LONG-TERM MONITORING OF THE GREAT BARRIER REEF

Status Report

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Executive Summary

The Great Barrier Reef World Heritage Area has great economic importance as well as immense aesthetic value, 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 about 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.

This report presents a synthesis of monitoring data collected up to the 2003 field season.

Broadscale manta tow surveys have been carried out in 11 latitudinal sectors spanning the length of the GBR for a period of 18 years (1986-2003) and have significantly increased our understanding of the crown-of-thorns-starfish (COTS) phenomenon. The perimeters of 88 reefs were surveyed using manta tow in 2003.

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 2003.

Major results were:

Crown-of-thorns starfish

- The percentage of reefs on the GBR with outbreaks of COTS had not changed since surveys in 2000. Active or Incipient Outbreaks were observed on 11% of the 88 reefs surveyed in 2003. This is the same percentage as in 2002 and 2001. The highest percentage of reefs with Active Outbreaks recorded prior to 2001 in the 18 years of surveys was 17% in 1987, 1999 and 2000.

A similar pattern is seen in the overall density of COTS on the GBR. The overall mean number of COTS per tow in 2003 was 0.78. This has increased from 2002 (when the mean was 0.50 COTS per tow) but was less than in 2001 (1.07). 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. , Cairns and Innisfail sectors decreased between 1999 and 2003.
- COTS numbers increased substantially in the Townsville sector and there was an increase in the Cape Upstart sector. This is consistent with a southward drift seen in previous waves of outbreaks 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 tenfold from 2000 to 2001 (mean of 17 COTS per tow) before dropping to less than 5 COTS per tow in 2002 (mean of 4.9) and 2003 (mean of 4.1). These are still high densities.
- There were no significant changes in COTS abundance within the other five GBR sectors.

Coral Cover

The salient changes on the Great Barrier Reef over the eleven years to 2003 reflect the impact of cyclones and COTS, and to a lesser extent bleaching and disease, on reef communities and their subsequent recovery from such disturbances. Key results were:

- The highest mean value for cover of living coral on the perimeter of reefs (henceforth: reef-wide live coral cover) in 2003 (52%) occurred on inshore reefs in the northern Cape Grenville sector. The recorded value for reef-wide live cover was higher (62%) on outer-shelf reefs in the Pompey sector but only one reef (Ben Reef) was surveyed.
- Lowest value for reef-wide live coral cover (3%) in 2003 was on middle shelf reefs in the Innisfail sector and a single inshore reef (Green Is Reef) in the Cairns sector. Reefs in the Innisfail sector had large COTS populations in the recent past as well as mass bleaching in 1998.
- Surveys of permanent survey sites on northeast faces of 48 reefs in 2003 found that cover of hard coral was highest in the Capricorn Bunker sector (67%), followed by reefs in the outer shelf region of the Cooktown / Lizard Is. sector (55%). These regions have been recovering from storm damage over the 11 years of intensive surveys.
- Hard coral cover on permanent survey sites was lowest on the reefs of the inshore region of the Cairns sector (8%) in 2003. These reefs have been affected by COTS, coral bleaching and in some cases, by cyclones.
- Hard coral cover increased on the permanent survey sites over the 11 years of surveys in the outer shelf region of the Cooktown / Lizard Is. sector and the Capricorn Bunker

sector, though the rate of increase has slowed since 1999. Reefs in these regions were damaged by storms in the late 1980s but now have high coral cover.

- Hard coral cover on the permanent survey sites in the inner regions of the Cairns and Townsville sectors declined since the mid-1990s due to coral bleaching and COTS.
- Hard coral cover on the permanent survey sites is currently declining on the middle shelf reefs of the Townsville sector due to COTS population outbreaks.
- The incidence of coral diseases in all regions was the highest recorded, with the exception of middle shelf and outer shelf reefs in the Townsville sector.

Reef fishes

While abundance of many groups of fishes showed significant long term and current trends in various regions, there were only a few instances where a majority of groups in a region showed a consistent trend:

- The majority of larger, more mobile fish families, and damselfish genera, increased in abundance over the 11 years of surveys in the Capricorn Bunker sector. Several groups, such as surgeonfishes, butterflyfishes, parrotfishes, wrasses and coral associated damselfishes, continued to increase over the last two years. Coral cover increased greatly in this region from very low levels recorded in 1989; the changes in fish assemblages reflect this.
- Abundances of two genera of coral associated damselfish increased over the eleven years of survey at all reefs in the Cooktown / Lizard Is. sector; this again reflects large increases in coral cover in this region.
- In other sectors, most families of larger mobile fishes showed little net change in abundance over the 11 years of surveys. Most families also did not change in abundance over the last two surveys, though slightly more increased than decreased.
- In other sectors, most damselfish genera showed little net change in abundance over the 11 years of surveys.
- Abundances in the majority of damselfish genera increased over the last two surveys in the Cooktown / Lizard Is., Cairns, Townsville and Whitsunday sectors.
- Only one reef (Havannah Is., in the Townsville inner-shelf region) showed substantial declines in the majority of groups, reflecting a large decline in coral cover. Rabbitfishes however increased on this reef.
- Abundance in a sizeable minority of damselfish genera declined on reefs in the Swain sector over the last two surveys.

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 the 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 changes in reef communities on the GBR. The GBR World Heritage Area (GBRWHA) includes the GBR Marine Park, administered by the Commonwealth 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 northeast 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 individual reef scale organised by latitude (sector) and cross-shelf position (Section 4). Data from broadscale manta tow surveys are presented from 1986 to 2003. Data from intensive sampling of reef fish and benthic communities and are presented from 1993 to 2003. Because of the biological imperative to look at periods longer than one year and the increasing complexity of statistical functions required to model variation over long periods a number of unique statistical analysis have been developed for this report (Appendix I). This is in contrast to previous reports (Sweatman et al. 1998, 2000) where linear models have been used to interpret data from the most recent six surveys rather than the entire data set.

This and previous reports (Sweatman et al. 1998, 2000, 2001) as well as up to date reporting of recent surveys are now available on the Institute's web site:

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

2. 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 positions across the shelf (inshore, middle 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 are only surveyed intensively in six of the sectors. 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 live 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 at selected	Counts of most mobile and non-cryptic fish

Selection of reefs

Initially, 52 "core" reefs were selected for annual survey. The reefs were widely distributed throughout the GBR and spanned the variation in 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 core 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, in each sector, three or more reefs were selected in each of three positions across the continental shelf: inshore, middle shelf and outer shelf.

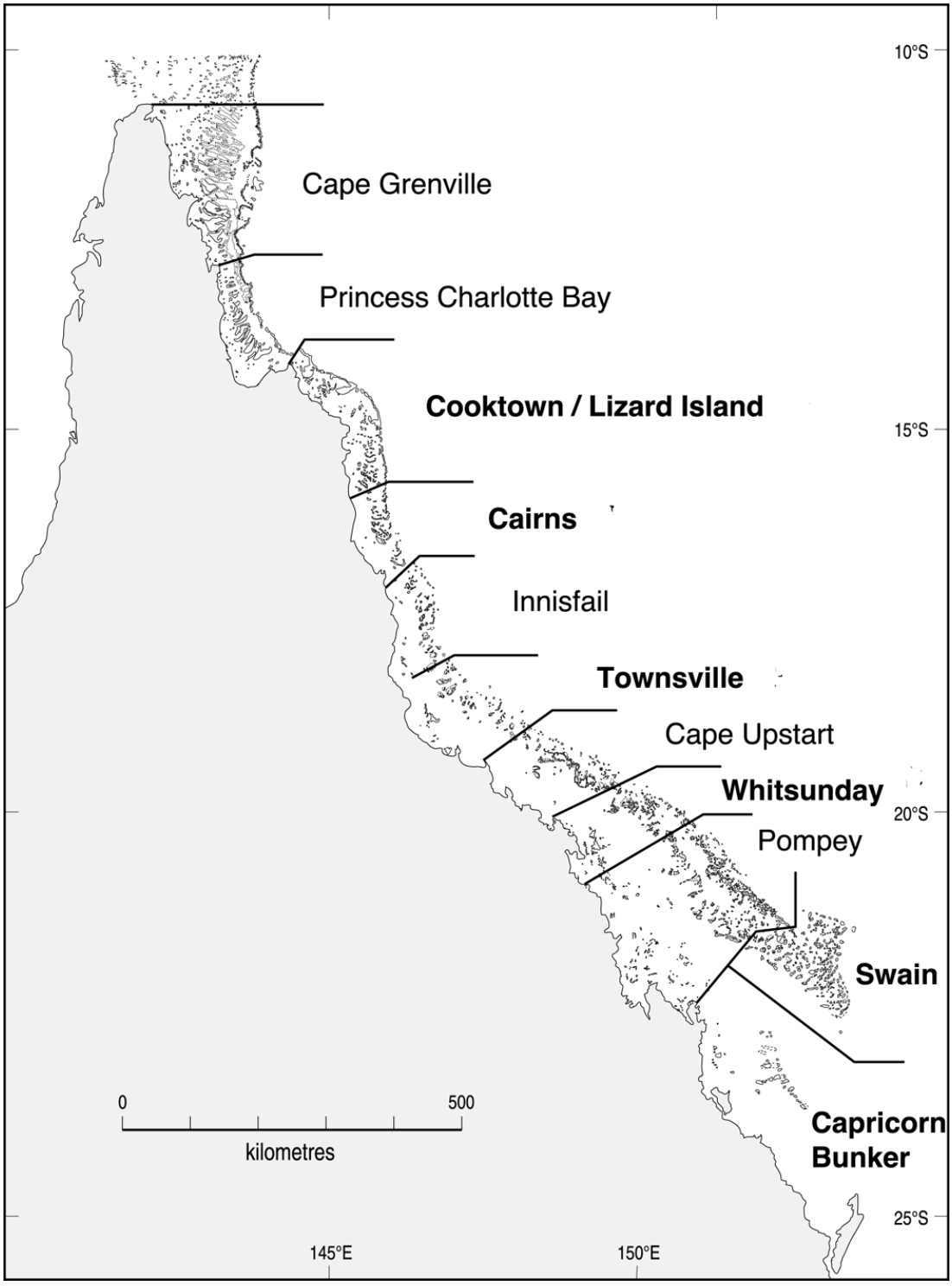

Figure 2.1 Map of the GBR showing the locations of latitudinal sectors. The six sectors where LTMP core survey reefs are located are shown in bold face type.

There are no inshore or middle 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 Swain reefs have been grouped with middle shelf reefs in this report.

The core survey reefs were chosen from the reefs within each region (sector by shelf position combination) 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 to core survey reefs and the full set of surveys is rarely completed because of bad weather and limited ship time. Maps and a listing of reefs surveyed in 2003 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 northeast flank of the reef. 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).

Surveys are made between July 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 July 2002 and June 2003 are referred to as 2003 surveys.

Forty-eight core reefs were sampled for fish and/or benthos in 2003 (Appendix B). Forty-four of these were also surveyed by manta tow; four inshore reefs could not be surveyed because of poor visibility. A further 44 reefs were surveyed by manta tow alone in 2003 (Appendix B).

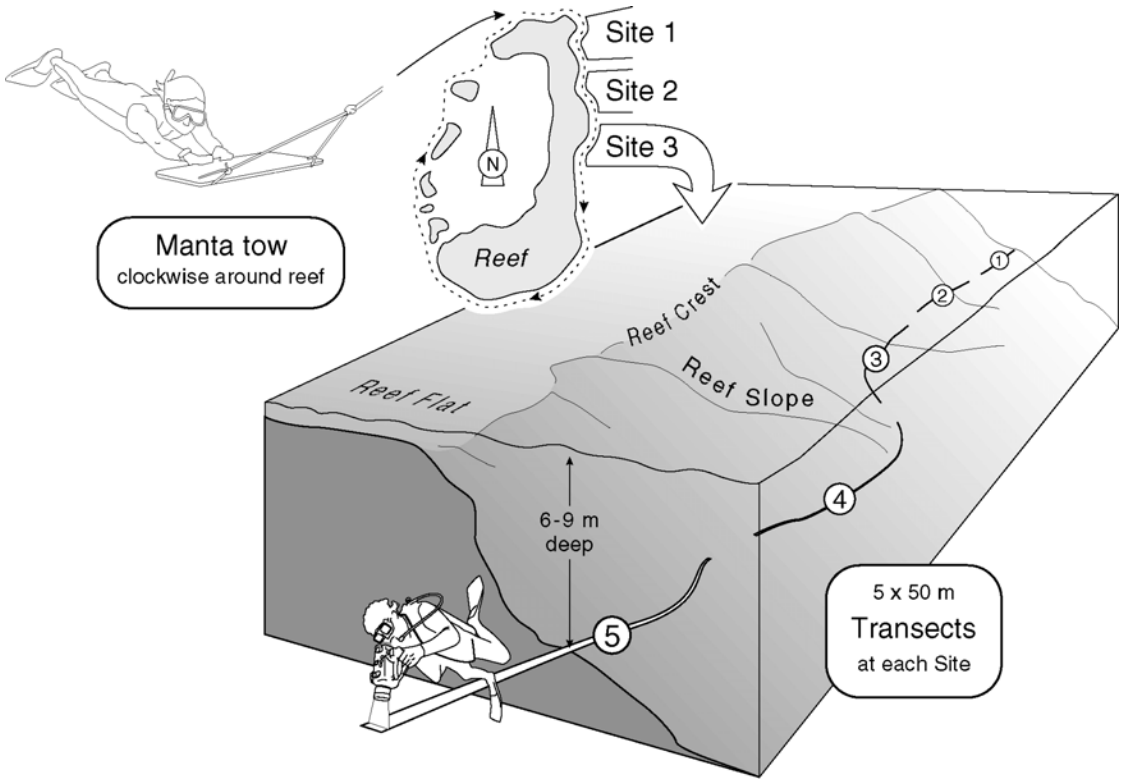

Figure 2.2: Schematic arrangement of sampling effort on a core survey reef.

Quality control

It is important to maintain consistency in the way data are collected and processed, so that differences that appear over time reflect differences in the populations of reef

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

Broadscale surveys	Miller IR, Coleman G and Abdo D (2004) Crown-of-thorns starfish and coral surveys using the manta tow and SCUBA search techniques. Standard Operational Procedure No. 8, 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	Abdo D, Burgess S, Coleman G, and K.Osborne (2003) Surveys of benthic reef communities using underwater video. Standard Operational Procedure No. 9, AIMS, Townsville. 48 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.

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).

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 living hard 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 18 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 occurs in two stages. First, all observers are trained before participating in the broadscale surveys (see Bass and Miller 1996). Second, where time permits, on each sampling trip, a sub-sample of 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.

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 Dead coral Soft coral	estimated cover (11 categories)	0 = 0% 1- = >0-5% 1+ = >5-10% 2- = >10-20% 2+ = >20-30% 3- = >30-40% 3+ = >40-50% 4- = >50-62.5% 4+ = >62.5-75% 5- = >75-87.5% 5+ = >87.5-100%
Visibility	distance categories (scale of 1-4)	1 = <6m 2 = 6-12m 3 = >12-18m 4 = >18m

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, 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.

Reef level trends in broadscale data on median live hard coral cover and average COTS density from manta tow surveys were calculated from the visual estimates of the number of COTS per tow and the live hard coral cover per tow. For each reef these data are provided on a per tow basis for the current survey year, to represent variability within a reef, and as reef averages in each survey year, to represent patterns over time. The reef-averaged data are then averaged over all reefs in each Sector to provide descriptive summaries for comparison among all Sectors of the GBR.

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 digital video camera held 25-30 cm above the substrate. Percent cover of corals and other benthic categories (Table 2.4) 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 (Abdo et al. 2003).

Table 2.4**:** Explanation of benthic categories.

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

Quality control

Quality control involves training new observers to use the video camera effectively in the field followed by initial training 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.

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 survey 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. Linear mixed-effects models were then used to estimate the temporal trend in the transformed annual estimates of abundance. The form of the temporal trend (i.e. no trend, linear, quadratic or smooth (nonlinear) trend) was determined by model selection (see Appendix I for a technical explanation).

The selected model was then used to estimate the overall trend (over all 11 annual surveys) and current trend for each core survey reef for each benthic category. Substantial increasing or decreasing trends in hard coral cover were defined as absolute annual changes of greater than 3% cover. Smaller changes (i.e. <3%) indicated no substantial trend. The number of reefs exhibiting increasing, decreasing or no trend in hard coral cover were then summed within each Sector. The proportions of reefs exhibiting each type of trend were then represented in arrow plots to facilitate GBR-wide comparisons.

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 during each field season. Estimating the cut off point for 0+ individuals and rules for exclusion or inclusion of individuals crossing transect boundaries are 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 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 analysis

Counts were summed over the five transects, giving estimates of abundance at each of the 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 damselfishes (Family Pomacentriidae) have been grouped into genera. This increases the power of the analyses, but complicates interpretation. Individual taxon was considered too rare to test if it occurred at an average density of less than one per transect in any year.

To look at trends in abundance of fishes on individual reefs, the abundances for each site were log transformed [ln(y + 1)] to reduce the influence of abundant taxa and to stabilise variances for analyses. Linear mixed-effects models were then used to estimate the temporal trend in the transformed annual estimates of abundance. The form of the temporal trend (i.e. no trend, linear, quadratic or smooth (nonlinear) trend) was determined by model selection (see Appendix I for a technical explanation). The selected model was then used to estimate the overall trend (over all 11 annual surveys) and current trend for each core survey reef. Substantial increasing or decreasing trends were defined as proportional annual changes of greater than 10%. Smaller proportional changes (i.e. <10%) indicated no substantial trend. The number of families of larger species, or the number of genera of smaller damselfishes, exhibiting increasing, decreasing or no trend were then summed on each reef and these numbers were summed over all reefs within each Sector. The proportions of each group of fishes exhibiting each type of trend were then represented in arrow plots to facilitate GBR-wide comparisons.

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3. 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. The mass bleaching of corals in 2002 did not cause dramatic mortality of corals below 6m depth where the survey sites were located, so most of the declines in coral cover are due to crown-of-thorns starfish activity, although there are isolated incidents of storm damage.

The analyses (Methods, Appendix I) of percent cover of benthic organisms and abundances of fishes on individual reefs identified two types of trends: average trends over the eleven annual surveys, and current trends: those evident over the two years prior to the 2003 survey. Trends for the GBR are summarised here by considering the proportions of core survey reefs in each sector that show increasing, decreasing, or no substantial 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 have decreased in the Cooktown / Lizard Is., Cairns and Innisfail sectors, but continued to increase in the Townsville sector and appeared in the Cape Upstart sector. This is consistent with observations of previous waves of outbreaks, where the incidence of reefs with new active outbreaks moved south over time. This presumably involves southward transport of larvae by the East Australian Current. Four reefs in the Swain sector had active outbreaks and overall COTS numbers on Swain reefs were very high. These outbreaks appear to be independent of the main southward moving wave of COTS infestations.

There was a general increase in hard coral cover in the Capricorn Bunker sector over the 11 surveys (Fig. 3.2). Storms removed much of the coral from these reefs in 1988 (Fig. 3.1), but by 2003 the intensive survey sites in the Capricorn Bunker sector had the highest coral cover values in any region. The rate of increase in coral cover has slowed since 1999. Outer shelf reefs in the Cooktown / Lizard Is. sector showed a similar pattern, though the cover values for this sector were moderated by the limited recovery on middle shelf reefs in the sector after COTS outbreaks. The general situation in the Swain sector was that coral cover had increased, on average, on reefs without COTS, though the dramatic declines in coral cover on the reefs with high COTS numbers dominated trends in coral cover across the sector. Coral cover was declining on the majority of reefs in the Townsville sector in 2003, due to the build up of COTS.

The general increasing trend in families of larger, more mobile reef fishes in the Capricorn Bunker sector over the past eleven years (Fig. 3.3) was associated with the increasing coral cover and habitat complexity. Most reefs in most sectors showed no net trends in abundances of larger reef fishes over 11 years, but a sizable minority of families showed current increasing trends in the Cooktown / Lizard Is., Cairns, Townsville and Whitsunday sectors.

Explanation of summary plots

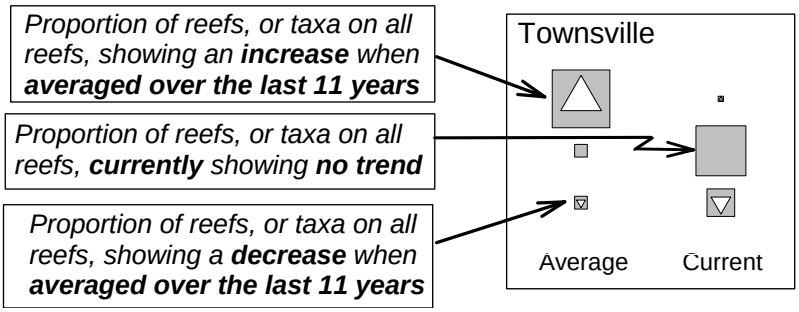
Trends in reef-wide cover of hard coral and in COTS estimated from broadscale surveys are represented by conventional line graphs and histograms (Fig. 3.1).

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 represents the average trends over the past eleven years while the right hand set represents current trends based on the last two years. Dimensions of the three filled squares reflect the proportion of taxa on survey reefs in each sector showing substantial (>3% change in hard coral cover; >10% proportional change in fish abundance) 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 (Figs. 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).

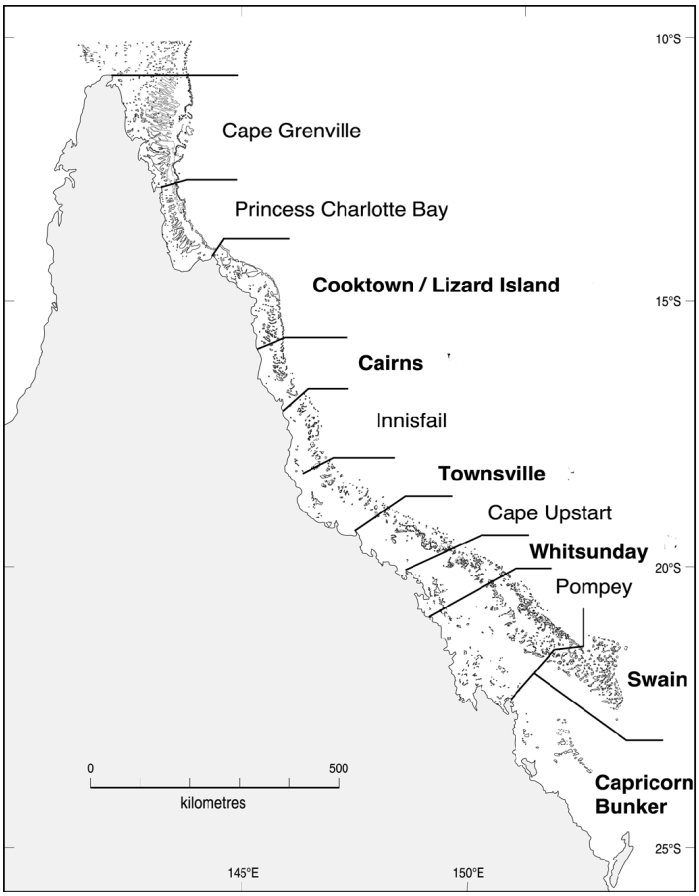
Taxa that were too rare to allow a trend to be estimated were omitted.

An annotated example:



Several genera of damselfishes increased in abundance over the 11 survey 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 Bunker sector were associated with the increase in coral cover. A majority of damselfish genera showed an increasing current trend on these reefs too. 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. Abundances of the majority of damselfish genera increased over the last two surveys in all sectors, with the exception of the Swain sector, where the minority of the damselfish genera declined over the past two years.

Summary of crown-of-thorns starfish activity on the Great Barrier Reef 1986-2003



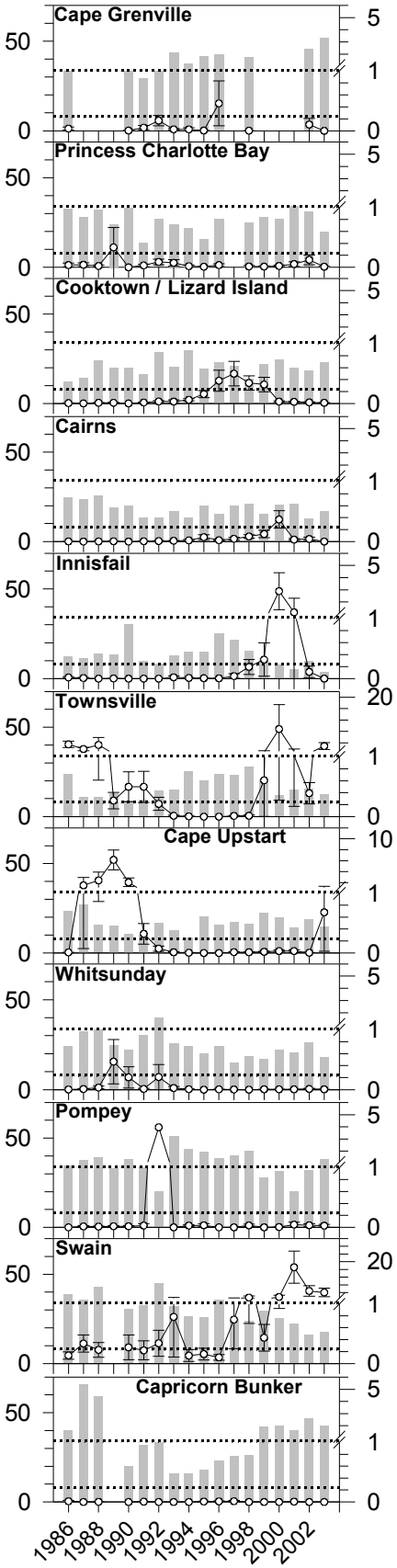


Figure 3.1 Summary of COTS populations and live coral cover for each survey sector on the GBR since 1986. Bar charts show mean live coral cover in each year (left hand axis); line plots show COTS abundances (COTS/tow ±SE) in each year (right hand axis). Lower dotted line = Incipient outbreak level (0.22 COTS/tow), upper dotted line = Active outbreak level (1.0 COTS/tow).

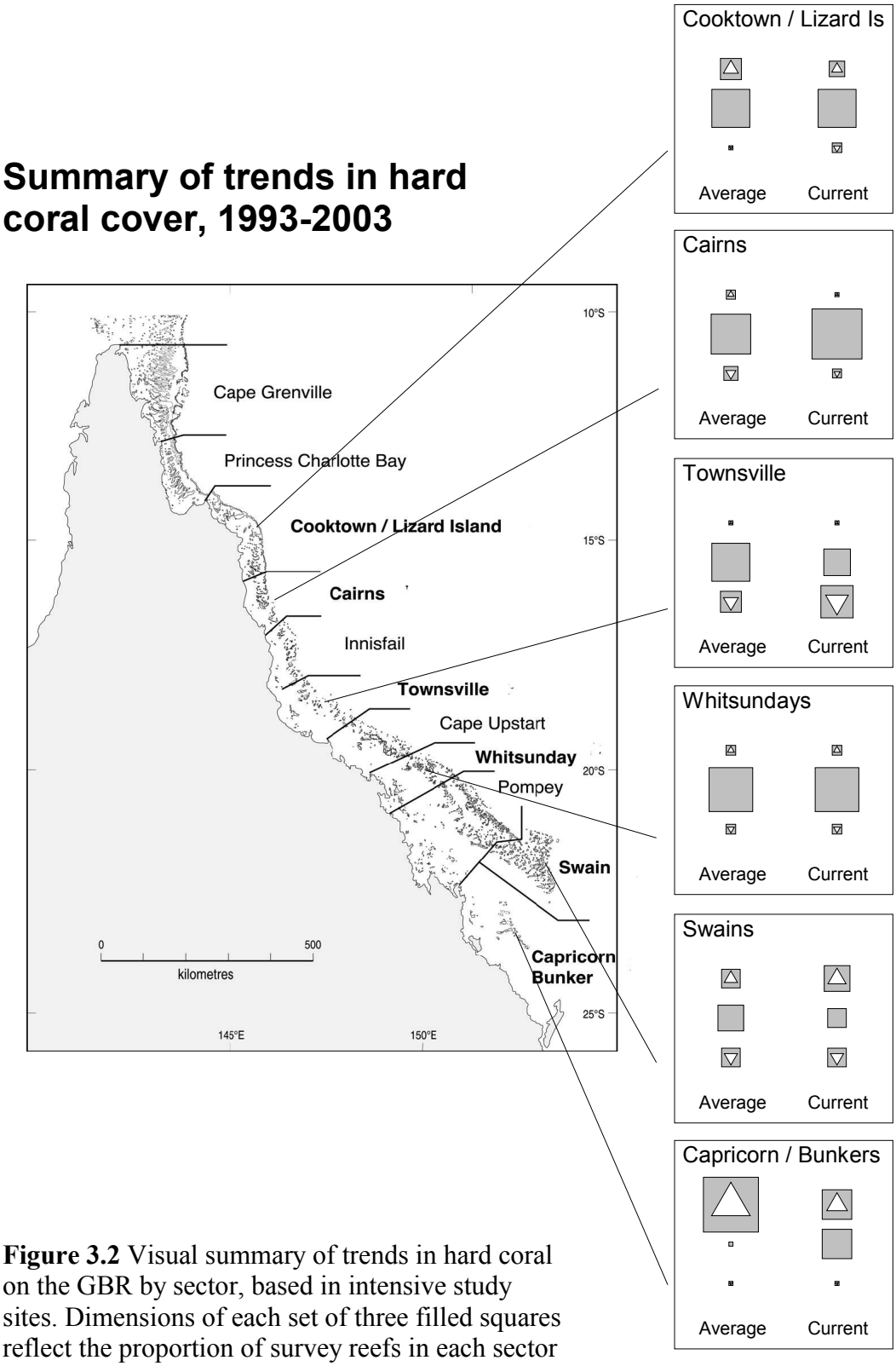


Figure 3.2 Visual summary of trends in hard coral on the GBR by sector, based in intensive study sites. Dimensions of each set of three filled squares reflect the proportion of survey reefs in each sector showing substantial (>3%) increasing or decreasing trends or no trend. Arrow heads indicate direction of trend. For each sector, the left hand set of squares shows the average trend over the past eleven years; right hand set shows current trends.

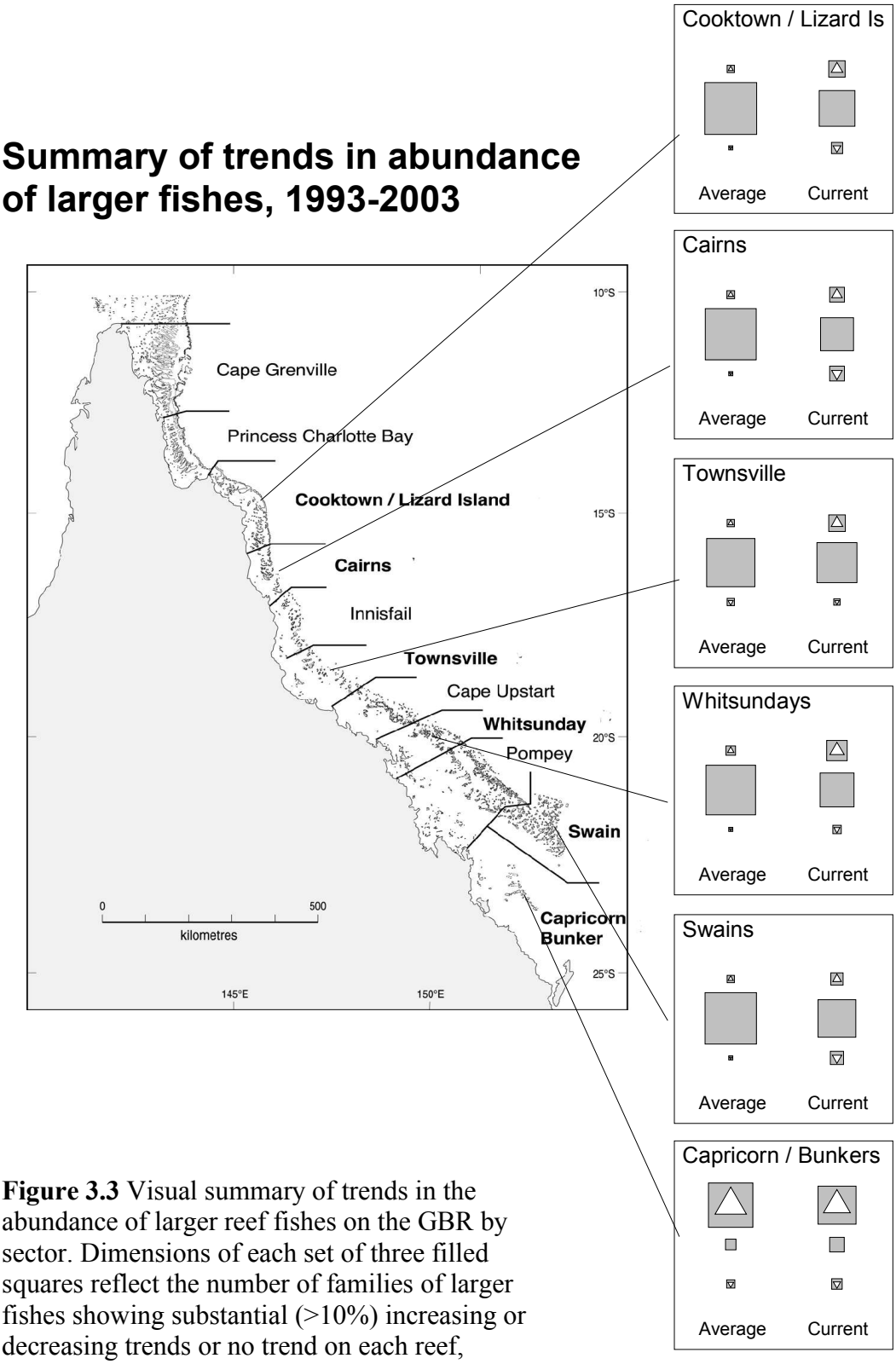


Figure 3.3 Visual summary of trends in the abundance of larger reef fishes on the GBR by sector. Dimensions of each set of three filled squares reflect the number of families of larger fishes showing substantial (>10%) increasing or decreasing trends or no trend on each reef, summed over all survey reefs in each sector and shown as a proportion. Arrow heads indicate direction of trend. For each sector, the left hand set of squares shows the average trend over the past eleven years; right hand set shows current trends.

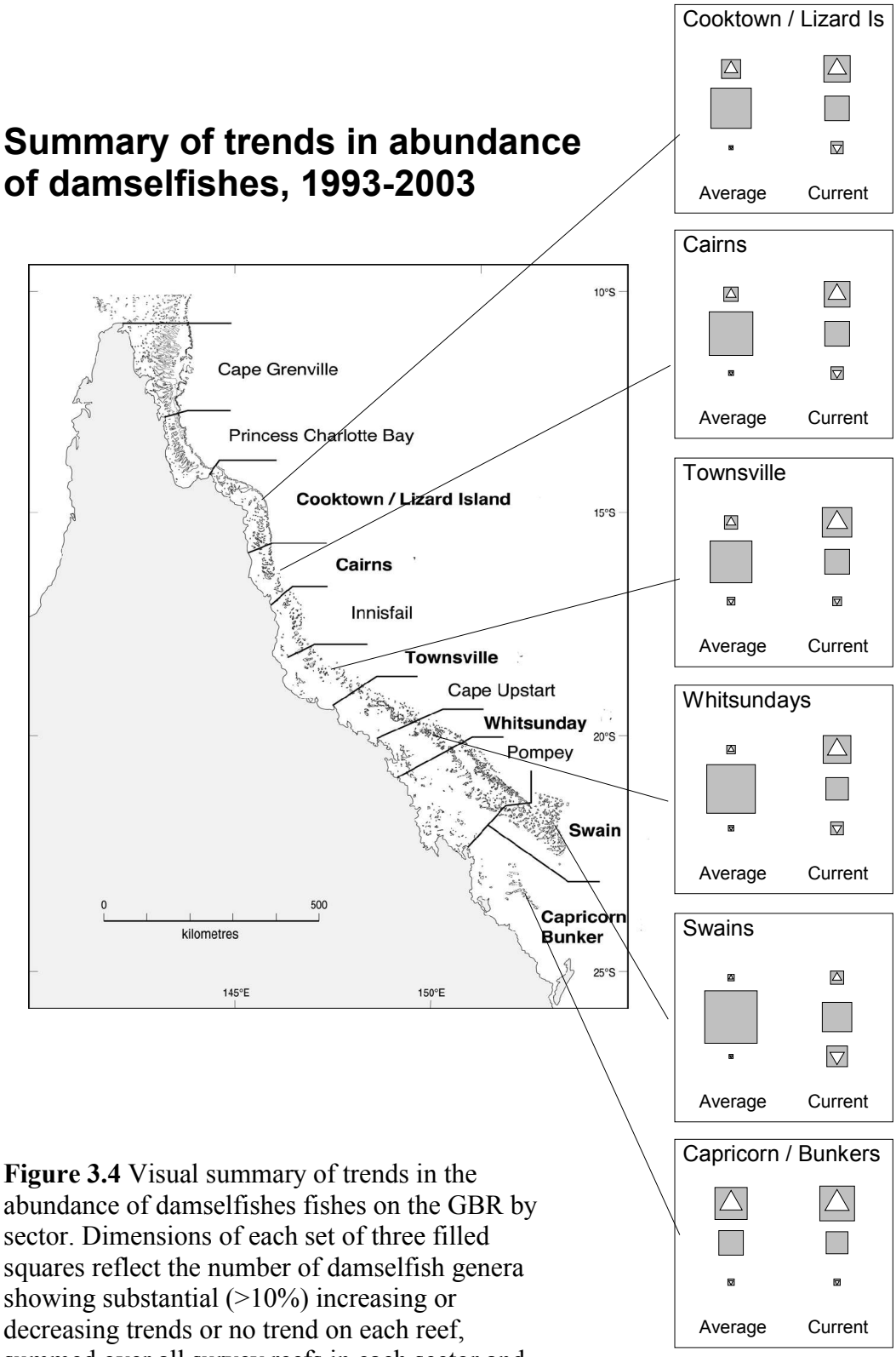


Figure 3.4 Visual summary of trends in the abundance of damselfishes fishes on the GBR by sector. Dimensions of each set of three filled squares reflect the number of damselfish genera showing substantial (>10%) increasing or decreasing trends or no trend on each reef, summed over all survey reefs in each sector and shown as a proportion. Arrow heads indicate direction of trend. For each sector, the left hand set of squares shows the average trend over the past eleven years; right hand set shows current trends.

4. Reefs of the Great Barrier Reef: status and trends

Explanation of the reef pages

This section contains data on each reef surveyed in the 2002 and 2003 field seasons. In Figure A, an aerial photograph of each reef shows the size and orientation of the reef, location of fixed transects and the manta tow path. Dotted lines indicate the manta tow path, numbered dots correspond to tow number and the solid line indicates the area covered by fixed transects. The physical geography of the reef is described below the aerial photograph. The sectors are presented in order from north to south. Reefs are ordered alphabetically within the sectors, with the core survey reefs first, followed by reefs that are only surveyed by manta tow. Data on benthic organisms and fishes are only presented for the 48 core reefs where permanent monitoring sites are located.

Manta tow surveys

Figure B is a histogram showing coral cover categories recorded by observers for each two minute manta tow for the most recent survey. This information provides an overview of the current status of a reef in terms of spatial distribution of coral cover and COTS around the reef perimeter.

Figure C provides an overview of the reef over the history of manta tow surveys. Median coral cover and the number of COTS per tow counted for each year are presented.

Benthic video surveys

For benthic organisms, three figures (D, E, and F) describe the trends in percent cover over 11 survey years for the major benthic groups, for major benthic families and for groups within the family Acroporidae, respectively. The trend lines are estimated from linear mixed-effects models (see Methods and Appendix I) the points are the observed reef mean percent cover. A fourth figure (G) is included for reefs where coral disease was observed. The figure shows the frequency of colonies affected by black band disease and white syndrome disease in each survey year since 1999.

Visual fish census surveys

Another four figures (H, I, J and K) on the facing page show the trends in fish abundance over 11 survey years for the reef fish groups where abundance was greater than 5 per site for at least one survey. Figures H and I show trends in the major reef fish families and Figures J and K show trends in the damselfish genera. The trend lines are estimated from linear mixed-effects models (see Methods and Appendix I) the points are the observed reef mean abundance.

Written summary

A summary of the status and trends is given for each reef.

Index

Cape Grenville

Reef Pages

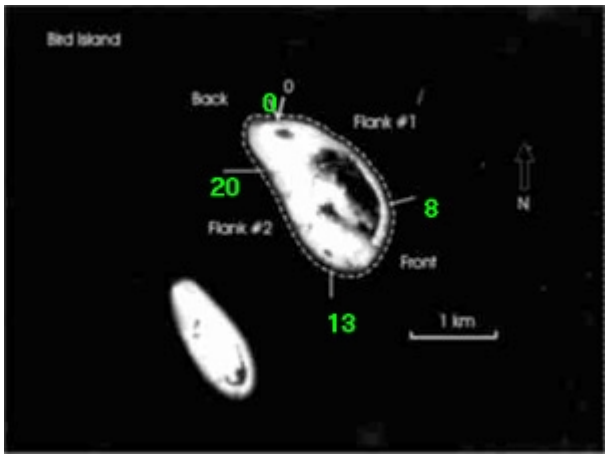
BIRD IS'S

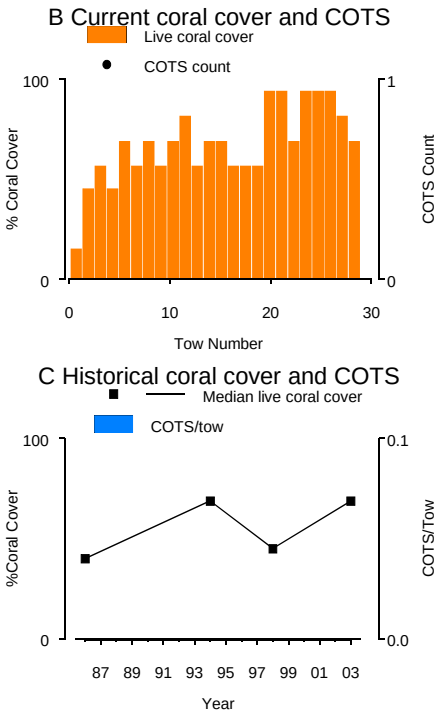
Surveyed July 2002.

