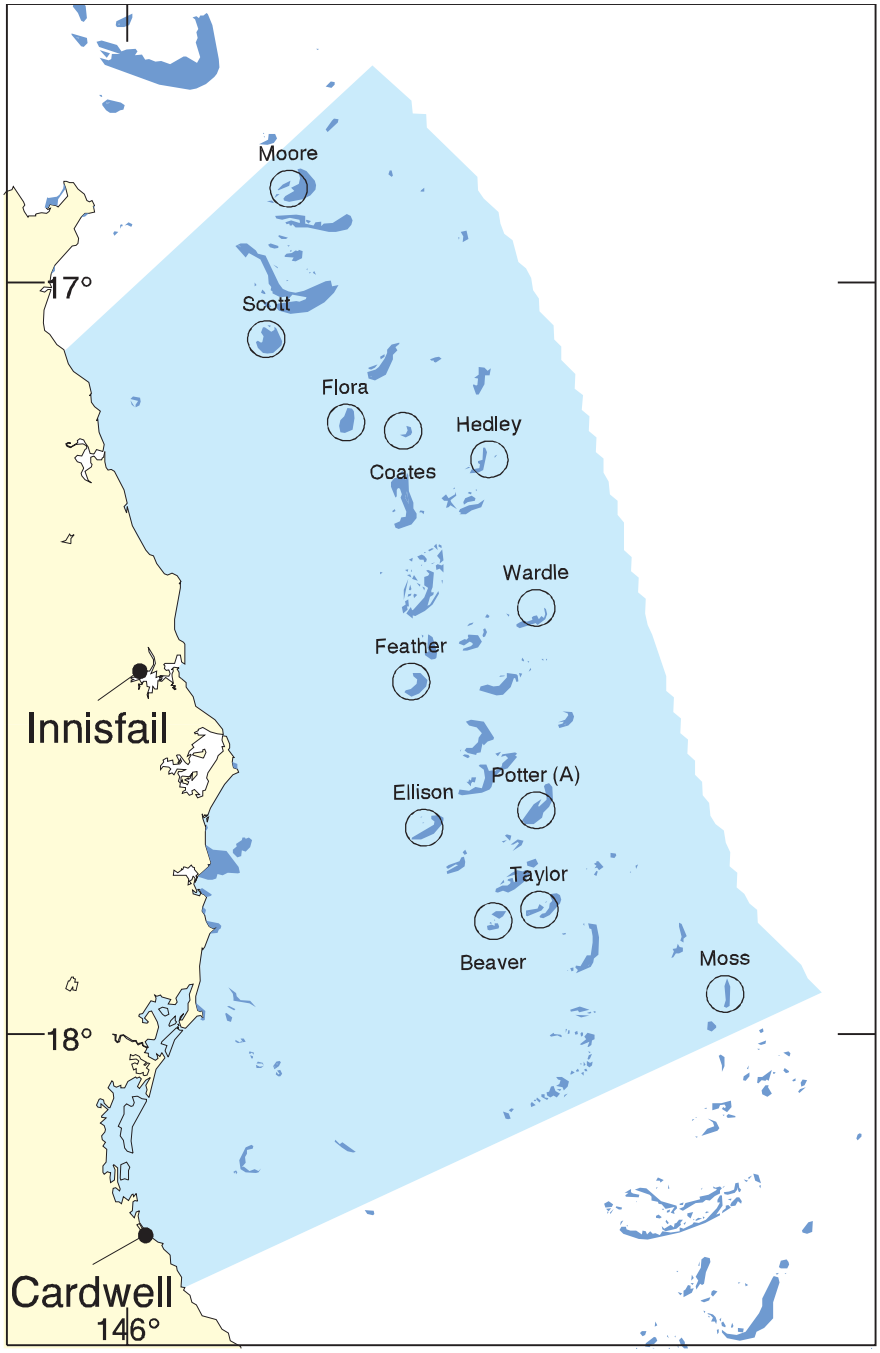
Cairns Sector



- Fish and Benthos

○ Manta Tow

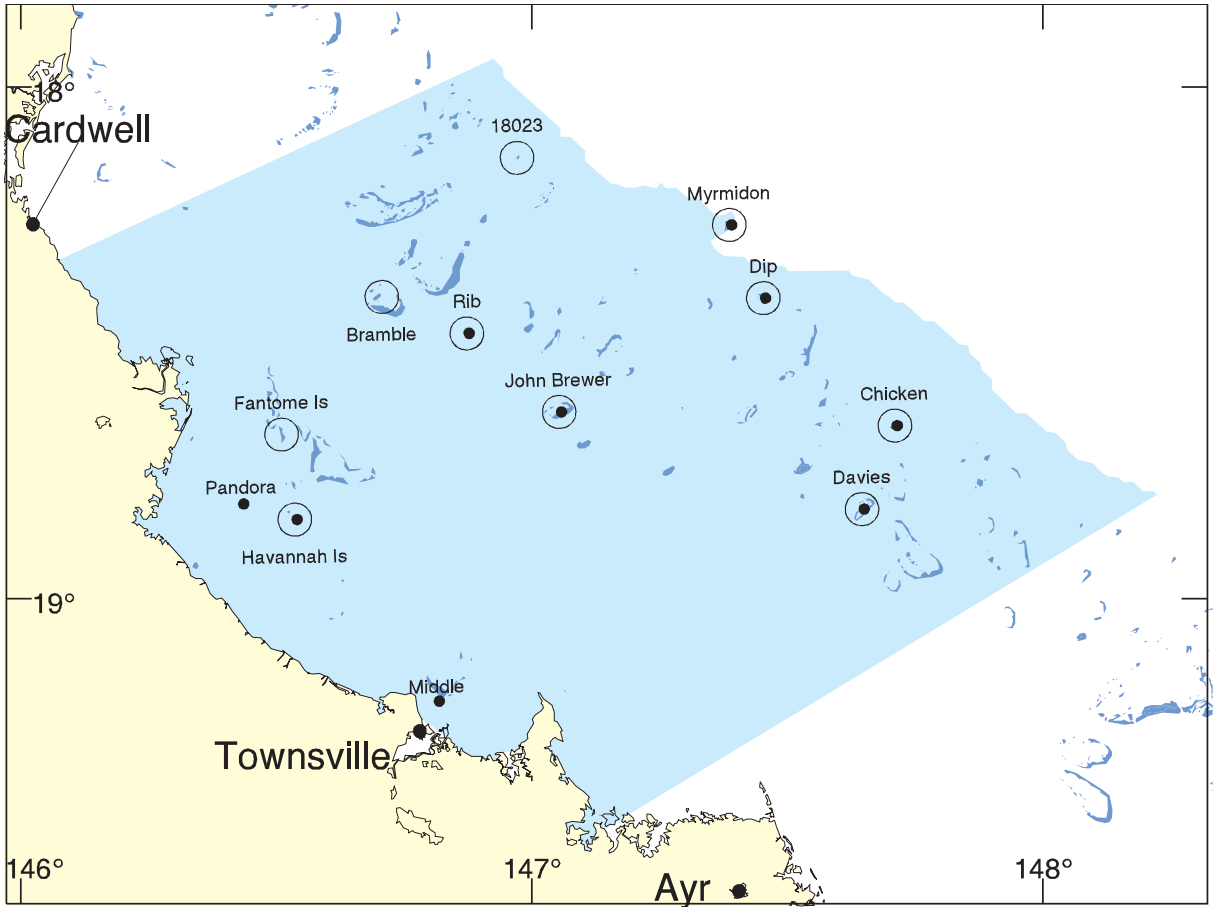
Innisfail Sector



- Fish and Benthos

○ Manta Tow

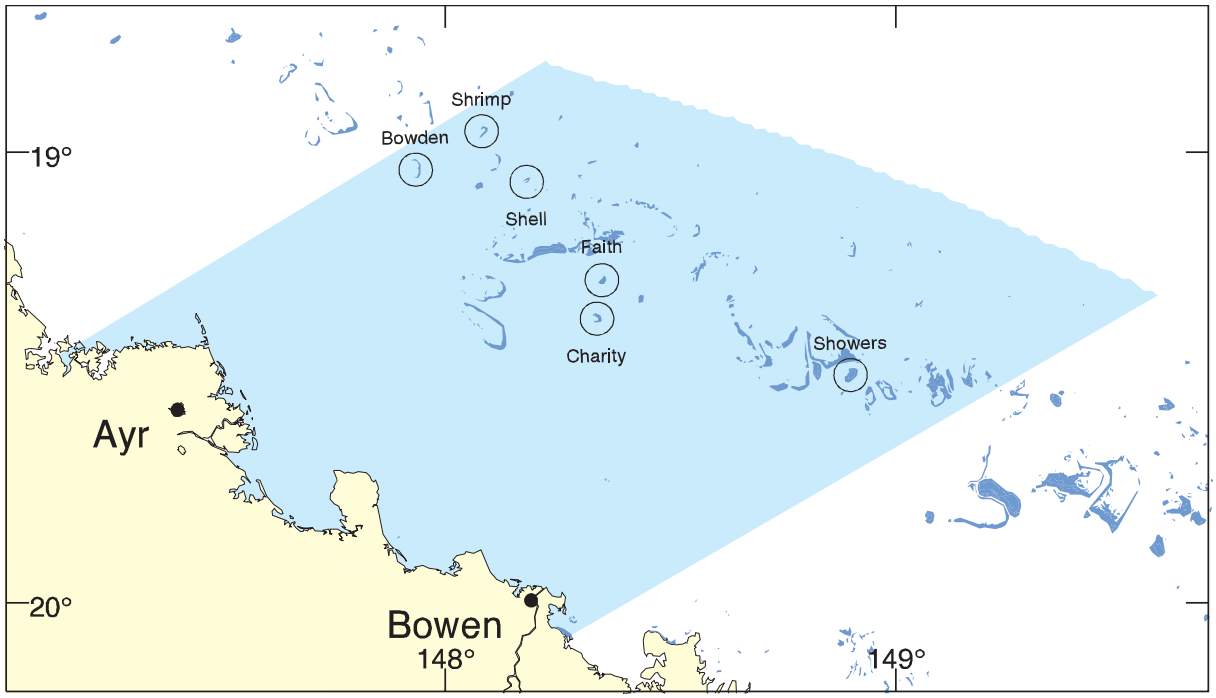
Townsville Sector



• Fish and Benthos

○ Manta Tow

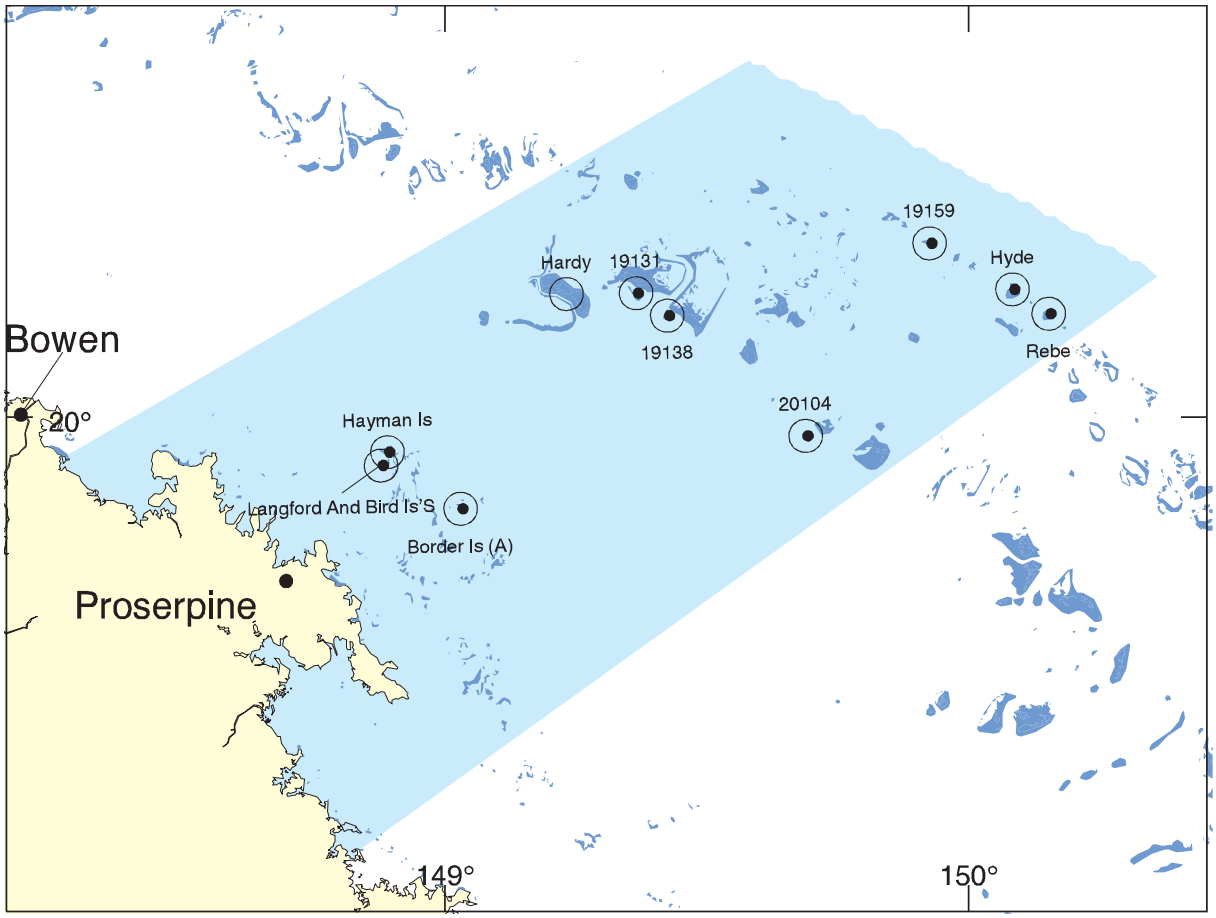
Cape Upstart Sector



- Fish and Benthos

○ Manta Tow

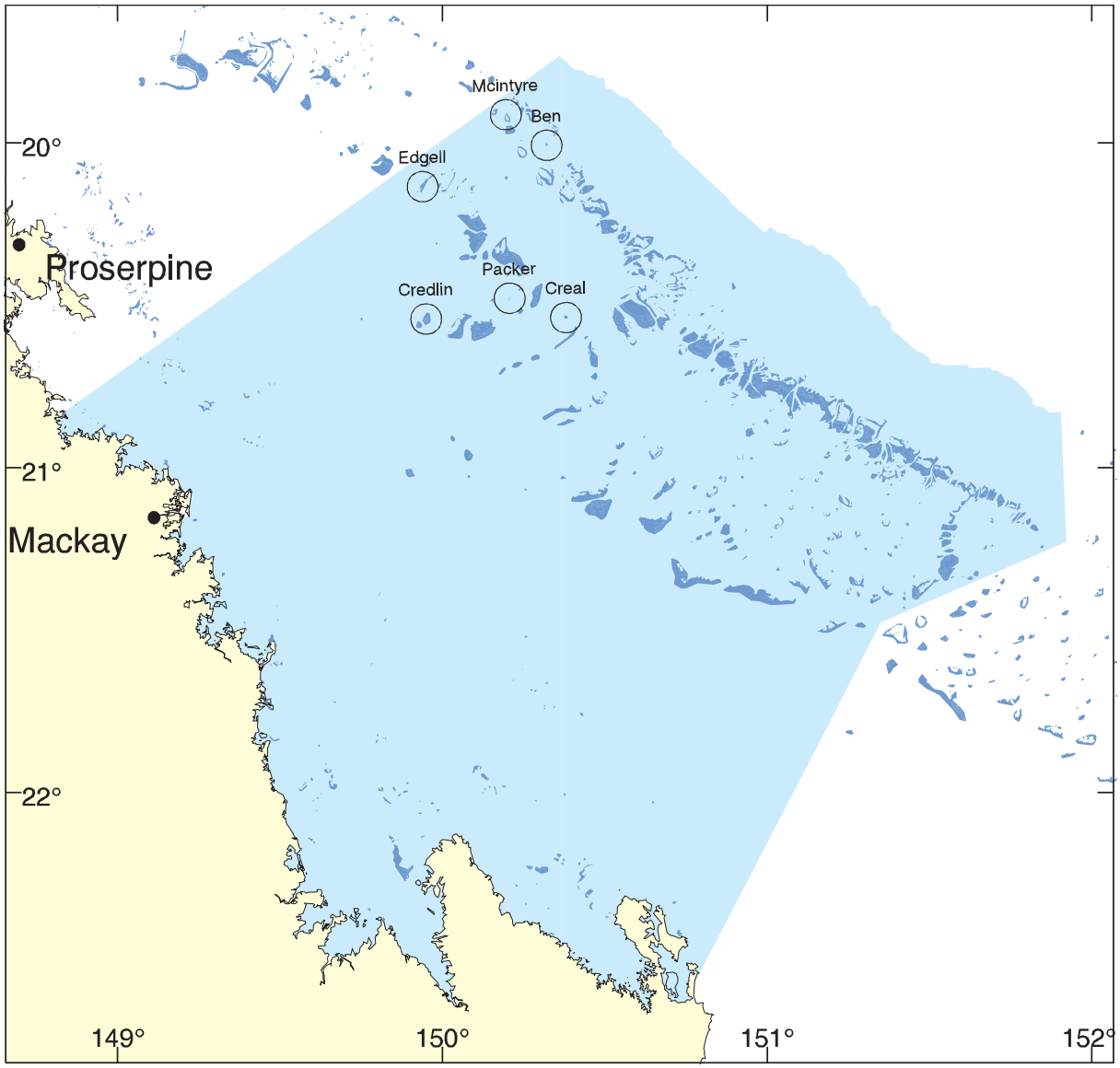
Whitsunday Sector



- Fish and Benthos

- Manta Tow

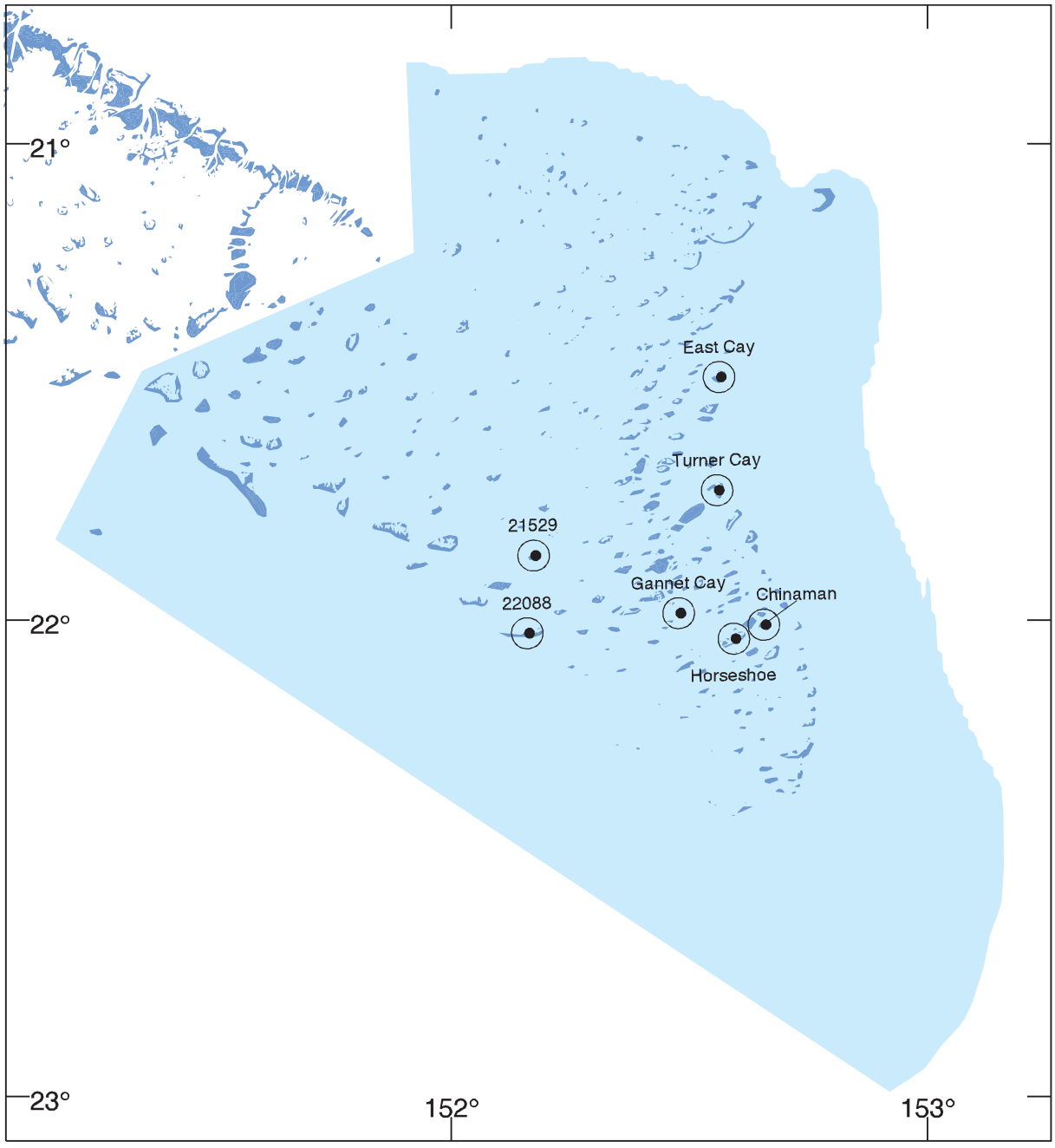
Pompey Sector



- Fish and Benthos

- Manta Tow

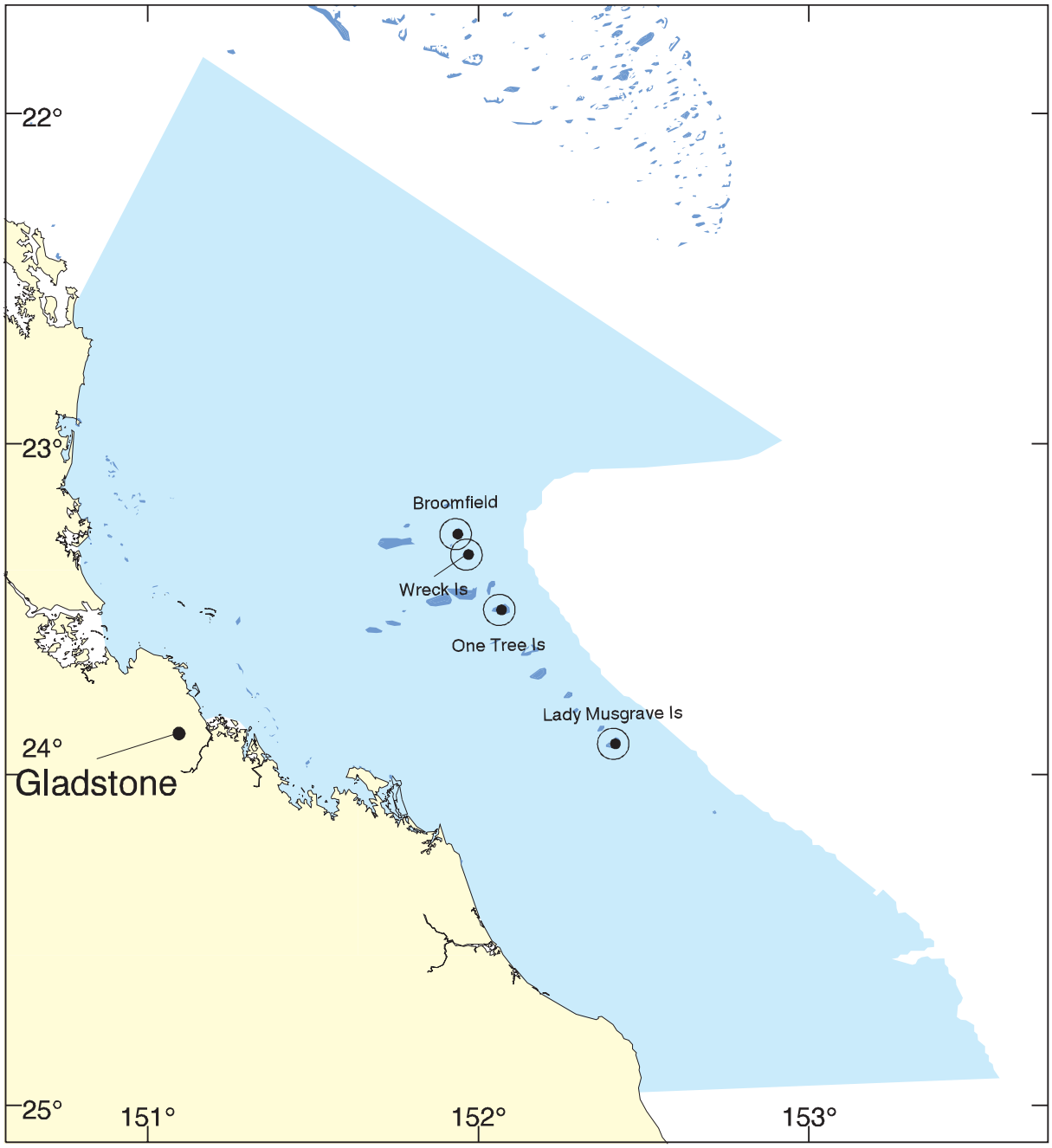
Swains Sector



• Fish and Benthos

○ Manta Tow

Capricorn Bunker Sector



- Fish and Benthos

- Manta Tow

Appendix B

Summary of reefs surveyed in 2000. Reef ID refers to the GBRMPA Gazetteer.
Sampling codes:
B = benthos, F = reef fishes, f = small fish species only, M = manta tow.