This reef has only been surveyed four times since 1986. Over this time there was an initial increase followed by a subsequent decline in reef-wide live coral cover through to 1998. The decline may be attributable, in part, to Cyclone Nathan, which influenced this area in March 1998. Since this time reef-wide live coral cover has continued to increase and was very high (50-75%) during this survey. No COTS have ever been observed and the reef was classified as No Outbreak. No bleaching or coral disease was observed during manta tow surveys in 2003.

Figure 4.1

A





Bird Is'S (No. 11-167) is an inner shelf planar reef with an area of 1.2 sq.km.

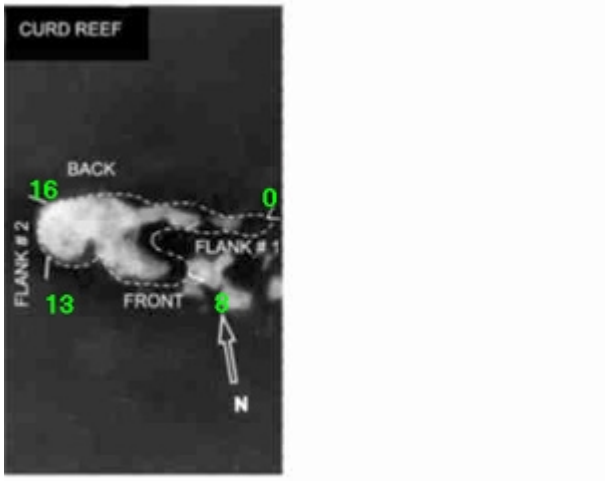
CURD

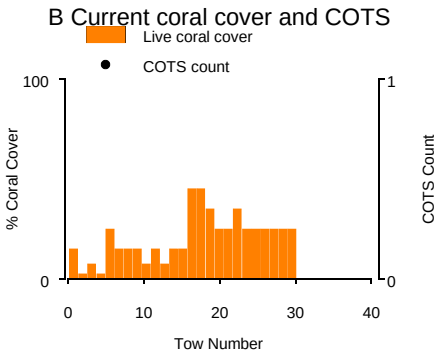
Surveyed July 2001.

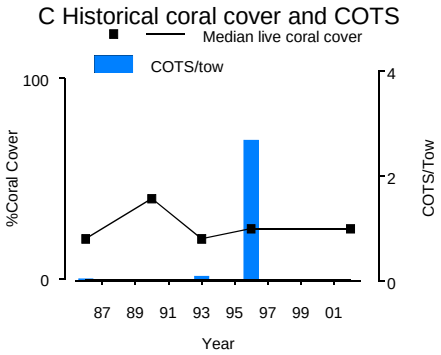
Curd Reef has been surveyed five times since 1986. It was surveyed previously in 1996 when there was an Active Outbreak of COTS. Reef-wide live coral cover on Curd Reef has remained relatively stable at a moderate to high (20-40%) level since 1986. While it is quite possible that outbreaking COTS populations had some effect on coral cover in the years since 1996, surveys in 2002 found no COTS and the reef was classified as Recovering. No bleaching or coral disease was recorded from this reef during manta tow surveys in 2002.

Figure 4.2

A







Curd (No. 12-102) is an inner shelf reef patches reef with an area of 21.9 sq.km.

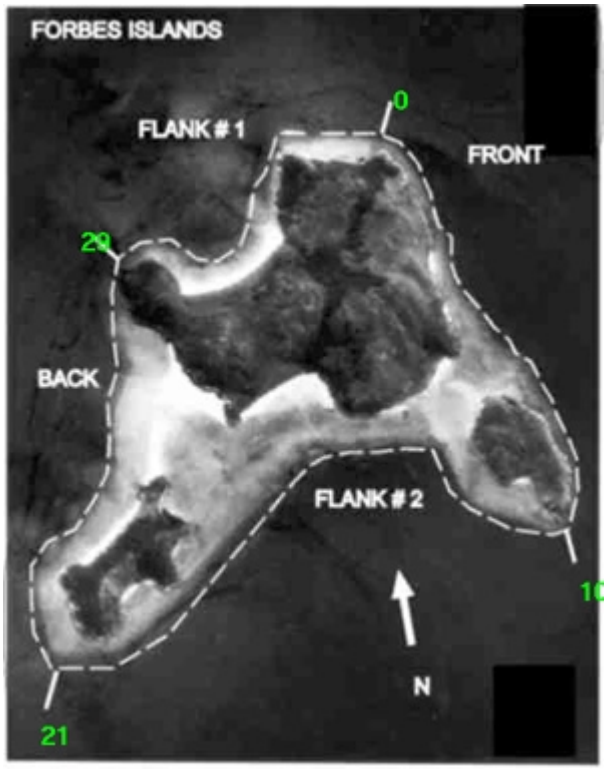
FORBES IS'S

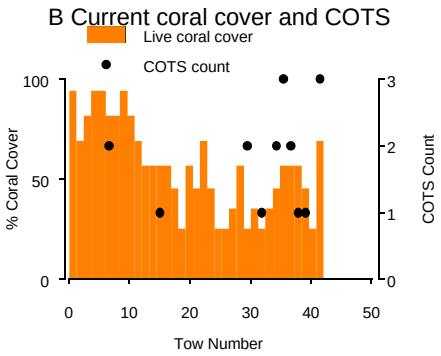
Surveyed July 2001.

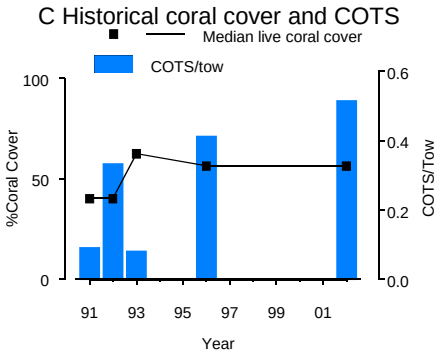
This reef has been surveyed five times since 1991. Incipient Outbreak levels of COTS were recorded from this reef in 1992, 1996 and during the most recent surveys in 2002. Apparently the reef has been able to sustain this level of COTS activity because reef-wide live coral cover has changed little since 1991 and remains at a very high (50-75%) level. Forbes Islands Reef was classified as Incipient Outbreak in 2002. No coral bleaching and only a low level of white syndrome disease (restricted to small numbers of scattered coral colonies) was recorded from this reef during manta tow surveys in 2002.

Figure 4.3

A







Forbes Is'S (No. 12-016) is a middle shelf fringing reef with an area of 1.2 sq.km.

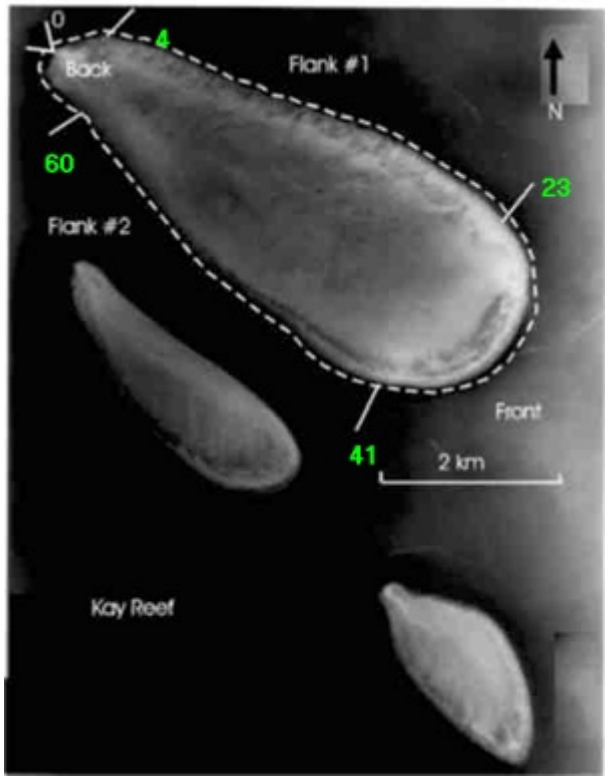
KAY

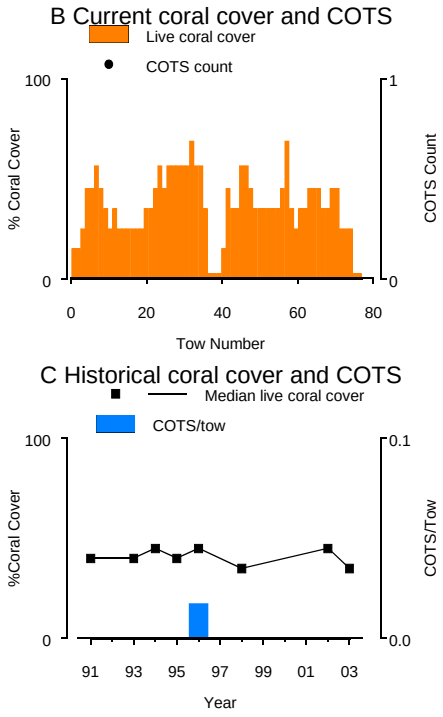
Surveyed July 2002.

This reef has been surveyed regularly using manta tow since 1991. Reef-wide live coral cover has been relatively stable at a high level (30-50%) through to 2003. The reef remained classified as No Outbreak. Whilst small numbers of COTS were recorded in 1996, they were below levels that would be expected to reduce reef-wide live coral cover. A low level of bleaching (small numbers of scattered colonies) was recorded during 2003 as well as a low level of black band disease and white syndrome disease.

Figure 4.4

A





Kay (No. 12-010) is an inner shelf planar reef with an area of 7.5 sq.km.

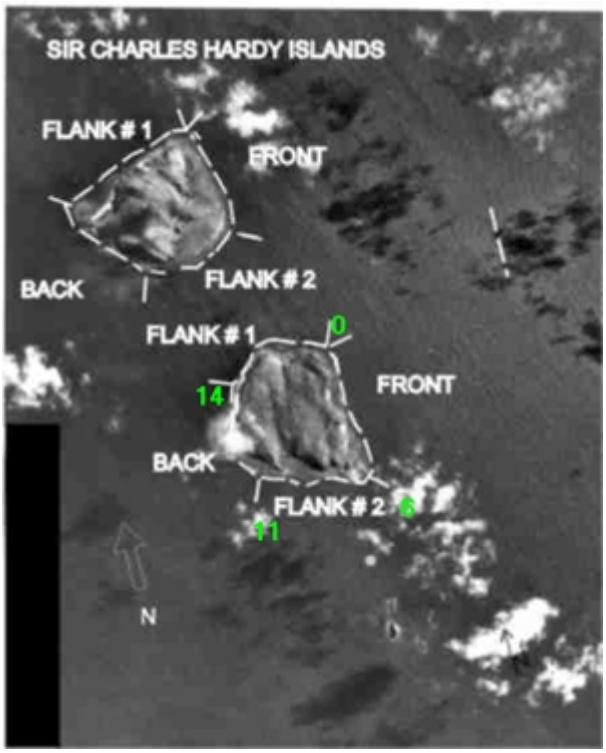
SIR CHARLES HARDY (1)

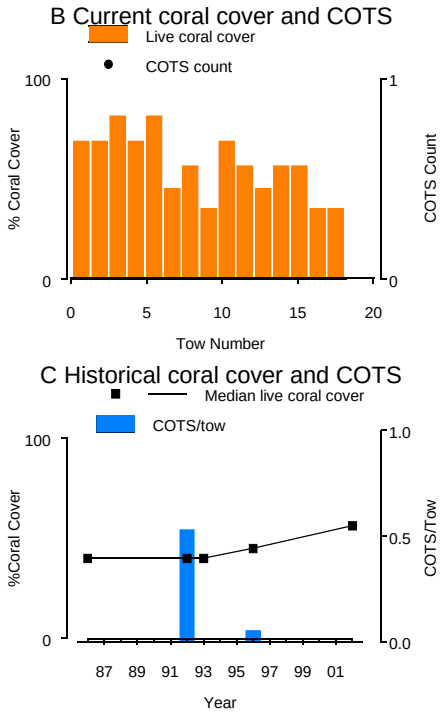
Surveyed July 2001.

This reef has been surveyed five times since 1986. COTS were recorded at Incipient Outbreak levels in 1992, but have been absent in the majority of survey years. Reef-wide live coral cover has increased from high (30-50%) in 1986 to a very high level (50-75%) recorded in 2002. No coral bleaching and only low levels of white syndrome disease (restricted to small numbers of scattered coral colonies) were observed during manta tow surveys in 2002.

Figure 4.5

A





Sir Charles Hardy (1) (No. 11-184) is a middle shelf fringing reef with an area of 3 sq.km.

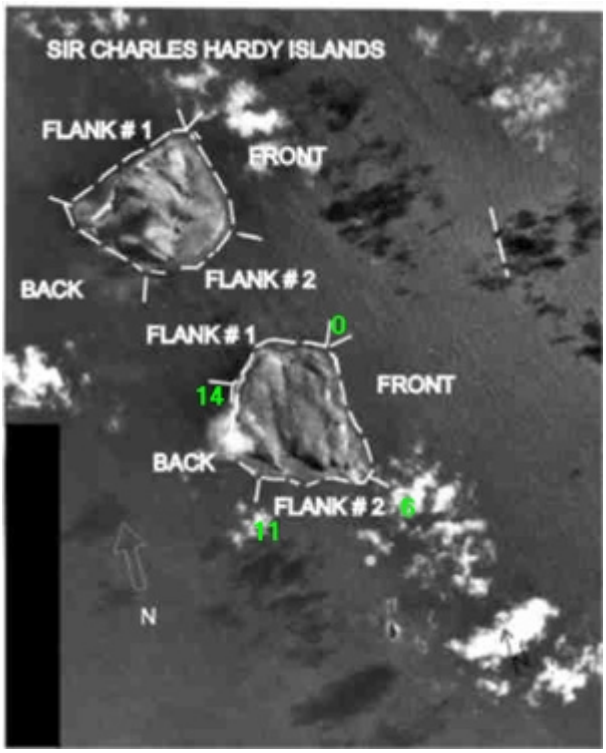
SIR CHARLES HARDY (2)

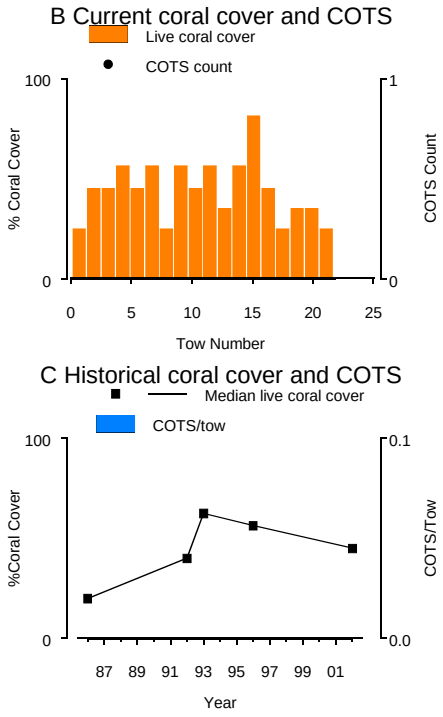
Surveyed July 2001.

This reef has been surveyed five times since 1986. Small numbers of COTS were recorded from this reef once in 1996. Reef-wide coral cover increased from a moderate (10-30%) level in 1986 to a very high level (50-75%) recorded in 1996. Surveys in 2002 recorded high reef-wide live coral cover (30-50%). No coral bleaching and only low levels of black band disease and white syndrome disease were observed during manta tow surveys in 2002 (affecting small numbers of scattered coral colonies).

Figure 4.6

A





Sir Charles Hardy (2) (No. 11-184) is a middle shelf fringing reef with an area of 3 sq.km.

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Princess Charlotte Bay

Reef Pages

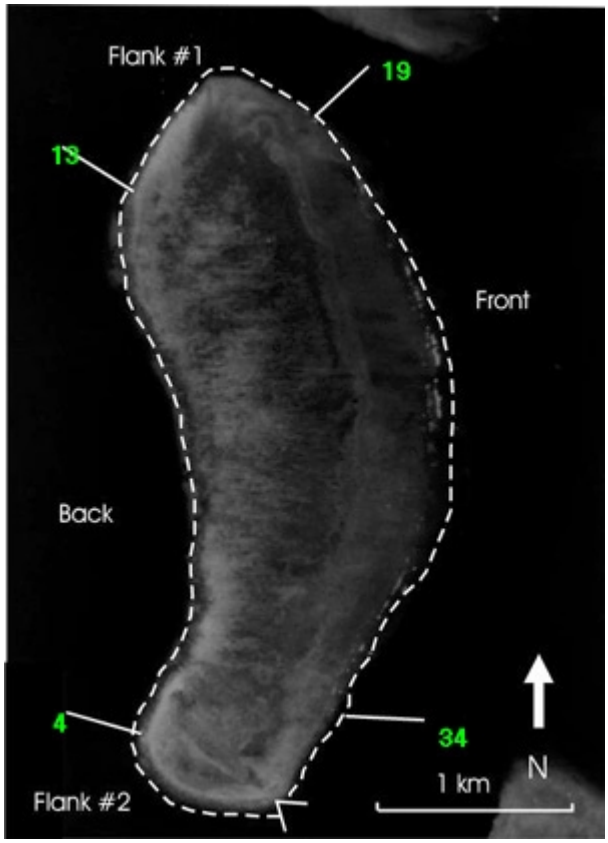
13040

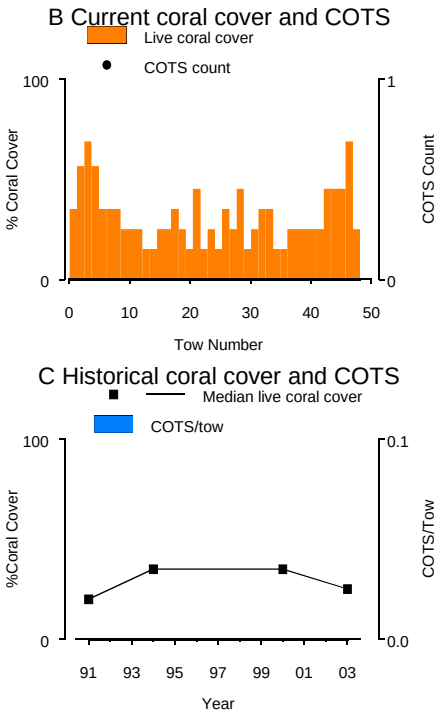
Surveyed July 2002.

Reef 13040 has been manta tow surveyed four times since 1991. Reef-wide live coral cover increased to a high level (30-50%) in 1994, where it remained through to the last survey in 2003. No COTS have ever been observed during manta tow surveys and the reef was classified as No Outbreak. Low levels of bleaching and white syndrome disease were observed in 2003 (restricted to small numbers of individual coral colonies).

Figure 4.7

A





13040 (No. 13-040) is an outer shelf planar reef with an area of 3.1 sq.km.

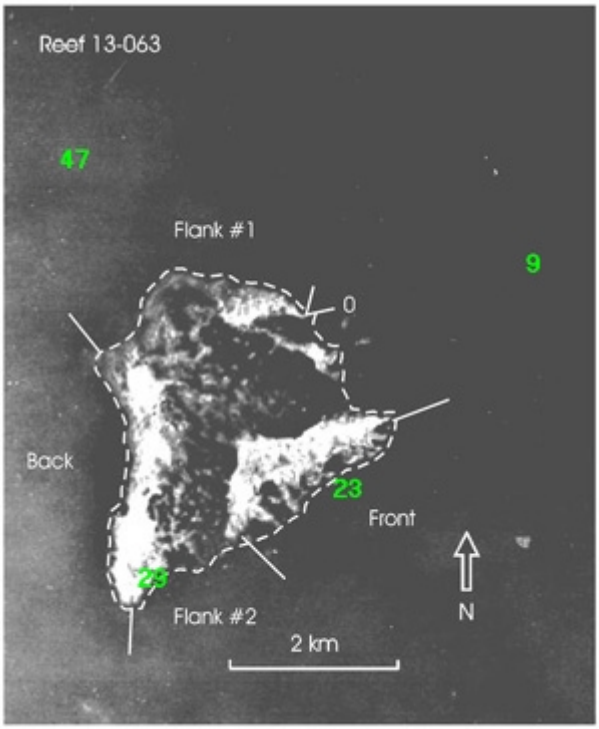
13063

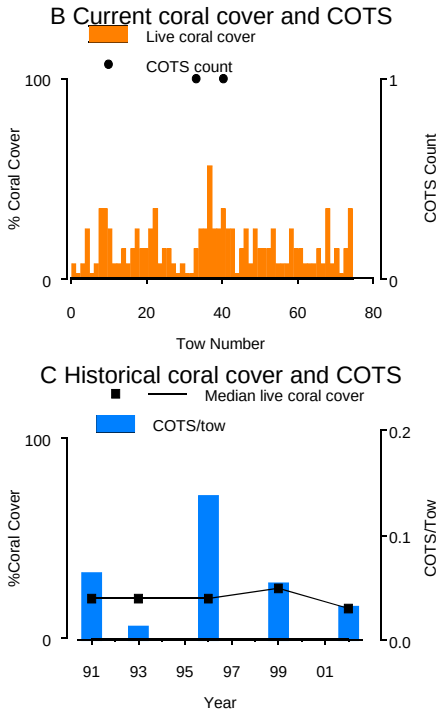
Surveyed July 2001.

This reef has been surveyed five times since 1991. In that time reef-wide live coral cover has remained at moderate levels (10-30%). COTS have been recorded on all surveys but have remained below levels that would be expected to reduce reef-wide coral cover. In 2002 this reef was classified as No Outbreak. No bleaching and only low levels of black band disease and white syndrome disease were recorded during manta tow surveys on this reef in 2002 (restricted to a small number of individual coral colonies).

Figure 4.8

A





13063 (No. 13-063) is a middle shelf reef patches reef with an area of 16.9 sq.km.

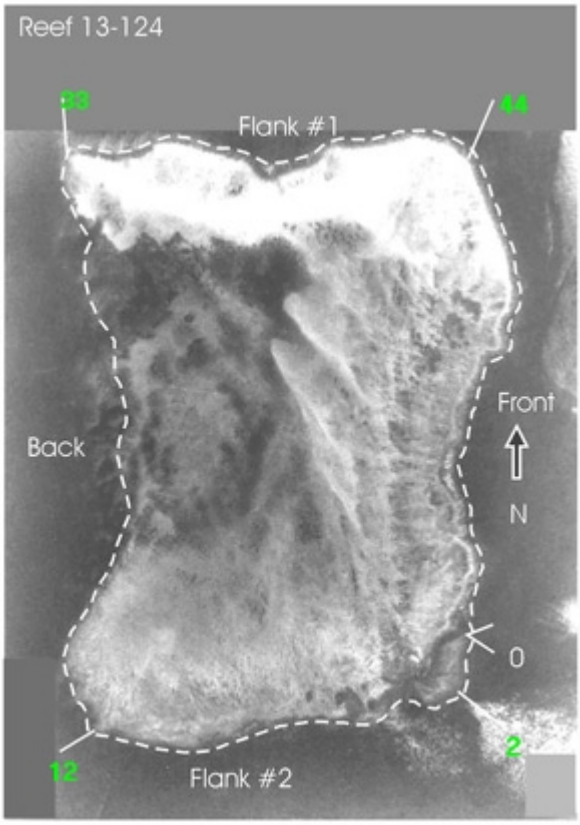
13124

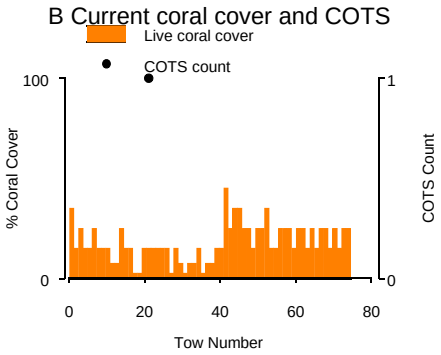
Surveyed July 2002.

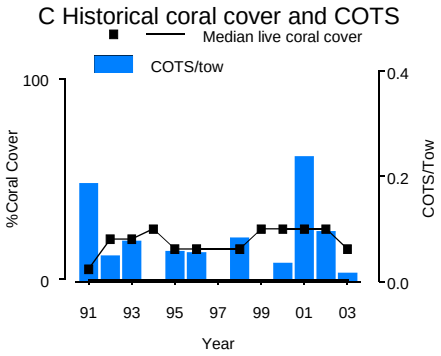
Reef 13124 has been surveyed regularly by manta tow since 1991. Reef-wide coral cover has remained at moderate levels of 10-30%. COTS have been consistently recorded on this reef, though in most years they have been at densities considered too low to reduce reef-wide live coral cover. Only small numbers of COTS were observed during the most recent survey in 2003 but there was a small decrease in reef-wide live coral cover. Cover was still moderate at 10-30% and the reef was still classified as No Outbreak. No bleaching and only low levels of black band disease and white syndrome disease were recorded (restricted to small numbers of scattered coral colonies).

Figure 4.9

A







13124 (No. 13-124) is a middle shelf crescentic reef with an area of 11.3 sq.km.

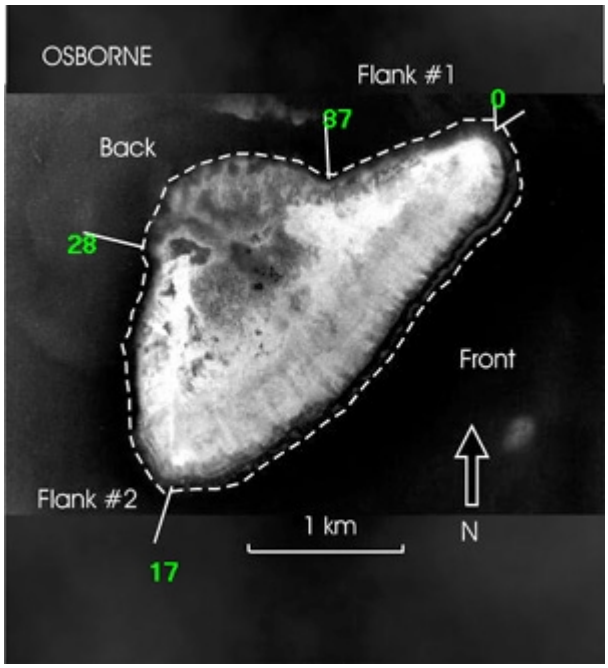
OSBORNE

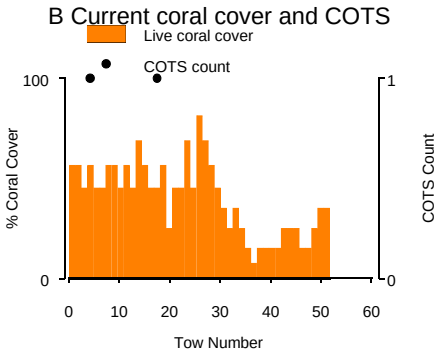
Surveyed July 2001.

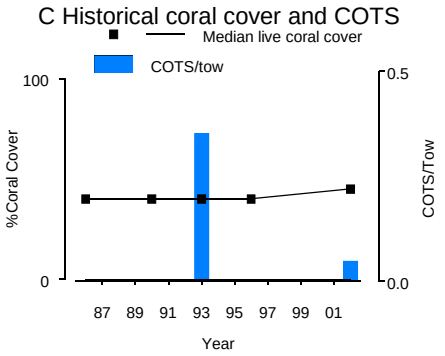
This reef has been surveyed five times since 1986. Over this time reef-wide live coral cover has remained relatively stable at a high level (30-50%). Incipient Outbreak levels of COTS were recorded in 1993 but they appear to have had little affect on reef-wide live coral cover. COTS were recorded during surveys in 2002 but in numbers well below those that would be expected to cause significant coral mortality. Osborne Reef was classified as No Outbreak in 2002. No bleaching and only low levels of black band disease and white syndrome disease (restricted to small numbers of individual coral colonies) were recorded during manta tow surveys in 2002.

Figure 4.10

A







Osborne (No. 13-006) is an inner shelf planar reef with an area of 5 sq.km.

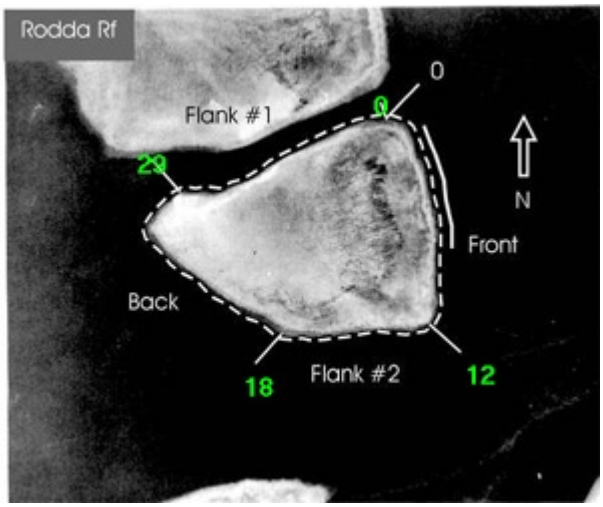
RODDA

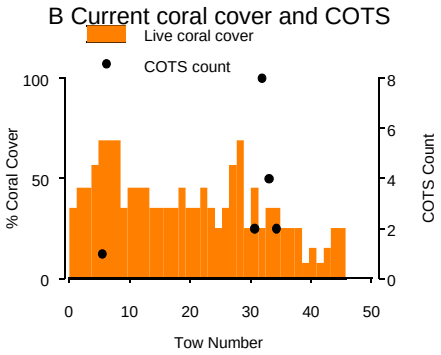
Surveyed July 2001.

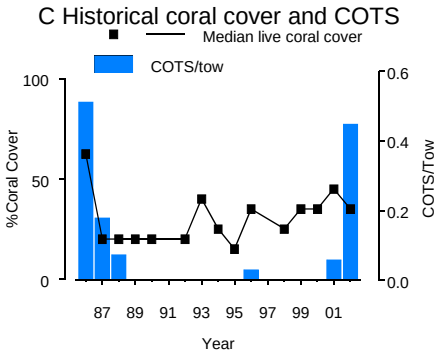
Rodda Reef has been surveyed by manta tow fifteen times between 1986 and 2002. Data suggests a rapid decline in overall reef-wide live coral cover from a very high level (50-75%) in 1986 to a moderate level (10-30%) in 1987, probably due to outbreak levels of COTS recorded on this reef in 1986. Reef-wide live coral cover remained at a moderate (10-30%) level up until 1995 then began to increase. Manta tow surveys in 2002 recorded increased COTS numbers and the reef was classified as an Incipient Outbreak. Reef-wide live coral cover was high (30-50%). No bleaching was observed and white syndrome disease was restricted to a few scattered colonies during manta tow surveys in 2002.

Figure 4.11

A







Rodda (No. 13-127) is an outer shelf planar reef with an area of 4.39 sq.km.

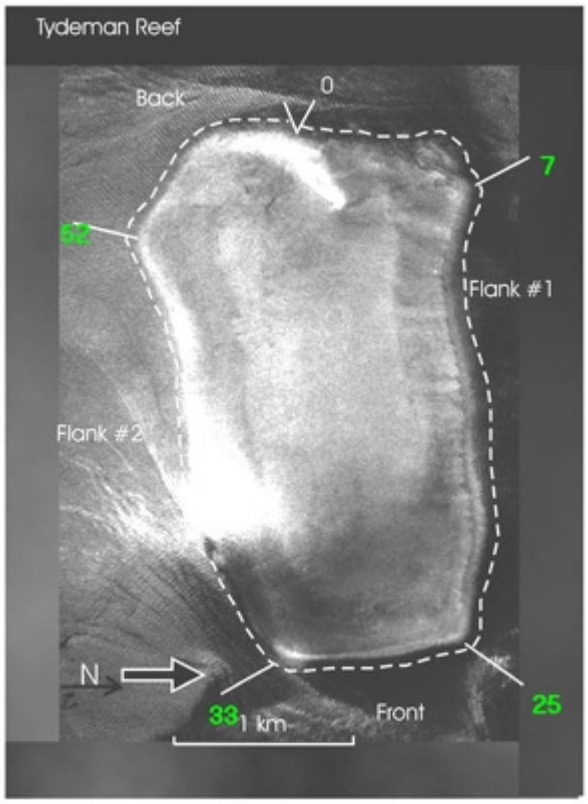
TYDEMAN

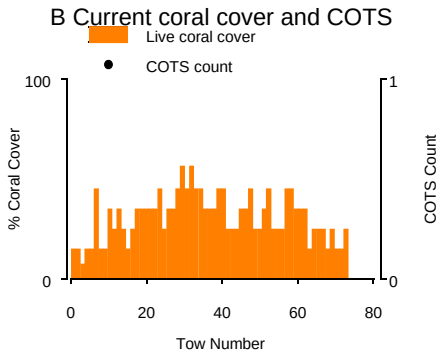
Surveyed July 2001.

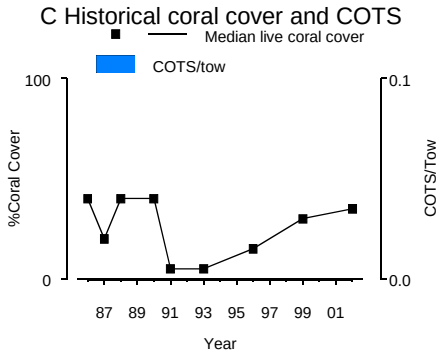
This reef has been surveyed regularly since 1986 using manta tow. No COTS have been recorded over this time. While initially high, reef-wide live coral cover declined dramatically to a low level (0-10%) between 1990 and 1991. This was likely due to Cyclone Ivor, which passed close by in March 1990. Since then the coral has recovered steadily to the present high level (30-50%). In 2002 the reef was classified as No Outbreak. No bleaching was recorded during manta tow surveys, but white syndrome disease was common (ten or more coral colonies affected per two-minute manta tow) on the back and first flank of the reef.

Figure 4.12

A







Tydeman (No. 13-133) is an outer shelf planar reef with an area of 10 sq.km.

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Cooktown / Lizard Island

Reef Pages

CARTER

Surveyed July 2002.

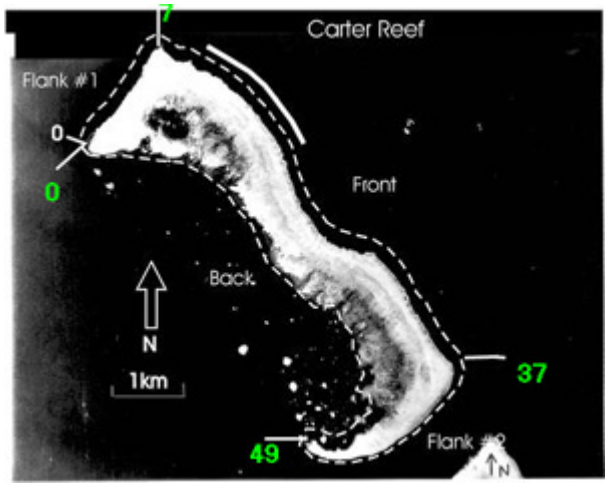
Carter Reef is a Preservation Reef within the GBRMP and so has the highest protection status available. The reef has a history of manta tow surveys dating back to 1986. Reef-wide live coral cover remained stable from 1986 to 1990 before dropping appreciably in 1991. Although COTS were observed on the reef at this time they were well below the level that results in significant reef-wide coral mortality. The decline in coral cover was almost certainly a result of Cyclone Ivor which affected the region in March 1990. Massive damage to the windward margin of the reef was observed during the 1991 surveys (done in November 1990). Coral cover has subsequently recovered on the front reef but very low cover on the back reef reduces the reef-wide average. Reef-wide live coral cover was high at 30-50% in 2003, continuing the trend of increase since 1991 and Carter Reef was classified as No Outbreak. No bleaching was recorded during manta tow surveys in 2003. White syndrome disease (WSD) was generally restricted to scattered colonies around the reef perimeter except for the front reef. Here live coral cover was highest and WSD was common (affecting 10 or more individual hard coral colonies per two-minute tow).

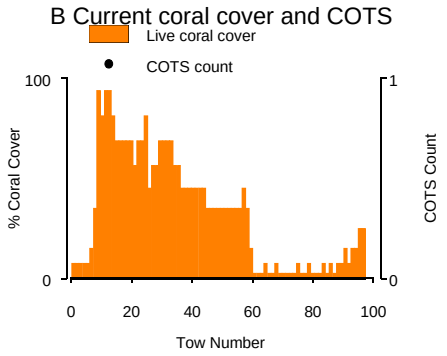
In 1992 algae was the dominant benthic group on the video survey sites. This group has been largely replaced by hard coral, which increased from 13% in 1992 to 67% in 1999. Coral cover subsequently decreased to an average of 57% cover in 2003. Tabulate *Acropora* spp. dominated the benthic community with an average cover of 31% and cover of branching *Acropora* continued to increase up to 2003. The corallivorous snail, *Drupella* spp. was observed at a density of 60/ha during SCUBA searches.

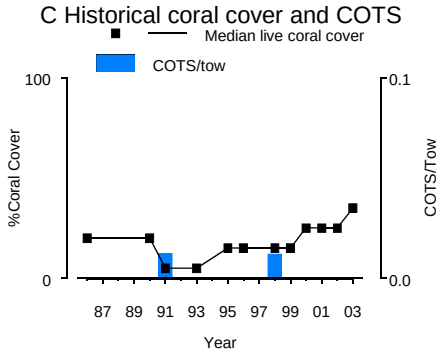
Changes in the fish community over the survey period are strongly correlated to the increase in coral cover. Increasing coral cover has resulted in declining abundance of grazing species and an increase in the abundance of fish that rely on coral for food or shelter. The surgeonfishes *Acanthurus nigrofuscus* and *Ctenochaetus* spp., parrotfishes *Scarus spinus* and *S. chameleon* were notable examples of grazing fishes showing steady declines, while several *Chromis* spp., *Plectroglyphidodon dickii* and *Chaetodon trifascialis* showed marked increases with increasing coral cover through to 2003.

Figure 4.13

A

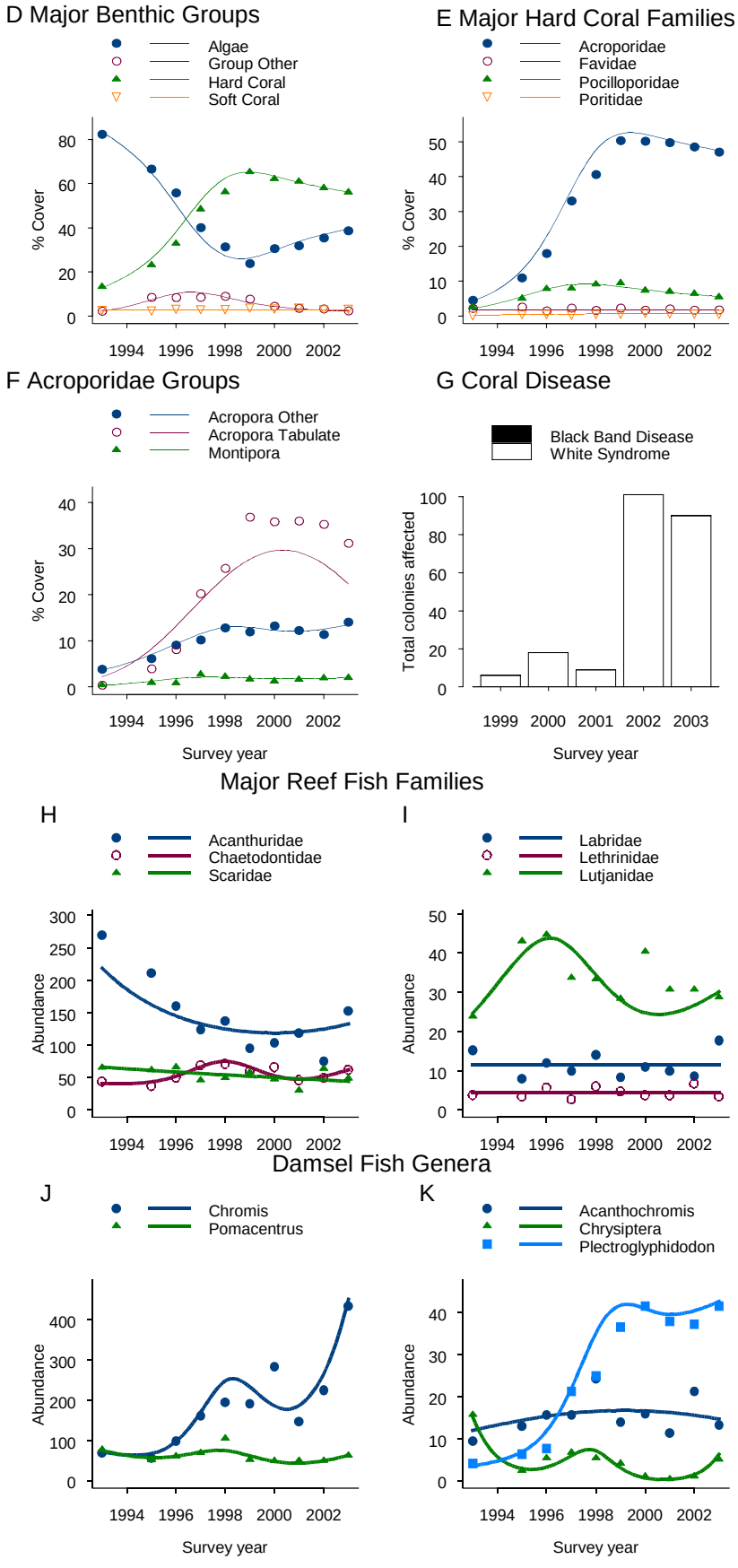






Carter (No. 14-137) is an outer shelf ribbon reef with an area of 13.7 sq.km.