Sector	Shelf Position	Reef ID	Reef Name	Year Surveyed
				2000
Princess Charlotte Bay	Inshore	14017	Clack	M
Princess Charlotte Bay	Mid-Shelf	13041	Celebration	M
		13124	13124	M
Princess Charlotte Bay	Outer-Shelf	13040	13040	M
		13121	13121	M
		13127	Rodda	M
Cooktown / Lizard Is	Inshore	14120	Turtle B	M
		14123	Martin	MBF
		14126	Linnet	MBF
		14131	Decapolis	BF
		15005	Three Isles	M
		15012	Boulder	M
Cooktown / Lizard Is	Mid-Shelf	14056	14056	M
		14064	Ingram And Beanley Is'S	M
		14109	Fly	M
		14114	Macgillivray	MBF
		14116	Lizard Is	MBF
		14143	North Direction Is	MBF
		15009	Forrester	M
		15027	Marx	M
		15084	Irene	M
Cooktown / Lizard Is	Outer-Shelf	14085	Hilder	M
		14137	Carter	MBF
		14138	Yonge	MBF
		14139	No Name	MBF
		14152	14152	M
		15032	Ribbon No.6	M
		15085	Lena	M

Sector	Shelf Position	Reef ID	Reef Name	Year Surveyed
				2000
Cairns	Inshore	16028	Low Islets	MBF
		16049	Green Is	BF
		16054	Fitzroy Is	BF
Cairns	Mid-Shelf	15093	Pickersgill	M
		16015	Mackay	MBF
		16017	16017	M
		16024	16024	M
		16044	Middle Cay (B)	M
		16057	Hastings	MBF
		16060	Michaelmas	MBF
		16068	Thetford	MBF
Cairns	Outer-Shelf	15090	Andersen	M
		15094	Escape (1)	M
		15099	Agincourt No.1	MBF
		15099	Agincourt No.3	M
		16019	St. Crispin	MBF
		16025	Opal (2)	MBF
		16058	Hope	M
Innisfail	Mid-Shelf	16071	Moore	M
		17004	Scott	M
		17010	Flora	M
		17011	Coates	M
		17034	Feather	M
		17044	Ellison	M
		17051	Beaver	M
		17064	Taylor	M
Innisfail	Outer-Shelf	17014	Hedley	M
		17032	Wardle	M
		17059	Potter (A)	M
		17068	Moss	M
Townsville	Inshore	18051	Pandora	BF
		18053	Fantome Is	M
		18065	Havannah Is	MBF
		19011	Middle	Bf
Townsville	Mid-Shelf	18029	Bramble	M
		18032	Rib	MBF
		18075	John Brewer	MBF
		18096	Davies	MBF
Townsville	Outer-Shelf	18023	18023	M
		18034	Myrmidon	MBF
		18039	Dip	MBF
		18086	Chicken	MBF