Figure 4.13 (Cont).



DECAPOLIS

Surveyed August 2002.

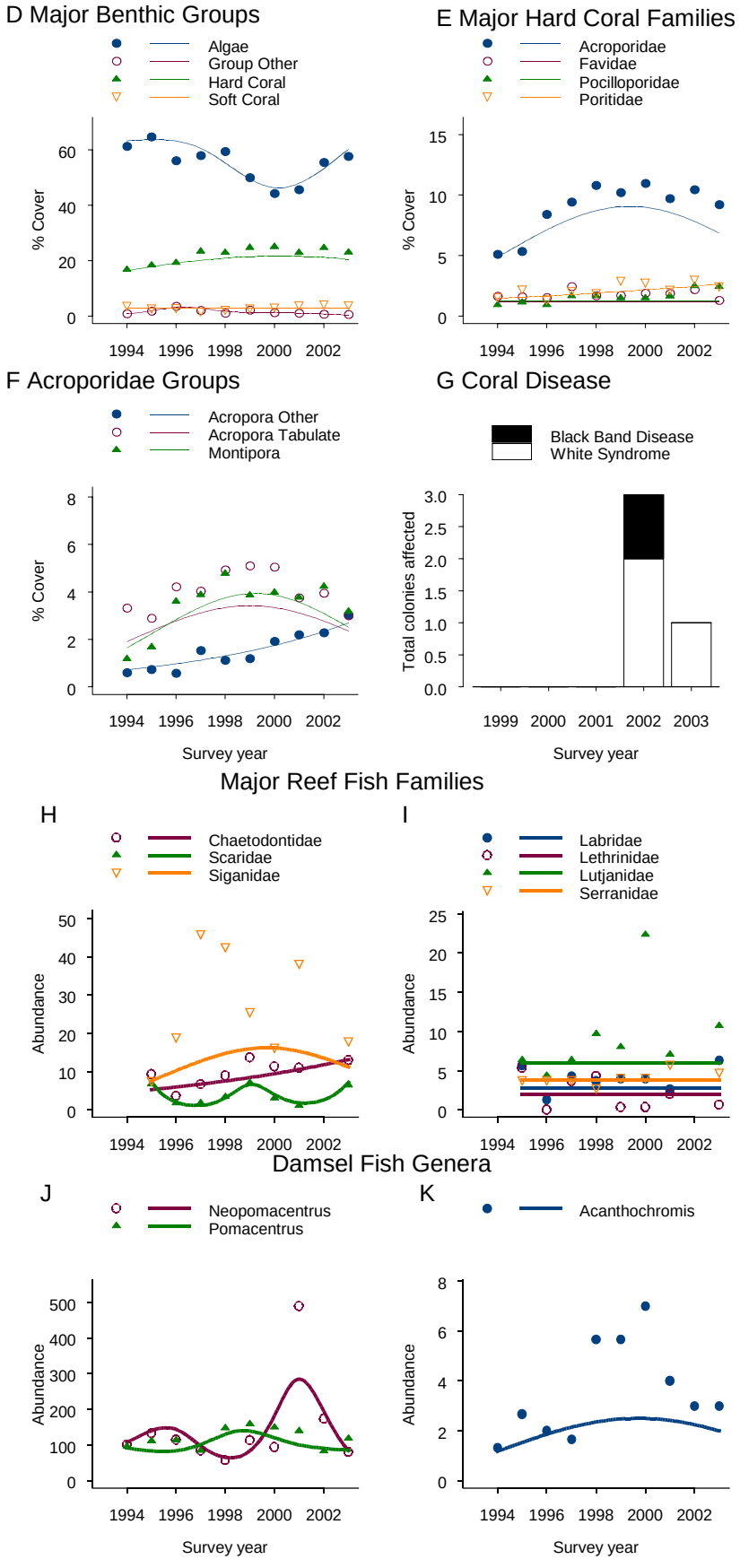
We do not survey this reef by manta tow due to poor water clarity. However the survey sites cover most of the perimeter of the reef.

This reef had the highest cover of macro algae of all reefs surveyed using video transects. Cover of macro algae has increased over the two previous survey years and averaged 57% in 2003, though this increase may reflect a slight seasonal shift in sampling. Cover of hard corals was stable over the preceding seven years of survey and was 23% in 2003. Cover of soft corals was also stable though low. There is a high diversity of hard coral on this reef and abundant gorgonians from the family Ellisellidae and Antipatharians (Black Coral). The number of colonies with coral diseases counted during SCUBA searches was very low with the first record occurring in 2003. The density of corallivorous snails *Drupella* spp. was 6.7/ha.

Due to the lack of benthic structure on Sites 1 and 3 and the close proximity to the coast, the reef fish community is relatively depauperate. Fish abundance has varied (especially in the Siganidae due to variable numbers of a resident school of *Siganus lineatus*), though variability could be due as much to the poor visibility during some surveys as to real changes in population densities. On the whole, the stable coral community is reflected in a largely stable fish fauna. (no photo)

Decapolis (No. 14-131) is an inner shelf planar reef with an area of .4 sq.km.

Figure 4.14 (Cont).



LINNET

Surveyed August 2002.

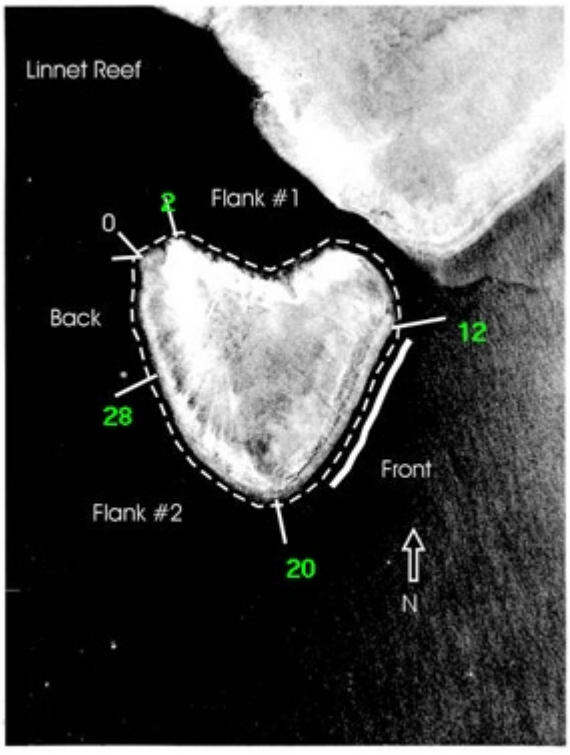
This reef has an extensive history of manta tow surveys since 1986. COTS have been recorded on this reef since 1995. In 1996 COTS numbers represented an Incipient Outbreak. Low numbers of COTS were observed in 2003 and the reef was reclassified as No Outbreak. There has been little appreciable change in reef-wide live coral cover which has generally remained moderate (10-30%). Reef-wide live coral cover declined between 1999 and 2000, presumably as a result of COTS feeding activity, but then stabilised. No bleaching was recorded. White syndrome disease was present in 2003 but was restricted to a few scattered coral colonies.

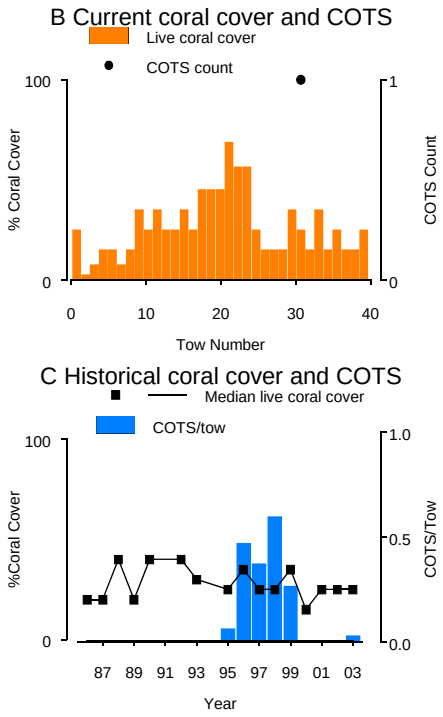
In the intensive study sites, coral cover has fluctuated around an overall increasing trend and was 51% in 2003. Cover of algae showed a corresponding decline to 40% cover. Increase in cover of hard corals is largely due to growth of corals within the family Acroporidae. Corals of the family Faviidae have also increased with percent cover of *Echinopora* rising from 3% to 6% in 2003. *Drupella* spp. were observed at a density of 580/ha during the most recent SCUBA search surveys and a sharp increase in coral diseases was also recorded. The number of colonies with disease is currently moderate.

The majority of large reef fish show no obvious trends in abundance over the 11 years of survey though several species of Chaetodontidae were more abundant in 2003 than on any prior survey. This is not surprising given the steadily increasing coral cover. While a few damselfish species, including *Chromis atripectoralis* and *Pomacentrus brachialis*, continued to increase, abundance of many species reached a plateau several years ago. The numerically dominant *Pomacentrus moluccensis* is one example of this. *Acanthochromis polyacanthus* continued to decline from a peak population in 1999.

Figure 4.15

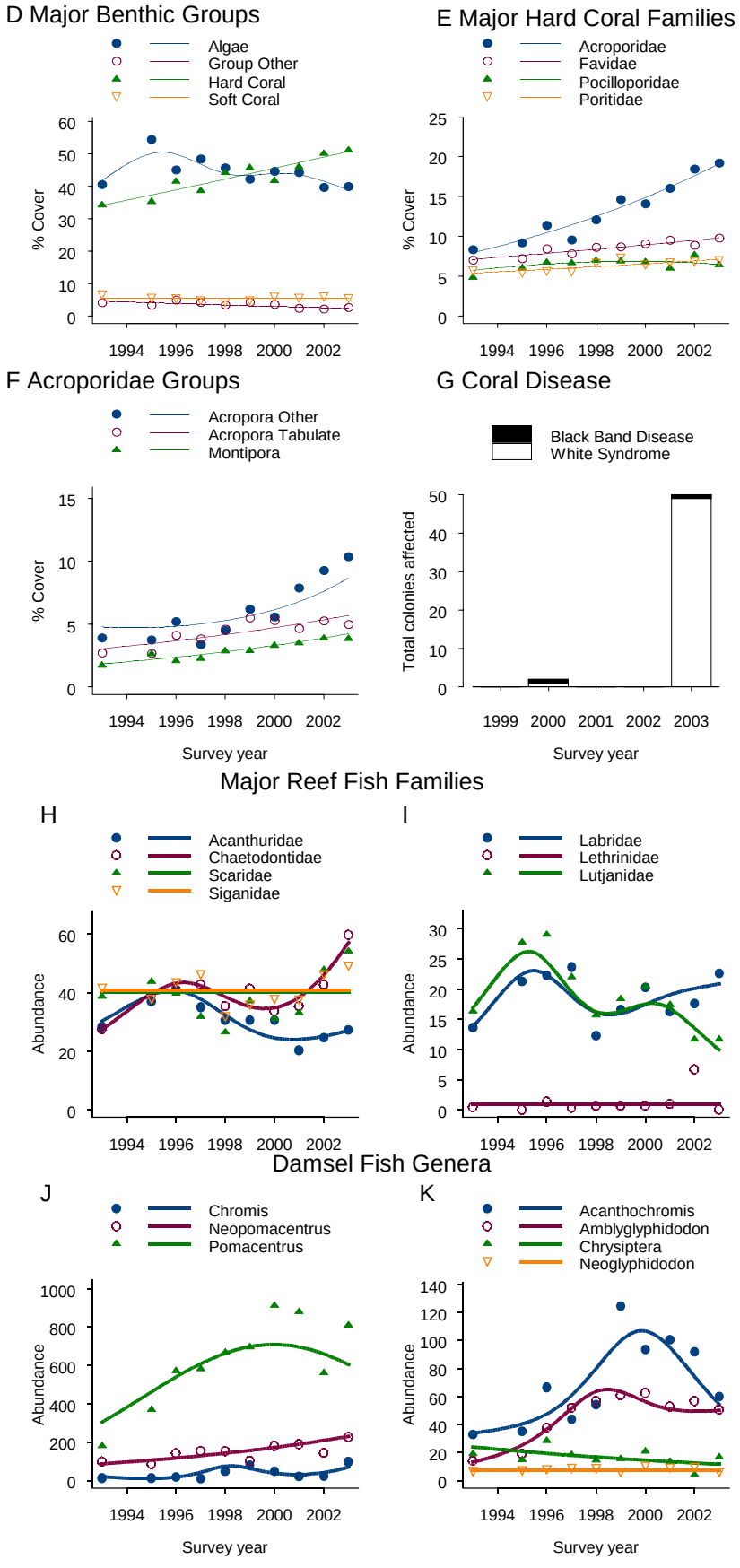
A





Linnet (No. 14-126) is an inner shelf planar reef with an area of 3.5 sq.km.

Figure 4.15 (Cont).



LIZARD IS

Surveyed July 2002.

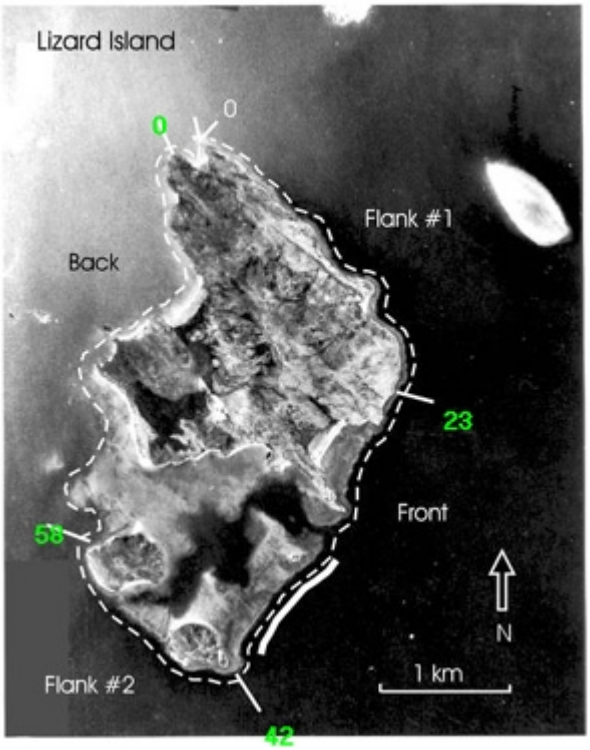
This reef has been surveyed using manta tow since 1986 when it was considered to be Recovering from previous COTS activity. From 1996 until 1999 the reef was classified as Active Outbreak. Since 1998 reef-wide live coral has shown an increasing trend, though it was still low (1-10%) in 2003. The reef has been classified as Recovering since 1999 even though small numbers of COTS were observed during the 2003 surveys. No bleaching and a few scattered coral colonies with white syndrome disease were recorded during manta tow surveys in 2003.

Cover of hard coral on the intensive study sites has remained at low to moderate levels since 1995. In 2003, cover of hard coral averaged 15%. Cover of algae averaged 63%. Hard and soft corals were equally represented in the coral community with Alcyoniidae and Poritidae being the most abundant families. The persistent increasing trend in *Porites* is likely to be a result of avoidance of this coral genus by COTS. There has been a very low incidence of coral disease recorded on SCUBA search since 1999. Two COTS were observed during the 2003 SCUBA searches: one adult and one juvenile, while *Drupella* spp. were observed at a density of 167/ha.

The majority of larger mobile fish show no consistent trends. Overall, Scaridae increased during the survey period, however there was high variability within most species. *Scarus flavipectoralis* and *S. rivulatus* showed the most consistent increases. Among damselfishes there were few obvious trends though *Pomacentrus moluccensis, P. brachialis* and *Chrysiptera talboti* all showed marked increases in 2003 following five to six years of decline. *Acanthochromis polyacanthus* declined from a peak in 1999 reaching its lowest level since surveys began.

Figure 4.16

A



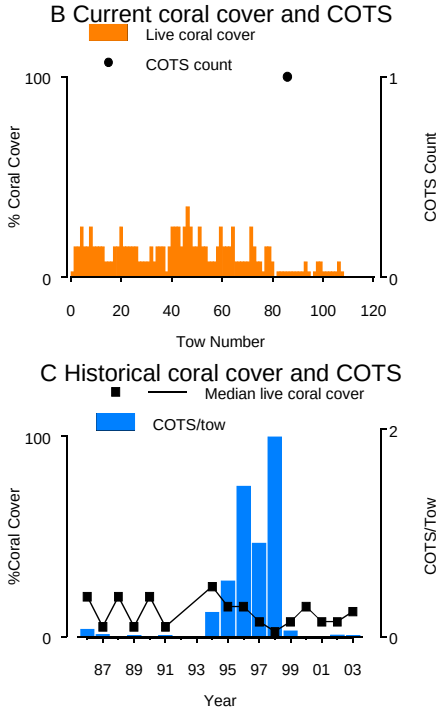
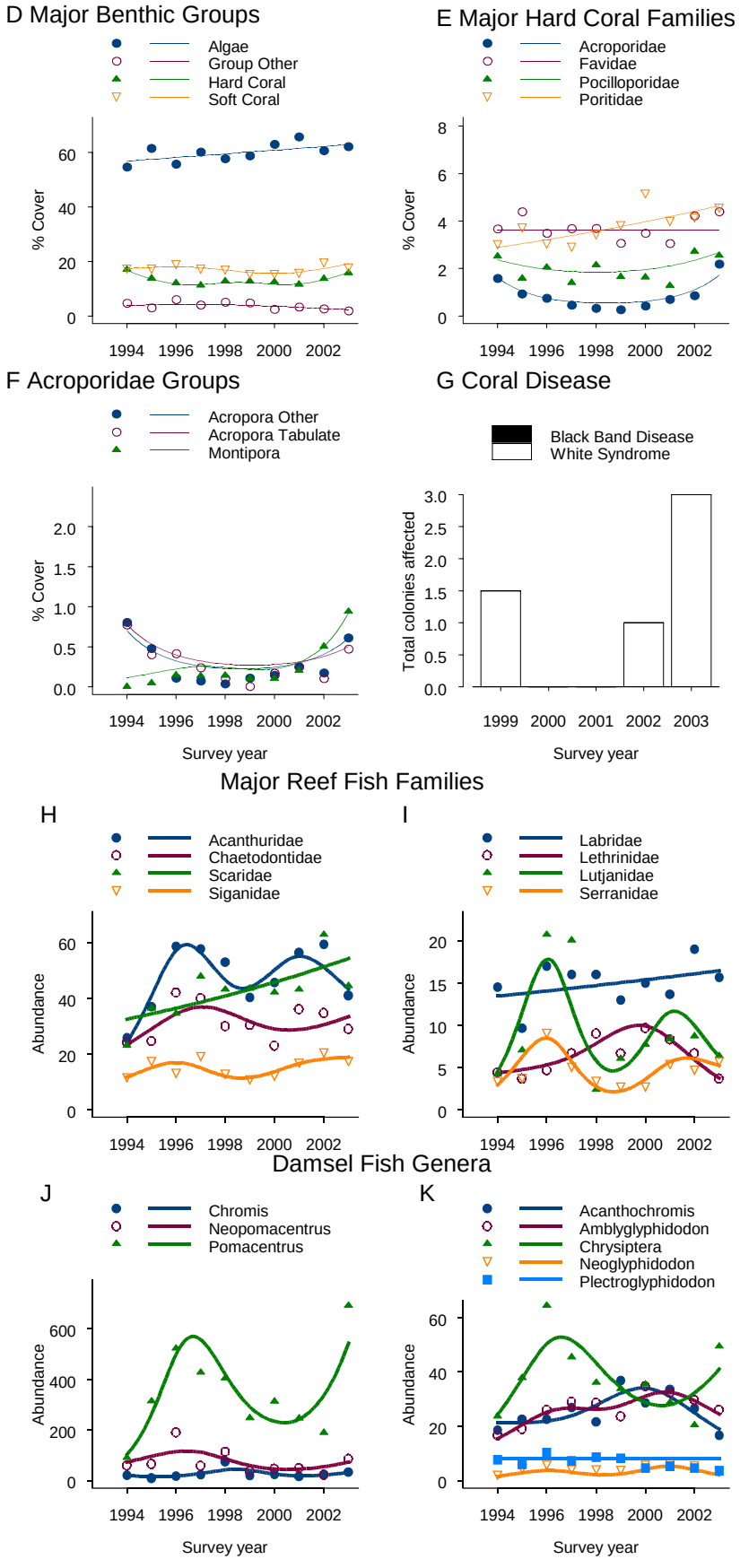


Figure 4.16 (Cont).



MACGILLIVRAY

Surveyed July 2002.

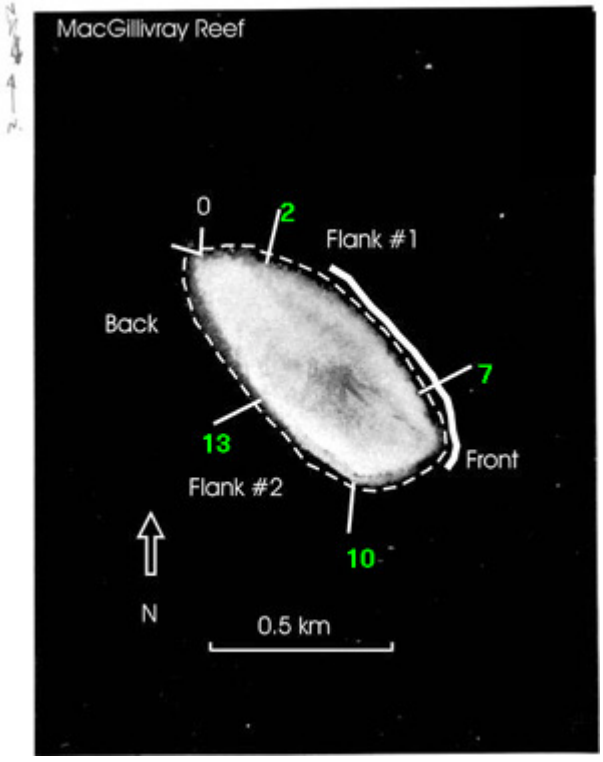
This reef has been surveyed using manta tow since 1986 when it was classified as Recovering from previous COTS activity. Reef-wide live coral cover remained high until 1994. In 1993 elevated COTS populations were recorded and the reef was reclassified as Incipient Outbreak. COTS remained at or around Incipient Outbreak levels on this reef until 1998. There was then a corresponding gradual decline in reef-wide live coral cover to moderate (10-30%) levels in 1998. Since then, coral cover has remained moderate (10-30%). No bleaching, disease or COTS were recorded during manta tow surveys in 2003 and the reef remained classified as Recovering.

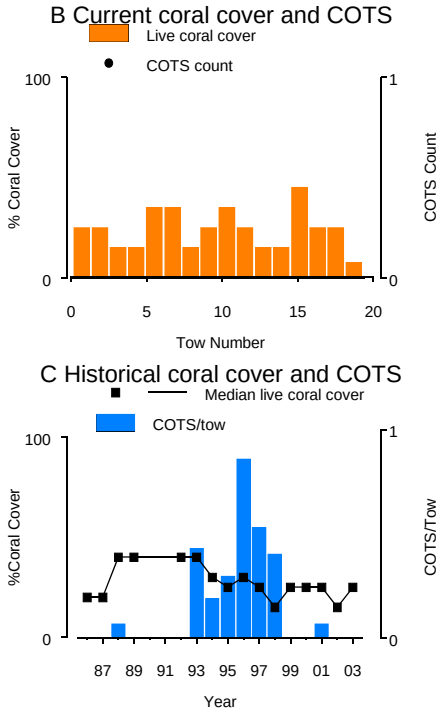
On the intensive survey sites, cover of hard coral was moderate, averaging 19% in 2003. Several coral families showed slow increasing trends following the impact of COTS in the mid-90s. Cover of soft coral and algae has remained stable and in 2003 averaged 6% and 52% respectively. The coral community was dominated by massive *Porites*. Percent cover of this genus has remained constant at approximately 10%. Very low numbers of colonies with coral diseases were recorded during SCUBA searches in 2003. *Drupella* spp. were also recorded at a density of 7/ha.

The larger mobile fish families were either stable or showed slight increases. Scaridae have increased at a slow rate while Acanthuridae, Chaetodontidae and Labridae all showed a curvilinear pattern with a peak around 1996 then a period of decline followed by the recent increases. Within the damselfish community marked increases in the most abundant species of *Pomacentrus* and also *Chrysiptera talboti* ended periods of decline in these genera.

Figure 4.17

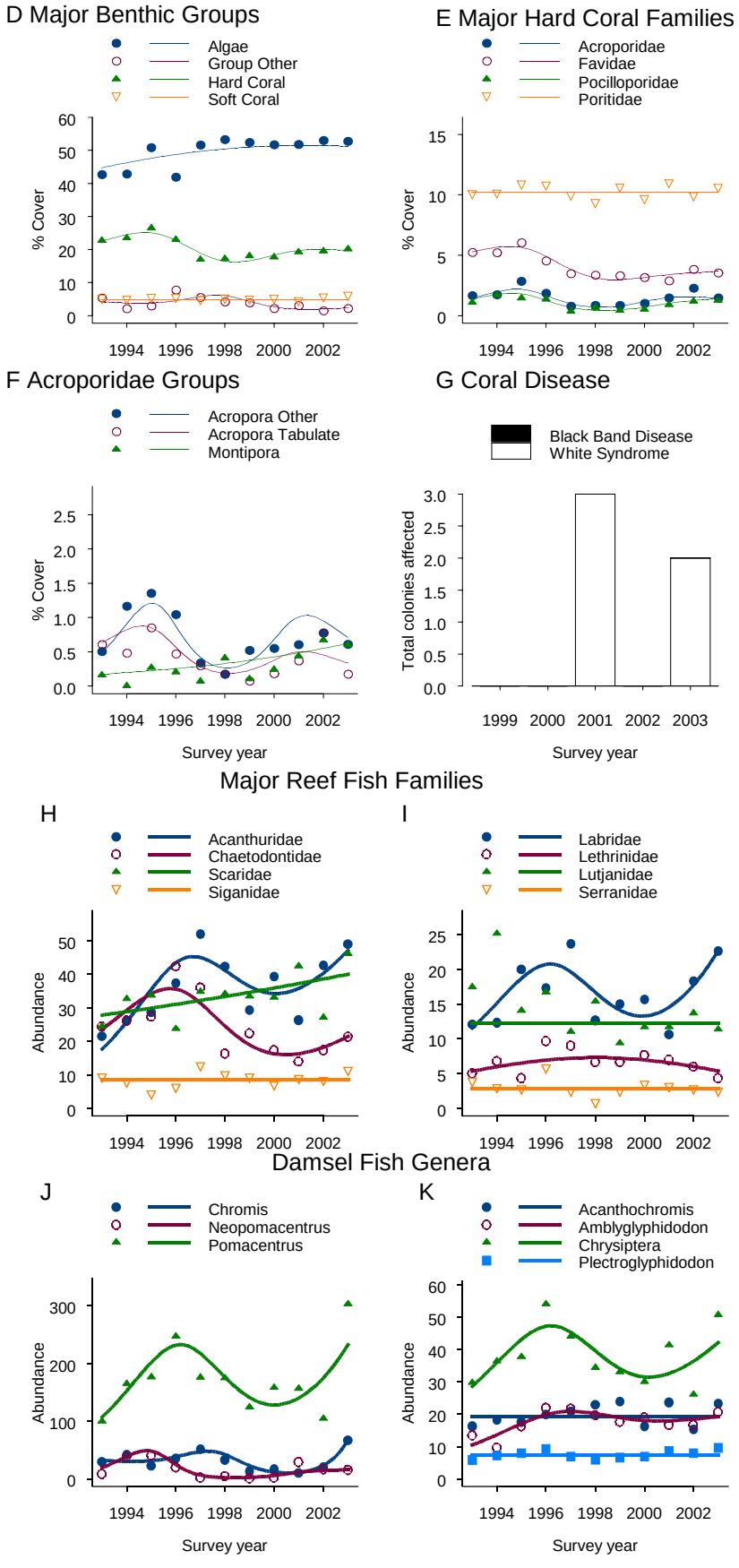
A





Macgillivray (No. 14-114) is a middle shelf planar reef with an area of .5 sq.km.

Figure 4.17 (Cont).



MARTIN

Surveyed August 2002.

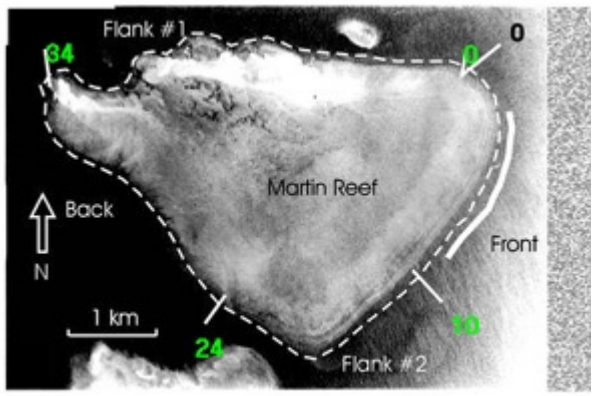
This reef has been surveyed extensively using manta tows since 1990. Reef-wide live coral cover had not changed significantly and was moderate (10-30%) in 2003. COTS populations were at outbreak levels in 1998 and 1999, but no COTS have been seen during manta tow surveys since that time. This reef was classified as No Outbreak. No bleaching was recorded and white syndrome disease was present but only a few affected coral colonies were recorded during manta tow surveys in 2003.

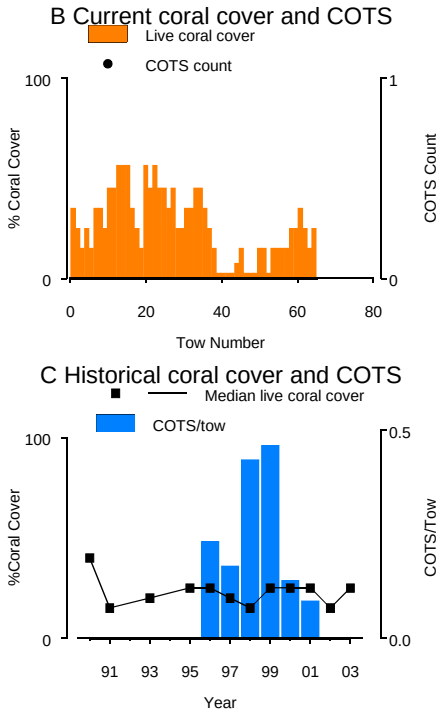
Hard coral cover on the intensive survey sites was 19% in 2003. There was some evidence of a downward trend in total coral cover over time due to elevated numbers of COTS and low levels of bleaching in 1999. Cover of soft coral has remained stable at 5%. The increasing trend in algae appears to be mostly due to colonisation of sand and rubble and the decline in coral. The decline in the family Pocilloporidae is probably due to bleaching mortality. Few colonies with coral diseases were observed on SCUBA search until 2003 when low levels were observed. *Drupella* spp. were recorded during the SCUBA searches, at a density of 20/ha along with one small COT (6-15cm.).

Most families of larger mobile fish species show no consistent trend over the survey period. Scaridae, Acanthuridae and Labridae all fluctuate around an overall increasing trend over the 11 years of survey. Trends in the damselfish community are largely driven by changes in a few abundant species. *Pomacentrus moluccensis* and *Amblyglyphidodon curacao* both declined in recent surveys and have driven the observed trends for these genera.

Figure 4.18

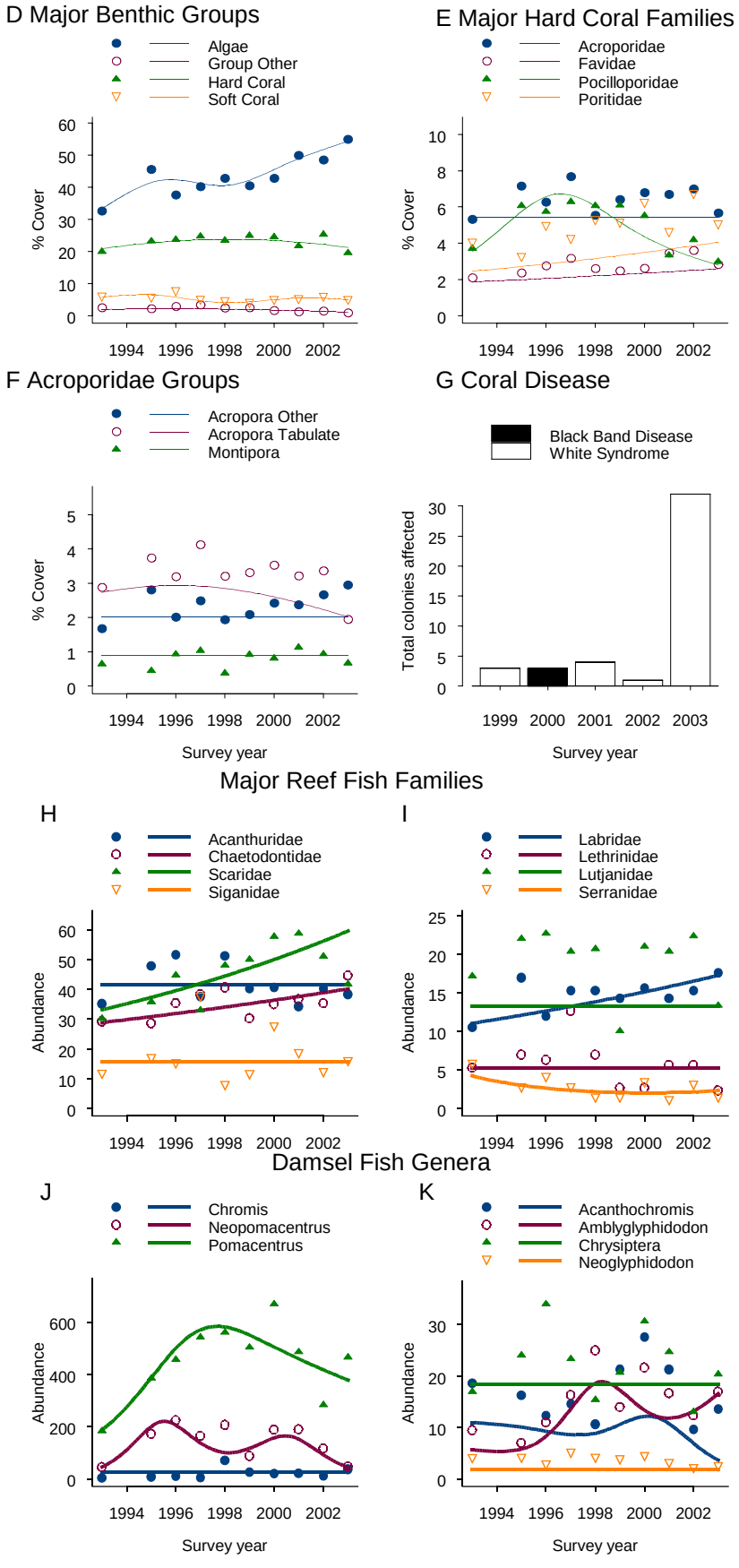
A





Martin (No. 14-123) is an inner shelf planar reef with an area of 10.1 sq.km.

Figure 4.18 (Cont).



NO NAME

Surveyed July 2002.

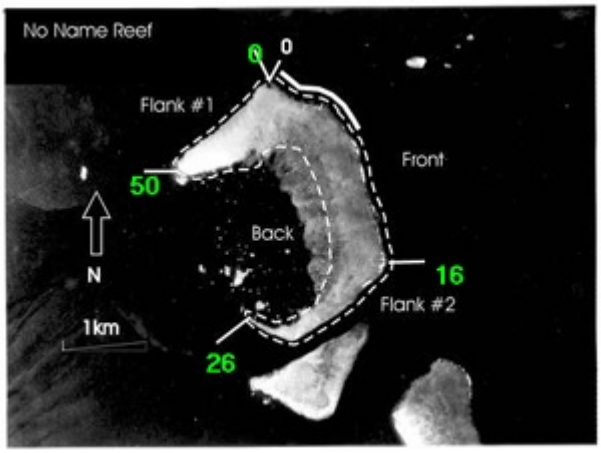
This reef has an extensive history of manta tow surveys from 1986. No COTS have been recorded during manta tow surveys and it remains classified as No Outbreak. Cyclone Ivor passed by this region in 1990 and caused significant physical damage. Reef-wide coral cover has subsequently increased to the high cover (30-50%) seen in 2003. No bleaching was recorded during the 2003 manta tow surveys and on most of the reef perimeter white syndrome disease (WSD) was restricted to few colonies. However, on the front reef, where coral cover was highest, WSD was common (affecting 10 or more individual hard coral colonies per two-minute tow).

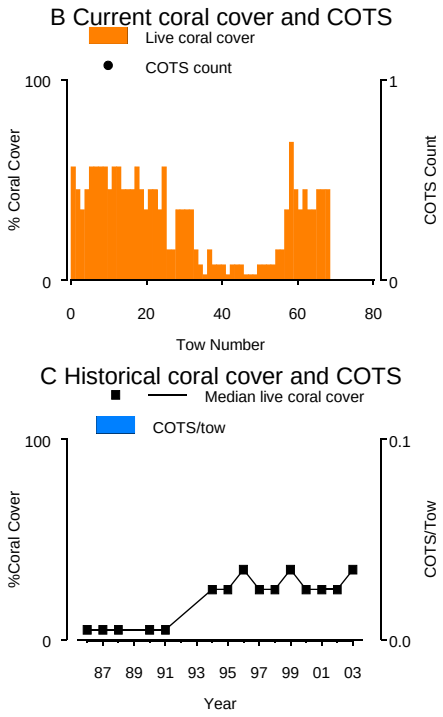
Cover of hard coral on the intensive survey sites increased from 21% in 1994 to a peak of 59% in 1999. This was primarily due to increases in the cover of fast growing tabulate *Acropora* corals from approximately 5% in 1994 to 30% in 1999. Coral cover declined slightly to 49% in 2003. SCUBA search counts recorded a dramatic increase in white syndrome disease in 2002 and it is likely that disease led to the observed decline in coral cover. In 2003 the level of coral disease was moderate and *Drupella* spp. were observed on the transects at a density of 33/ha. Algae and soft coral have not shown clear trends in recent surveys; in 2003 they averaged 35% and 6% cover respectively.

The fish community initially tracked the changing benthic environment with the herbivorous Acanthuridae decreasing while those species more reliant on the structure offered by coral cover increased. Surveys in 2003 highlighted increases in a number of species of damselfishes following several years of low or decreasing abundance; in particular *Chromis ternatensis*, *C. margaritifer*, *Pomacentrus lepidogenys* and *P. philippinus*.

Figure 4.19

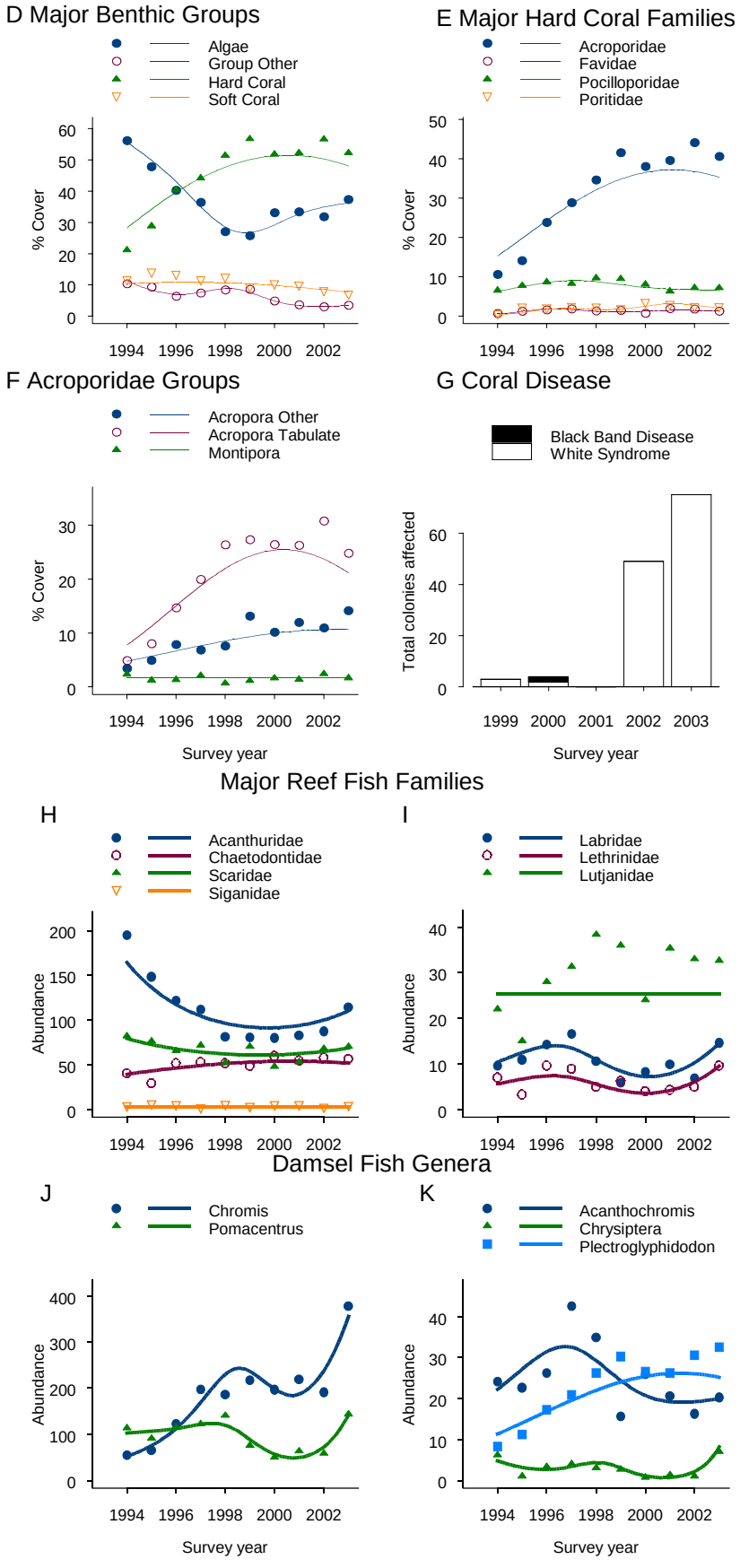
A





No Name (No. 14-139) is an outer shelf ribbon reef with an area of 7 sq.km.

Figure 4.19 (Cont).



NORTH DIRECTION IS

Surveyed July 2002.

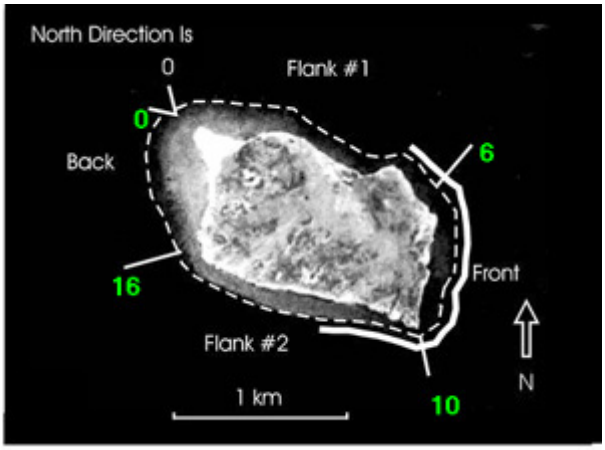
This reef was initially surveyed using manta tow in 1989 and has been surveyed annually since 1994. Reef-wide live coral cover increased between 1989 and 1994 before declining through to 1998. COTS activity is the most likely cause of the observed decline with the reef classified as Incipient Outbreak up until 1996. No COTS were observed in the 2003 survey. Reef-wide live coral cover was moderate (10-30%) in 2003. Low levels of coral bleaching (restricted to small numbers of individual coral colonies) and white syndrome disease were observed during manta tow surveys in 2003. This reef has been classified as Recovering since 1997.

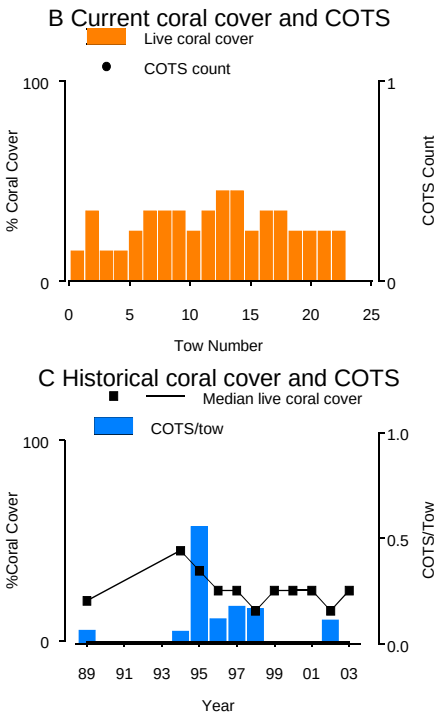
On the intensive survey sites cover of hard corals had increased and in 2003 averaged 25%. Soft coral cover remained low averaging less than 2%, while cover of algae was stable at 62%. The coral community was not dominated by any one family with each of the four major families showing increasing trends. Very low numbers of colonies with coral diseases were recorded on SCUBA search in 1999, 2002 and 2003. Large densities of *Drupella* spp. have been consistently observed since 1994 with 1127/ha recorded in 2003.

The majority of larger mobile fish families show no consistent trends. An increase in the family Labridae in 2003 was due to *Cheilinus fasciatus* while declines in Lethrinidae reflected reduced abundance of *Monotaxis grandoculis* and *Lethrinus atkinsoni*. In the damselfish community there were no long term trends though as at other reefs in the region, *Chrysiptera talboti* showed a marked increase in 2003.

Figure 4.20

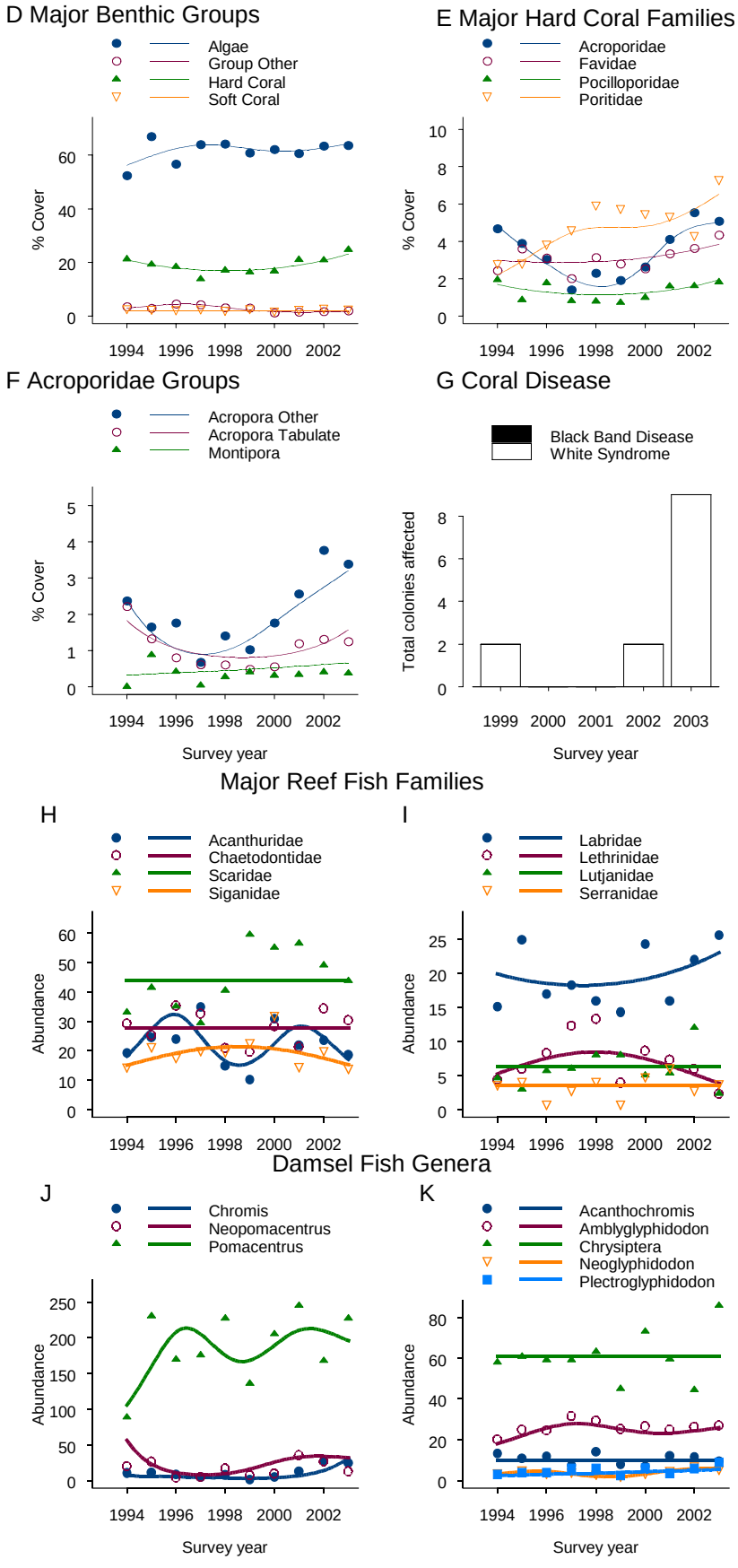
A





North Direction Is (No. 14-143) is a middle shelf fringing reef with an area of .9 sq.km.

Figure 4.20 (Cont).



YONGE

Surveyed July 2002.

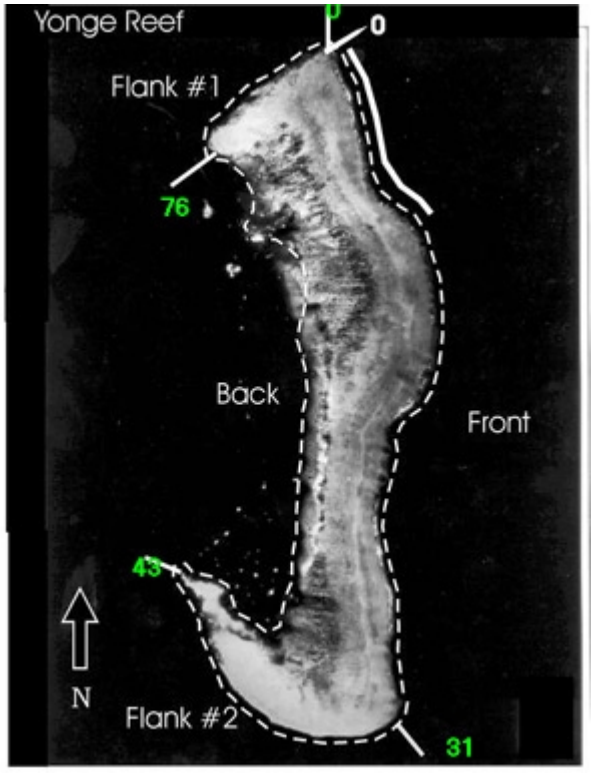
This reef has been surveyed annually using manta tow since 1992. COTS have only been observed on one occasion (1994) at extremely low density. Yonge Reef was classified as No Outbreak in 2003. Reef-wide live coral cover increased to moderate levels (10-30%) by 2000 before a slight decline in 2002 and 2003. This reef has been recovering from the effects of Cyclone Ivor (which passed through the area in 1990). Low levels of bleaching were recorded during manta tow surveys in 2003. While white syndrome disease affected relatively few colonies around the reef perimeter overall, it was common on the front reef where coral cover was highest, affecting 10 or more coral colonies per two-minute tow.

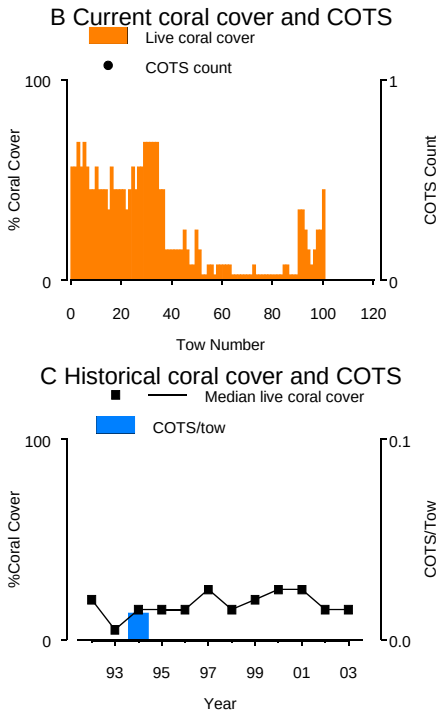
In 1992 algae was the dominant benthic group in the intensive survey sites. This group has now largely been replaced by hard coral which increased from 13% in 1992 to 61% in 2001. Coral cover averaged 57% in 2003. The benthic community is dominated by tabulate *Acropora*, which that reached a maximum cover of 34% in 2001 and averaged 28% in 2003. Branching and digitate *Acropora* have continued to increase while corals in family Pocilloporidae show the same trend as tabulate *Acropora*. Records of coral disease increased dramatically in SCUBA search counts in 2002. Low levels of coral disease were recorded in 2003 and *Drupella* spp. were recorded at a density of 287/ha.

In 2003 there were small increases in the abundance of several species of Acanthuridae and Scaridae, reversing a decade of declining trends. Coral-associated species in the family Chaetodontidae continued to increase, as did most of the abundant species of damselfish. Increases in *Chromis ternatensis* and *Acanthochromis polyacanthus* were responsible for the strong increases in those genera. In the genus *Plectroglyphidodon*, *P. dickii*, *P. johnstonianus* and *P. lacrymatus* continued to increase in abundance.

Figure 4.21

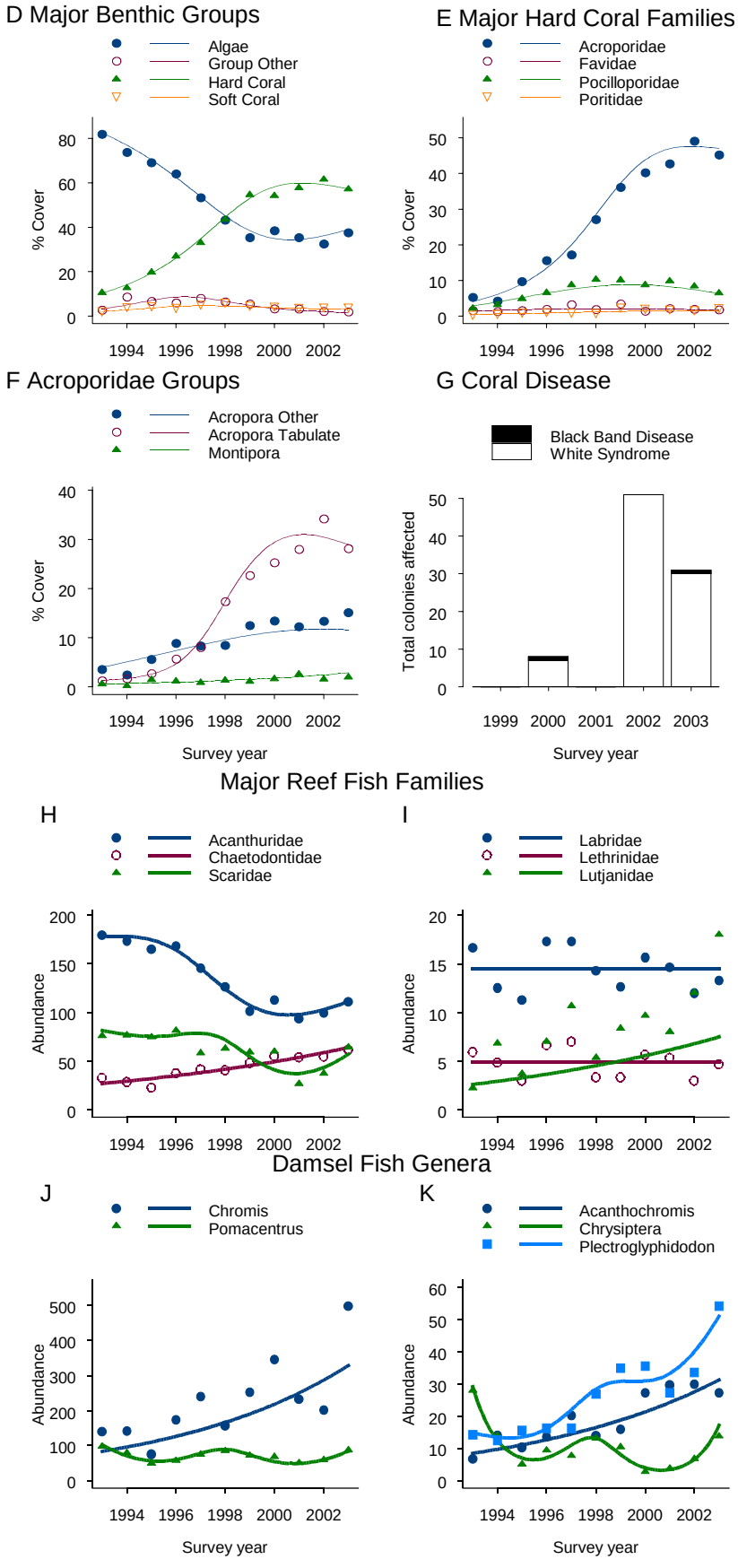
A





Yonge (No. 14-138) is an outer shelf ribbon reef with an area of 11.1 sq.km.

Figure 4.21 (Cont).



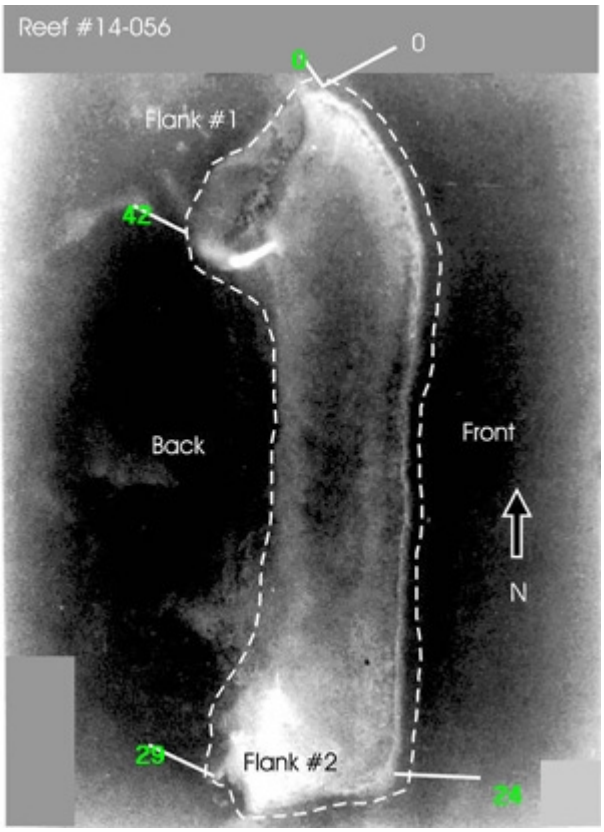
14056

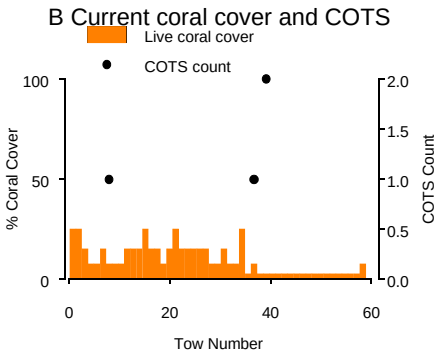
Surveyed July 2001.

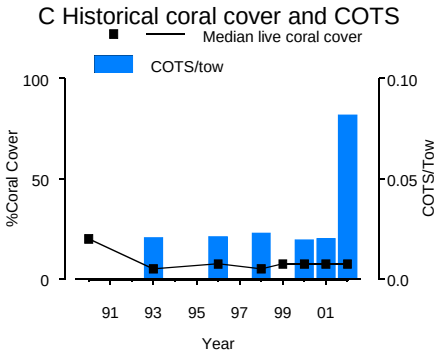
This reef has been surveyed eight times since 1990. Initially reef-wide live coral cover was moderate (10-30%) before declining in the early nineties to the current low (1-10%) level where it has stabilised. COTS have been observed on this reef in most survey years though generally in numbers lower than would be considered sufficient to cause significant reef-wide live coral mortality. Manta tow surveys in 2002 indicated reef-wide live coral cover remained low (1-10%). The reef was classified as No Outbreak. No bleaching or white syndrome disease of hard corals was recorded during manta tow surveys in 2002.

Figure 4.22

A







14056 (No. 14-056) is a middle shelf crescentic reef with an area of 7.8 sq.km.

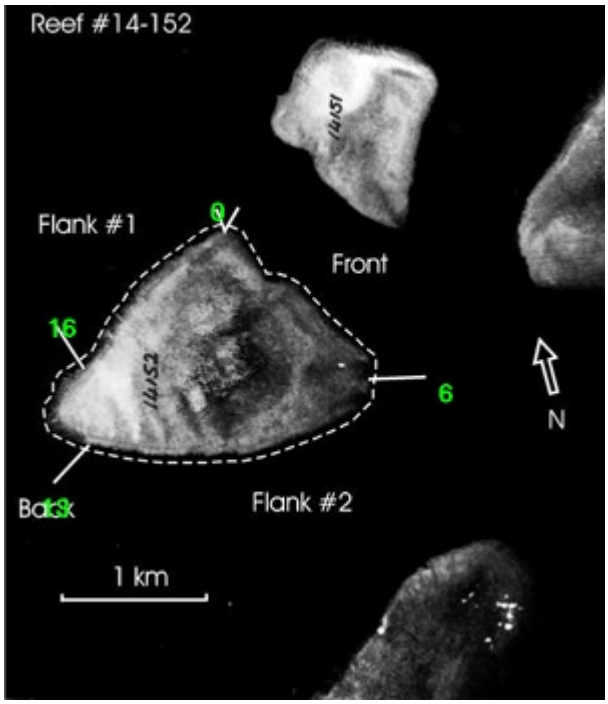
14152

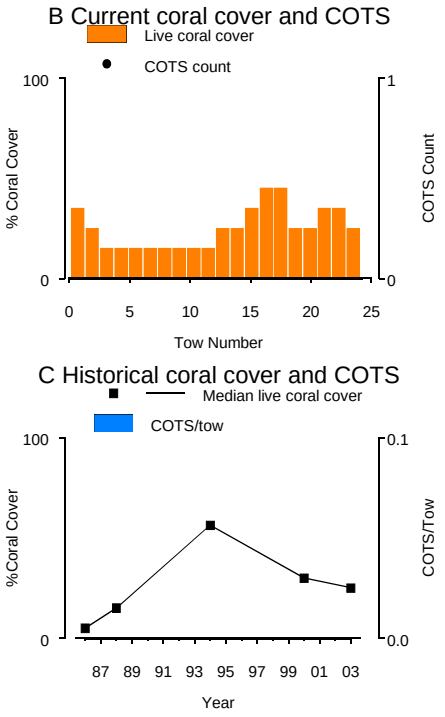
Surveyed August 2002.

This reef has been surveyed five times since 1986. Initially reef-wide live coral cover was low (1-10%) and the reef was considered to be Recovering. Reef-wide live coral cover subsequently increased to a very high level (50-75%) in 1994 and the reef was reclassified as No Outbreak. Surveys in 2003 revealed that reef-wide live coral cover had declined to a moderate level (10-30%). COTS have not been recorded from this reef and the reason for this decline is unknown. The reef remains classified as No Outbreak. No bleaching was recorded and only a few coral colonies with white syndrome disease were recorded during manta tow surveys in 2003.

Figure 4.23

A





14152 (No. 14-152) is an outer shelf planar reef with an area of 1.5 sq.km.

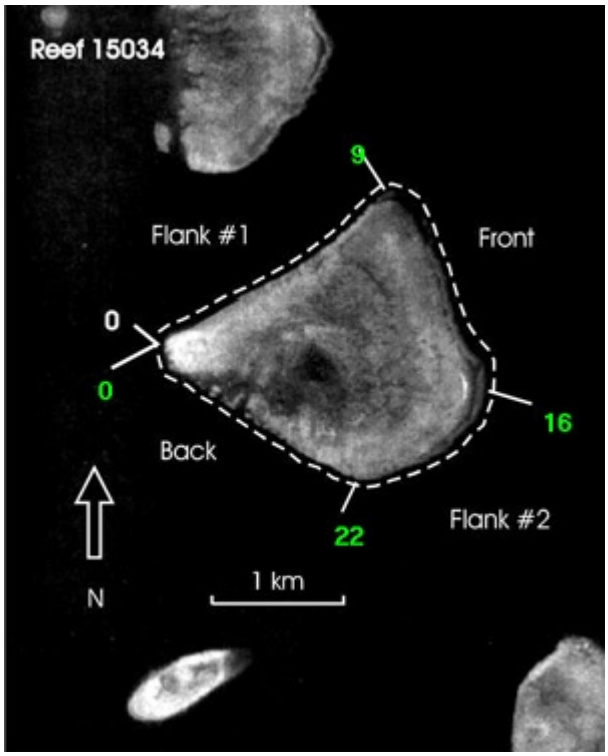
15034

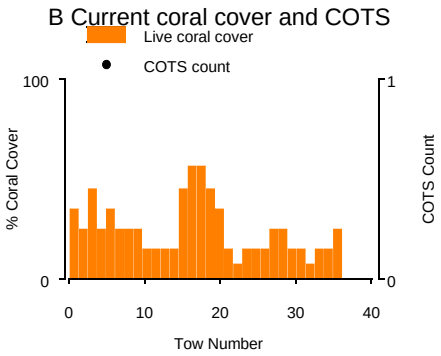
Surveyed September 2001.

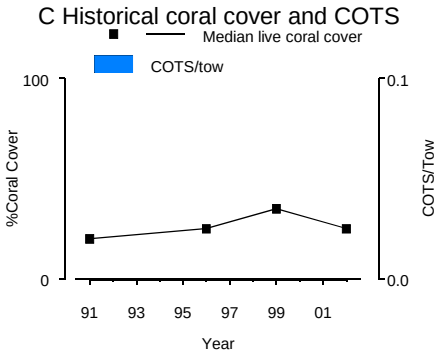
This reef has been surveyed four times since 1991 when it was initially classified as No Outbreak. Reef-wide live coral cover increased from moderate (10-30%) to high (30-50%) up until 1999. Surveys in 2002 showed a small decline in coral cover to moderate (10-30%) levels. No COTS have been recorded from this reef on any survey and it remains classified as No Outbreak. No bleaching and only low levels (restricted to small numbers of individual coral colonies) of white syndrome disease were recorded from this reef during manta tow surveys in 2002.

Figure 4.24

A







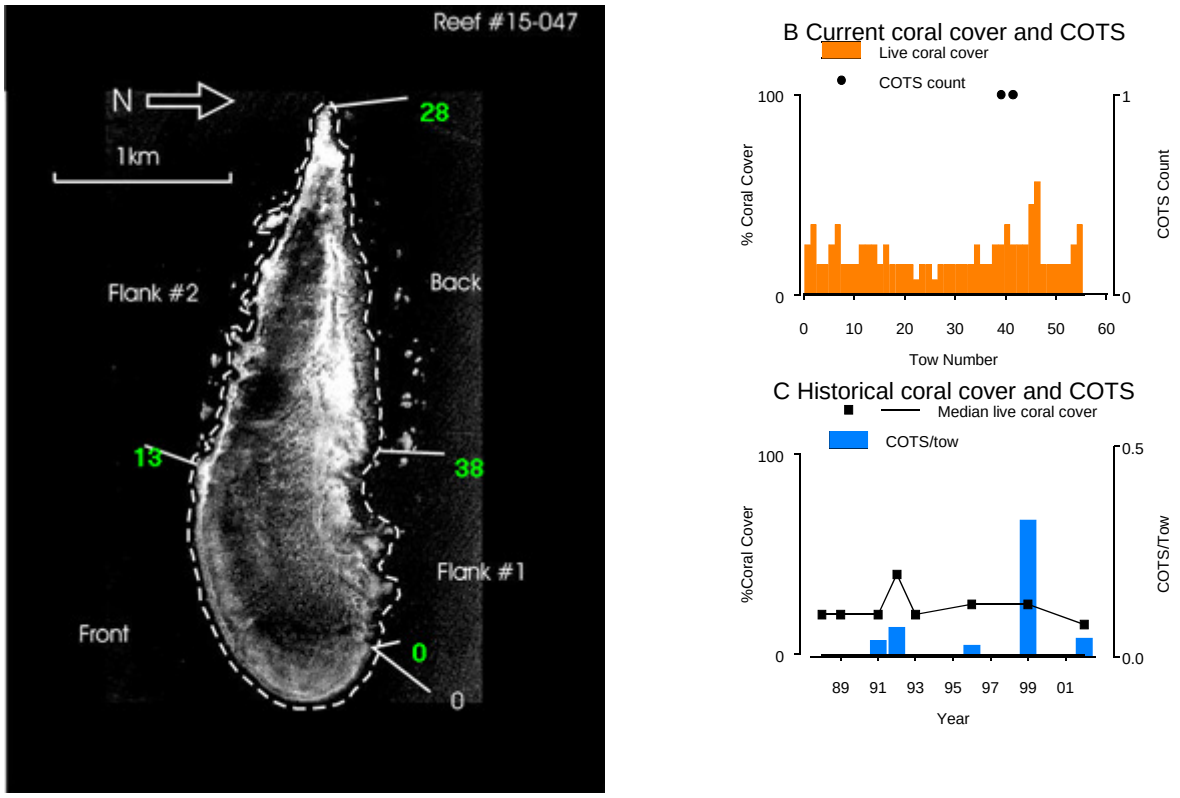
15034 (No. 15-034) is an outer shelf ribbon reef with an area of 2.9 sq.km.

15047

Surveyed September 2001.

This reef was first surveyed in 1988 when reef-wide live coral cover was moderate (10-30%). In subsequent years low numbers of COTS were recorded in 5 of 6 surveys and had reached Incipient Outbreak levels in 1999. As a result reef-wide live coral cover declined but was still moderate (10-30%) in 2002. No bleaching was observed during manta tow surveys and white syndrome disease was restricted to a small number of scattered coral colonies.

Figure 4.25 A



15047 (No. 15-047) is a middle shelf crescentic reef with an area of 4.89 sq.km.

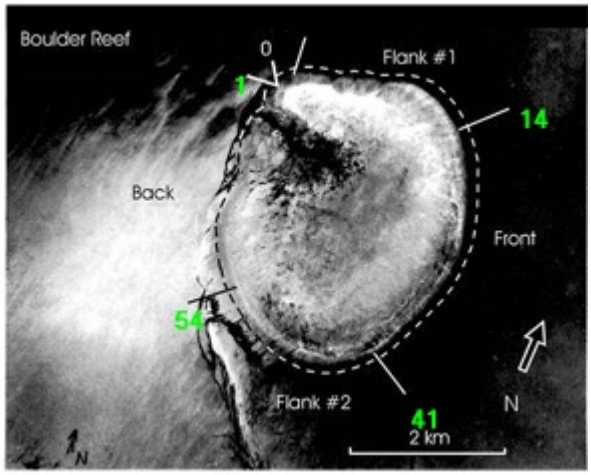
BOULDER

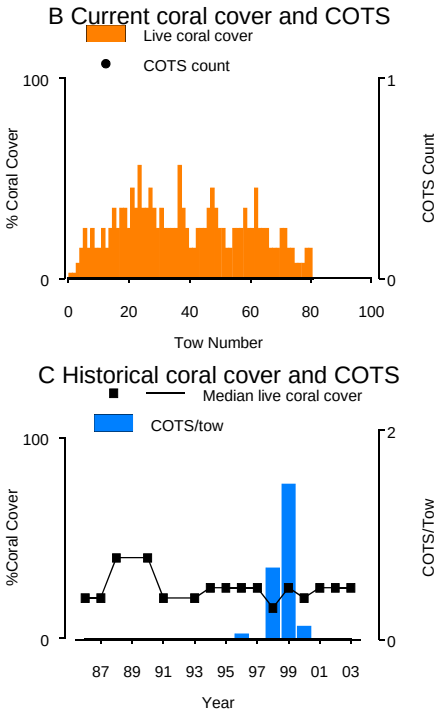
Surveyed July 2002.

This reef has been surveyed extensively since 1986. Early surveys found that reef-wide live coral cover increased, peaking around 1990, and then remained stable at moderate levels (10-30%) through to 2003. COTS were first recorded on this reef in 1996 and reached Incipient Outbreak levels in 1998. Surveys in 1999 revealed further increases in COTS and the reef was reclassified as an Active Outbreak. However, elevated COTS numbers were relatively short lived and no COTS have been observed on this reef since 2001. Live coral cover was only slightly affected during the outbreak and the reason for the decline in COTS numbers is uncertain. The reef was classified as Recovering in 2003. Coral cover remained at a moderate level (10-30%). Manta tow surveys in 2003 recorded only a few scattered colonies showing bleaching or white syndrome disease.

Figure 4.26

A





Boulder (No. 15-012) is an inner shelf crescentic reef with an area of 12.6 sq.km.

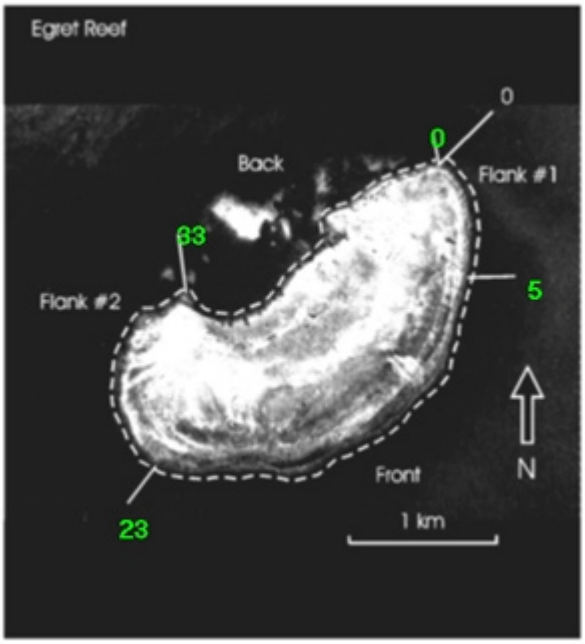
EGRET

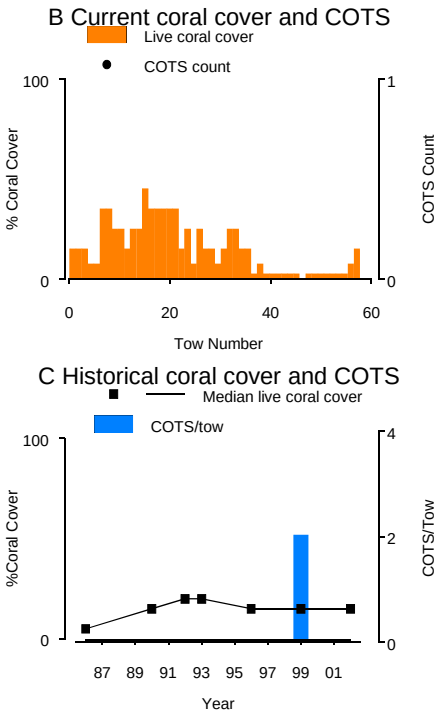
Surveyed September 2001.

This reef has been surveyed extensively since 1986. Reef-wide live coral cover initially increased and has remained stable at moderate levels (10-30%) through to the survey in 2002. COTS were first recorded on this reef in 1992 and had reached Active Outbreak levels by 1999. No COTS have been observed on this reef since 2001 and this reef was classified as Recovering. The reason(s) for the decline in COTS numbers on this reef is unknown. No bleaching and only a few scattered colonies with white syndrome disease and black band disease were observed during manta tow surveys in 2002.

Figure 4.27

A





Egret (No. 15-013) is an inner shelf crescentic reef with an area of 9.7 sq.km.

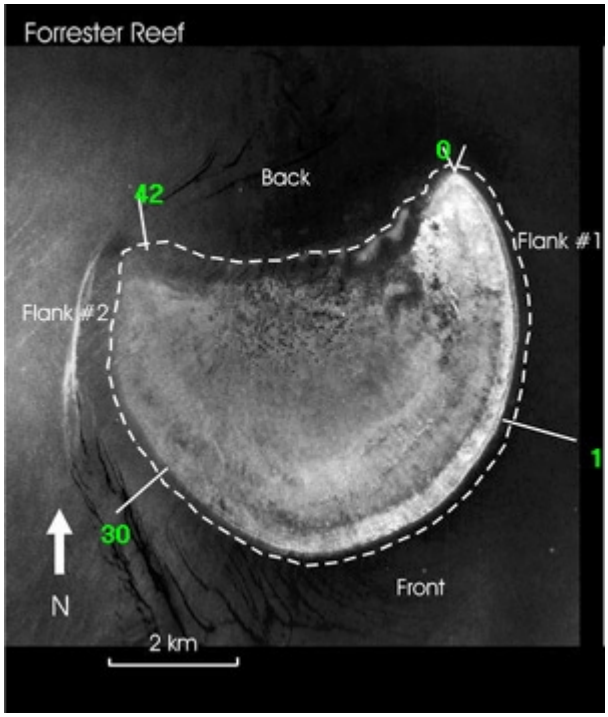
FORRESTER

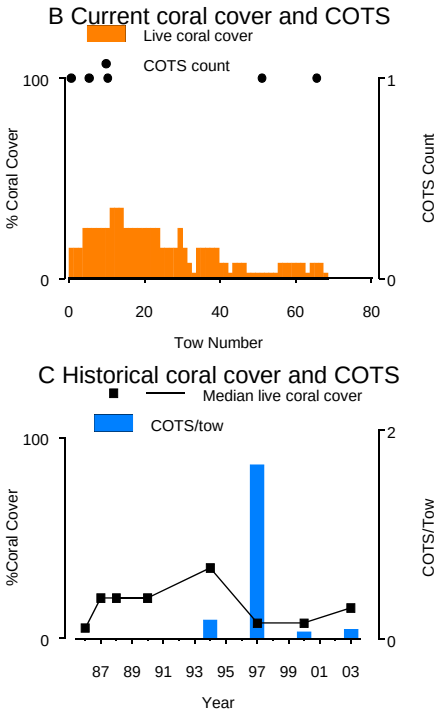
Surveyed August 2002.

This reef has been surveyed regularly since 1986. At the time of initial survey the reef was classified as Recovering from previous COTS activity. In the absence of COTS reef-wide live coral cover increased to a high level (30-50%) by 1994. Surveys in 1997 found substantial COTS activity and a marked decline in reef-wide live coral cover to less than 10%. The reef was then reclassified as an Active Outbreak. Surveys in 2000 indicated that COTS were present in low numbers and the reef was reclassified to Recovering. Surveys in 2003 found small numbers of COTS present but reef-wide live coral cover was beginning to increase and had reached a moderate level (10-30%). Forrester Reef was still classified as Recovering. Low levels (restricted to small numbers of colonies) of bleaching, white syndrome disease and black band disease were recorded during manta tow surveys in 2003.

Figure 4.28

A





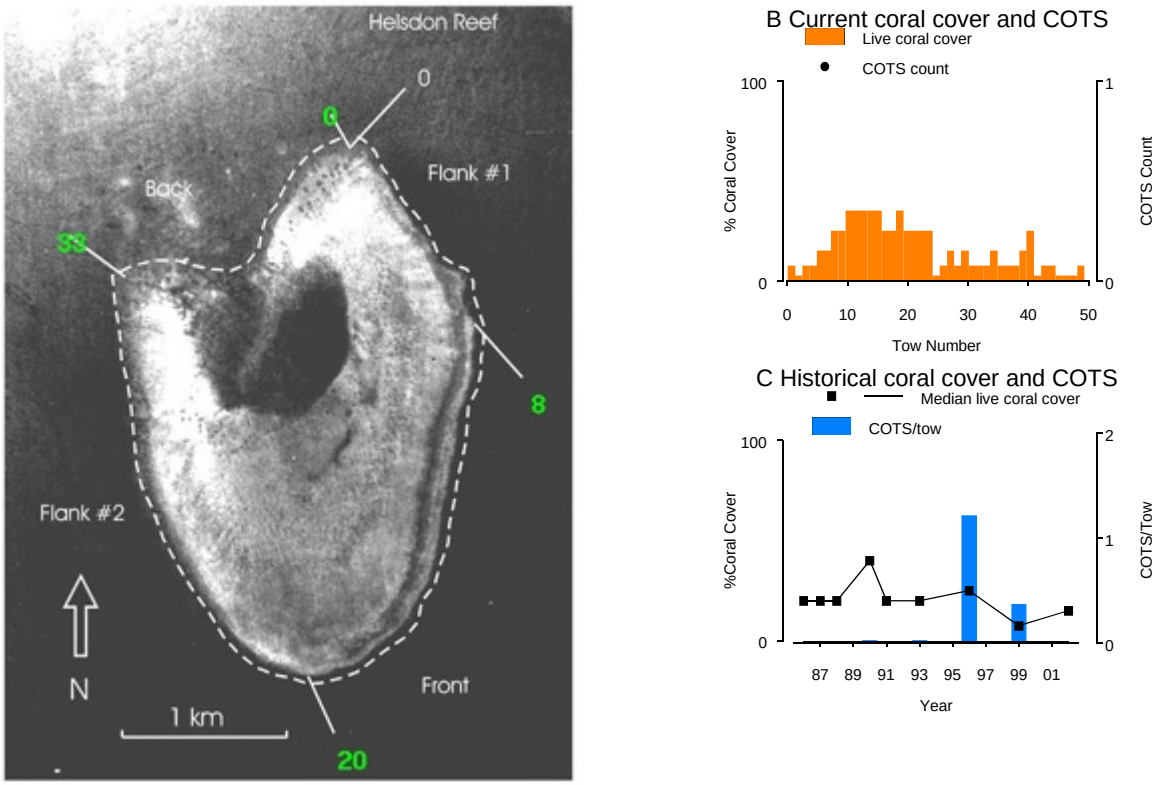
Forrester (No. 15-009) is a middle shelf planar reef with an area of 13.2 sq.km.

HELSDON

Surveyed July 2001.

First surveyed in 1986 this reef was initially classified as Recovering and had moderate (10-30%) reef-wide live coral cover. COTS numbers reached Active Outbreak levels during surveys conducted in 1996 and 1999 when coral cover decreased to low levels (1-10%), most likely due to COTS feeding activity. In 2002 no COTS were seen and reef-wide live coral cover was moderate at 10-30%. No bleaching was observed and low levels of black band disease and white syndrome disease were recorded from a small number of individual coral colonies during manta tow surveys in 2002.

Figure 4.29



Helsdon (No. 14-135) is a middle shelf Crescentic reef with an areaod 1.06 sq.km.