Sector	Shelf Position	Reef ID	Reef Name	Year Surveyed
				2000
Cape Upstart	Mid-Shelf	18118	Shrimp	M
		19019	Bowden	M
		19028	Shell	M
		19044	Faith	M
		19047	Charity	M
		19076	Showers	M
Whitsunday	Inshore	20014	Hayman Is	MBF
		20019	Langford And Bird Is'S	MBF
		20067	Border Is (A)	MBF
Whitsunday	Mid-Shelf	19131	19131	MBF
		19135	Hardy	M
		19138	19138	MBF
		20104	20104	MBF
Whitsunday	Outer-Shelf	19159	19159	MBF
		19207	Hyde	MBF
		19209	Rebe	MBF
Pompey	Mid-Shelf	19219	Mcintyre	M
		20112	Edgell	M
		20145	Packer	M
		20287	Credlin	M
		20297	Creal	M
Pompey	Outer-Shelf	20113	Ben	M
Swain	Mid-Shelf	21529	21529	MBF
		21556	Gannet Cay	MBF
		22088	22088	MBF
		22102	Chinaman	MBF
		22104	Horseshoe	MBF
Swain	Outer-Shelf	21305	East Cay	MBF
		21562	Turner Cay	MBF
Capricorn/Bunker	Outer-Shelf	23048	Broomfield	MBF
		23051	Wreck Is	MBF
		23055	One Tree Is	MBF
		23082	Lady Musgrave Is	MBF

Appendix C

A. List of large, mobile fish species that would be counted on 5 m wide transects

Acanthuridae
Acanthurus (grouped)
Acanthurus albipectoralis
Acanthurus auranticavus
Acanthurus Bariene
Acanthurus blochii
Acanthurus dussumieri
Acanthurus grammoptilus
Acanthurus lineatus
Acanthurus maculiceps
Acanthurus mata
Acanthurus nigricans
Acanthurus nigricauda
Acanthurus nigrofuscus
Acanthurus nigroris
Acanthurus olivaceus
Acanthurus pyroferus
Acanthurus spp.
Acanthurus thompsoni
Acanthurus triostegus
Acanthurus xanthopterus
Ctenochaetus (grouped)
Naso lituratus
Naso tuberosus
Naso unicornus
Paracanthurus hepatus
Zebrasoma scopas
Zebrasoma veliferum

Chaetodontidae
Chaetodon aureofasciatus
Chaetodon auriga
Chaetodon baronessa
Chaetodon bennetti
Chaetodon citrinellus
Chaetodon ephippium
Chaetodon flavirostris
Chaetodon kleinii
Chaetodon lineolatus
Chaetodon lunula
Chaetodon melannotus
Chaetodon mertensii
Chaetodon meyerii
Chaetodon ocellicaudus
Chaetodon ornatissimus
Chaetodon pelewensis
Chaetodon plebeius
Chaetodon punctatofasciatus
Chaetodon rafflesi
Chaetodon rainfordi
Chaetodon reticulatus
Chaetodon speculum
Chaetodon trifascialis
Chaetodon trifasciatus
Chaetodon ulietensis
Chaetodon unimaculatus
Chaetodon vagabundus
Chelmon rostratus
Forcipiger flavissimus
Forcipiger longirostrus
Hemitaurichthys polylepis

Labridae
Cheilinus fasciatus
Cheilinus undulatus
Choerodon fasciatus
Coris gaimard
Epibulus insidiator
Gomphosus varius
Halichoeres hortulanus
Hemigymnus fasciatus
Hemigymnus melapterus
Macropharyngodon spp.

Lethrinidae
Lethrinus atkinsoni
Lethrinus erythracanthus
Lethrinus harak
Lethrinus laticaudus
Lethrinus lentjan
Lethrinus miniatus
Lethrinus nebulosus
Lethrinus obsoletus
Lethrinus olivaceus
Lethrinus ornatus
Lethrinus rubrioperculatus
Lethrinus semicinctus
Lethrinus xanthochilus
Monotaxis grandoculis

Lutjanidae
Lutjanus adetti
Lutjanus argentimaculatus
Lutjanus biguttatus
Lutjanus bohar
Lutjanus boutton
Lutjanus carponotatus
Lutjanus fulviflamma
Lutjanus fulvus
Lutjanus gibbus
Lutjanus johnii
Lutjanus kasmira
Lutjanus lemniscatus
Lutjanus lutjanus
Lutjanus monostigma
Lutjanus quinquelineatus
Lutjanus rivulatus
Lutjanus russelli
Lutjanus sebae
Lutjanus semicinctus
Lutjanus vittus
Macolor (grouped)

Scaridae
Bolbometopon muricatum
Calotomus carolinus
Cetoscarus bicolor
Chlorurus bleekeri
Chlorurus japanensis
Chlorurus microrhinos
Chlorurus sordidus
Hipposcarus longiceps
Scarus (grouped)
Scarus altipinnis
Scarus chameleon
Scarus dimidiatus
Scarus flavipectoralis
Scarus forsteni
Scarus frenatus
Scarus ghobban
Scarus globiceps
Scarus longipinnus
Scarus niger
Scarus oviceps
Scarus psittacus
Scarus rivulatus
Scarus rubroviolaceus
Scarus schlegeli
Scarus spinus
Scarus spp.

Serranidae
Plectropomus areolatus
Plectropomus laevis
Plectropomus leopardus
Plectropomus maculatus
Variola louti

Siganidae
Siganus argenteus
Siganus corallinus
Siganus doliatus
Siganus fuscescens
Siganus javus
Siganus lineatus
Siganus puellus
Siganus punctatissimus
Siganus punctatus
Siganus vulpinus

Zanclidae
Zanclus cornutus

B. List of damselfish species that would be counted on 1 m wide transects

Acanthochromis polyacanthus
Amblyglyphidodon aureus
Amblyglyphidodon curacao
Amblyglyphidodon leucogaster
Amphiprion akindynos
Amphiprion chrysopterus
Amphiprion clarkii
Amphiprion melanopus
Amphiprion percula
Amphiprion perideraion
Cheiloprion labiatus
Chromis acares
Chromis agilis
Chromis amboinensis
Chromis atripectoralis
Chromis atripes
Chromis chrysura
Chromis flavomaculata
Chromis iomelas
Chromis lepidolepis
Chromis lineata
Chromis margaritifer
Chromis nitida
Chromis retrofasciatus
Chromis ternatensis
Chromis vanderbilti
Chromis viridis
Chromis weberi
Chromis xanthura
Chrysiptera biocellata
Chrysiptera flavipinnis
Chrysiptera rex
Chrysiptera rollandi
Chrysiptera talboti
Dascyllus aruanus
Dascyllus melanurus
Dascyllus reticulatus
Dascyllus trimaculatus
Dischistodus melanotus
Dischistodus perspicillatus
Dischistodus prosopotaenia
Dischistodus pseudochrysopoecilus
Hemiglyphidodon plagiometopon
Neoglyphidodon melas
Neoglyphidodon nigroris
Neoglyphidodon polyacanthus
Neopomacentrus azysron
Neopomacentrus bankieri
Neopomacentrus cyanomos
Plectroglyphidodon dickii
Plectroglyphidodon johnstonianus
Plectroglyphidodon lacrymatus
Plectroglyphidodon leucozona
Pomacentrus adelus
Pomacentrus amboinensis
Pomacentrus australis
Pomacentrus bankanensis
Pomacentrus brachialis
Pomacentrus chrysurus
Pomacentrus coelestis
Pomacentrus grammnorhyncus
Pomacentrus imitator
Pomacentrus lepidogenys
Pomacentrus moluccensis
Pomacentrus nagasakiensis
Pomacentrus philippinus
Pomacentrus tripunctatus
Pomacentrus vaiuli
Pomacentrus wardi
Pomachromis richardsoni
Premnas biaculeatus
Stegastes apicalis
Stegastes fasciolatus
Stegastes gasgoinei
Stegastes nigricans

Appendix D

General status of crown-of-thorns starfish in each sector on the Great Barrier Reef for survey year 2000.

D1. Status of crown-of-thorns starfish (COTS) in each sector in 2000. AO = Active outbreak, IO = Incipient outbreak, RE = Recovering, NO = No outbreak.