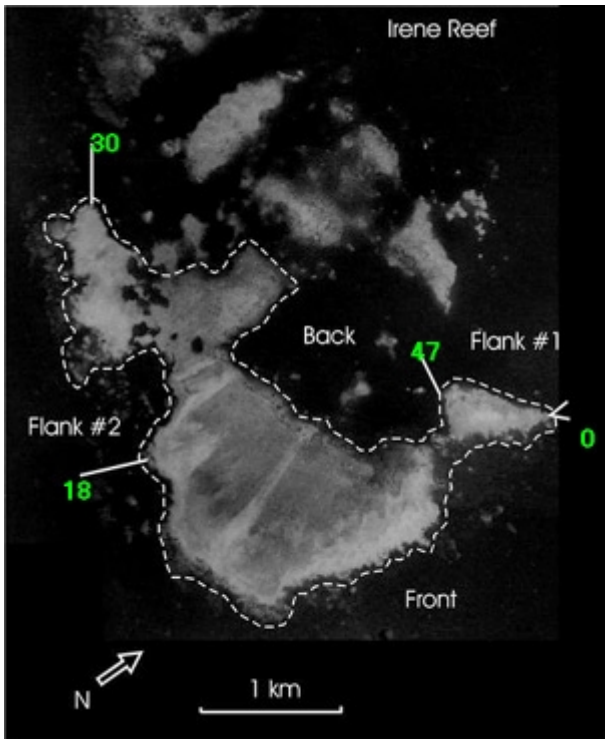
IRENE

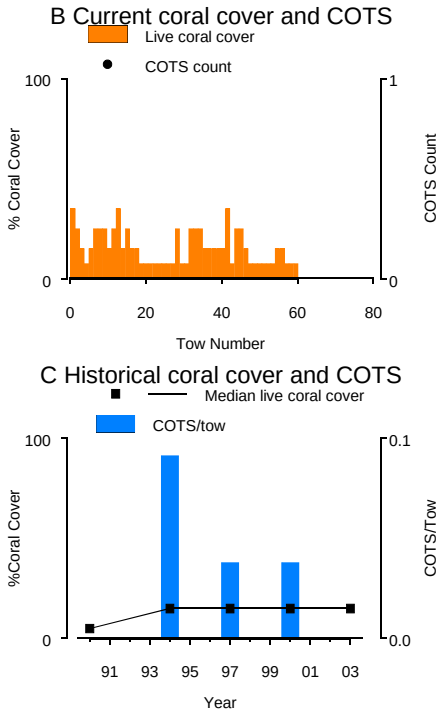
Surveyed October 2002.

Irene Reef has been surveyed five times since 1990. Over this time reef-wide live coral cover has remained at moderate levels (10-30%). Although COTS have been observed on this reef during the three surveys prior to 2003, they have been present in numbers too low to cause significant reef-wide live coral mortality. Irene Reef remains classified as No Outbreak. Manta tow surveys in 2003 recorded no bleaching while white syndrome disease was present, though restricted to small numbers of coral colonies.

Figure 4.30

A





Irene (No. 15-084) is a middle shelf reef patches reef with an area of 13 sq.km.

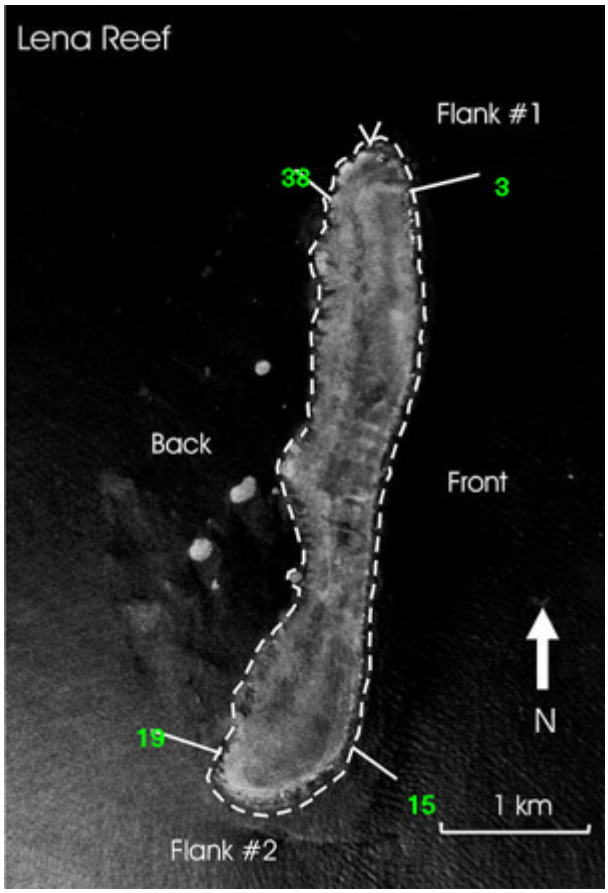
LENA

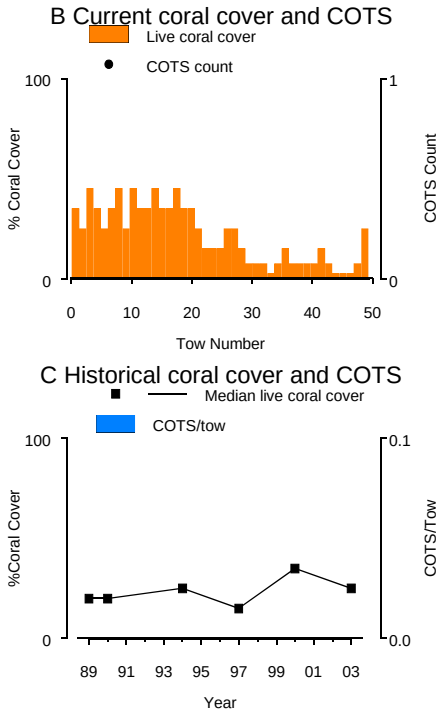
Surveyed August 2002.

This reef has been surveyed six times since 1989. Reef-wide live coral cover has generally remained at a moderate level (10-30%). Reef-wide live coral cover decreased slightly between 2000 and 2003 to be moderate (10-30%). No COTS have been recorded from this reef on any survey and it remains classified as No Outbreak. Low levels of coral bleaching (restricted to small numbers of scattered coral colonies) and of white syndrome disease were observed during manta tow surveys in 2003.

Figure 4.31

A





Lena (No. 15-085) is an outer shelf ribbon reef with an area of 7.1 sq.km.

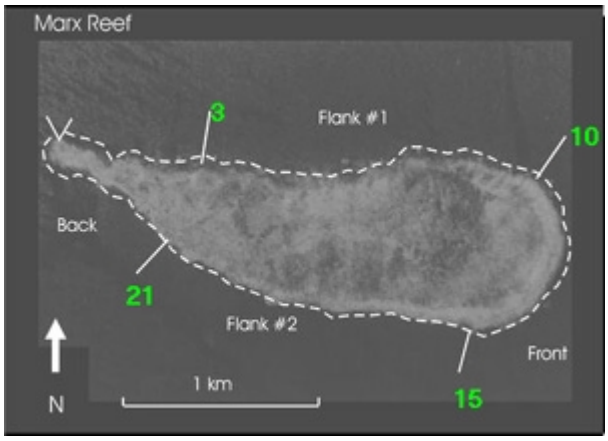
MARX

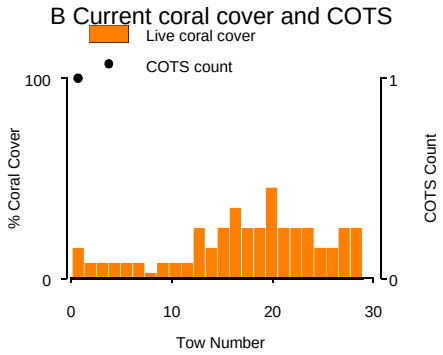
Surveyed August 2002.

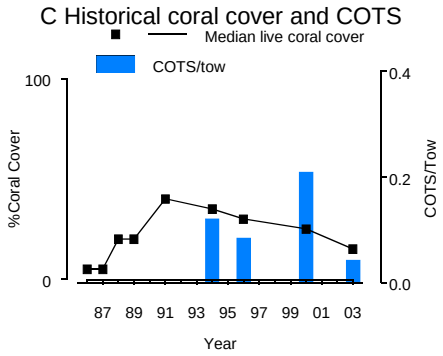
This reef has been surveyed regularly since 1986. Initially reef-wide live coral cover was low (1-10%) increasing steadily to a high level (30-50%) by 1991. COTS were first observed on this reef in 1994 and reached just below Incipient Outbreak densities in 2000. In line with increased COTS activity, there was a decline in reef-wide live coral cover to moderate levels (10-30%) in 2003. Small numbers of COTS were again observed during recent surveys and the reef remains classified as No Outbreak. Low levels of coral bleaching (restricted to small numbers of scattered coral colonies) and white syndrome disease were observed during manta tow surveys in 2003.

Figure 4.32

A







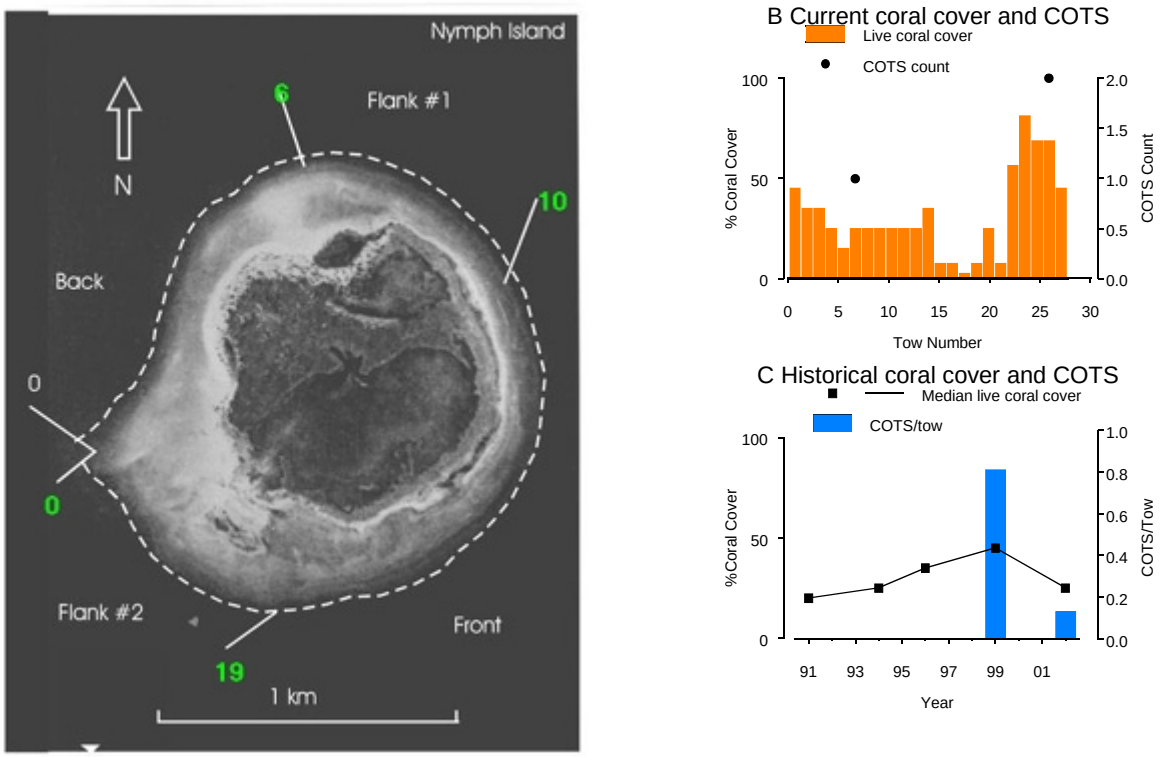
Marx (No. 15-027) is a middle shelf planar reef with an area of 1.9 sq.km.

NYMPH IS

Surveyed July 2001.

This reef has been surveyed five times since 1991 when it was first classified as No Outbreak. During the initial years of surveys reef-wide live coral cover increased from moderate (10-30%) to high coral cover (30-50%) by 1999 when an Incipient Outbreak of COTS was recorded on this reef. Surveys in 2002 showed that COTS activity has declined to below outbreak levels. There had been a corresponding decline in reef-wide live coral cover to a moderate level of 10-30%. This decline is most likely due to COTS feeding activity. Nymph Island Reef is currently classified as No Outbreak. Coral bleaching, black band disease and white syndrome disease were restricted to a few individual coral colonies during manta tow surveys in 2003.

Figure 4.33 A



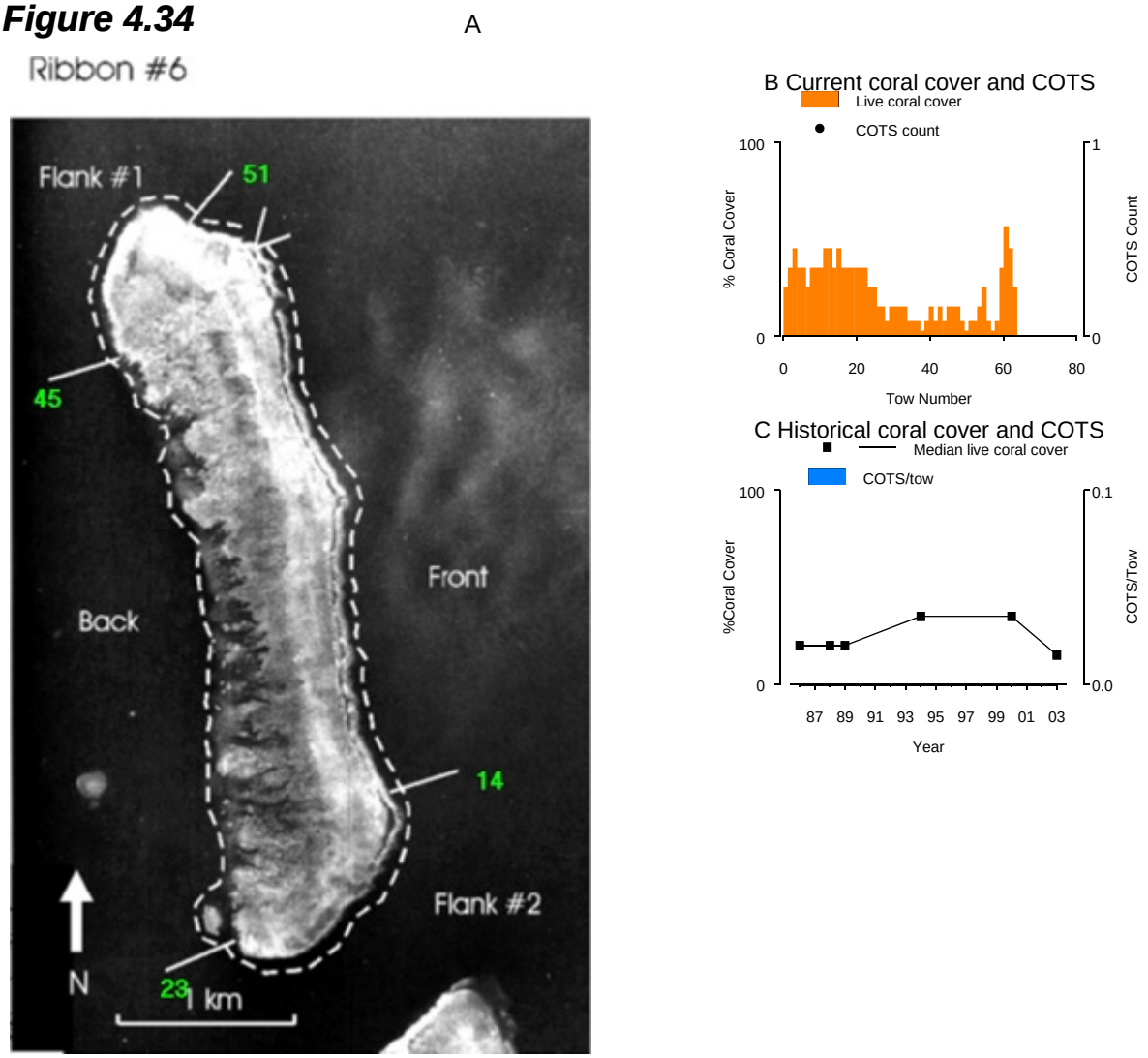
Nymph Is (No. 14-115) is a middle shelf planar reef with an area of 1.6 sq.km.

RIBBON NO.6

Surveyed August 2002.

This reef has been surveyed six times since 1986. Reef-wide live coral cover remained moderate (10-30%) through the 1980s before increasing to a high level (30-50%) during the 1990*s*. Surveys in 2003 showed reef-wide live coral cover had declined to a moderate (10-30%) level. In the absence of COTS or other obvious disturbance, the reason for this decline is unknown. No COTS were observed during this survey and the reef remains classified as No Outbreak. Low levels of coral bleaching and white syndrome disease (restricted to small numbers of isolated coral colonies) were observed during manta tow surveys in 2003.

Figure 4.34



Ribbon No.6 (No. 15-032) is an outer shelf ribbon reef with an area of 10.4 sq.km.

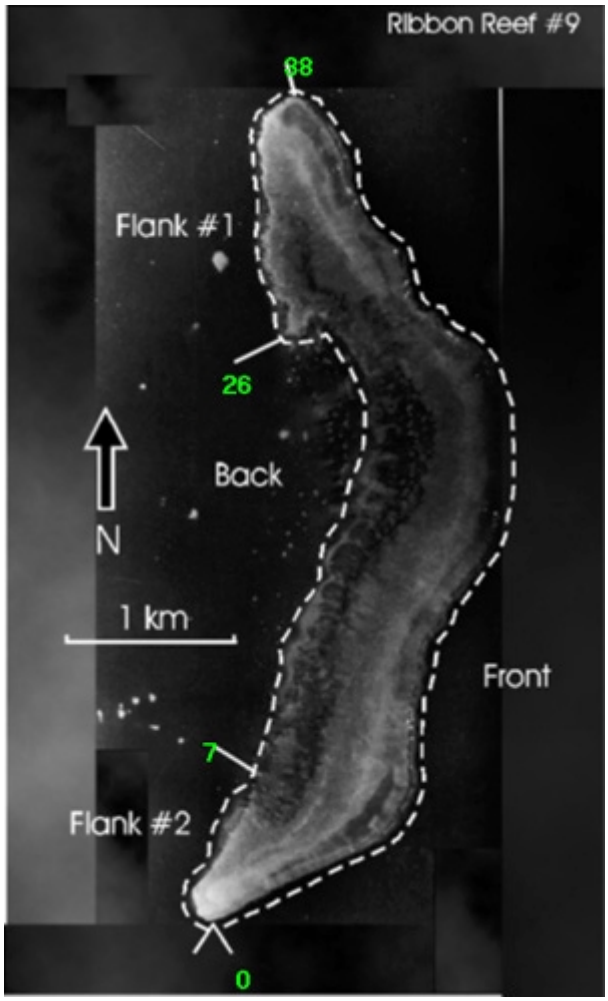
RIBBON NO.9

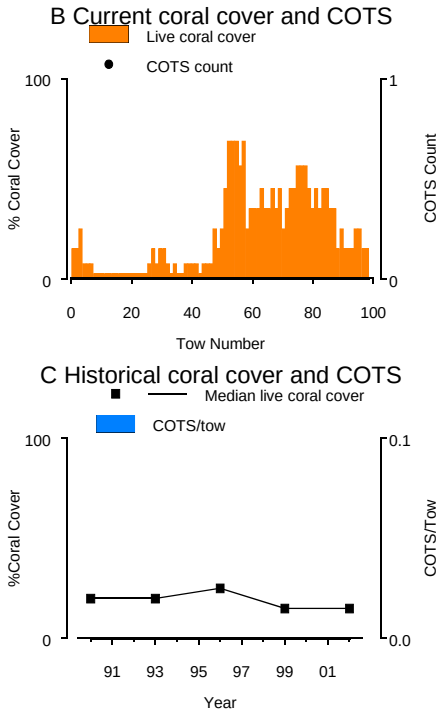
Surveyed July 2001.

This reef has been surveyed five times since 1990 when it was classified as Recovering from COTS activity prior to the commencement of surveys. Since then reef-wide live coral cover has remained at a moderate level (10-30%). No COTS have been recorded from this reef during any of our surveys and it was classified as Recovering in 2002. Bleaching and white syndrome disease were observed on small numbers of scattered coral colonies in 2002.

Figure 4.35

A





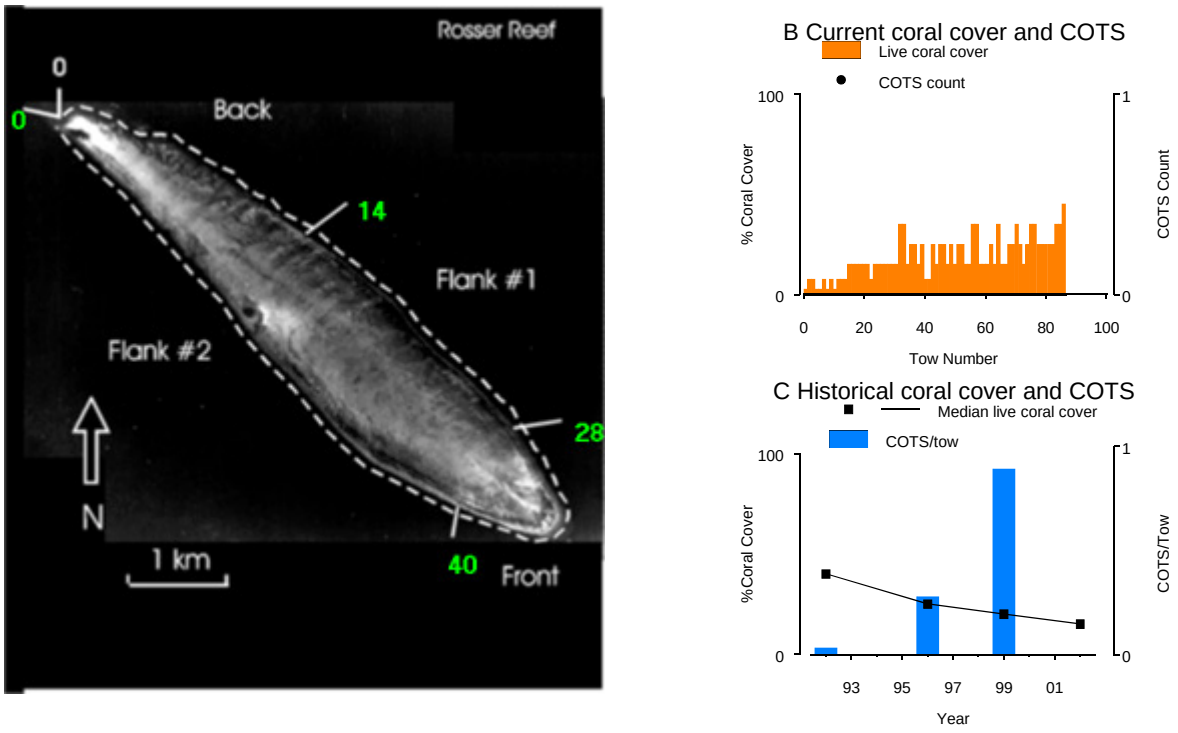
Ribbon No.9 (No. 14-154) is an outer shelf ribbon reef with an area of 18.8 sq.km.

ROSSER

Surveyed July 2001.

This reef has been surveyed four times since 1992 when it was classified as No Outbreak. Initial surveys showed reef-wide live coral cover to be high (30-50%) but surveys in 1996 and 1999 recorded Incipient Outbreak levels of COTS. Increased COTS activity was matched by a corresponding decline in reef-wide live coral cover to moderate levels (10-30%). Surveys in 2002 indicate that COTS are no longer active on this reef and that reef-wide live coral cover remains at moderate levels. Rosser Reef was classified as Recovering in 2002. Low levels (restricted to a few scattered coral colonies) of black band disease and white syndrome disease were recorded during manta tow surveys in 2002.

Figure 4.36 A



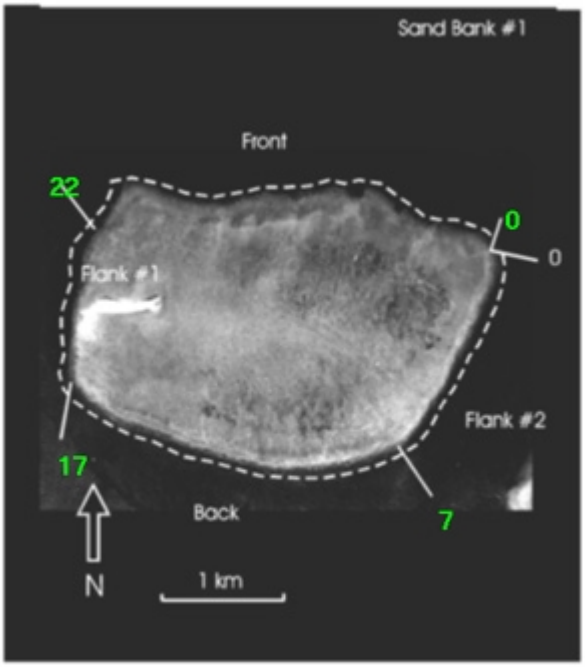
Rosser (No. 15-081) is a middle shelf planar reef with an area of 7.2 sq.km.

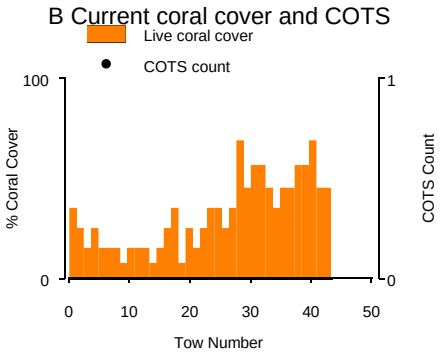
SANDBANK NO.1

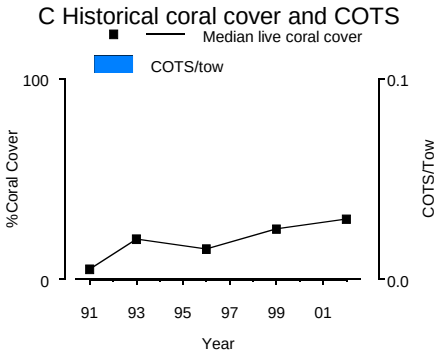
Surveyed July 2001.

This reef has been surveyed five times since 1991 when it was classified as No Outbreak. Since this time reef-wide live coral cover has shown a steady increase from the initial low cover (1-10%) to a current high level (30-50%). No COTS have been recorded from this reef at any survey and it remains classified as No Outbreak. Manta tow surveys in 2002 found that for most of the reef perimeter, black band disease and white syndrome disease were generally rare, being restricted to a few scattered colonies. However, this was not so on the front reef area where white syndrome disease was common, infecting 10 or more coral colonies per two-minute tow.

Figure 4.37 A







Sandbank No.1 (No. 14-045) is an outer shelf planar reef with an area of 5.3 sq.km.

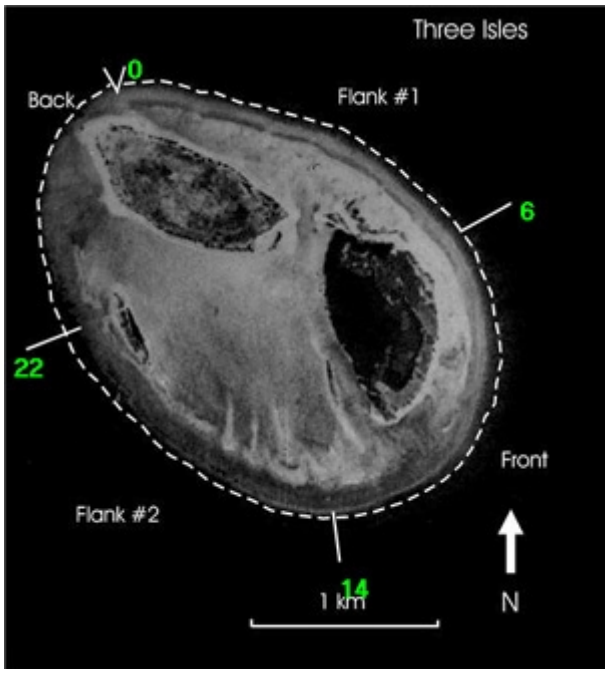
THREE ISLES

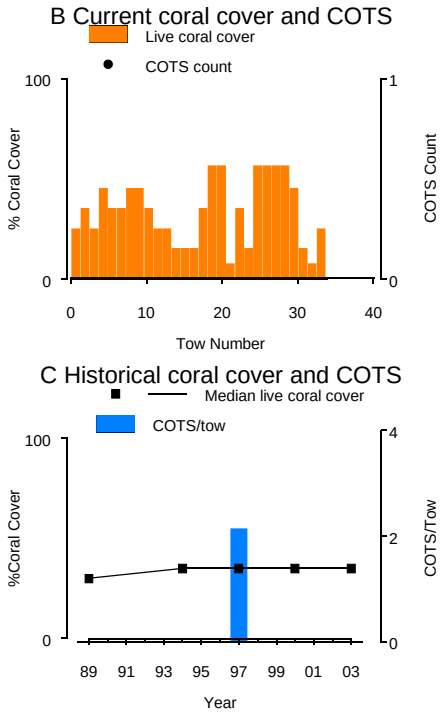
Surveyed July 2002.

This reef has been sampled on five occasions since 1989. Reef-wide live coral cover has remained high (30-50%). COTS were observed in substantial numbers on this reef in 1997 and the reef was reclassified as an Active Outbreak. During the 2000 survey no COTS were recorded and the reef was reclassified as Recovering. Surveys in 2003 showed little change and the reef was still classified as Recovering. No bleaching or disease was recorded during manta-tow surveys in 2003.

Figure 4.38

A





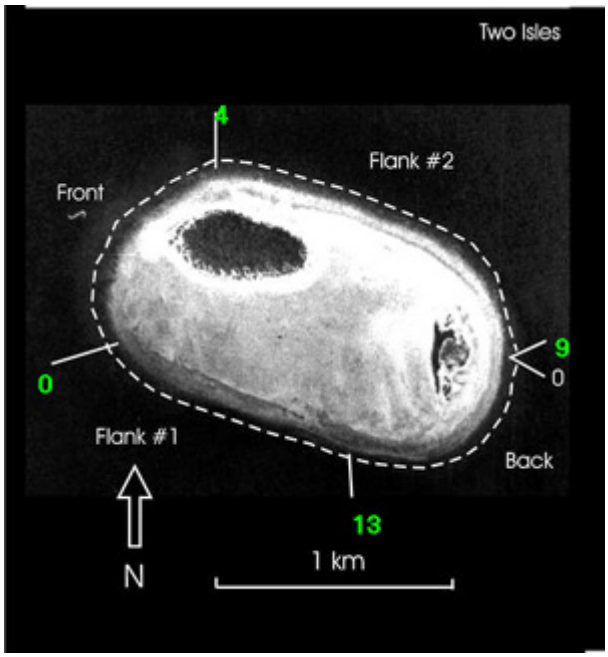
Three Isles (No. 15-005) is an inner shelf planar reef with an area of 1.6 sq.km.

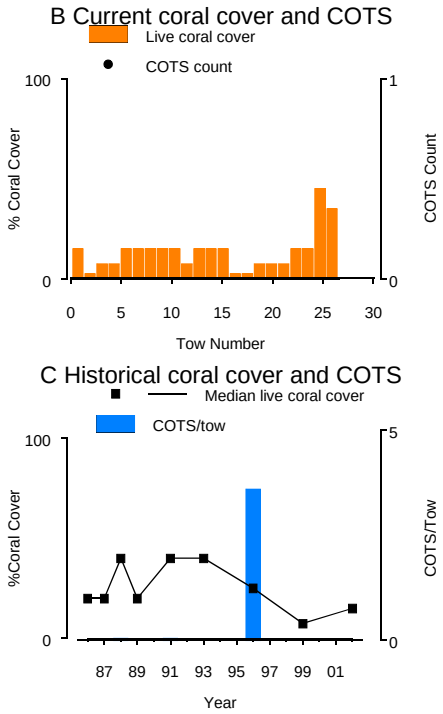
TWO ISLES

Surveyed July 2001.

This reef has been surveyed several times since 1986. Reef-wide live coral cover was initially moderate (10-30%), peaking around 1993 and then decreasing to a low level (0-10%) following an Active Outbreak of COTS in 1996. No COTS were seen in 2002 and this reef was classified as Recovering. Reef-wide live coral cover was moderate (10-30%). No bleaching was recorded during manta tow surveys in 2002 and white syndrome disease was restricted to a few scattered coral colonies.

Figure 4.39 A





Two Isles (No. 15-002) is an inner shelf planar reef with an area of 1.8 sq.km.

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Cairns

Reef Pages

AGINCOURT NO.1

Surveyed October 2002.

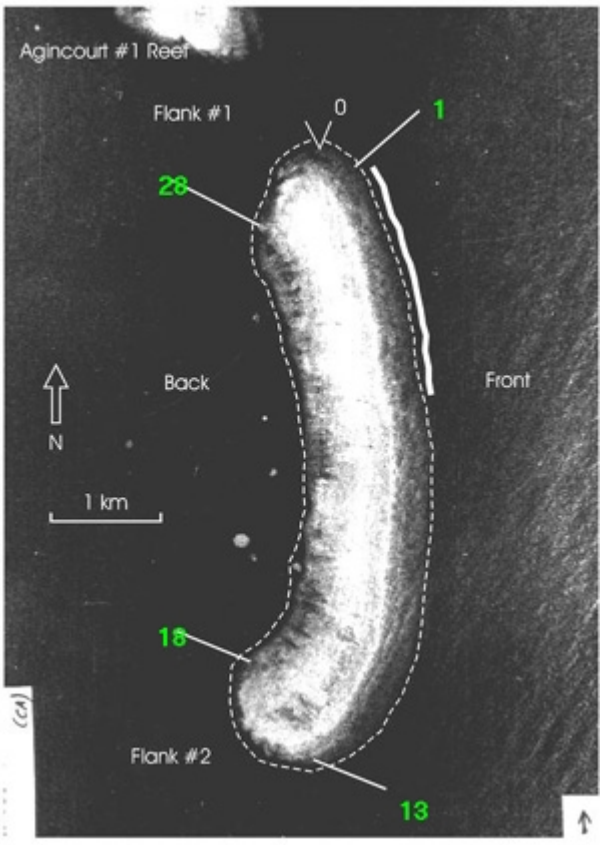
Agincourt Reef No.1 was first surveyed using manta tows in 1989, and has been surveyed annually since 1994. Reef-wide live coral cover increased to a high level (30-50%) in 2000, then decreased to a moderate level (10-30%) in 2003. The cause of decline is uncertain, as no COTS have been recorded on this reef in any survey year. No bleaching was observed in manta tow surveys in 2003 and white syndrome disease affected only a few dispersed coral colonies.

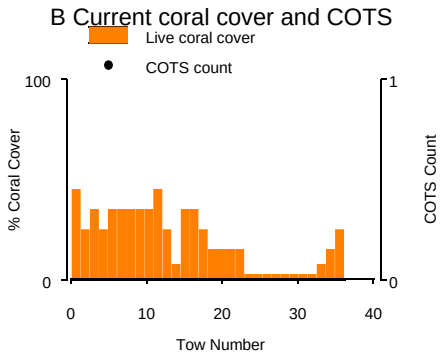
The increase in hard coral cover over the 10 year survey period was largely due to increases in tabulate and digitate *Acropora* spp. In 2003, *Acropora* made up 25% of the cover. *Pocillopora* spp. have also increased slowly but consistently. Soft coral abundance was around 15% and stable. The density of corallivorous snails *Drupella* spp. was 20/ha in 2003.

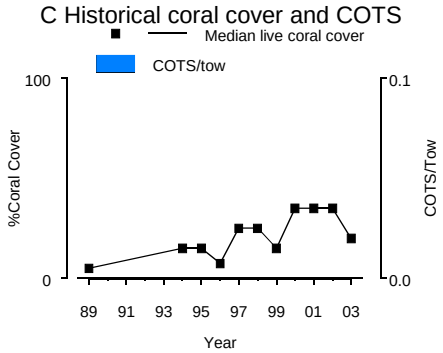
Strong declines in abundance of Acanthuridae on this reef mirror similar declines on other outer shelf reefs in this region and reflect changes in abundance of *Ctenochaetus* spp., *Acanthurus nigrofuscus* and to a lesser extent *Zebrasoma scopas*. The family Scaridae was the only other taxon that showed long term declines, though individual species have been more variable with only *Scarus globiceps* and *Chlorurus sordidus* showing declining trends. Several species of butterflyfishes (Chaetodontidae) have increased, presumably in response to increasing coral cover. These included *Chaetodon trifascialis* and *C. baronessa*. Numbers of the coral-associated damselfish *Plectroglyphidodon dickii* have also increased steadily with coral cover which accounts for the increased abundance of this genus. Fluctuations in the numerically dominant *Pomacentrus lepidogenys* drive the variation within that genus.

Figure 4.40

A

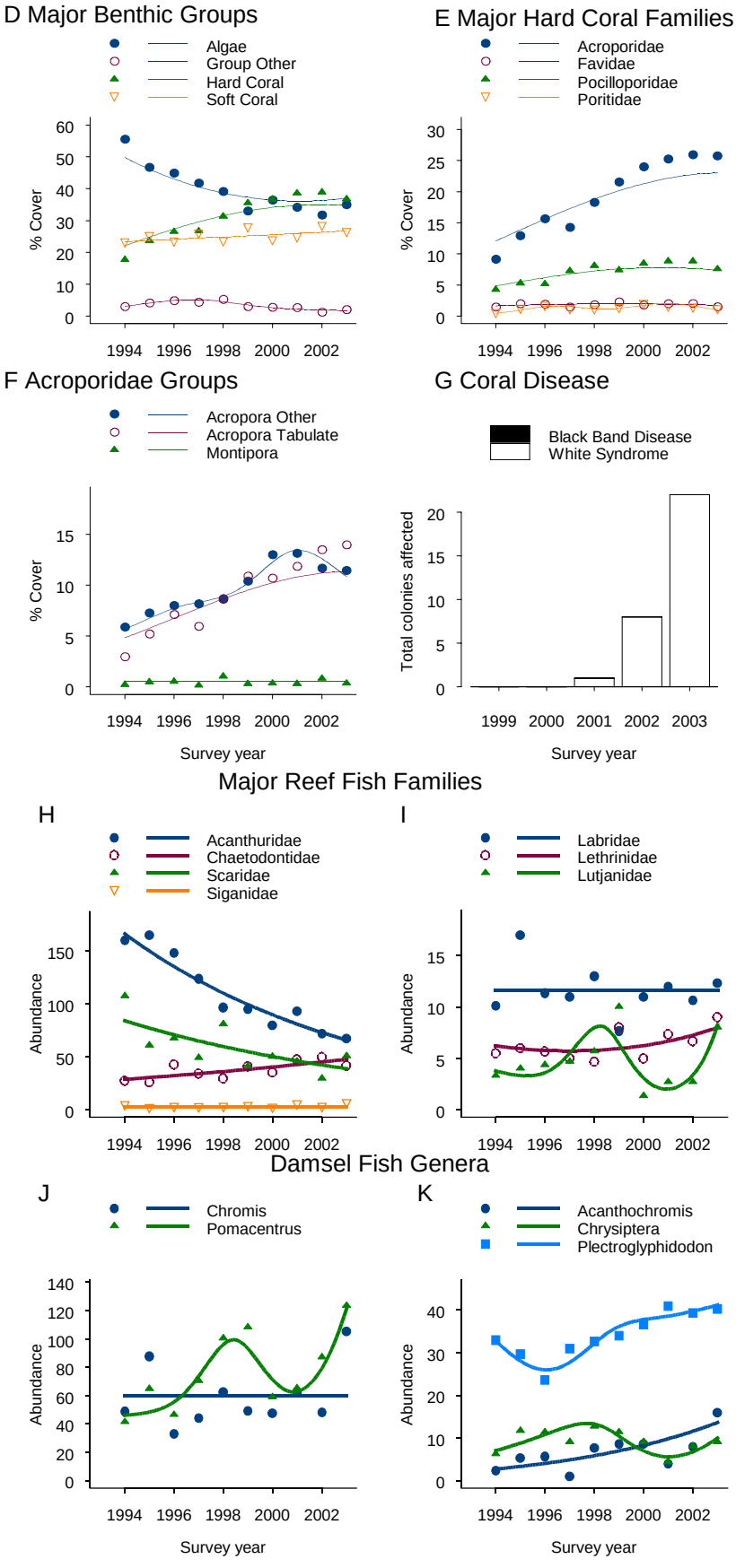






Agincourt No.1 (No. 15-099) is an outer shelf ribbon reef with an area of 5.1 sq.km.

Figure 4.40 (Cont).



FITZROY IS

Surveyed November 2002.

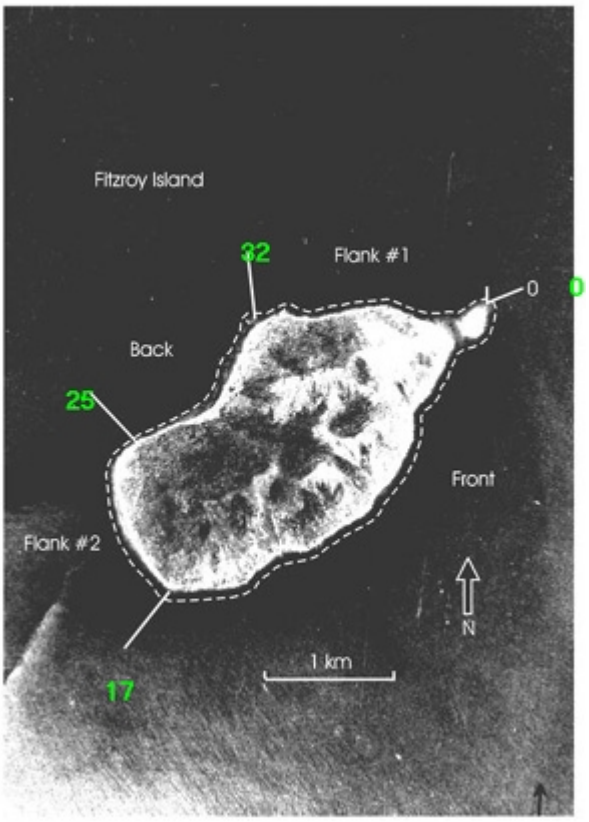
This reef has been surveyed extensively since 1986. Reef-wide live coral cover was initially moderate (10-30%) before falling to a low level (1-10%) between 1989 and 1990, probably as a result of the 1989 flood on the northern GBR (surveys in 1989 were conducted at a time when the reef was bathed in flood waters). Coral cover increased between 1995 and 1998 and then declined in 1999. A large proportion of corals on this reef were bleached at the time of survey in 1998. Small numbers of COTS were also observed during manta tows at this time. Surveys in 1999 recorded many dead standing coral colonies, particularly tabulate *Acropora* spp. that, on the basis of their weathered state, died approximately twelve months previously. This time frame for mortality coincides with the 1998 bleaching event. Reef-wide live coral cover remained very low (<5%) in 2002. No COTS have been recorded on this reef in recent surveys and it was classified as No Outbreak. No bleaching or coral disease was recorded during manta tow surveys of this reef in 2002. Manta tow surveys were not carried out on this reef in 2003 due to poor visibility.

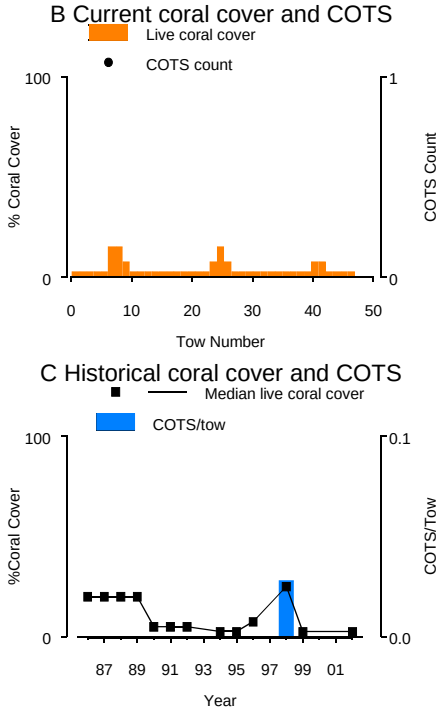
Detailed surveys of fixed sites show hard coral cover declined following the summer of 1999. Hard coral decreased to less than 10% and has not yet recovered. A similar pattern of decline was observed in all four main hard coral families except Poritidae (this family being highly variable). Crown-of-thorns predation is the most likely cause, with bleaching also probably responsible for low levels of mortality on the sites. The cover of soft corals is stable at 16%.

The decline in coral cover is reflected in the fish community at this reef. While a few previously numerically dominant species have maintained similar population levels to those observed prior disturbance the majority of species show marked declines over the last few years.

Figure 4.41

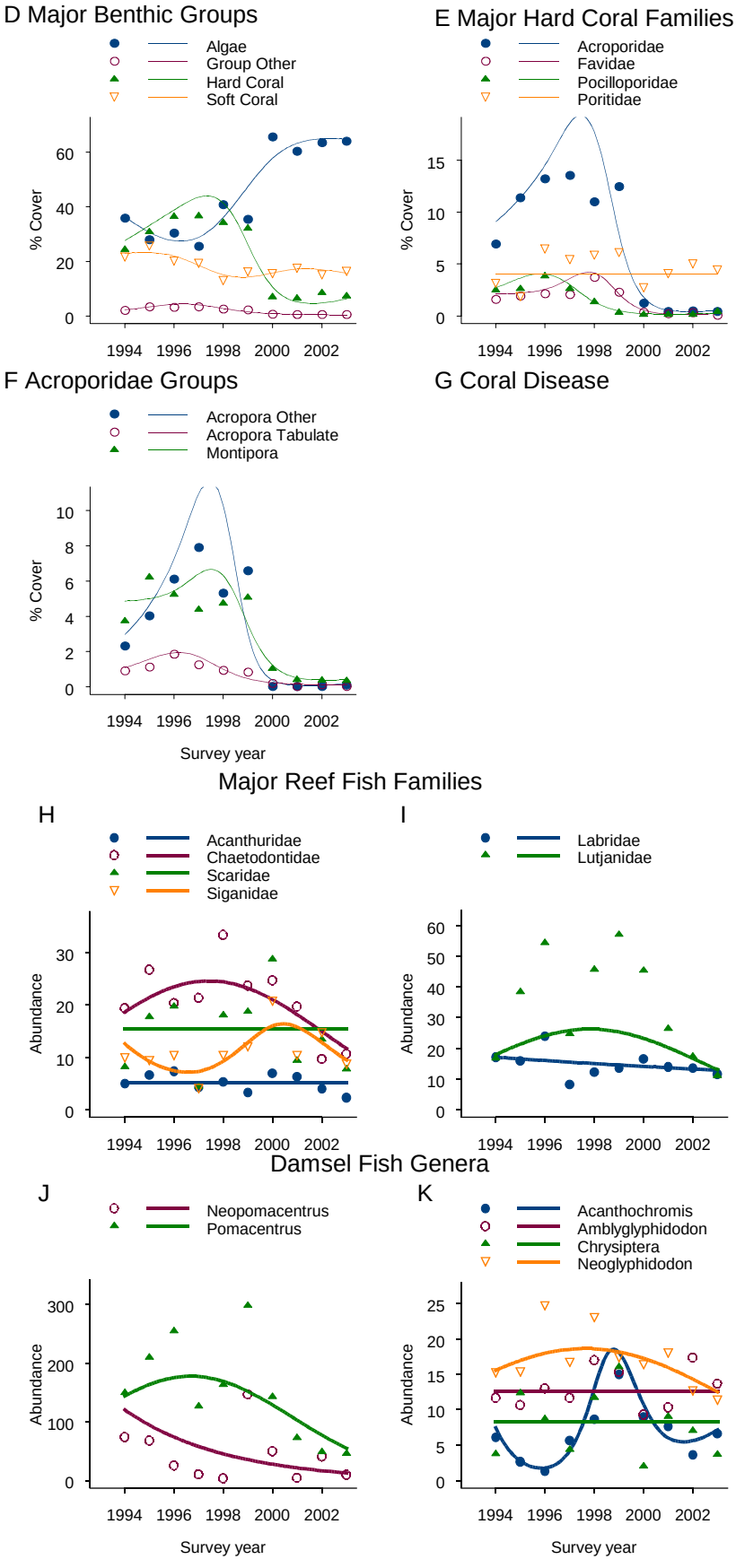
A





Fitzroy Is (No. 16-054) is an inner shelf fringing reef with an area of .2 sq.km.

Figure 4.41 (Cont).



GREEN IS

Surveyed October 2002.

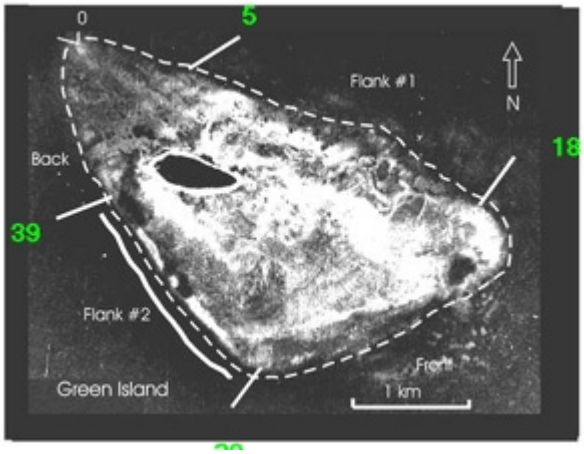
This reef has been surveyed extensively since 1986, when it was classified as Recovering from a previous COTS outbreak. Since then, reef-wide live coral cover has shown little change. An apparent small recovery in reef-wide live coral cover in 1995 and 1996 subsequently stalled as COTS numbers on this reef rose again. COTS have not been observed in manta tows since 1999. Surveys in 2003 indicate reef-wide coral cover remains very low (<5%). Whilst Green Island reef was classified as Recovering in 2003, there is little evidence of recovery over the past 5 years. No bleaching was observed and white syndrome disease was restricted to small numbers of individual coral colonies during manta tow surveys in 2003.

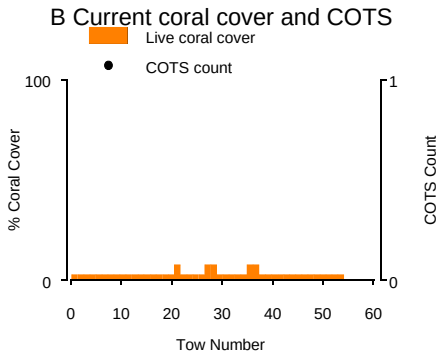
Detailed surveys of fixed sites since 1993 show that hard coral cover was the lowest recorded of all our survey sites on the GBR (5% in 2003). Cover of all coral groups was declining or stable. Soft coral was stable at 5%. Algae cover has slowly increased with the decrease of hard coral and was 75% in 2003. COTS are still present on the reef: one juvenile COTS was observed on the survey sites in 2002 and one adolescent COTS was observed in 2003. *Drupella* spp. were also observed during 2003 at a density of 40/ha.

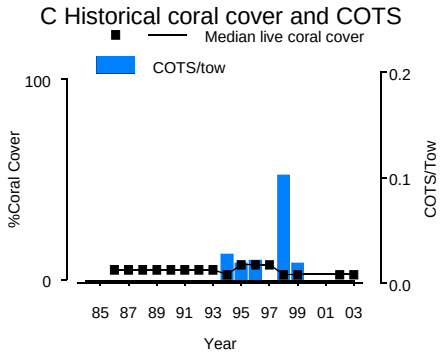
The majority of fish species showing trends have declined in abundance. For the more coral-associated species, including several butterflyfishes and damselfishes, declining numbers have coincided with the reduction in coral cover. This pattern was slightly obscured by a strong recruitment of a number of damselfish species resulting in observed increases in 1999. However, these species have all subsequently declined. Several parrotfishes have also declined over the last decade. The only exception to the general declining abundance of reef fishes was the family Siganidae: this was due to a slight increasing trend in one species *Siganus doliatus*.

Figure 4.42

A

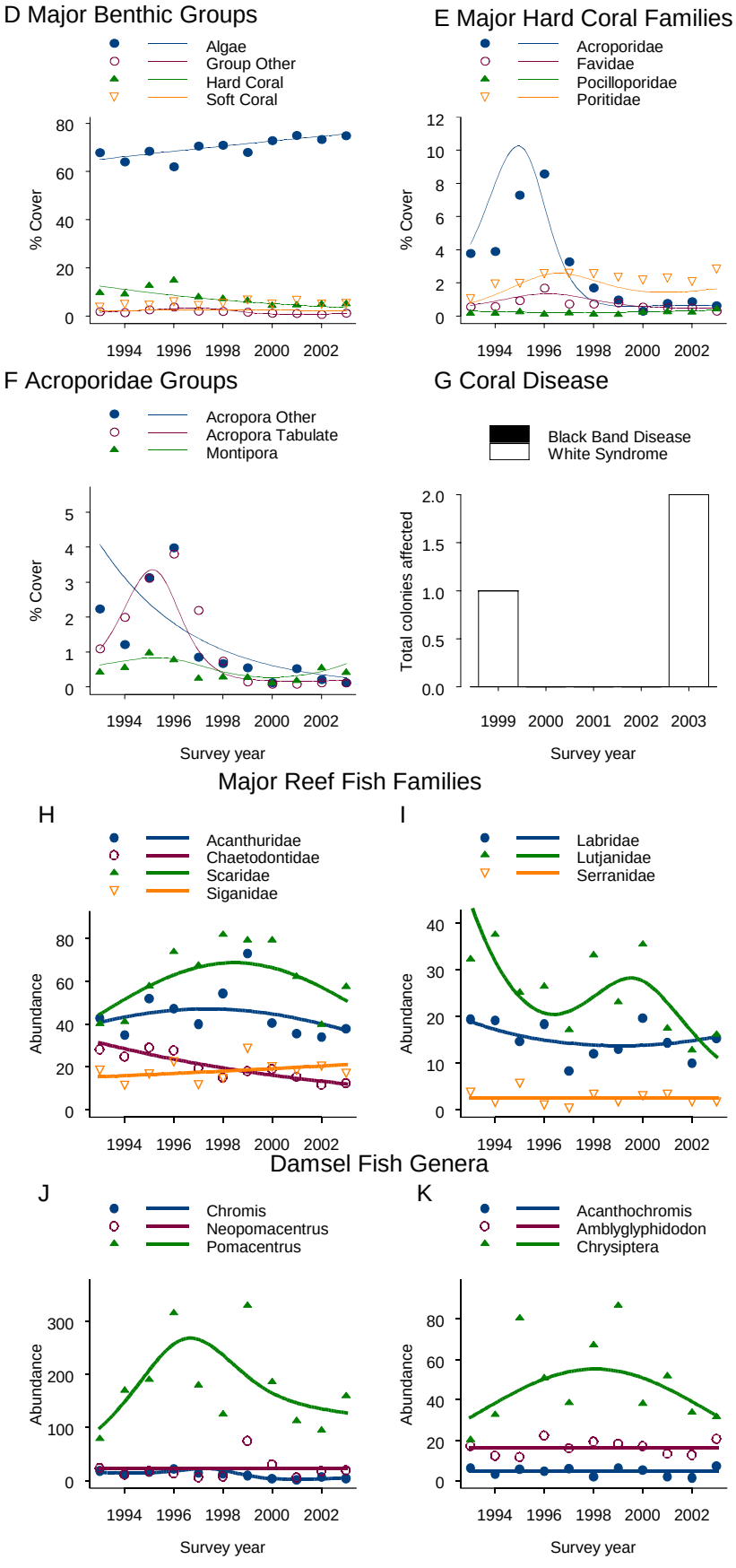






Green Is (No. 16-049) is an inner shelf planar reef with an area of 7.1 sq.km.

Figure 4.42 (Cont).



HASTINGS

Surveyed November 2002.

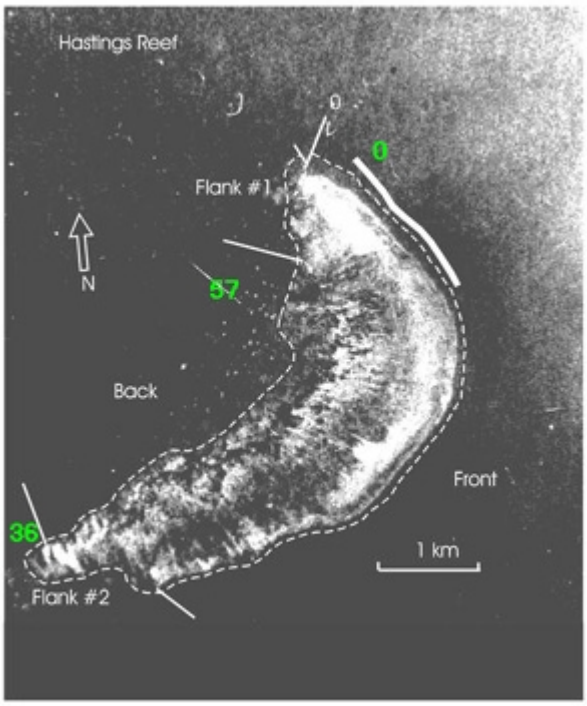
Hastings Reef has been surveyed extensively since 1986. Reef-wide live coral cover has generally remained at moderate levels (10-30%). COTS numbers increased on this reef in 2000 and the reef was then reclassified as Incipient Outbreak. COTS numbers peaked in 2002 with a corresponding decline in coral cover. Surveys in 2003 failed to detect any COTS and the reef was reclassified as No Outbreak. Reef-wide live coral cover was low (1-10%). No bleaching was observed and white syndrome disease was restricted to small numbers of scattered coral colonies.

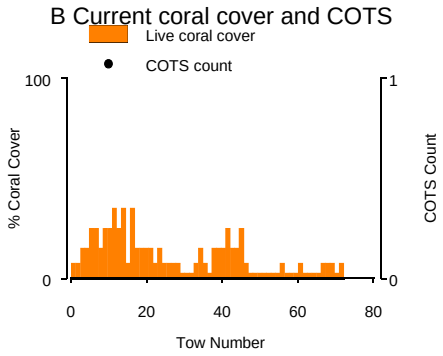
Hard coral cover on the fixed sites reached its highest level in 1999 (31%) and in 2003 was 25%. Tabulate *Acropora* has been increasing over the survey period, while the decline in the category "*Acropora* Other" is a result of mortality in Isopora *Acropora* possibly due to bleaching. *Drupella* spp. were observed during SCUBA searches at a density of 120/ha.

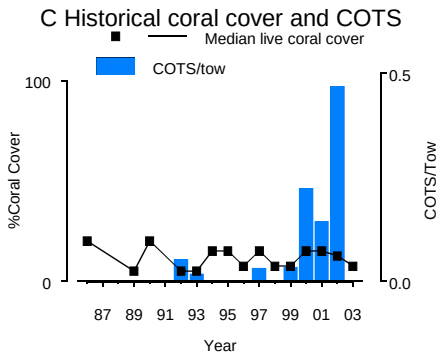
The relatively stable coral community was reflected in the fish community which showed few strong trends. A strong recruitment event prior to the 1999 surveys resulted in subsequent increases in several Damselfish species, most notably *Pomacentrus lepidogenys* and *Neopomacentrus azysron*. Slight increases in Tabulate *Acropora* over the last few years were correlated with increased numbers of *Chaetodon trifascialis*; a species which is strongly associated with live coral. The observed decline of Acanthuridae abundance was primarily due to a steady decline in *Ctenochaetus* spp. For the Scaridae the decline was most evident in *Scarus globiceps* and *S. altipinnis*, both species being in very low abundance or absent in recent surveys.

Figure 4.43

A

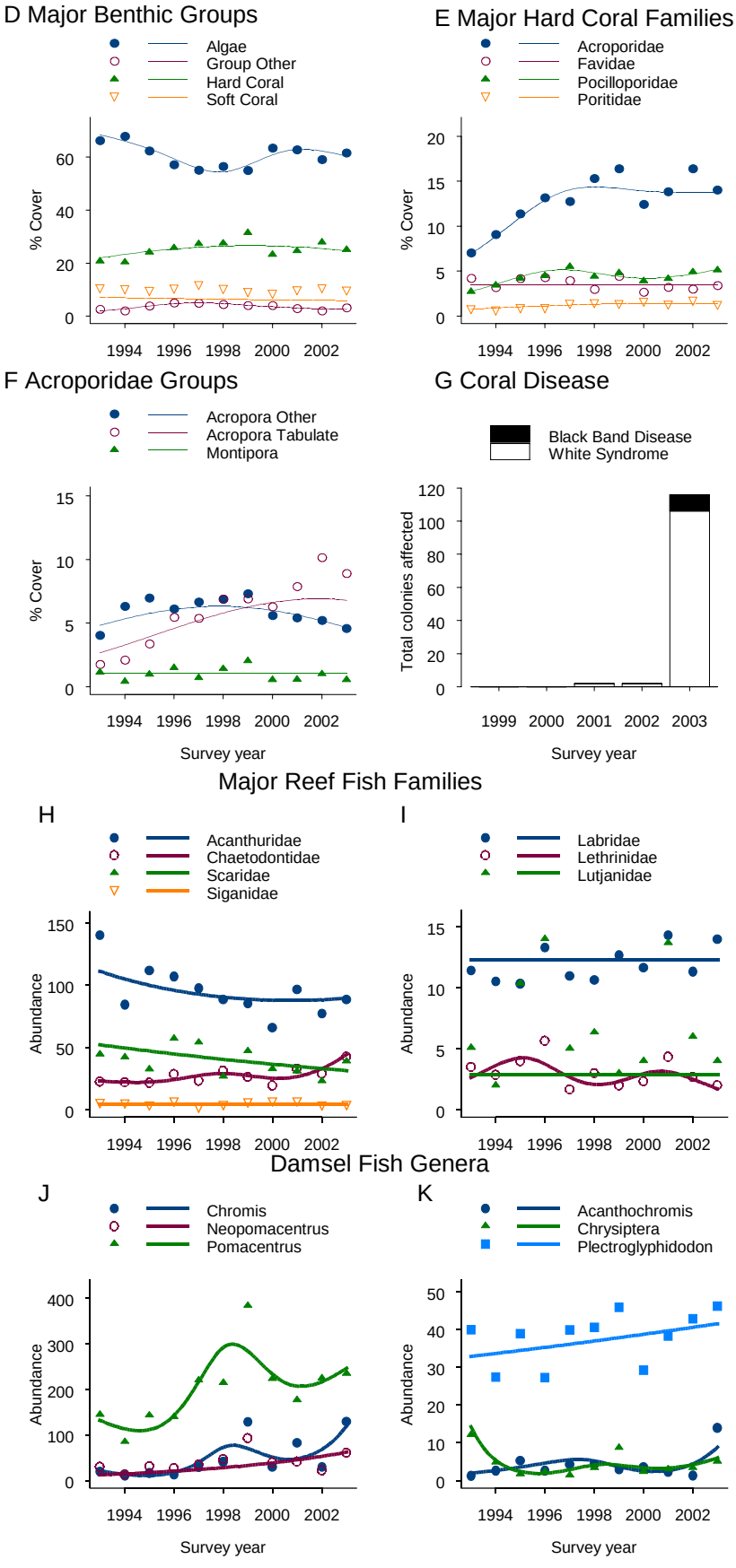






Hastings (No. 16-057) is a middle shelf crescentic reef with an area of 10.2 sq.km.

Figure 4.43 (Cont).



LOW ISLETS

Surveyed November 2002.

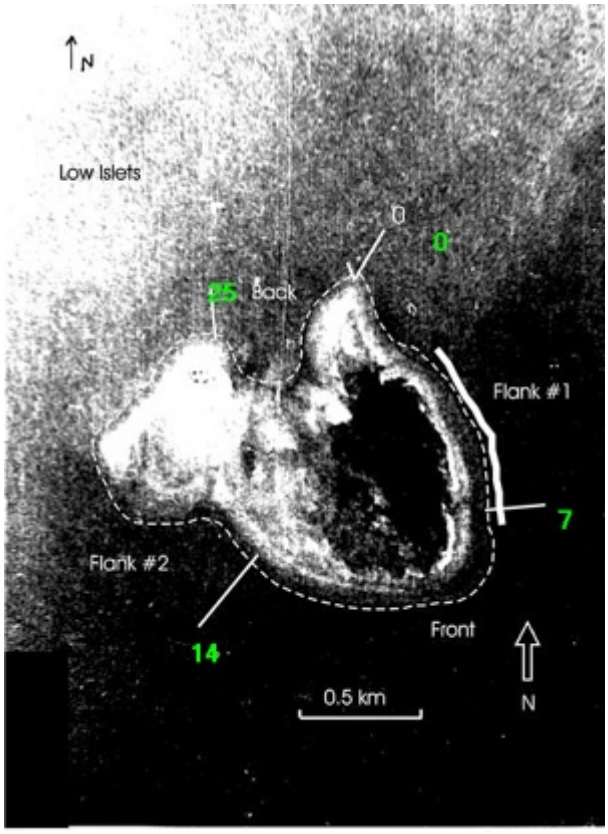
This reef has been surveyed extensively since 1986. Until recently there had been no clear trend in reef-wide live coral cover, which had remained at moderate to high levels. COTS were recorded on this reef for the first time in 1998. In 1999 there was a marked decline in reef-wide live coral cover. This was due to the combined effects of increasing COTS activity, coral bleaching and Tropical Cyclone Rona. Surveys in 2002 show that reef-wide coral cover remains at the lowest levels recorded since the beginning of surveys (5-10%). No coral bleaching or disease was recorded from this reef during surveys in 2002. Manta tow surveys were not carried out on this reef in 2003 due to low visibility.

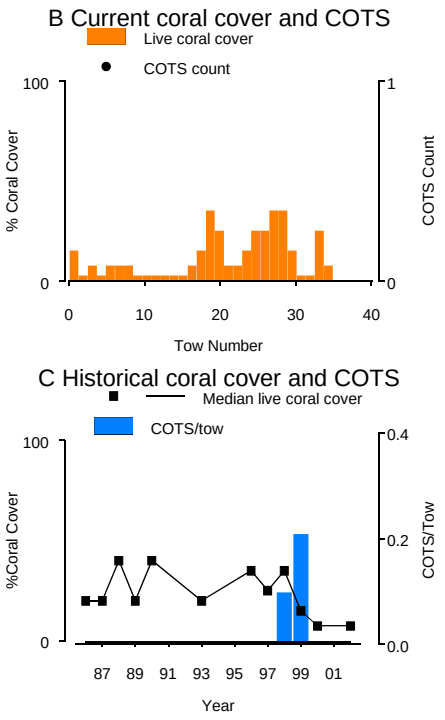
The coral community on the intensive survey sites has been affected by multiple impacts. Hard Coral reached a maximum of 40% in 1996 and had been stable at around 10% since 2000, with all families declining over that period. Studies following Cyclone Rona showed the direct impact was to reduce coral cover by 10%. Soft coral has also decreased from a maximum of 17% in 1995 to 7% in 2003. Low Isles experienced high water temperatures in the summer of 2002 which is likely to further slow recovery.

The decline in the coral community by 2000 was reflected by declines in several coral-associated fish species. The damselfish *Pomacentrus moluccensis* and the butterflyfishes *Chaetodon aureofasciatus* and *C. trifasciatus* were obviously affected. Two species which increased are the snapper *Lutjanus vitta* and rabbitfish *Siganus doliatus*. For the most part however fish populations on the reef have been variable.

Figure 4.44

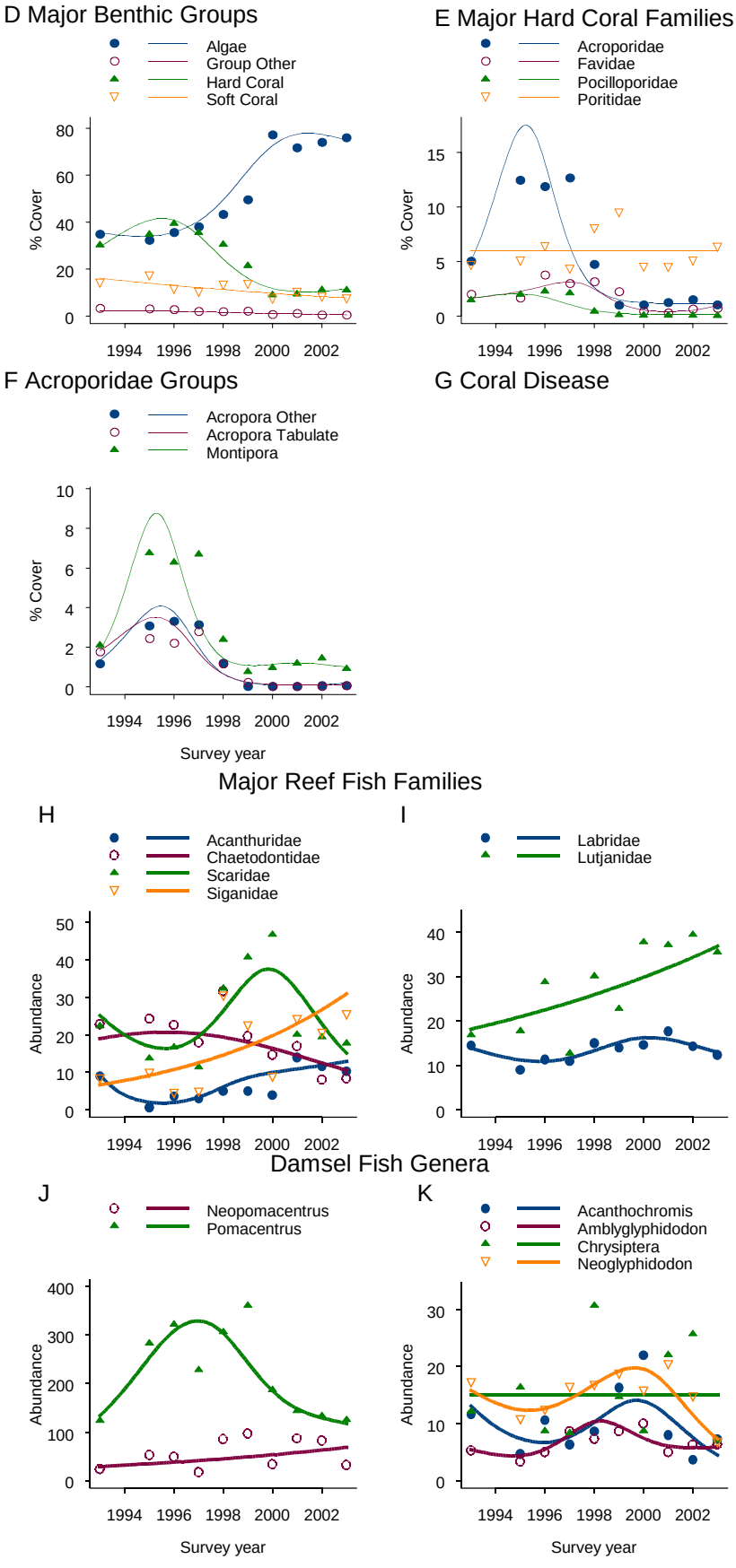
A





Low Islets (No. 16-028) is an inner shelf planar reef with an area of 2.3 sq.km.

Figure 4.44 (Cont).



MACKAY

Surveyed October 2002.

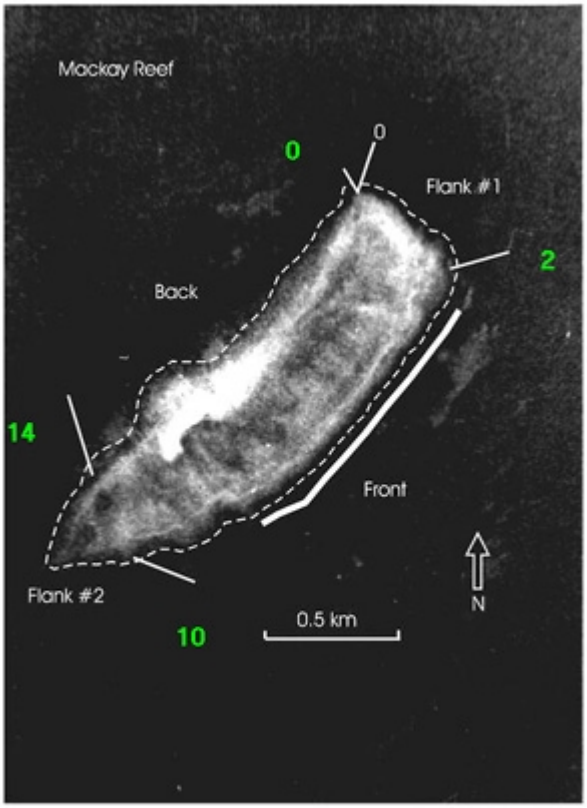
Mackay Reef was classified as Recovering from prior COTS activity in 1986 and has been surveyed 13 times. Reef-wide live coral cover rose to a high level (30-50%) in 1993, when COTS were recorded in low numbers. COTS numbers built up and peaked in 1998 when the reef was classified as an Incipient Outbreak. Increased COTS activity coincided with a gradual decline in reef-wide live coral cover to moderate levels (10-30%). Mackay Reef was also affected by Tropical Cyclone Rona which crossed the area in 1999. In 2003 manta tow surveys recorded a few bleached coral colonies and a few colonies with white syndrome disease. The reef was classified as Recovering. The density of corallivorous snails *Drupella* spp. was 106.7/ha in 2003.

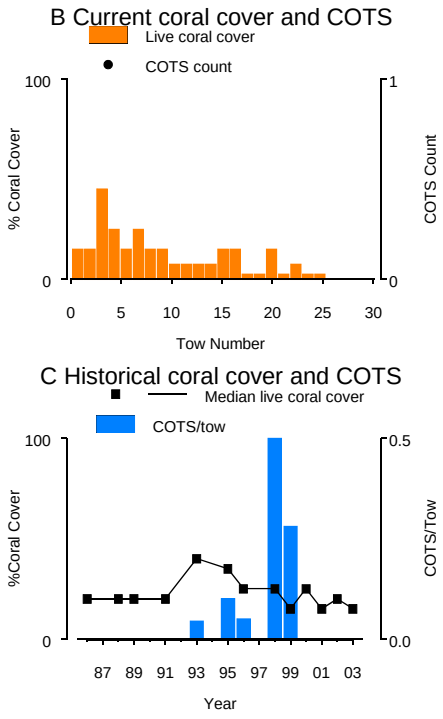
Hard coral cover on the intensive survey sites reached its highest level in 1999 (31%) and was 25% in 2003. The increase in Faviidae was due to *Echinopora* spp. The decline in Poritidae was due to small declines in branching and submassive *Porites* spp. and *Goniopora* spp.

Few clear trends were evident in the fish community at this reef. The recent decline in the damselfish genus *Pomacentrus* was primarily due to declines in the numerically dominant *P. moluccensis* following a peak in abundance in 1999, though several other species in this genus also declined over the past several surveys.

Figure 4.45

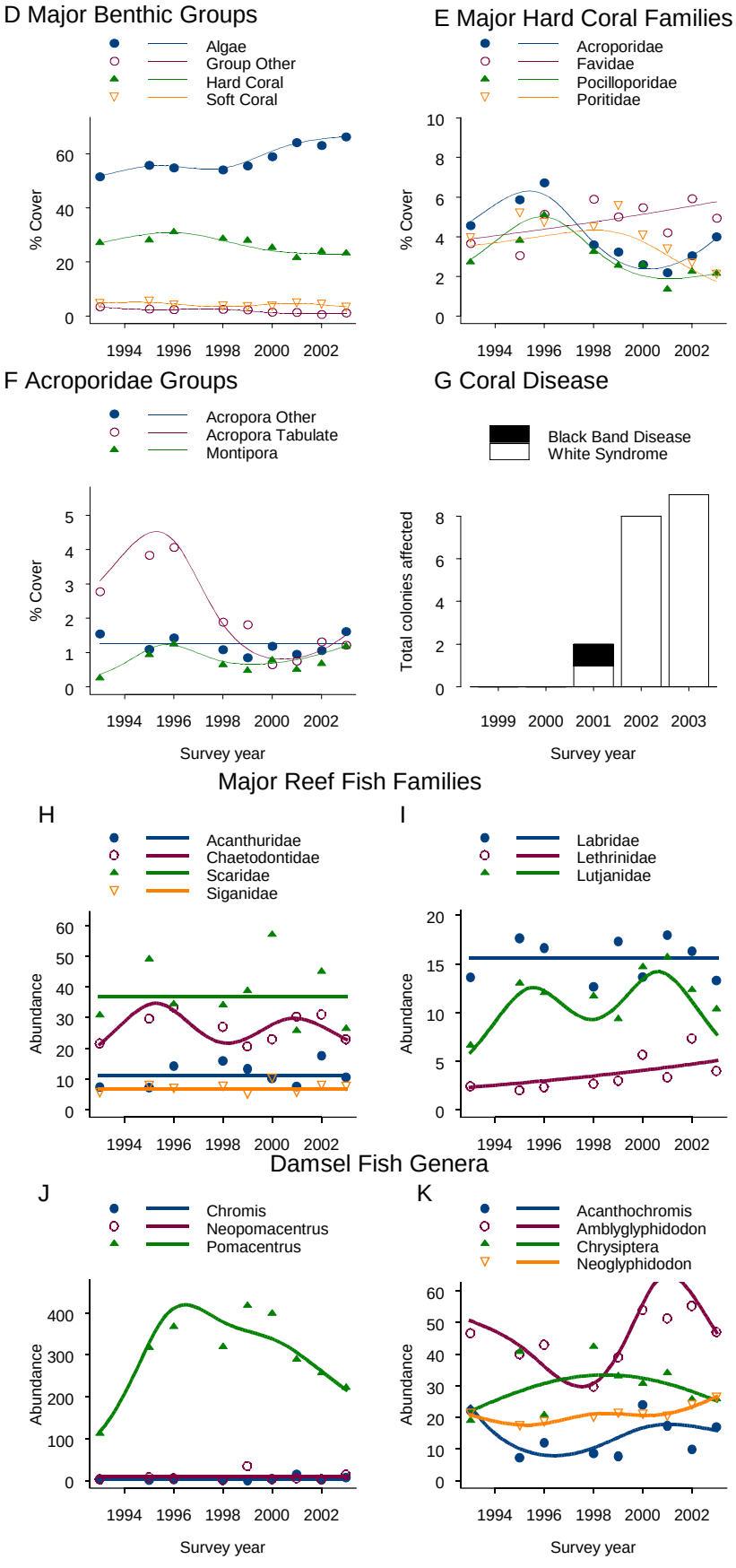
A





Mackay (No. 16-015) is a middle shelf planar reef with an area of 4.2 sq.km.

Figure 4.45 (Cont).



MICHAELMAS

Surveyed November 2002.

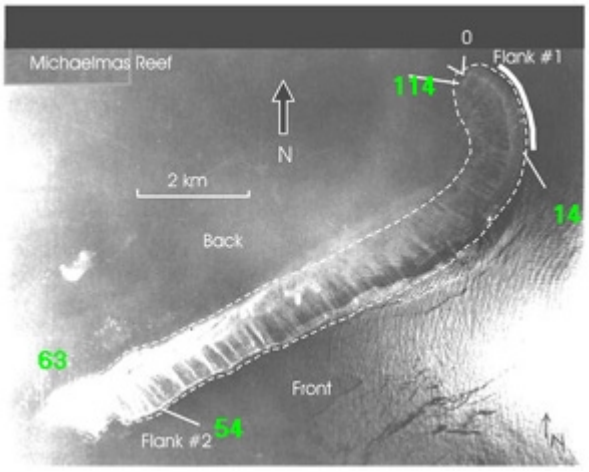
Michaelmas Reef has been surveyed extensively since 1986. Reef-wide live coral cover dropped from moderate to low levels in the initial years of survey and remained generally low (1-10%) through to 2003. COTS populations have been a common feature since 1993. 2003 was the first year since 1991 that COTS have not been recorded from this reef. Whilst overall COTS numbers have been below outbreaking levels they have had localised impact on coral communities in small areas of what is a very large reef. Michaelmas Reef remains classified as No Outbreak. No bleaching was observed in 2003 and white syndrome disease was restricted to small numbers of scattered coral colonies.

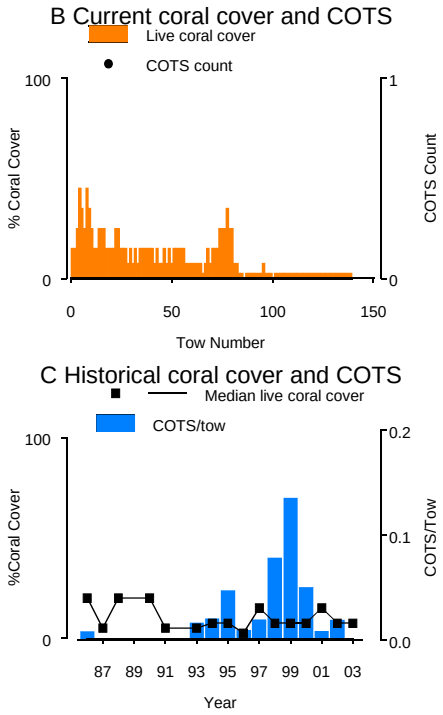
The cover of hard coral on the intensive survey sites has reached a plateau. Cover increased to a maximum of 26% in 1999 and in 2003 was stable at 25%. Tabulate *Acropora* had an increasing trend over the survey period and in 2003 was 9% while soft coral cover was moderately high and stable at around 30%. 2003 SCUBA searches found *Drupella* spp. present at a density of 73/ha.

Several species of butterflyfishes have increased in abundance on this reef. *Chaetodon citrinellus* showed a steady increase over the decade of sampling while *C. trifascialis* and *C. trifasciatus*, which were in very low abundance, have shown increasing trends with the increase in coral cover. This positive correlation with coral cover was also evident in several damselfishes of the genus *Chromis*, including *C. atripectoralis*, *C. ternatensis* and *C. margaritifer*. Abundances of the surgeonfish *Ctenochaetus* spp. were higher in 2002 and 2003 resulting in the increasing trend for Acanthuridae.