Sector	No. of Reefs	No. COTS/ tow	No. COTS	Number (%) of Reefs with COTS	Median category (range) coral cover		Mean % Coral Cover ± SE	% AO or IO reefs	% RE reefs	% NO reefs
Princess Charlotte Bay	6	0.02	7	3 (50)	2+/3-	(2- to 3-)	28.66 ± 3.75	0	33.33	66.7
Cooktown / Lizard Island	21	0.03	32	8 (38)	2+	(1+ to 3+)	25.93 ± 1.73	0	47.62	52.4
Cairns	16	0.37	287	10 (62)	2+	(1+ to 3-)	22.69 ± 1.89	43.75	12.5	43.8
Innisfail	12	3.07	2046	8 (67)	1+	(1- to 2+)	10.26 ± 2.00	41.67	50	8.33
Townsville	10	3.49	1705	5 (50)	2-	(1- to 2+)	14.9 ± 2.86	30	30	40
Cape Upstart	6	0.03	7	3 (50)	2-/2+	(2- to 2+)	21.28 ± 1.64	0	50	50
Whitsunday	10	0.002	1	1 (10)	2-/2+	(2- to 3-)	24.69 ± 2.51	0	20	80
Pompey	6	0.004	1	1 (17)	2+/3+	(2- to 3+)	36.34 ± 5.72	0	0	100
Swain	7	1.27	441	5 (71)	2+	(1+ to 3+)	28.91 ± 3.66	42.86	14.29	42.9
Capricorn Bunker	4	0	0	0 (0)	3-/3+	(3- to 4-)	45.79 ± 1.71	0	0	100

Appendix E

Percentage cover of selected groups of benthic organisms recorded from each region in 2000 Survey.

Figures are regional means.

CG = Cape Grenville, PC = Princess Charlotte Bay, CL = Cooktown / Lizard Is, CA = Cairns, TO = Townsville, WH = Whitsundays, SW = Swains, CB = Capricorn / Bunkers. I= Inshore, M = Mid-shelf, O = Outer shelf

Sector	Shelf	Hard Coral	Soft Coral	Algae	Acroporidae	Favidae	Pocilloporidae	Poritidae	Acropora Tabulate	Acropora Other	Montipora
CL	I	30.4	4.5	43.7	10.6	4.5	4.6	5.1	4.6	3.3	2.7
CL	M	15.6	7.2	58.8	1.3	3.0	1.0	6.7	0.3	0.8	0.2
CL	O	55.9	5.7	33.8	42.7	1.1	8.0	2.0	29.1	12.2	1.4
CA	I	6.6	9.2	71.6	0.8	0.4	0.1	3.1	0.1	0.0	0.7
CA	M	23.2	14.2	55.6	10.1	3.6	3.1	2.2	5.6	3.7	0.8
CA	O	25.7	31.1	37.7	16.2	1.5	4.4	2.6	6.5	9.2	0.5
TO	I	29.3	10.8	45.9	4.4	1.6	0.1	13.8	0.8	2.0	1.6
TO	M	28.0	2.3	62.5	16.0	3.0	2.7	3.0	8.7	5.7	1.5
TO	O	32.4	13.6	47.7	13.4	6.1	5.0	3.6	4.3	6.8	2.1
WH	I	28.8	22.5	28.6	9.8	3.9	0.7	8.3	0.7	3.6	5.5
WH	M	26.4	1.3	66.1	8.8	7.0	2.7	3.4	1.7	1.7	5.4
WH	O	26.7	34.0	24.4	12.9	2.8	3.1	5.0	5.1	6.5	1.3
SW	M	32.7	9.4	54.1	17.2	2.8	2.9	6.5	3.8	7.6	5.7
SW	O	26.3	31.0	37.0	10.2	3.0	3.2	6.4	6.0	2.8	1.4
CB	O	61.8	3.6	31.2	57.5	1.7	0.8	0.8	49.2	6.5	1.8

Appendix F

Summary counts of the different fish taxa recorded from each region in 2000 Survey.
Figures are regional means for the sums of individuals on 15 transects (3 sites) on each survey reef.

F1. Number of larger more mobile fishes recorded in the regions in the 199899 survey.

CG = Cape Grenville, PC = Princess Charlotte Bay, CL = Cooktown / Lizard Is, CA = Cairns, TO = Townsville, WH = Whitsundays, SW = Swains, CB = Capricorn / Bunkers. I= Inshore, M = Mid-shelf, O = Outer shelf

Sector	Shelf	Acanthuridae	Chaetodontidae	Labridae	Lethrinidae	Lutjanidae	Scaridae	Serranidae	Siganidae	Zanclidae
CL	I	75	80	40	4	64	92	10	81	0
CL	M	116	69	55	26	24	130	11	50	0
CL	O	297	181	35	13	74	154	3	5	16
CA	I	52	58	51	5	118	154	8	49	0
CA	M	158	74	42	9	28	142	3	20	2
CA	O	242	103	34	12	6	234	2	9	4
TO	I	3	50	28	0	23	75	6	12	0
TO	M	96	89	38	3	4	196	6	34	0
TO	O	205	68	29	7	2	138	7	7	2
WH	I	7	73	46	1	36	60	7	23	0
WH	M	38	45	45	3	15	190	15	30	0
WH	O	217	98	27	2	4	103	7	35	5
SW	M	133	73	49	5	8	255	23	59	5
SW	O	185	100	42	3	2	193	14	14	5
CB	O	178	258	41	16	14	164	8	2	8

F2. Number of damselfishes recorded in the regions in the 2000 survey.

CG = Cape Grenville, PC = Princess Charlotte Bay, CL = Cooktown / Lizard Is, CA = Cairns, TO = Townsville, WH = Whitsundays, SW = Swains, CB = Capricorn / Bunkers. I= Inshore, M = Mid-shelf, O = Outer shelf

Sector	Shelf	Acantho-chromis	Amblygly-phidodon	Amphip-rion	Chromis	Chrysip-tera	Dascyllus	Dischist-odus	Neogly-phidodon	Neopoma-centrus	Plectrogly-phidodon	Poma-centrus	Poma-chromis	Premnas	Stegastes
CL	I	129	84	0	72	51	9	2	15	463	0	1728	0	1	0
CL	M	52	80	2	47	138	22	5	11	59	18	674	0	0	1
CL	O	69	1	1	828	4	5	0	0	0	104	166	0	0	0
CA	I	36	36	0	4	49	0	2	36	115	1	514	0	0	1
CA	M	31	45	2	186	35	9	5	17	204	70	802	0	0	13
CA	O	18	8	1	140	23	3	0	4	12	80	245	0	0	0
TO	I	40	5	0	0	0	0	0	25	322	0	202	0	0	0
TO	M	35	70	5	265	36	1	4	65	249	22	897	0	0	6
TO	O	19	5	3	193	19	8	0	1	116	124	491	0	0	24
WH	I	64	66	0	150	184	1	1	4	211	0	1018	0	0	0
WH	M	5	8	1	28	51	0	0	0	1347	0	1250	0	0	10
WH	O	12	39	2	102	26	2	0	23	63	48	678	0	0	1
SW	M	5	147	5	673	25	0	0	6	140	8	1814	0	0	2
SW	O	13	57	3	74	15	0	1	14	14	24	720	0	0	10
CB	O	5	0	0	145	18	1	0	0	14	21	730	0	0	0

Appendix G

Mean Percentage cover of selected groups of benthic organisms recorded from each reef in 2000 Survey.

Sector	Reef	Reef ID	Shelf	Algae	Hard Coral	Soft Coral	Acro-poridae	Favii-dae	Pocillo-poridae	Pori-tidae	*Acropora* Tabulate	*Acropora* Other	*Monti-pora*
CL	Martin	14123	I	42.5	24.4	4.8	6.8	2.6	5.5	6.2	3.5	2.4	0.8
CL	Linnet	14126	I	44.5	41.7	5.8	14.0	9.0	6.8	6.4	5.2	5.5	3.3
CL	Decapolis	14131	I	44.1	24.9	2.9	10.9	1.9	1.5	2.7	5.0	1.9	4.0
CL	Macgillivray	14114	M	51.6	17.7	4.9	1.0	3.1	0.5	9.6	0.2	0.5	0.2
CL	Lizard Is	14116	M	62.8	12.4	15.2	0.4	3.5	1.6	5.1	0.2	0.1	0.1
CL	North Direction I	14143	M	61.9	16.7	1.4	2.6	2.5	1.0	5.4	0.5	1.7	0.3
CL	Carter	14137	O	30.4	62.0	3.2	50.0	1.5	7.3	0.8	35.7	13.1	1.2
CL	Yonge	14138	O	38.1	54.0	4.0	40.0	1.2	8.6	1.9	25.1	13.3	1.6
CL	No Name	14139	O	32.9	51.7	9.9	38.0	0.6	8.0	3.2	26.3	10.1	1.5
CA	Low Islets	16028	I	76.9	8.9	7.1	1.0	0.4	0.0	4.5	0.0	0.0	1.0
CA	Green Is	16049	I	72.5	4.1	5.0	0.3	0.5	0.2	2.2	0.1	0.1	0.1
CA	Fitzroy Is	16054	I	65.3	6.8	15.5	1.2	0.3	0.1	2.7	0.2	0.0	1.0
CA	Mackay	16015	M	58.8	25.2	3.7	2.6	5.4	2.6	4.1	0.6	1.2	0.8
CA	Hastings	16057	M	63.2	23.2	8.2	12.4	2.6	3.9	1.5	6.3	5.6	0.5
CA	Michaelmas	16060	M	42.4	21.5	29.7	12.7	3.1	2.7	1.3	7.0	4.8	0.9
CA	Thetford	16068	M	57.8	23.0	15.4	13.0	3.1	3.2	1.8	8.6	3.5	0.9
CA	Agincourt No.1	15099	O	36.2	36.6	23.6	23.9	1.7	8.4	1.9	10.6	13.0	0.3
CA	St. Crispin	16019	O	32.1	21.0	39.8	10.5	1.8	2.9	4.6	6.0	3.8	0.6
CA	Opal (2)	16025	O	44.7	19.5	30.0	14.3	1.1	1.9	1.5	2.8	10.9	0.6
TO	Pandora	18051	I	44.0	41.6	8.4	0.6	2.0	0.1	23.2	0.2	0.2	0.2
TO	Havannah Is	18065	I	69.9	11.3	15.2	7.2	1.1	0.0	1.0	0.1	5.1	1.9
TO	Middle	19011	I	23.8	35.0	9.0	5.3	1.7	0.1	17.1	2.0	0.7	2.6
TO	Rib	18032	M	63.9	28.4	2.1	22.5	1.4	1.3	1.0	12.3	8.4	1.8
TO	John Brewer	18075	M	66.1	21.0	2.3	14.5	1.8	1.9	0.8	9.6	4.1	0.8
TO	Davies	18096	M	57.4	34.5	2.6	11.0	6.0	4.8	7.3	4.3	4.7	2.0
TO	Myrmidon	18034	O	37.9	33.7	21.8	10.3	9.1	3.2	4.9	2.8	3.4	3.7
TO	Dip	18039	O	57.4	26.4	8.4	12.8	3.3	5.3	2.2	3.1	8.1	1.5
TO	Chicken	18086	O	47.9	37.0	10.5	17.1	6.0	6.5	3.7	6.9	9.0	1.2
WH	Hayman Is	20014	I	32.0	42.1	16.3	22.9	5.5	1.3	2.8	1.0	6.5	15.4
WH	Langford And Bi	20019	I	30.0	16.8	18.6	3.0	3.1	0.5	6.3	0.4	2.3	0.2
WH	Border Is (A)	20067	I	23.8	27.7	32.5	3.5	3.2	0.2	15.9	0.5	1.9	1.0
WH	19131	19131	M	57.4	34.8	0.6	10.7	13.3	2.0	4.0	1.2	1.8	7.7
WH	19138	19138	M	73.0	20.6	1.2	5.7	5.5	3.2	3.2	0.8	2.0	2.9
WH	20104	20104	M	68.1	23.9	2.3	10.1	2.4	2.7	3.1	3.1	1.3	5.7
WH	19159	19159	O	29.8	40.3	18.1	25.9	4.0	4.3	1.7	8.9	15.2	1.8
WH	Hyde	19207	O	21.3	18.9	43.9	6.7	1.9	2.4	5.6	3.3	2.6	0.8
WH	Rebe	19209	O	22.1	20.9	39.9	6.1	2.7	2.5	7.7	3.0	1.6	1.3
SW	21529	21529	M	40.4	50.5	1.6	33.4	2.4	3.9	7.0	4.1	22.7	6.6
SW	Gannet Cay	21556	M	72.6	17.2	7.3	10.1	1.0	1.1	2.6	0.5	5.7	3.8
SW	22088	22088	M	55.3	33.1	8.5	13.8	2.0	3.3	10.7	3.2	2.5	8.1
SW	Chinaman	22102	M	36.9	35.4	25.3	13.8	5.0	4.0	8.6	6.8	4.5	2.4
SW	Horseshoe	22104	M	65.2	27.1	4.2	14.7	3.7	2.1	3.5	4.5	2.5	7.8
SW	East Cay	21305	O	37.3	20.5	34.2	5.9	1.8	4.0	5.8	2.7	2.0	1.2
SW	Turner Cay	21562	O	36.8	32.1	27.7	14.5	4.1	2.4	7.0	9.2	3.6	1.6
CB	Broomfield	23048	O	37.5	48.3	7.0	43.3	2.2	0.6	1.0	32.2	7.5	3.6
CB	Wreck Is	23051	O	23.0	69.3	5.7	64.6	2.4	0.4	0.8	55.2	7.2	2.2
CB	One Tree Is	23055	O	31.4	64.3	1.5	59.3	1.3	0.9	1.1	52.3	6.1	0.9
CB	Lady Musgrave I	23082	O	32.7	65.4	0.2	62.7	0.9	1.1	0.2	57.1	5.1	0.4

Appendix H

Summary counts of the different fish taxa recorded from each reef in 2000 Survey.
Figures are the sums of individuals on 15 transects (3 sites) on each survey reef.

H1. Number of larger more mobile fishes recorded in the reefs in the 2000 survey.

Sector	Reef	Reef ID	Shelf	Acanthuridae	Chaetodontidae	Labridae	Lethrinidae	Lutjanidae	Scaridae	Serranidae	Siganidae	Zanclidae
CL	Martin	14123	I	122	105	47	8	63	173	10	82	0
CL	Linnet	14126	I	92	101	61	2	61	93	8	113	0
CL	Decapolis	14131	I	11	34	12	1	67	9	12	48	0
CL	Macgillivray	14114	M	118	52	47	23	35	99	10	20	0
CL	Lizard Is	14116	M	137	69	45	29	23	126	8	36	0
CL	North Direction I	14143	M	93	85	73	26	15	165	14	95	1
CL	Carter	14137	O	311	197	33	11	121	140	4	0	12
CL	Yonge	14138	O	339	165	47	17	29	179	2	1	21
CL	No Name	14139	O	241	180	25	12	72	144	2	13	15
CA	Low Islets	16028	I	12	44	44	1	113	140	11	26	0
CA	Green Is	16049	I	122	57	59	12	106	237	9	60	0
CA	Fitzroy Is	16054	I	21	74	50	1	136	86	3	62	0
CA	Mackay	16015	M	31	69	41	17	44	171	6	31	0
CA	Hastings	16057	M	198	58	35	7	12	98	1	19	3
CA	Michaelmas	16060	M	142	102	27	2	27	74	3	14	2
CA	Thetford	16068	M	261	67	64	9	27	224	2	16	2
CA	Agincourt No.1	15099	O	240	106	33	15	4	150	2	4	6
CA	St. Crispin	16019	O	162	126	46	15	1	378	1	13	3
CA	Opal (2)	16025	O	323	76	23	7	13	175	2	9	2
TO	Pandora	18051	I	3	73	22	0	34	25	8	20	0
TO	Havannah Is	18065	I	2	26	34	0	11	125	3	4	0
TO	Rib	18032	M	97	110	33	3	9	145	7	33	0
TO	John Brewer	18075	M	96	73	41	2	2	231	4	42	0
TO	Davies	18096	M	94	84	41	3	1	212	7	26	0
TO	Myrmidon	18034	O	204	70	27	0	1	148	4	1	4
TO	Dip	18039	O	285	64	20	12	2	109	3	6	1
TO	Chicken	18086	O	126	69	39	10	2	157	13	14	0
WH	Hayman Is	20014	I	6	64	40	0	15	46	5	13	0
WH	Langford And Bi	20019	I	11	106	60	2	61	112	5	33	0
WH	Border Is (A)	20067	I	3	49	38	0	33	21	12	22	0
WH	19131	19131	M	43	34	33	2	1	163	23	16	0
WH	19138	19138	M	33	62	49	2	28	268	13	38	0
WH	20104	20104	M	38	38	53	5	16	140	9	37	0
WH	19159	19159	O	159	156	28	2	7	80	7	74	4
WH	Hyde	19207	O	229	76	30	0	3	123	8	3	4
WH	Rebe	19209	O	263	62	22	5	1	105	5	27	7
SW	21529	21529	M	6	89	36	17	7	195	41	41	0
SW	Gannet Cay	21556	M	46	42	53	5	8	286	34	112	7
SW	22088	22088	M	85	51	33	1	3	158	16	20	5
SW	Chinaman	22102	M	203	79	55	2	5	270	13	27	4
SW	Horseshoe	22104	M	327	103	69	1	15	365	10	96	8
SW	East Cay	21305	O	203	86	31	2	0	114	14	16	5
SW	Turner Cay	21562	O	167	114	52	4	3	272	13	11	5
CB	Broomfield	23048	O	199	196	42	41	3	183	7	3	3
CB	Wreck Is	23051	O	191	295	47	11	43	133	12	5	9
CB	One Tree Is	23055	O	76	265	38	12	5	170	5	0	8
CB	Lady Musgrave I	23082	O	247	277	36	0	6	170	6	0	13

H2. Number of damselfishes recorded in the regions in the 2000 survey.