Figure 4.46

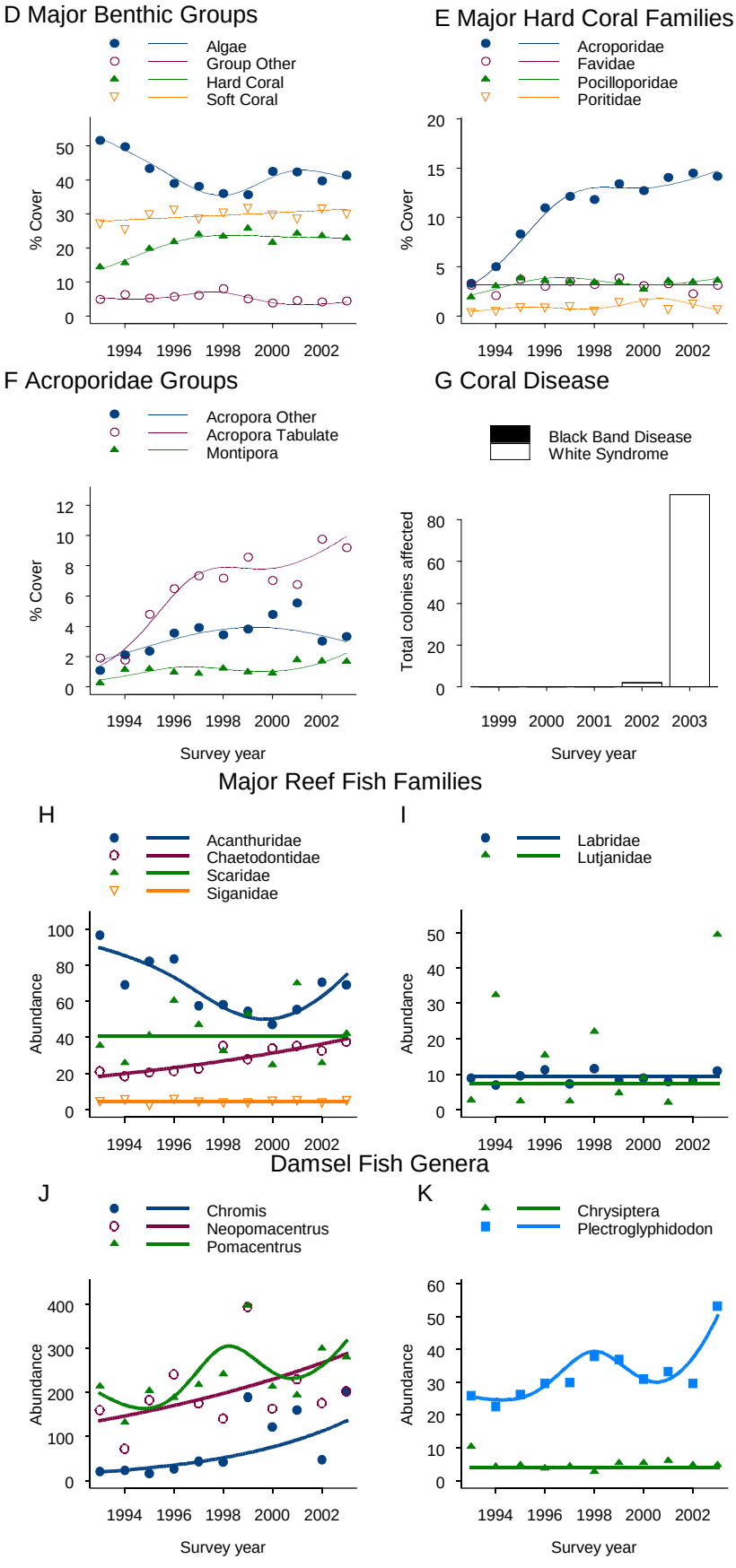
A





Michaelmas (No. 16-060) is a middle shelf crescentic reef with an area of 30 sq.km.

Figure 4.46 (Cont).



OPAL (2)

Surveyed November 2002.

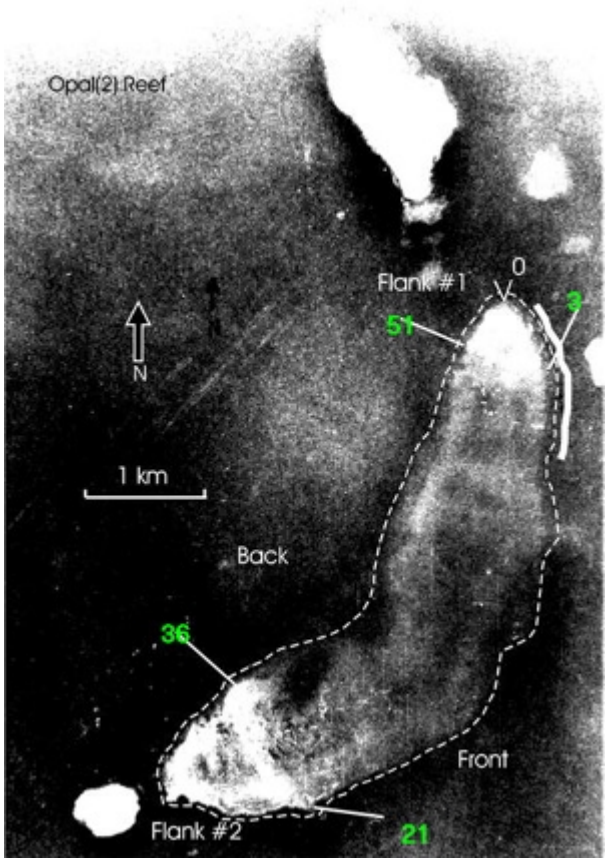
This reef has been surveyed twelve times since 1986. Until 1999 reef-wide live coral cover remained at moderate levels (10-30%). There were high COTS densities on this reef (2 COTS per tow) in 2000 which was reclassified as Active Outbreak. As a result of the COTS feeding, reef-wide live coral cover then declined to a low level (1-10%) in 2003. Low densities of COTS were recorded on this reef in 2001 and 2002 and none were seen during the 2003 survey. The reef was reclassified as Recovering in 2001. No bleaching was recorded and white syndrome disease was restricted to a few scattered coral colonies in 2003.

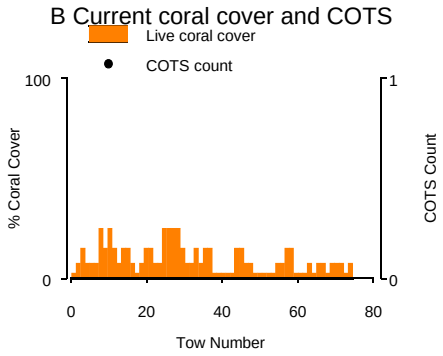
Hard coral cover has declined slightly on the intensive survey sites and was moderate at 19% in 2003. Algal cover usually shows an inverse relationship with hard coral cover. However, on this reef, algal cover has clearly fluctuated inversely with the abundance of soft coral. Soft coral cover was moderately high (30%) during the 2003 survey, having reached a maximum of 39% in 1996. *Drupella* spp. were observed during SCUBA searches at a density of 27/ha.

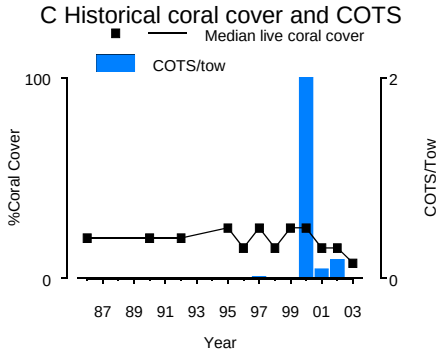
The relatively stable coral community was reflected in the overall lack of long term trends in the fish community. The only substantial trend was a decline in Acanthuridae. This decline was due to two species; *Acanthurus nigrofuscus* and *Ctenochaetus striatus*, and occurred generally on outer-shelf reefs of the Cairns and Cooktown / Lizard Is Sectors. Two species of *Pomacentrus* (*P. lepidogenys* and *P. philippinus*) showed a general increase. This was due to large increases in 1999 and 2003 rather than a steady increase over all surveys. Several other taxa showed similar marked increases in 2003.

Figure 4.47

A

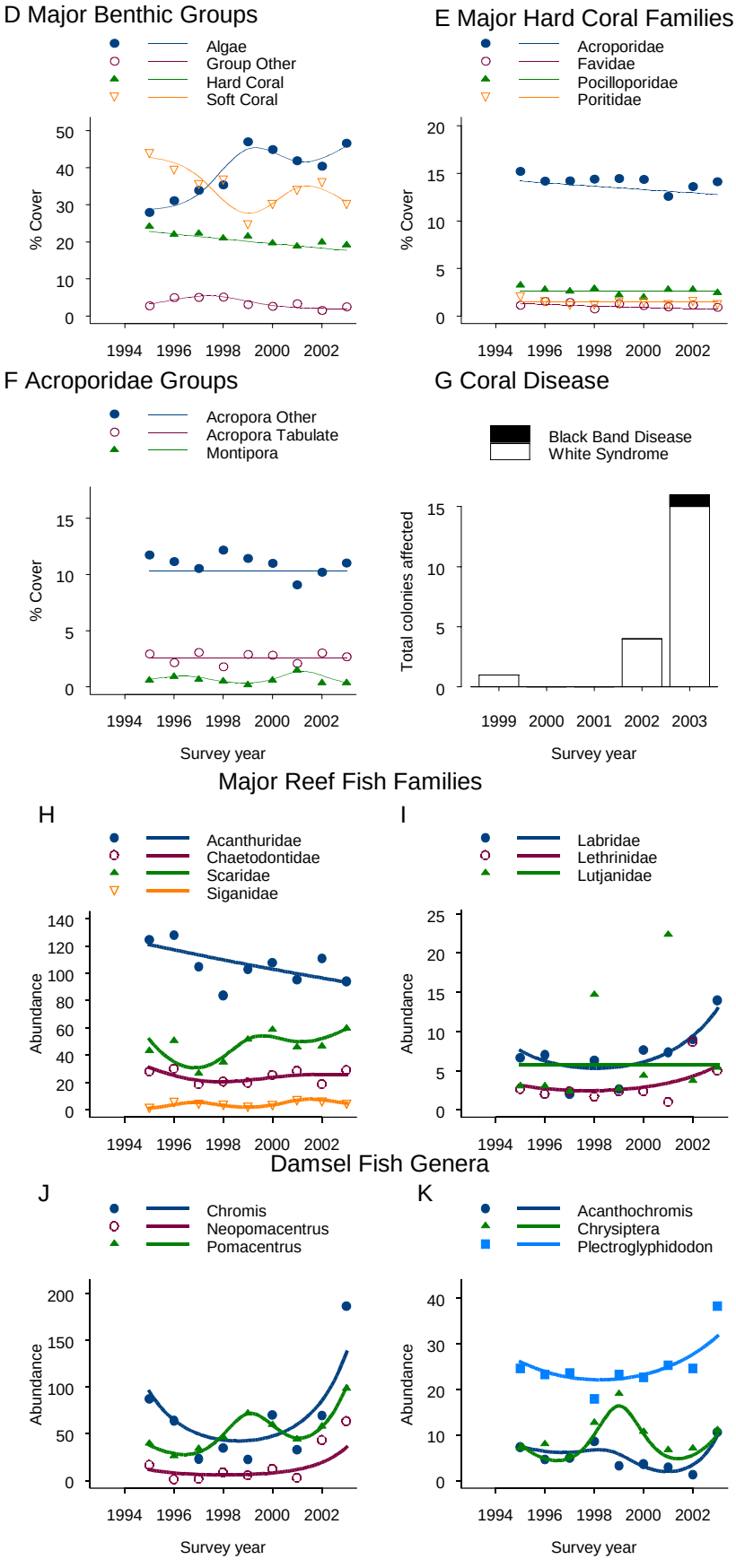






Opal (2) (No. 16-025) is an outer shelf crescentic reef with an area of 24.7 sq.km.

Figure 4.47 (Cont).



ST. CRISPIN

Surveyed October 2002.

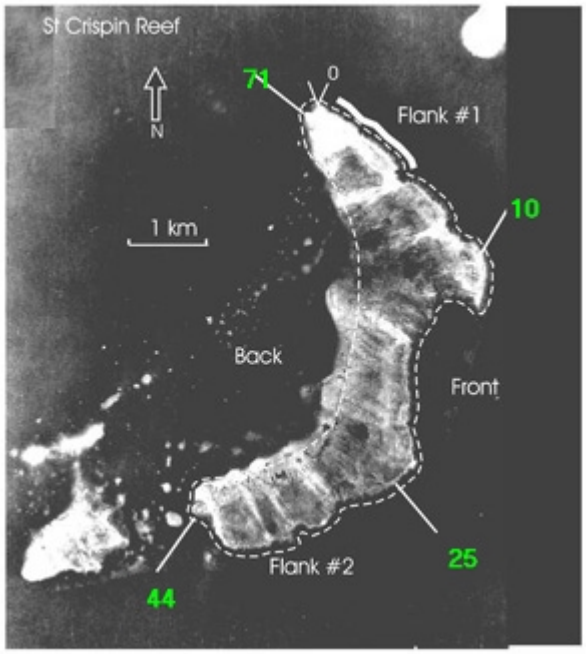
St Crispin Reef has been surveyed thirteen times since 1986. Over this time reef-wide live coral cover has remained at moderate levels (10-30%), but increased slightly in 2000. Low numbers of COTS were present in 1993. Numbers of COTS just below Incipient Outbreak levels were recorded in 2000 and may have resulted in a small decline in reef-wide live coral cover in subsequent surveys. Reef-wide live coral cover was moderate (10-30%) in 2003 and the reef was classified as No Outbreak. No bleaching and low levels of white syndrome disease and black band disease were observed on a few scattered coral colonies.

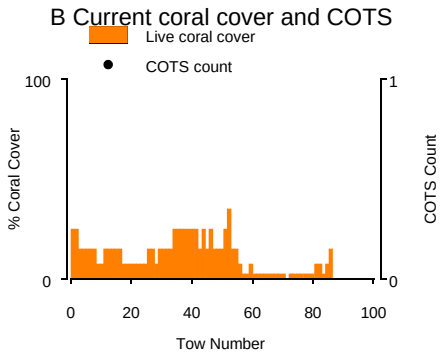
As at Opal Reef, the percent cover of algae appears to fluctuate inversely with the cover of soft coral. Soft coral cover had fallen to 33% in 2003 after reaching a maximum of 42% in 1999. Hard coral cover was moderate at 23% with increasing trends evident in *Acropora* spp. and *Pocillopora* spp. The density of corallivorous snails *Drupella* spp. was 40/ha in 2003.

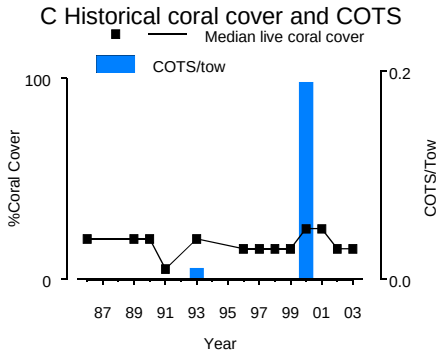
With the exception of declines in two species of Acanthuridae (*Acanthurus nigrofuscus* and *Ctenochaetus striatus*) the fish community showed no major trends over the first eight years of survey. In 2002 and 2003 this decline reversed. The upward population trends for *Acanthochromis*, *Chromis*, *Pomacentrus* and Labridae reflect increases in a number of species within these taxa over the past one or two surveys to 2003.

Figure 4.48

A

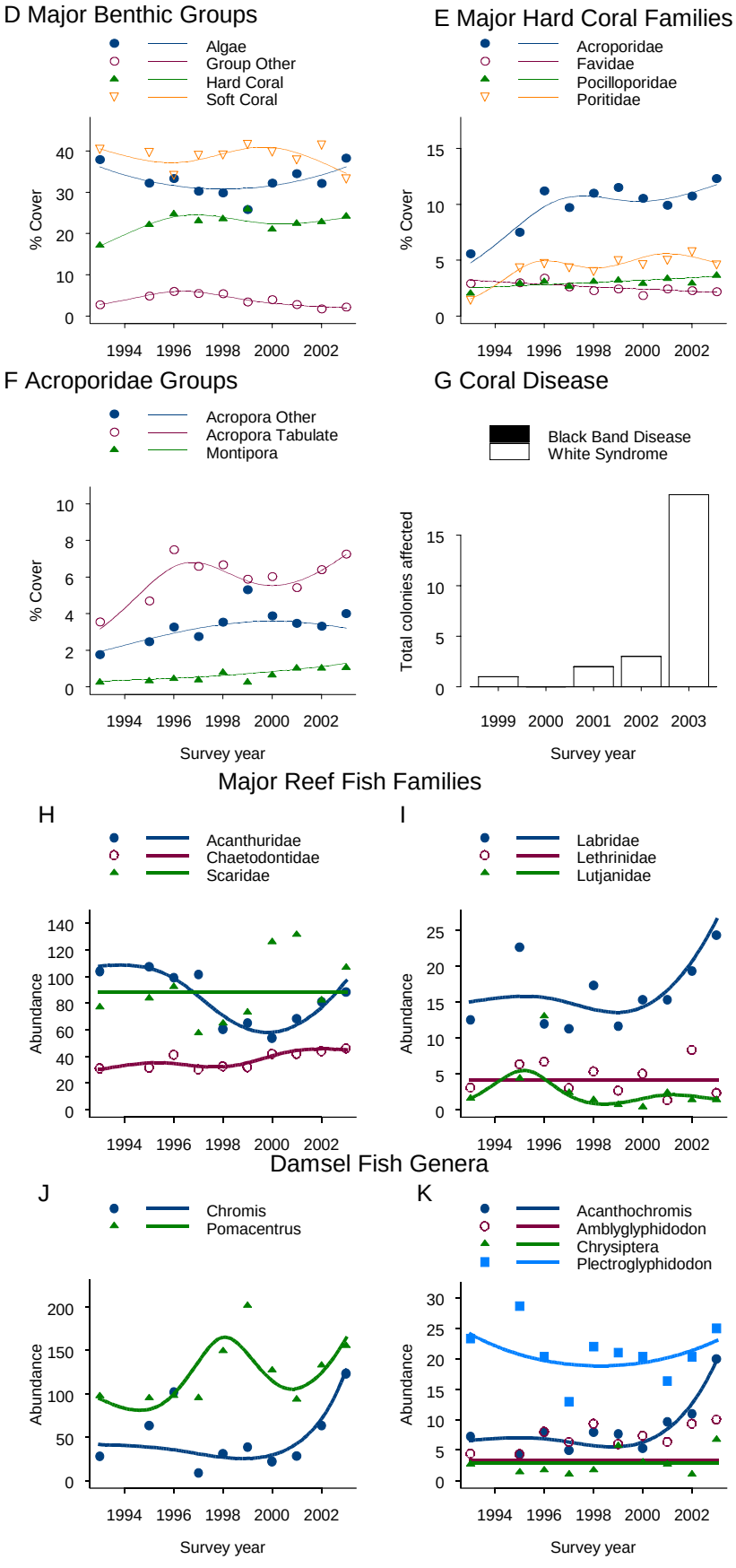






St. Crispin (No. 16-019) is an outer shelf crescentic reef with an area of 38.19 sq.km.

Figure 4.48 (Cont).



THETFORD

Surveyed November 2002.

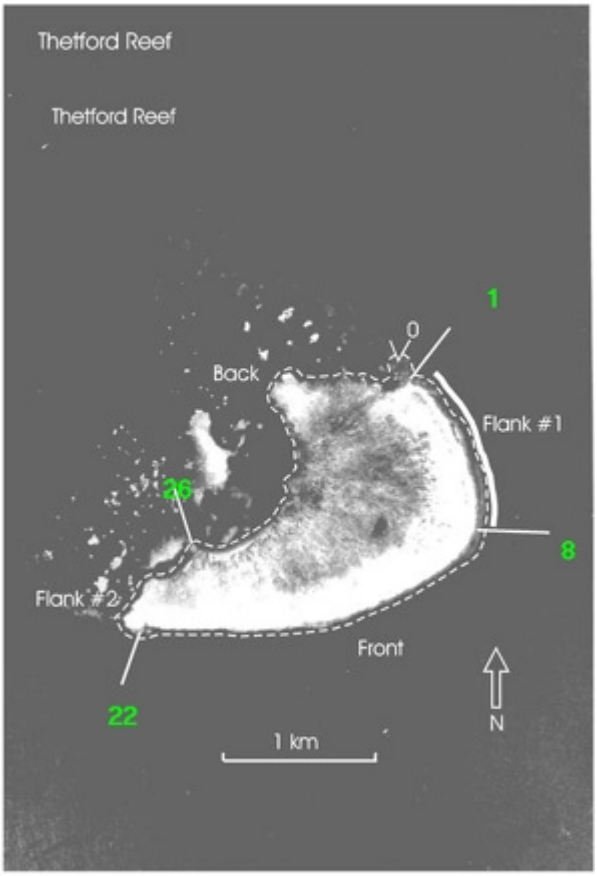
Thetford Reef has been surveyed fourteen times since 1986. Reef-wide live coral cover showed a declining trend till 1994. There was then a gradual increase to a moderate level (10-30%) by 1999. Surveys in 2000 indicated COTS numbers had increased on this reef and the reef was reclassified as Incipient Outbreak. Since then reef-wide live coral cover has declined to a low level (1-10%), most likely as a result of COTS feeding activity. No COTS were seen in 2003 and the reef is currently classified as Recovering. No bleaching was observed and white syndrome disease was restricted to a few scattered coral colonies.

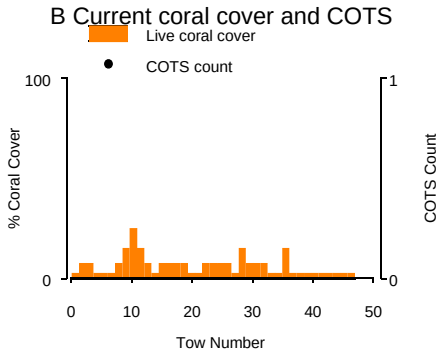
Reductions in coral cover since 2000 are attributed to crown-of-thorns feeding. Hard coral cover in 2003 is very low (4%). The largest decline is in *Acropora* spp. although Faviidae and Pocilloporidae also show declining trends. Soft coral cover has been stable over the survey period and in 2003 was 13%. *Drupella* spp. were observed during SCUBA searches at a density of 227/ha.

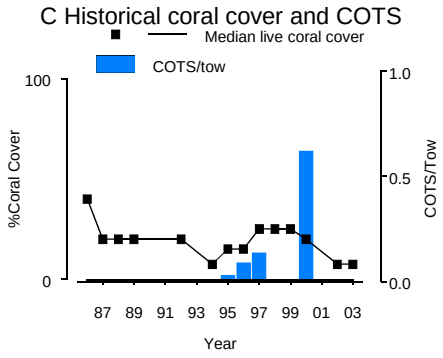
No long term trends are evident in the fish populations on this reef, though on the last two surveys, two species of Labridae, *Halichoeres hortulanus* and *Hemigymnus fasciatus* had higher numbers than previously recorded. Some species showed increasing trends, correlating with coral growth, until 1999, when they subsequently declined. This included several species of butterflyfishes (Chaetodontidae) along with some damselfish in the genus *Chromis*.

Figure 4.49

A

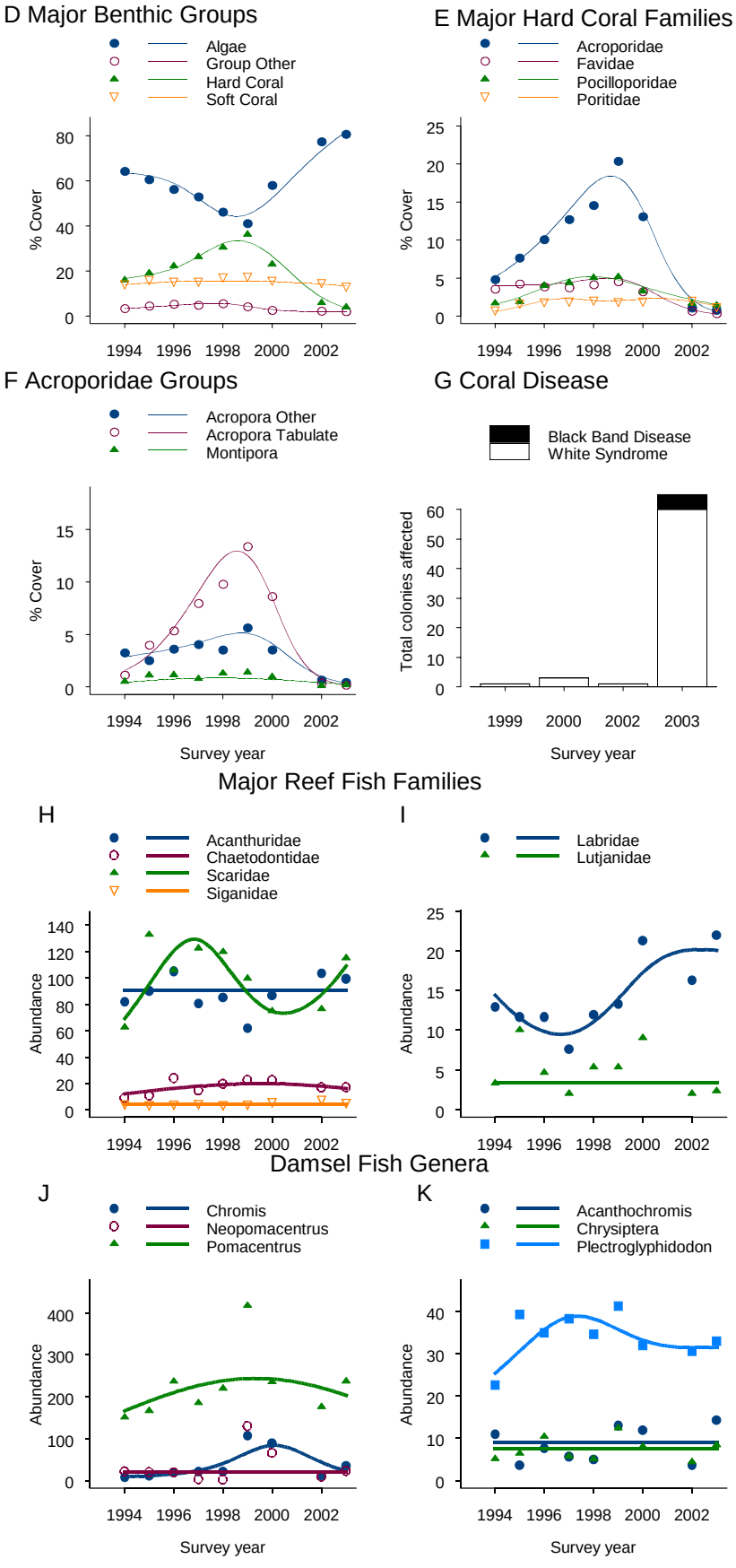






Thetford (No. 16-068) is a middle shelf crescentic reef with an area of 7.9 sq.km.

Figure 4.49 (Cont).



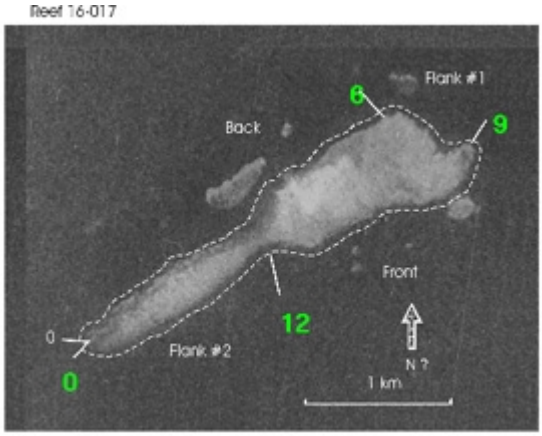
16017

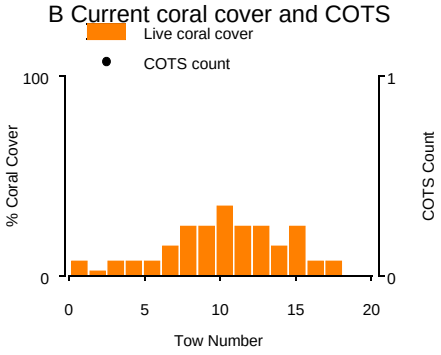
Surveyed October 2002.

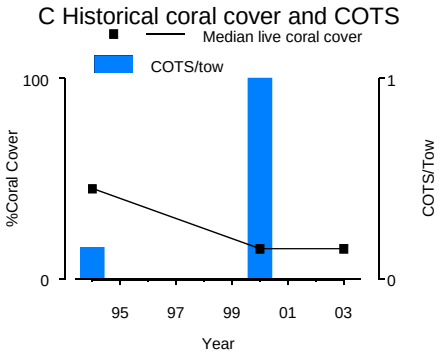
Reef 16017 has been surveyed three times since 1994 when reef-wide live coral cover was high (30-50%) and there was an incipient outbreak of COTS. Manta tow surveys in 2000 detected an increase in COTS activity and the reef was reclassified classified as an Active Outbreak. Reef-wide live hard coral cover declined to moderate levels (10-20%). Surveys in 2003 recorded no COTS and moderate coral cover. The reef was reclassified as Recovering. No bleaching was observed in 2003 and observations of white syndrome disease and black band disease were restricted to small numbers of dispersed coral colonies.

Figure 4.50

A







16017 (No. 16-017) is a middle shelf planar reef with an area of 2 sq.km.

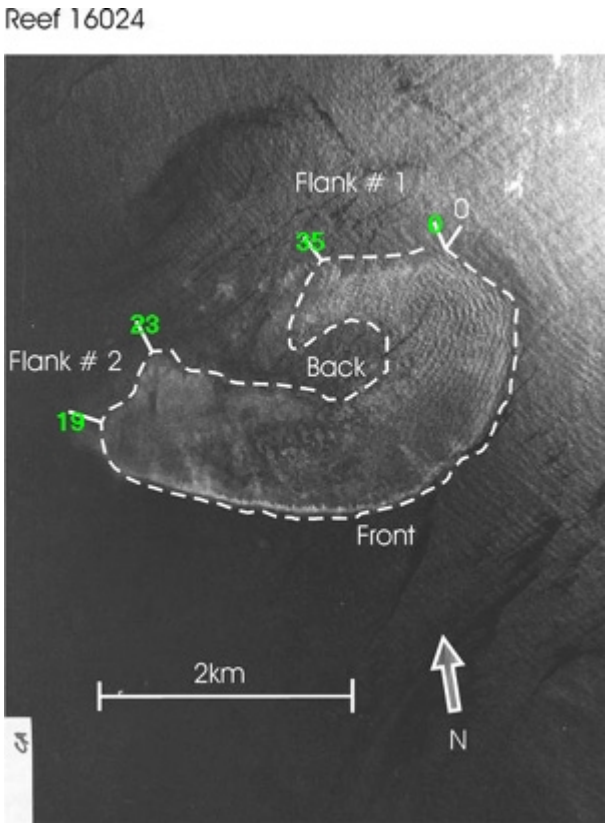
16024

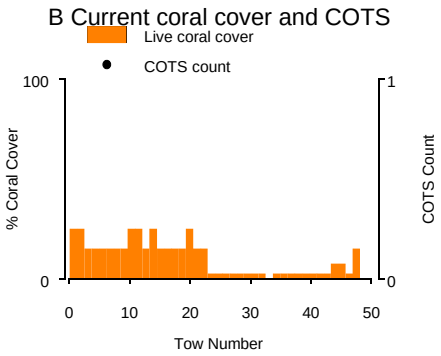
Surveyed October 2002.

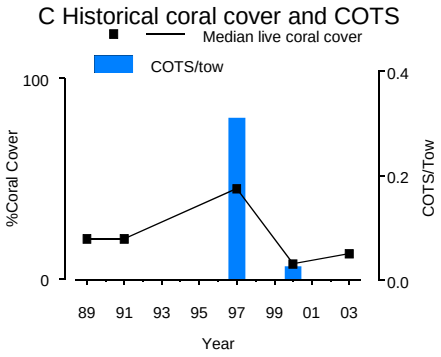
Chinamen Reef has been surveyed 5 times since 1989. Reef-wide live coral cover was high (40-50%) in 1997 but elevated COTS populations were present and it was reclassified from No Outbreak to Incipient Outbreak. Surveys in 2000 indicated reef-wide live coral cover had dropped to a low level (5-10%), most likely as a result of COTS feeding activity. Coral cover remained low in 2003. No COTS were observed in 2003 and the reef has been reclassified as No Outbreak. No bleaching was observed and white syndrome disease affected a few scattered coral colonies.

Figure 4.51

A







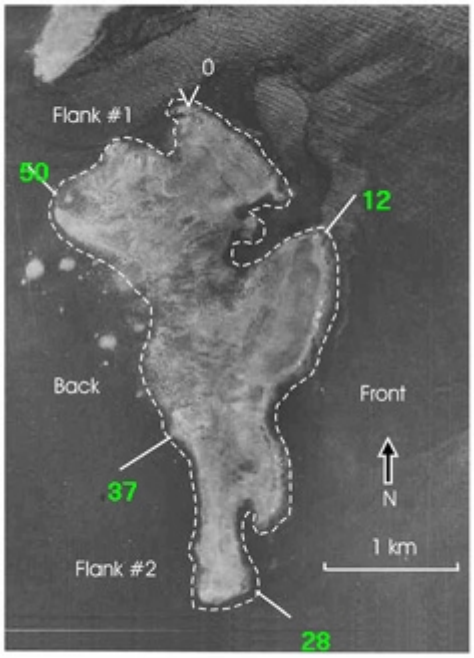
16024 (No. 16-024) is a middle shelf crescentic reef with an area of 5.6 sq.km.

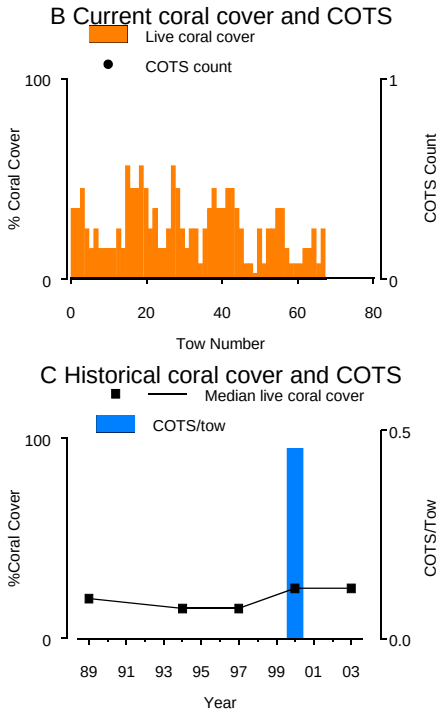
AGINCOURT NO.3

Surveyed October 2002.

This reef has been surveyed five times since 1989 when it was classified as No Outbreak. Reef-wide live coral remained at moderate levels (10-30%) up to 2003. Recovery of reef-wide live coral cover was hampered by a Incipient Outbreak of COTS in 2000. No COTS were recorded in 2003 and the reef was reclassified as No Outbreak. No bleaching was observed in 2003 and white syndrome disease was restricted to small numbers of dispersed coral colonies.

Figure 4.52 A





Agincourt No.3 (No. 15-099) is an outer shelf ribbon reef with an area of 12.5 sq.km.

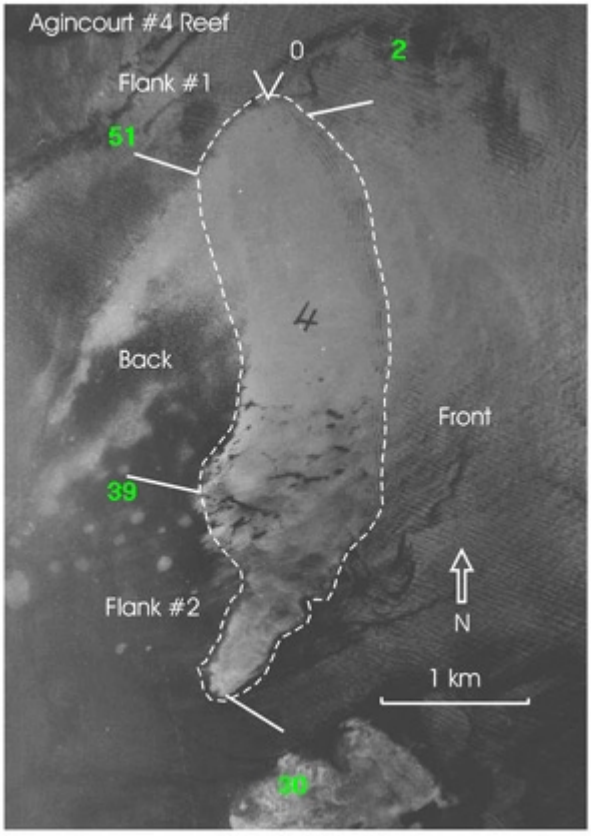
AGINCOURT NO.4

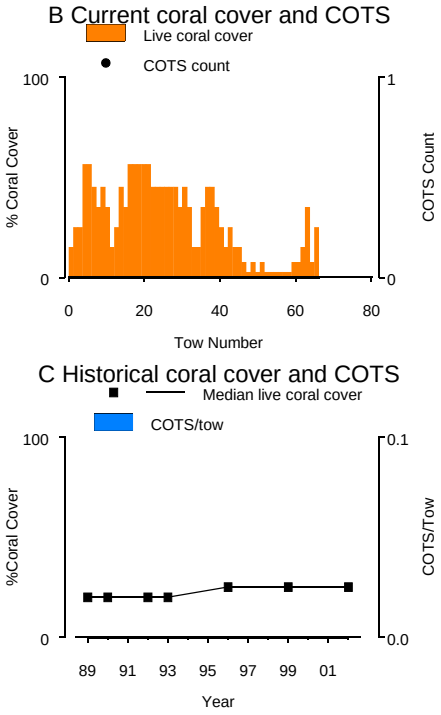
Surveyed September 2001.

This reef has been sampled on a regular basis since 1989. Reef-wide live coral cover has been moderate (10-30%) over this time. No COTS have been recorded from this reef in any survey. No bleaching was recorded, but white syndrome disease and black band disease were observed on small numbers of dispersed coral colonies in 2003.

Figure 4.53

A





Agincourt No.4 (No. 15-096) is an outer shelf ribbon reef with an area of 12.6 sq.km.

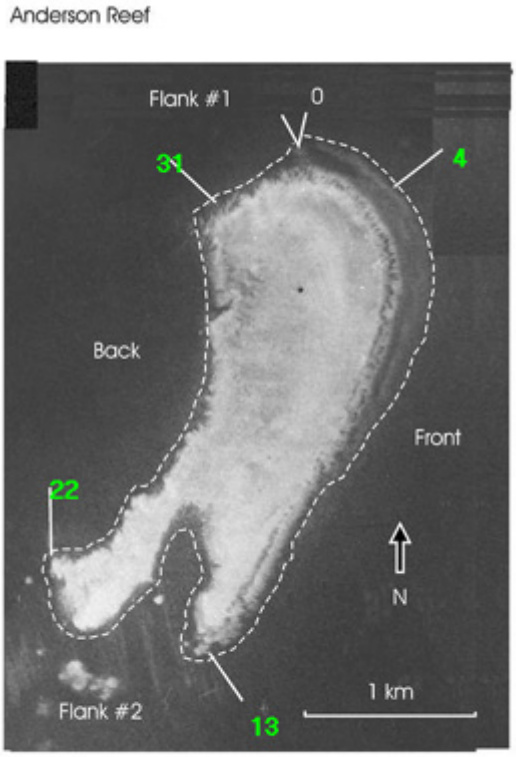
ANDERSEN

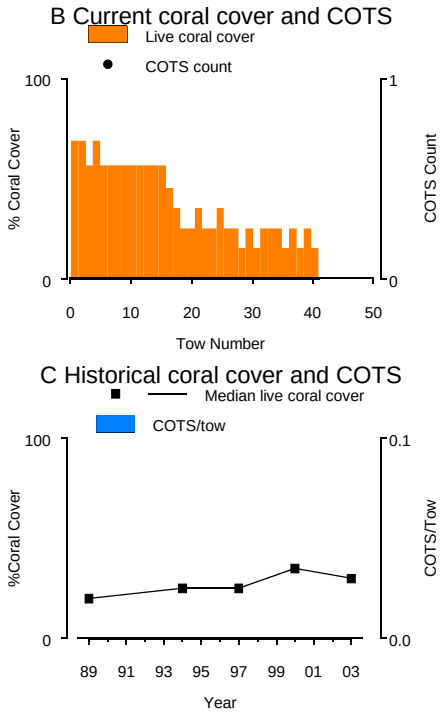
Surveyed October 2002.

Andersen Reef has been surveyed by manta tow five times since 1989. Reef-wide live coral cover showed a slow and steady increase from the moderate (10-30%) levels recorded in 1989 to a high level (30-50%) in 2003. No COTS have been observed on this reef in any survey and it was classified as No Outbreak in 2003. No bleaching was observed in manta tow surveys in 2003 and white syndrome disease affected a small number of dispersed coral colonies.