Sector	Reef	Reef ID	Shelf	Acanthochromis	Amblyglyphidodon	Chromis	Chrysiptera	Neoglyphidodon	Neopomacentrus	Plectroglyphidodon	Pomacentrus
CL	Martin	14123	I	83	65	66	92	13	565	0	2005
CL	Linnet	14126	I	282	188	149	62	30	540	1	2732
CL	Decapolis	14131	I	21	0	0	0	2	283	0	447
CL	Macgillivray	14114	M	49	57	50	90	7	7	21	474
CL	Lizard Is	14116	M	86	104	76	106	17	140	14	934
CL	North Direction I	14143	M	21	80	16	219	9	29	19	614
CL	Carter	14137	O	48	0	853	3	0	0	125	146
CL	Yonge	14138	O	82	0	1039	8	0	0	107	202
CL	No Name	14139	O	78	2	591	2	0	0	80	149
CA	Low Islets	16028	I	66	30	0	26	47	102	0	559
CA	Green Is	16049	I	16	51	12	114	11	91	2	557
CA	Fitzroy Is	16054	I	27	28	0	6	49	151	0	427
CA	Mackay	16015	M	72	162	15	92	63	9	3	1195
CA	Hastings	16057	M	11	2	91	7	2	120	88	670
CA	Michaelmas	16060	M	6	6	366	16	0	489	93	638
CA	Thetford	16068	M	36	11	271	24	2	199	96	706
CA	Agincourt No.1	15099	O	26	0	143	27	3	0	110	176
CA	St. Crispin	16019	O	16	22	66	9	7	0	61	381
CA	Opal (2)	16025	O	11	1	211	32	2	37	68	178
TO	Pandora	18051	I	40	4	0	0	38	661	0	213
TO	Havannah Is	18065	I	67	11	0	1	35	167	0	372
TO	Middle	19011	I	13	0	0	0	1	138	0	20
TO	Rib	18032	M	36	76	628	14	30	431	31	764
TO	John Brewer	18075	M	38	63	151	31	58	236	17	746
TO	Davies	18096	M	31	71	16	62	106	81	17	1180
TO	Myrmidon	18034	O	26	14	304	4	0	0	156	243
TO	Dip	18039	O	12	1	175	11	1	128	99	682
TO	Chicken	18086	O	20	0	99	42	1	221	116	549
WH	Hayman Is	20014	I	91	74	3	56	3	52	0	869
WH	Langford And Bi	20019	I	56	54	31	151	8	136	0	802
WH	Border Is (A)	20067	I	46	69	416	345	0	444	0	1384
WH	19131	19131	M	4	6	5	18	0	2670	0	1320
WH	19138	19138	M	9	17	33	58	0	747	0	1503
WH	20104	20104	M	1	2	45	77	0	625	0	927
WH	19159	19159	O	17	73	263	38	45	139	64	729
WH	Hyde	19207	O	16	25	23	22	10	6	31	766
WH	Rebe	19209	O	3	19	20	17	13	45	50	538
SW	21529	21529	M	3	168	1478	98	5	6	0	1681
SW	Gannet Cay	21556	M	10	296	1723	17	1	18	2	1753
SW	22088	22088	M	5	26	14	3	3	326	0	1790
SW	Chinaman	22102	M	6	83	135	4	16	269	32	2128
SW	Horseshoe	22104	M	0	160	15	4	3	81	4	1717
SW	East Cay	21305	O	12	51	1	15	14	9	12	423
SW	Turner Cay	21562	O	13	63	147	15	14	18	36	1017
CB	Broomfield	23048	O	11	0	169	18	1	47	17	709
CB	Wreck Is	23051	O	6	0	351	17	0	9	9	482
CB	One Tree Is	23055	O	0	0	27	19	0	0	9	1253
CB	Lady Musgrave I	23082	O	1	0	32	17	0	0	47	475

Appendix I

Statistical Analysis of the LTMP Survey Data

Analysis of Trends for Individual Reefs [see web pages]

Fish abundance data

The model chosen to describe fish counts (y_{ijklm} represents the natural logarithm of (number of fish + 1) of a particular taxon counted on site *l* for the k^{th} reef in the ij^{th} region at time *m*) was:

$$y_{ijklm} = \beta_{oijk} + \beta_{1ijk} x_{ijklm} + \beta_{2ijk} x_{ijklm}^2 + \varepsilon_{ijklm}$$

where

β_{oijk} represents the response at $x_{ijklm} = 0$ for the k^{th} reef in the ij^{th} region,

β_{1ijk} represents the instantaneous rate of change of the response at $x_{ijklm} = 0$ for the k^{th} reef in the ij^{th} region,

β_{2ijk} represents the curvature of the response for the k^{th} reef in the ij^{th} region,

x_{ijklm} is the coded survey number for the l^{th} site, k^{th} reef in the ij^{th} region at time *m*,

ε_{ijklm} is the error term

Coding of survey number

The data were analysed twice using the survey number coded as:

$$x_{iiklm} = (survey\ number - 5.5)$$

and

$$x_{ijklm} = (survey\ number - 8.0)$$

to allow direct estimation of β_{oijk} and β_{1ijk} at two different times during the survey period. When the survey number is centred around 5.5, the parameters β_{oijk} and β_{1ijk} represent the average value of the response over the previous six years for reef *ijk* and the linear change in the response over the period of the survey for reef *ijk*, respectively. When the survey number is centered around 8, the parameters β_{oijk} and β_{1ijk} represent the estimated average value of the response for reef *ijk* in the last survey year and the instantaneous linear change in the response for reef *ijk* in the last survey year, respectively.

Choosing a covariance structure

The errors were assumed to conform to a multivariate normal distribution with mean 0 and covariance structure Σ. The form of Σ was chosen as follows:

(1) the value of the likelihood was obtained for the model above assuming each of the following covariance structures:

(a) independence

(b) compound symmetry

(c) first order autoregressive

(d) autoregressive moving average (ARMA(1,1))

(e) Toeplitz

In each case the structure was assumed to be homogeneous for all reefs.

Table I1: Average minimum detectable rate of change (MDD) for abundances of different reef fish taxa based on means for sites on reefs. MDD over the last 6 years is the minimum detectable rate of change for the average trend, MDD (current) refers to minimum detectable rate of change at the most recent survey. Note that these values are absolute; they apply to both positive and negative rates of change. These values are used in conjunction with Appendix H and Figure I1, see figure caption.

Larger fishes	MDD over last 6 years	MDD (current)	Damselfishes	MDD over last 6 years	MDD (current)
Acanthuridae	0.17	0.62	*Acanthochromis*	0.22	0.78
Chaetodontidae	0.15	0.52	*Amblyglyphidodon*	0.14	0.49
Labridae	0.18	0.64	*Chromis*	0.35	1.24
Lethrinidae	0.26	0.92	*Chrysiptera*	0.23	0.83
Lutjanidae	0.26	0.92	*Neoglyphidodon*	0.19	0.67
Scaridae	0.22	0.79	*Neopomacentrus*	0.45	1.60
Serranidae	0.25	0.90	*Plectroglyphidodon*	0.14	0.50
Siganidae	0.28	1.00	*Pomacentrus*	0.15	0.53

(2) the likelihood ratio test was then used to compare nested models and to choose the simplest nested covariance structure which described the model adequately.

Power

The measure of power that was used for this analysis was the minimal detectable rate of change. This estimates the smallest rate of change significantly different from zero $(\Delta\beta_{1ij})$ that could be detected reliably (90% of the time at the 5% level of significance). This measure was calculated for each taxon at each reef using the following formula:

$$\Delta\beta_{1ijk} = se_{\beta_{1ijk}}(\phi(0.975) + \phi(0.90))$$

where

$se_{\beta_{1ijk}}$ is the standard error of the rate of change for reef *ijk*

$\phi(0.975)$ is the 97.5 percentile of the standard normal distribution which corresponds to a two sided test for and $\alpha = 0.05$

$\phi(0.90)$ is the 90th percentile of the standard normal distribution corresponding to a power of 90% (Zar 1984).

The average minimum detectable rate of change was tabulated on the logarithmic scale and can be converted to a rate of change on the count scale using Figure I1. To do this:

(1) estimate the mean abundance of fish ***per site*** for the reef of interest in the last survey year, see Appendix H (or the mean abundance of fish ***per reef*** for the region of interest, see Appendix F)

(2) find this value on the horizontal axis of Figure I1.

(3) draw a vertical line through this point until it intersects the two isopleths (or the margins of the figure) which bracket the minimal detectable rate of change of the taxa of interest (from Table I1)

(4) draw a horizontal line from each of these points to the left hand vertical axis

(5) the points of intersection on the vertical axis bracket the minimal detectable rate of change in abundance for the reef for interest.

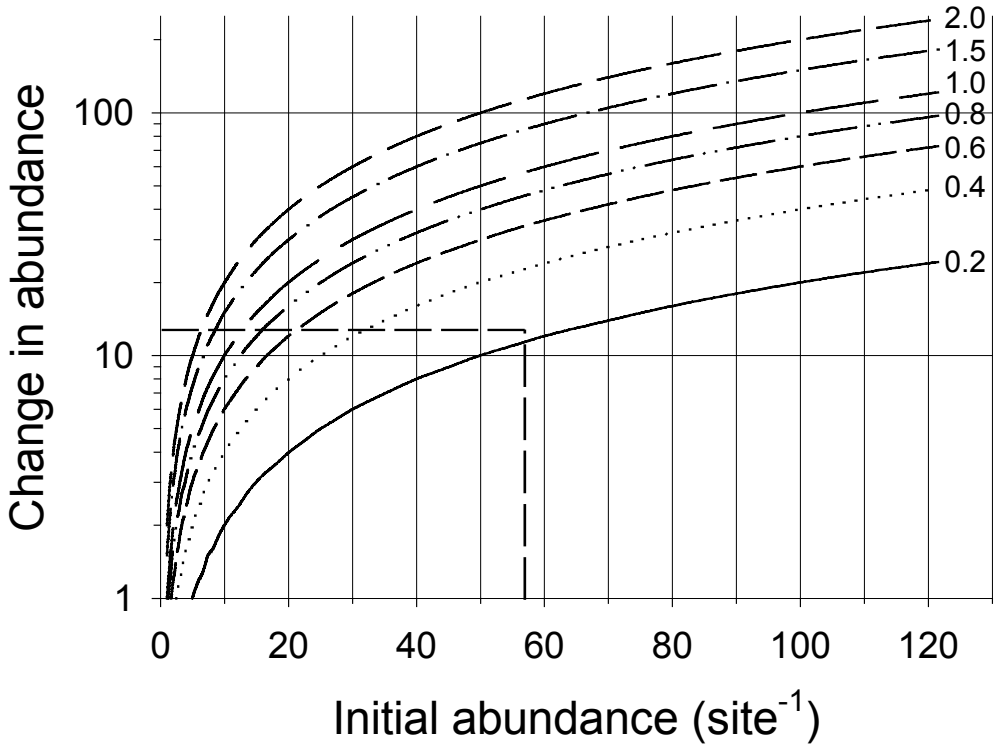


Figure I1: Relationship between mean abundance of fish per site and detectable rate of change in abundance for different values of minimum rate of change (MDD). Note detectable rate of change is given on a log scale. ***Interpretation:*** Drop-line gives an estimate of minimum detectable rate of change for **overall** trends in abundance of Scaridae at Mackay Reef in the Cairns sector. From Appendix F, mean abundance in 2000 was 171 fish per reef, thus the abundance *per site* was 171/3 = 57 (X axis). From Table I1, average minimum detectable rate of change over six years was 0.22. Using an interpolated MDD curve between those for MDD = 0.2 and MDD =0.4, the estimated minimum detectable rate of change would be a gain or loss of about 13 fish annually (~23%).

Benthic Cover Data

Estimates of coverage for the benthic groups are obtained by point sampling a 50 m transect recorded on videotape. Statistical analysis of these estimates differed from the analysis described for the fish taxa in the following ways:

1. the response (average percent cover of 5 transects) is transformed using the empirical logit:

$$log\left(\frac{p+cf}{100-p+cf}\right)$$

where p was the average percentage cover for a given benthic group and cf represented the correction factor for zero $\left(cf = \frac{1}{2} * \frac{1}{200} * \frac{1}{15} * 100\right)$ where $\frac{1}{2}$ is the correction factor suggested by McCullagh and Nelder (1989), $\frac{1}{200}$ averages this single point over the number

Table I2: Average minimum detectable rate of change (MDD) for percent cover of different taxa of benthic organisms based on means for sites on reefs. MDD over 6 years is the minimum detectable rate of change for the average trend, MDD (current) refers to the minimum detectable rate of change at the most recent survey. Note that these values are absolute: they apply to both positive and negative rates of change. These values are used in conjunction with Appendix G and Figure I2, see figure caption.

Taxon	MDD over 6 years	MDD (current)
Hard Corals	0.20	0.49
Acroporidae	0.28	0.73
Tabulate *Acropora* spp.	0.40	1.03
Other *Acropora* spp.	0.38	1.10
Montipora spp.	0.44	1.35
Faviidae	0.32	0.82
Pocilloporidae	0.34	0.95
Poritidae	0.30	0.88
Soft Corals	0.20	0.59
Algae	0.15	0.40

of points sampled for a video transect (200), $\frac{1}{15}$ average this number over the 15 transects and 100 puts this on a percentage scale).

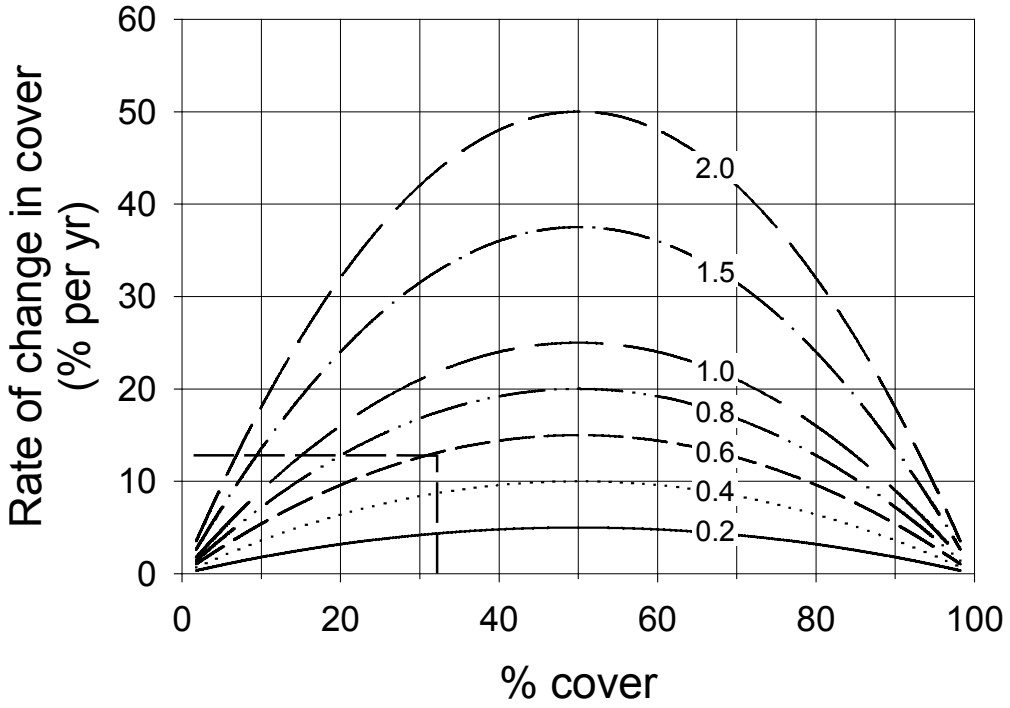


Figure I2: Relationship between cover of benthic taxa per site and detectable rate of change in percent cover for different values of minimum detectable difference (MDD) in rate of change. ***Interpretation:*** Drop-line gives an estimate of minimum detectable rate of change for the **current** trend in Soft Coral on Border Is Reef (Whitsundays sector). From Appendix G, mean cover in 2000 was 32.5% (X axis). From Table I2, the average minimum detectable rate of change is 0.59. Using an interpolated MDD curve between those for MDD = 0.4 and MDD = 0.6, the estimated minimum detectable current rate of change would be a gain or loss of about 13% bottom cover annually (40% of the average cover of soft corals).

(2) the statistical model is the same as that used for analysis of trends in abundance of the fish taxa.
(3) for the estimation of power: values of percent cover from Appendix G and MDDs from Table I2 are used in conjunction with Figure I2.

Table I3: Average minimum detectable rate of change for abundances of different reef fish taxa based on regional means for sites on reefs. MDD over 6 years is the minimum detectable rate of change for the average trend, MDD (current) refers to the minimum detectable rate of change at the most recent survey. Note that these values are absolute; they apply to both positive and negative rates of change. These values are used in conjunction with Appendix F and Figure K1, see figure caption.

Larger fishes	**MDD over 6 years**	**MDD (current)**	**Damselfishes**	**MDD over 6 years**	**MDD (current)**
Acanthuridae	0.24	0.47	*Acanthochromis*	0.27	0.76
Chaetodontidae	0.17	0.42	*Amblyglyphidodon*	0.23	0.51
Labridae	0.16	0.41	*Chromis*	0.54	1.42
Lethrinidae	0.33	0.91	*Chrysiptera*	0.33	0.85
Lutjanidae	0.28	0.81	*Neoglyphidodon*	0.26	0.56
Scaridae	0.22	0.62	*Neopomacentrus*	0.59	1.61
Serranidae	0.22	0.65	*Plectroglyphidodon*	0.20	0.43
Siganidae	0.30	0.97	*Pomacentrus*	0.18	0.48

Analysis of regional trends [Section 4]

Fish abundance and benthic cover data

The regional analysis for both groups was carried out using the same models from the corresponding reef trend analysis, with the following changes:

1. reef means were used instead of site means for the benthic cover analysis
2. reef means of $\ell n(count+1)$ were used instead of $\ell n(count+1)$ for the fish count data covariance structures which were heterogeneous across shelf position were considered.

Table I4: Average minimum detectable rate of change for percent cover of different taxa of benthic organisms based on regional means for sites on reefs. MDD over 6 years is the minimum detectable rate of change for the average trend, MDD (current) refers to the minimum detectable rate of change at the most recent survey. Note that these values are absolute: they apply to both positive and negative rates of change. These values are used in conjunction with Appendix E and Figure I2, see figure caption.

Taxon	**MDD over 6 years**	**MDD (current)**
Hard Corals	0.30	0.67
Acroporidae	0.37	0.83
Tabulate *Acropora* spp.	0.36	0.83
Other *Acropora* spp.	0.39	0.95
Montipora spp.	0.33	0.87
Faviidae	0.29	0.71
Pocilloporidae	0.34	0.79
Poritidae	0.31	0.75
Soft Corals	0.24	0.59
Algae	0.21	0.48

to estimate power: values for benthic cover or fish abundance are obtained from Appendices E or F and MDDs from Tables I3 or I4 are used in conjunction with Figures I1 or I2.

Broad scale survey data

The broad scale data are visual estimates of the average number of COTS per tow and the average hard coral cover per tow. The analysis of these data was based upon the use of summary statistics to obtain the best estimates of the sector trend. The sector trends were obtained in the following fashion:

(1) for each reef the following quadratic model was fit:

$$y_i = \beta_0 + \beta_1 x_i + \beta_2 x_i^2 + \varepsilon_i$$

where y_i represents the average coral cover or the $\ell n(average\,COTS\,count + 1)$ on a given reef for year *i*, β_o represents the average response at year Z, β_1 represents the rate of change at year Z, β_2 represents the curvature of the trend, x_i = (*survey number* – Z), and ε_i represents the error.

(2) for each reef the response for each year (including the years where observations are missing) was estimated using the model presented in (1).

(3) for each region, the estimate of the average response was obtained by averaging the predicted response for each reef for each year.

(4) finally, the average response was back transformed to the original scale where required.

Statistical computing

The SAS system software (SAS Institute Inc., Cary, NC, USA) was used for all analyses. The MIXED procedure was used to fit the statistical models described for the fish abundance and benthic cover data. The REG procedure was used to obtain the estimates described for the broad scale survey data.