Figure 4.54

A





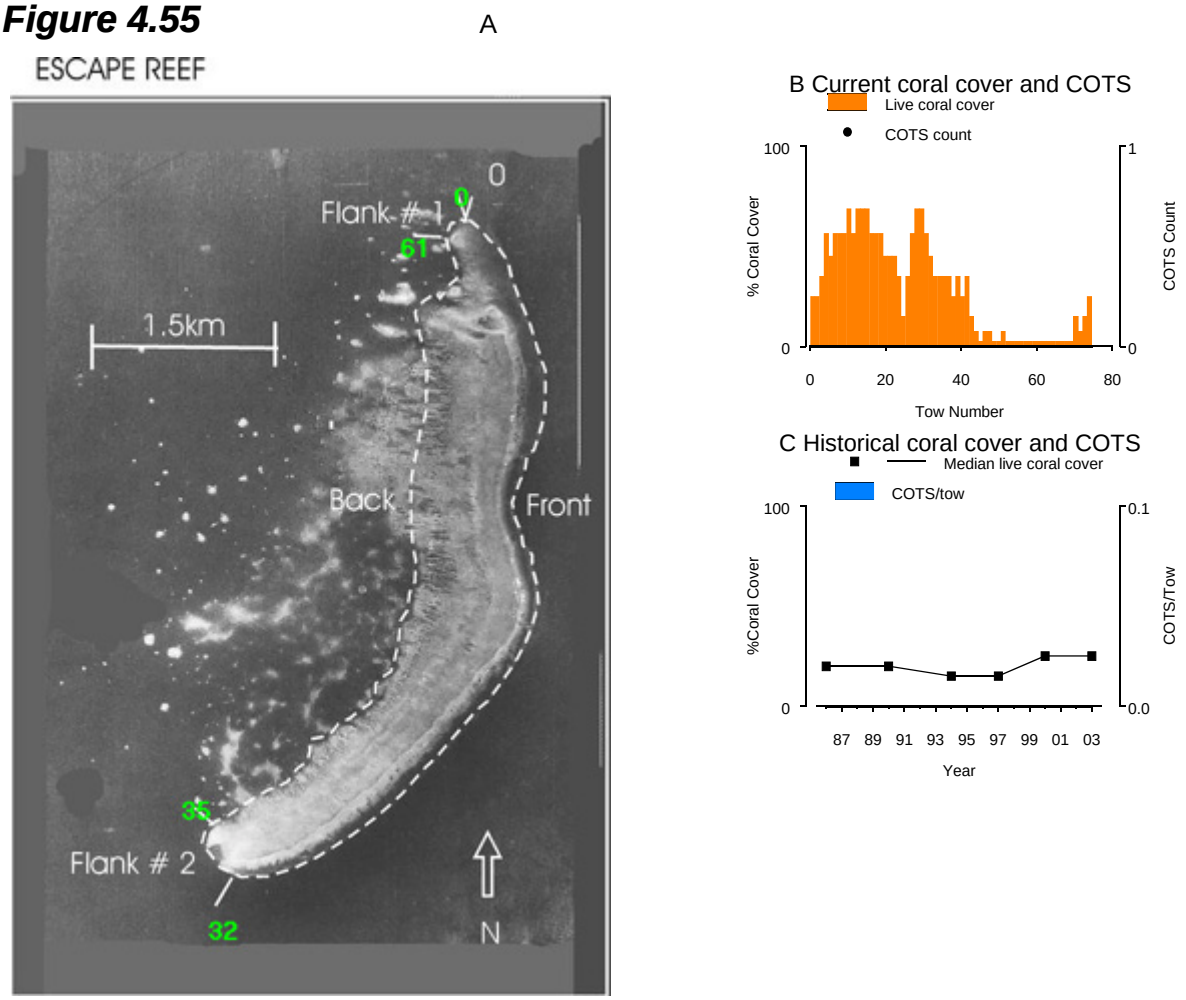
Andersen (No. 15-090) is an outer shelf ribbon reef with an area of 3.1 sq.km.

ESCAPE (1)

Surveyed October 2002.

Escape Reef has been sampled six times since 1986. Reef-wide live hard coral cover has remained relatively stable at a moderate level (10-30)% up until 2003. No COTS have been observed on this reef in any survey year and it remains classified as No Outbreak. No bleaching was observed and white syndrome disease occurred in small numbers of dispersed coral colonies in 2003.

Figure 4.55



Escape (1) (No. 15-094) is an outer shelf ribbon reef with an area of 21 sq.km.

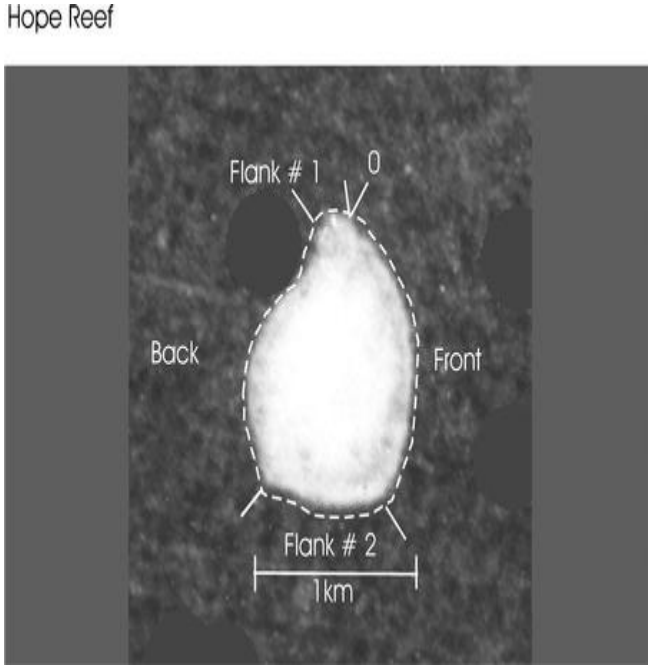
HOPE

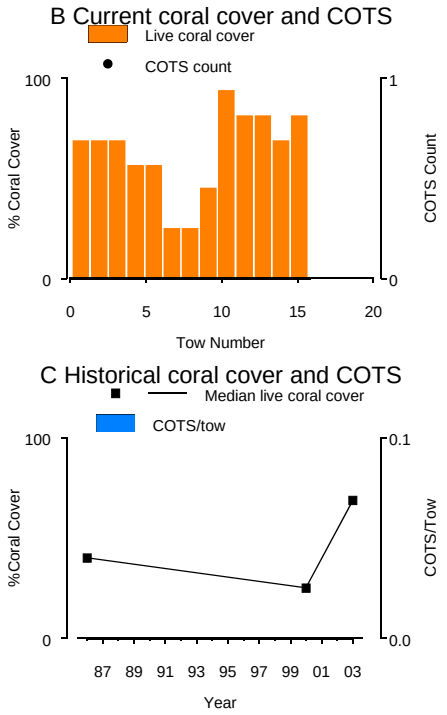
Surveyed November 2002.

This reef has been manta tow surveyed three times since 1986. There was a initial decline in reef-wide live coral cover from a high of 30-50% in 1996 to a moderate level of 10-30% in 2000. Reef-wide live coral cover had increased to a very high level (50-75%) in 2003 and observers remarked that coral cover was quite spectacular. Note that this is a submerged reef which is difficult to survey. High tides and moderate seas during surveys in 2000 and 2003 made it difficult to follow the same tow path which may account for some of the difference in reef-wide live coral cover. No COTS were observed and the reef remains classified as No Outbreak. Records of bleaching and disease are not available for this reef for 2003.

Figure 4.56

A





Hope (No. 16-058) is an outer shelf submerged reef with an area of .2 sq.km.

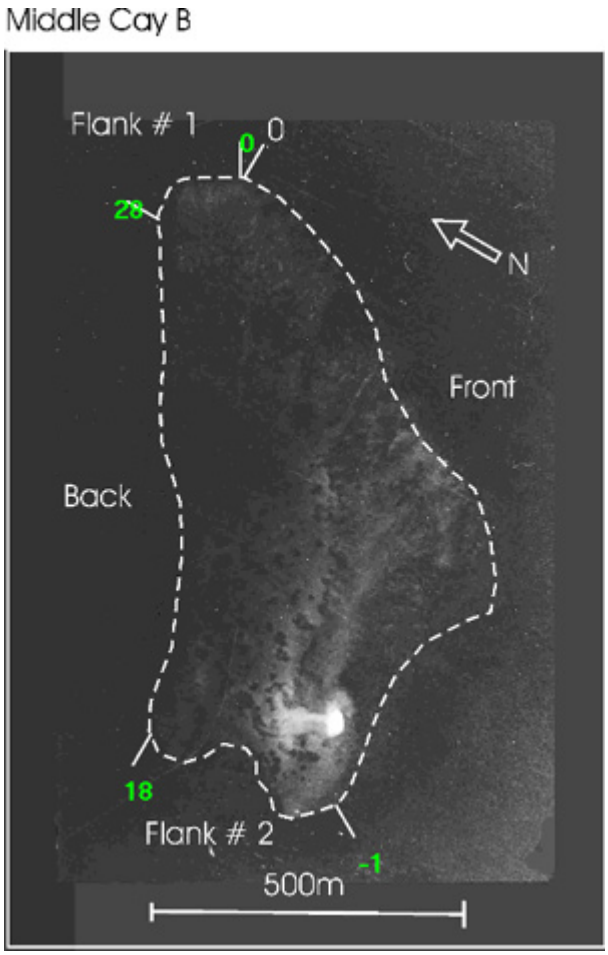
MIDDLE CAY (B)

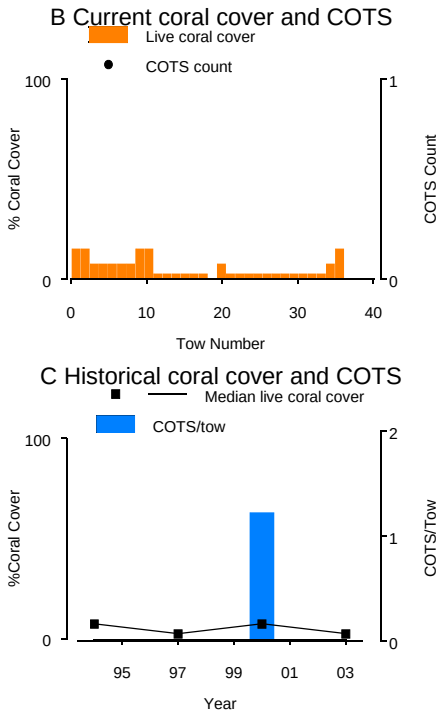
Surveyed November 2002.

This reef was initially classified as No Outbreak in 1994 and has been surveyed four times. Reef-wide live coral cover has remained at low levels (1-10%). In 2000, despite the low coral cover, a large COTS population was observed and the reef was reclassified as Active Outbreak. Surveys in 2003 showed a further reduction in reef-wide live coral cover (due to the COTS outbreak). However, no COTS were observed and consequently the reef has been reclassified as Recovering. No bleaching was observed and white syndrome disease was restricted to small numbers of scattered coral colonies.

Figure 4.57

A





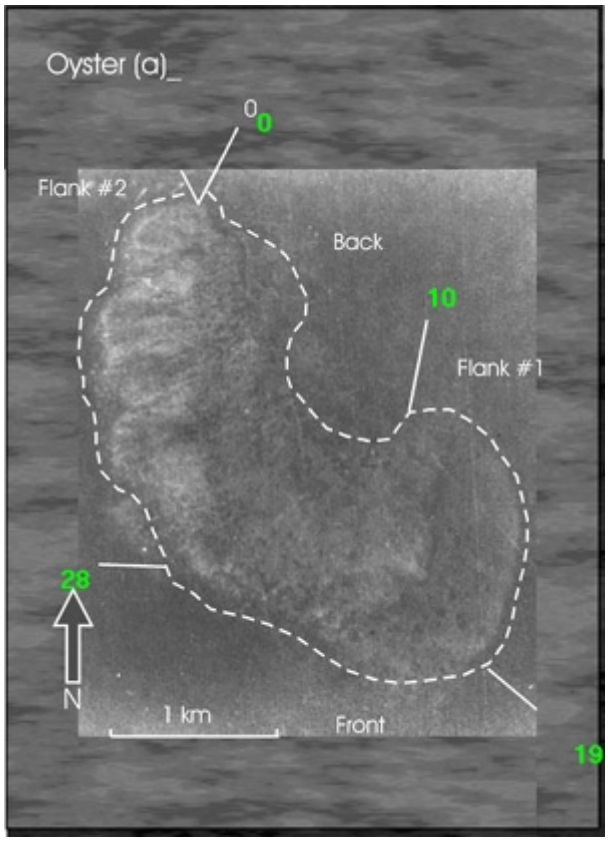
Middle Cay (B) (No. 16-044) is a middle shelf planar reef with an area of 6.25 sq.km.

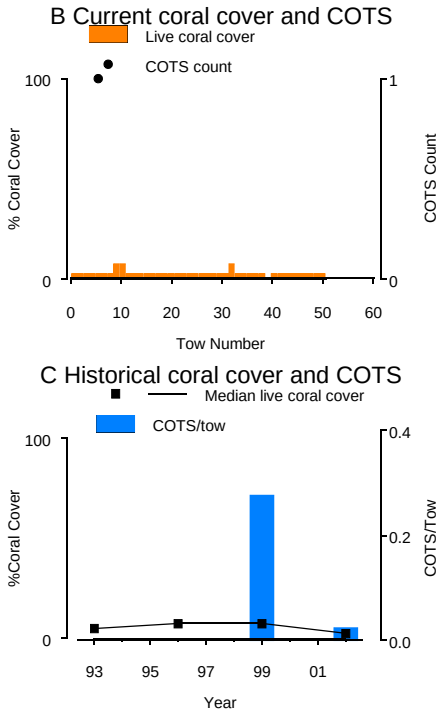
OYSTER (A)

Surveyed September 2001.

This reef has only been surveyed four times since 1993. There has been little change in reef-wide live coral cover which remained low (1-10%) in 2002. Surveys in 1999 found COTS at Incipient Outbreak levels. Manta tow surveys in 2002 found that COTS populations had since declined and reef-wide live coral cover remained low. The reef was classified as No Outbreak. No bleaching was observed and white syndrome disease was restricted to small numbers of scattered colonies in 2002.

Figure 4.58 A





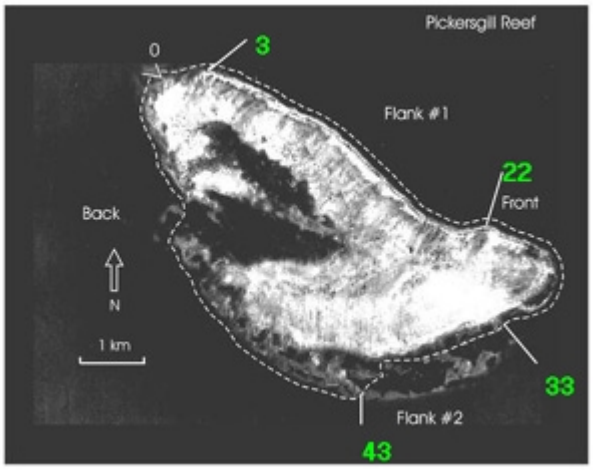
Oyster (A) (No. 16-043) is a middle shelf planar reef with an area of 14.5 sq.km.

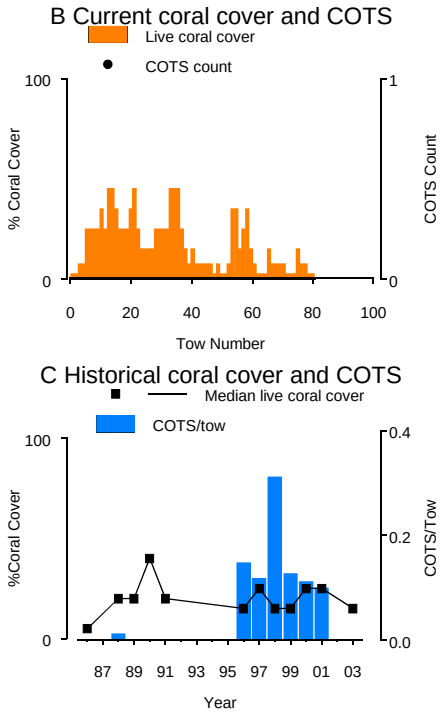
PICKERSGILL

Surveyed October 2002.

Pickersgill Reef has been surveyed by manta tow twelve times since 1986. Originally classified as Recovering from COTS activity prior to the first surveys, reef-wide live coral cover increased until 1990. Coral cover dropped appreciably in 1991. The reasons for this are uncertain; there were no large COTS populations but Cyclone Joy passed near the area in December 1990. After 1991 there was little change in coral cover although COTS numbers continued to grow up until 1998, when the reef was classified as an Incipient Outbreak. Persistent COTS populations at or below outbreak levels have hampered recovery on this reef and reef-wide live coral cover was moderate (10-30%) in 2003. No COTS were observed and the reef was classified as Recovering. No bleaching was recorded. For most of the reef perimeter, white syndrome disease and black band disease affected small numbers of dispersed coral colonies in 2003. However, white syndrome disease was relatively common (more than ten colonies affected per two-minute tow) on the front reef area where coral cover was highest.

Figure 4.59 A





Pickersgill (No. 15-093) is a middle shelf lagoonal reef with an area of 17 sq.km.

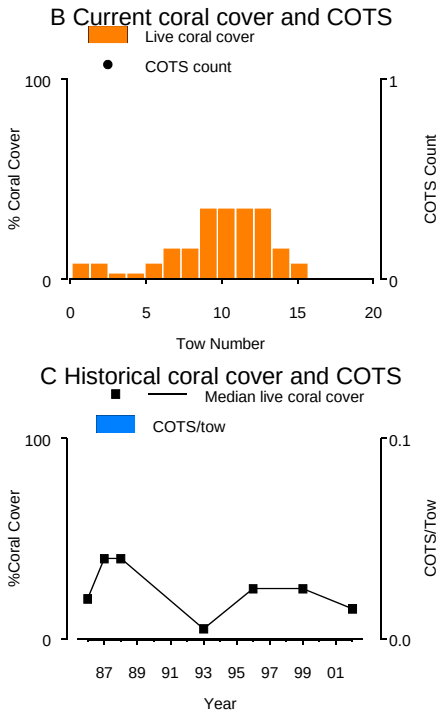
PIXIE

Surveyed September 2001.

This reef has been surveyed seven times since 1986. Reef-wide live coral cover was high (30-50%) during the late eighties before a significant drop in 1993. Given the interval between surveys and that no COTS had been seen, the cause of the drop in coral cover remains unknown. From 1993 reef-wide live coral cover recovered to some extent and was moderate (10-30%) in 2002. Though the most recent surveys indicate that this recovery may have stalled, Pixie reef was classified as Recovering from COTS activity prior to the start of surveys. No bleaching or coral disease was recorded from this reef in 2002.

No aerial

A



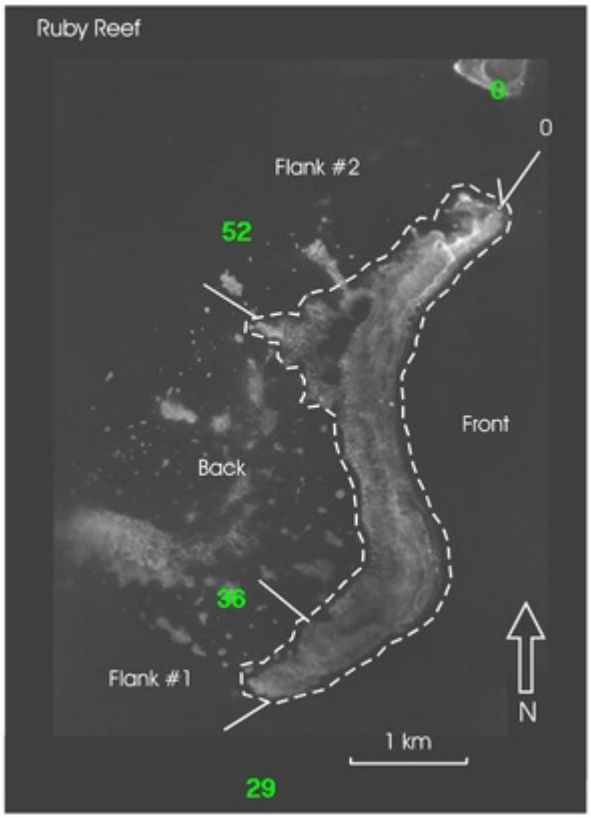
Pixie (No. 16-040) is a middle shelf planar reef with an area of .7 sq.km.

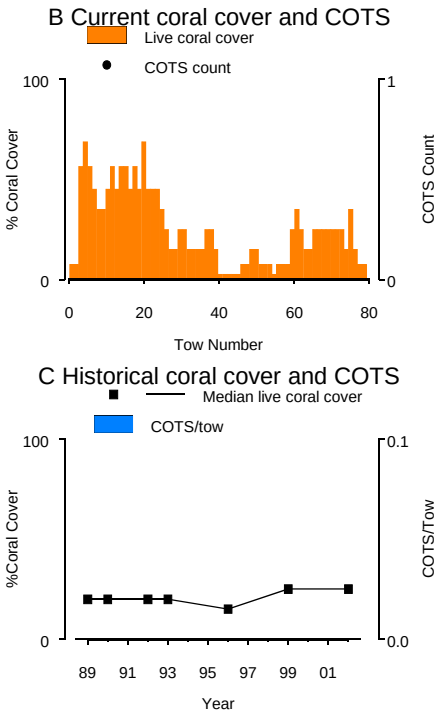
RUBY

Surveyed September 2001.

This reef has been surveyed seven times since 1989. Over this time there has been little change in reef-wide live coral cover which remained at moderate levels (10-30%) in 2002. No COTS have been observed on this reef, so it was classified as No Outbreak in 2002. No bleaching was recorded, however white syndrome disease and black band disease were observed on a few coral colonies during manta tow surveys in 2002.

Figure 4.61 A





Ruby (No. 15-088) is an outer shelf ribbon reef with an area of 12 sq.km.

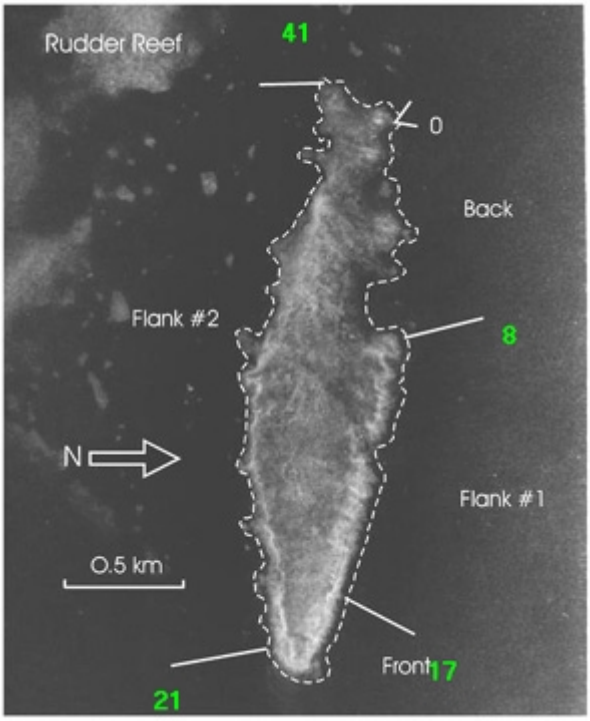
RUDDER

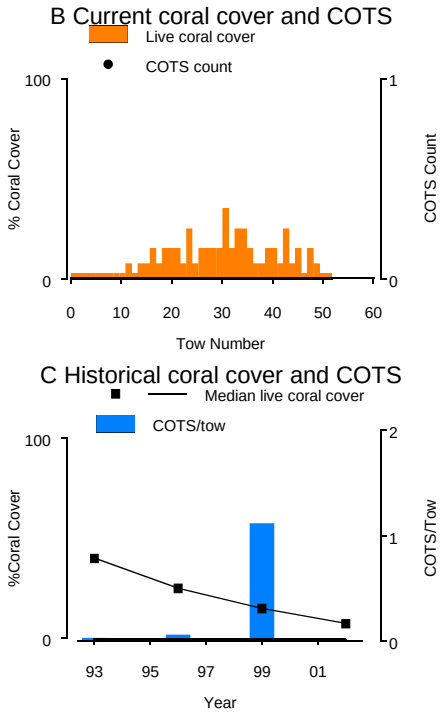
Surveyed September 2001.

This reef has been surveyed four times since 1993. Reef-wide live coral cover was initially high (30-50%), but COTS were recorded at each visit. COTS densities reached Active Outbreak levels in 1999. Reef-wide live coral cover declined steadily and was low (1-10%) in 2002. No COTS were recorded in 2002 and the reef was classified as Recovering. No bleaching was seen and white syndrome disease only affected a few scattered coral colonies.

Figure 4.62

A





Rudder (No. 16-023) is a middle shelf reef patches reef with an area of 0 sq.km.

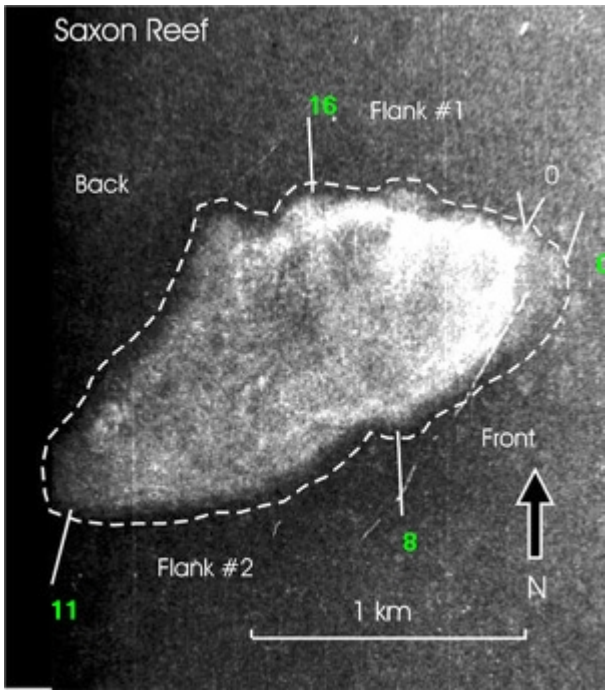
SAXON

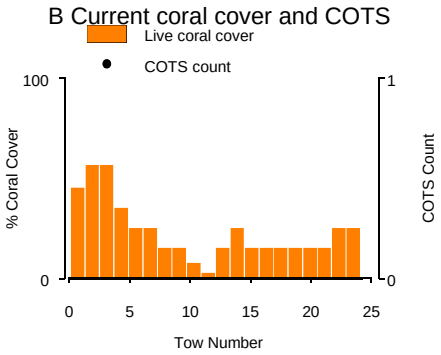
Surveyed September 2001.

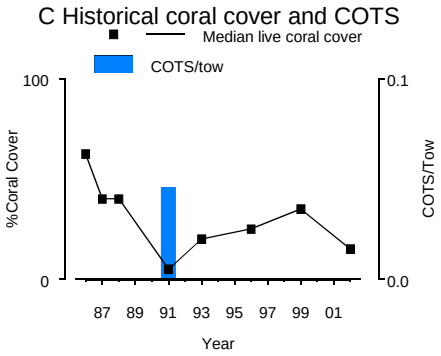
This reef has been surveyed on a regular basis since 1986. Reef-wide live coral cover was initially very high (50-75%) through the late 1980s, but declined in the early 1990s for unknown reasons, but possibly due to the persistent low numbers of COTS. From 1991 to 1999 reef-wide live coral cover recovered to a high level (30-50%) before declining to a moderate level (10-30%) in 2002. The reason for this decline is also unknown. No COTS were recorded from this reef during recent surveys and it was classified as No Outbreak in 2002. No bleaching was observed and white syndrome disease only affected a few scattered coral colonies in 2002.

Figure 4.63

A







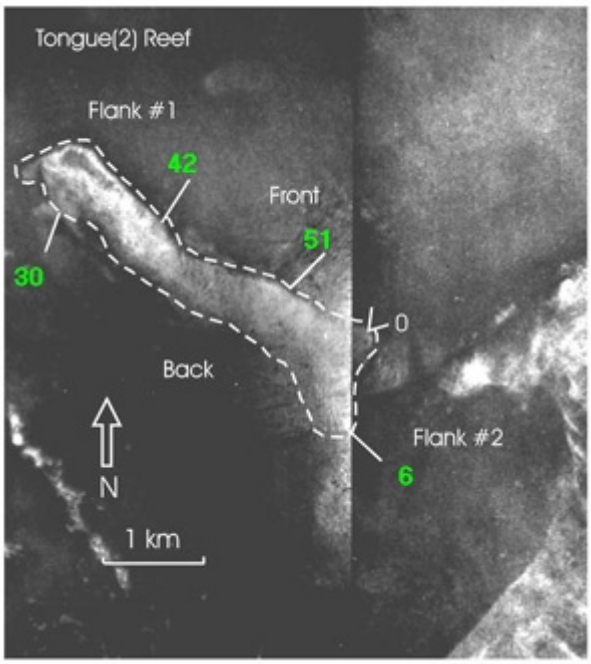
Saxon (No. 16-032) is a middle shelf planar reef with an area of 1.9 sq.km.

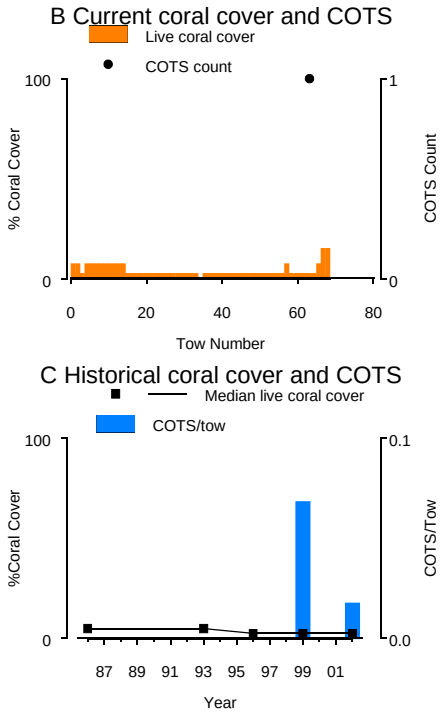
TONGUE (2)

Surveyed September 2001.

This reef has been surveyed five times since 1986. There has been little change in reef-wide live coral cover which remained low (1-10%) in 2002. Although COTS were recorded from this reef in 1999, their numbers were too low to cause much reduction in live coral cover. The reef was classified as No Outbreak in 2002. No bleaching was observed and white syndrome disease and black band disease were observed on a few scattered coral colonies.

Figure 4.64 A





Tongue (2) (No. 16-026) is a middle shelf crescentic reef with an area of 213.3 sq.km.

Innisfail

Reef Pages

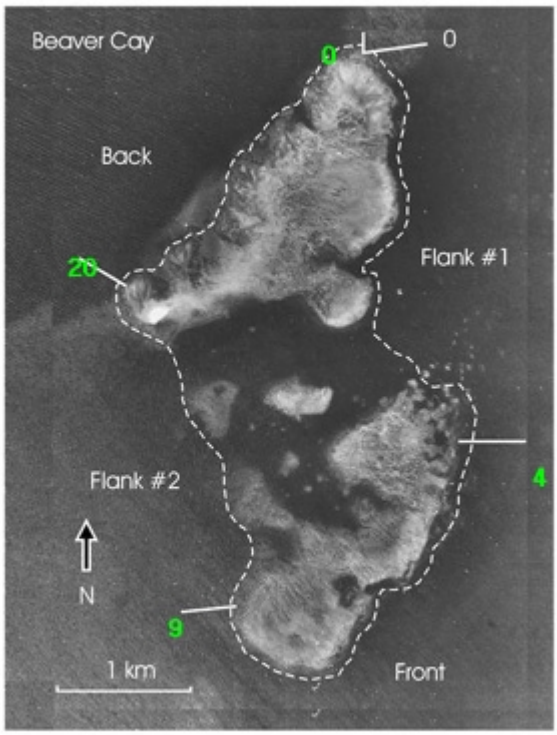
BEAVER

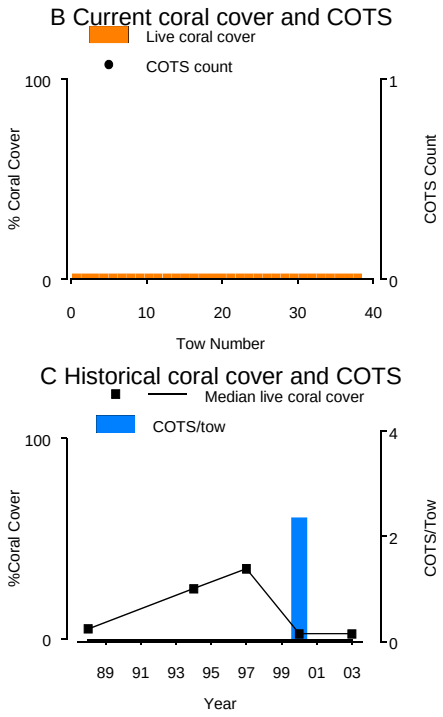
Surveyed October 2002.

Beaver Cay has been sampled five times since 1988. When originally surveyed, reef-wide live coral cover was low (1-10%) and the reef was classified as Recovering from previous COTS activity. Reef-wide live coral cover then increased to high levels (30-50%) in 1997. Surveys in 2000 found an Active Outbreak with numbers of COTS well in excess of those expected to reduce coral cover. There was then a marked decline in reef-wide live coral cover to a low level (1-10%) in 2003. No COTS were recorded and there was no coral disease or bleaching. The reef was reclassified as Recovering.

Figure 4.65

A





Beaver (No. 17-051) is a middle shelf reef patches reef with an area of 12.6 sq.km.

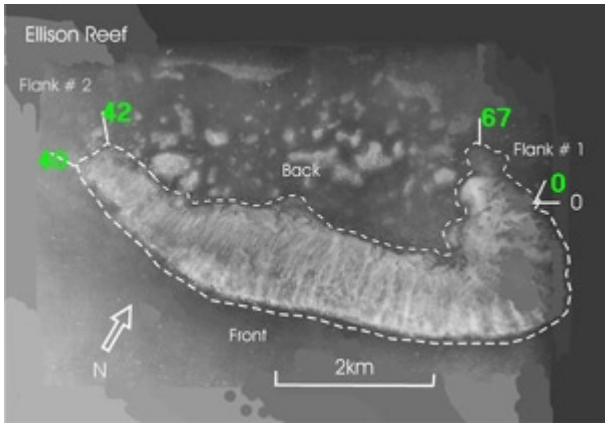
ELLISON

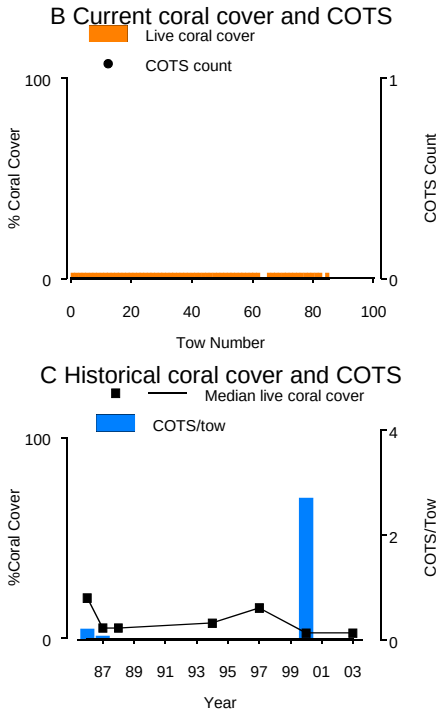
Surveyed November 2002.

This reef has been surveyed seven times since 1986. COTS have been seen on this reef in most survey years. Low numbers of COTS were recorded in 1986. The reef-wide live coral cover was moderate (10-30%) and the reef was classified as Recovering. Small numbers of COTS were seen again in the following year and reef-wide live coral cover had continued to decline to a low level (1-10%). Although the COTS density was below that generally expected to cause significant coral mortality, COTS were the most likely cause of the continued decline. Reef-wide live coral cover increased from 1987, peaking in 1997. Surveys in 2000 showed a dramatic increase in COTS activity and the reef was reclassified Active Outbreak. Reef-wide live coral cover declined again to a low level in 2003 due to COTS feeding activity. No COTS were seen in 2003 and the reef was reclassified as Recovering. No bleaching or coral disease was recorded.

Figure 4.66

A





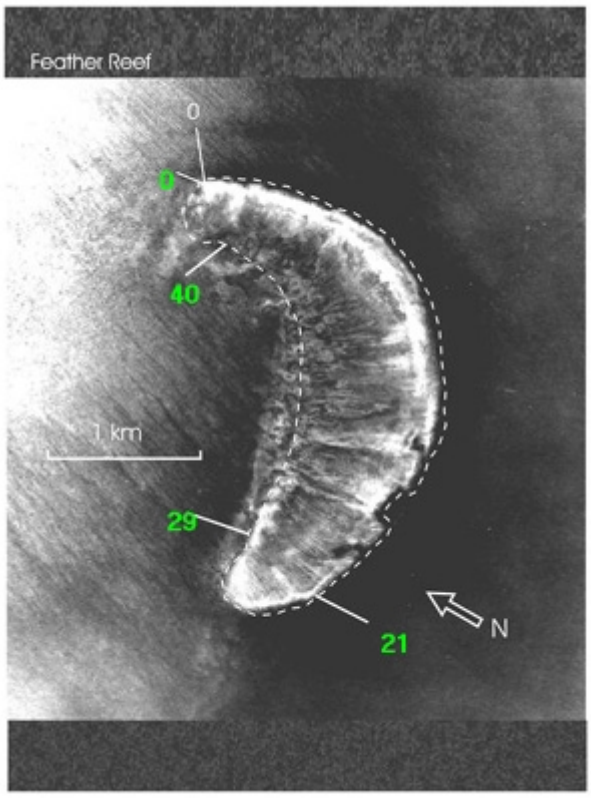
Ellison (No. 17-044) is a middle shelf crescentic reef with an area of 13.1 sq.km.

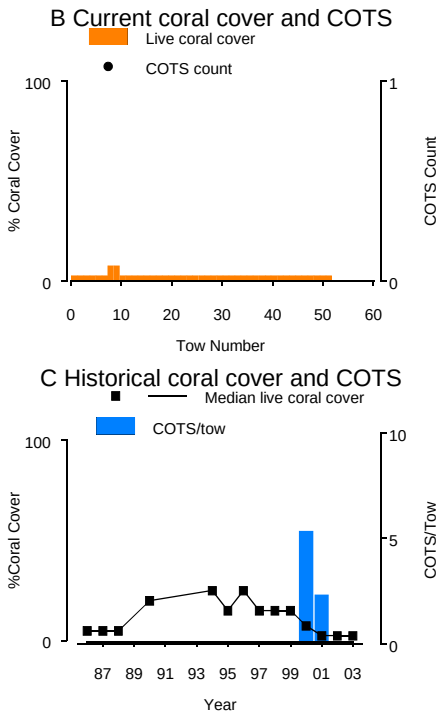
FEATHER

Surveyed November 2002.

This reef has been surveyed extensively since 1986. It was initially classified as Recovering from previous COTS activity. There was a gradual increase in reef-wide live coral cover to a moderate level during the late 1980s and early 1990s. The recovery of coral cover stalled in the mid 1990s, possibly due to the effects of cyclones (Cyclones Gillian, Ita and Justin were active in the area) and remained at moderate levels (10-30%) through the late 1990s. By 2000, reef-wide live coral cover had declined to a low level (1-10%) and there were large numbers of COTS. The reef was reclassified as Active Outbreak. By 2002 COTS numbers had declined and the reef was reclassified as Recovering. Reef-wide live coral cover was low in 2003 and the reef remained listed as Recovering. No bleaching or coral disease was observed.

Figure 4.67 A





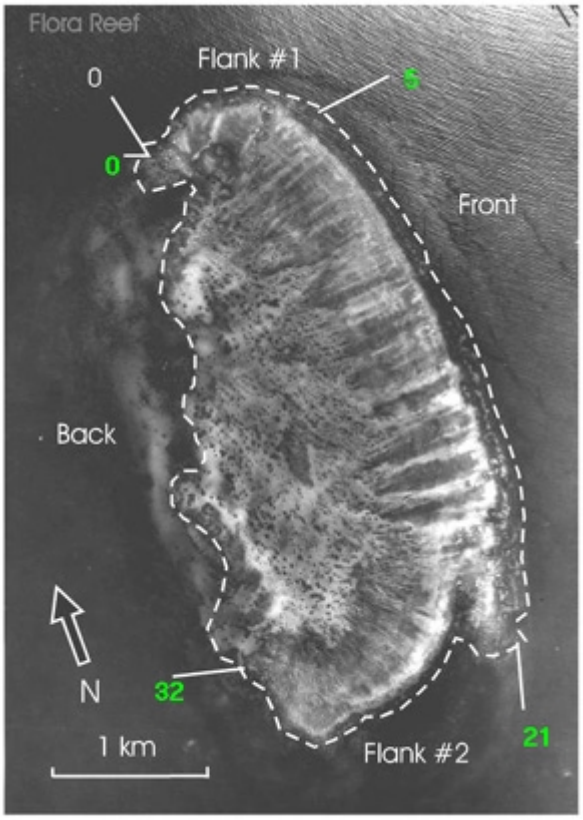
Feather (No. 17-034) is a middle shelf crescentic reef with an area of 14.1 sq.km.

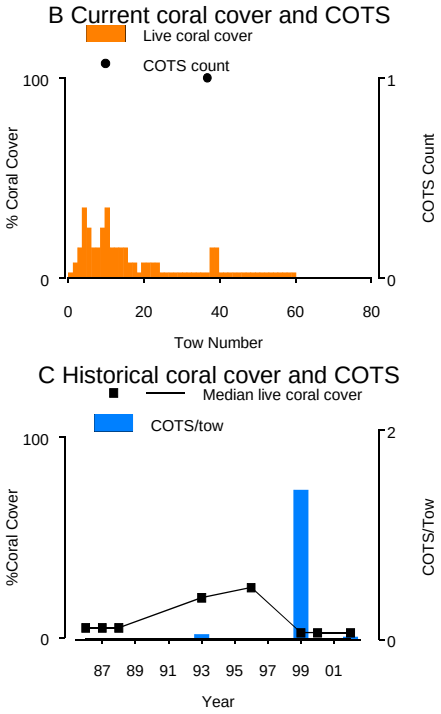
FLORA

Surveyed November 2001.

This reef has been surveyed eight times since 1986 when it was classified as Recovering from prior COTS activity. Reef-wide live coral cover was initially low (1-10%) and increased gradually to a moderate level (10-30%) by 1996. Surveys in 1999 found a decline in reef-wide live coral cover to a low level (1-10%). Large numbers of COTS were present and the reef was reclassified as an Active Outbreak. Although COTS certainly played an important role in the decline of live coral cover, bleaching, which was extensive on the GBR in 1998, may have also contributed. Small numbers of COTS were present in 2002. Reef-wide live coral cover was low and the reef was classified as Recovering. No bleaching was observed in 2002 and white syndrome disease was restricted to small numbers of scattered coral colonies.

Figure 4.68 A





Flora (No. 17-010) is a middle shelf crescentic reef with an area of 8.79 sq.km.

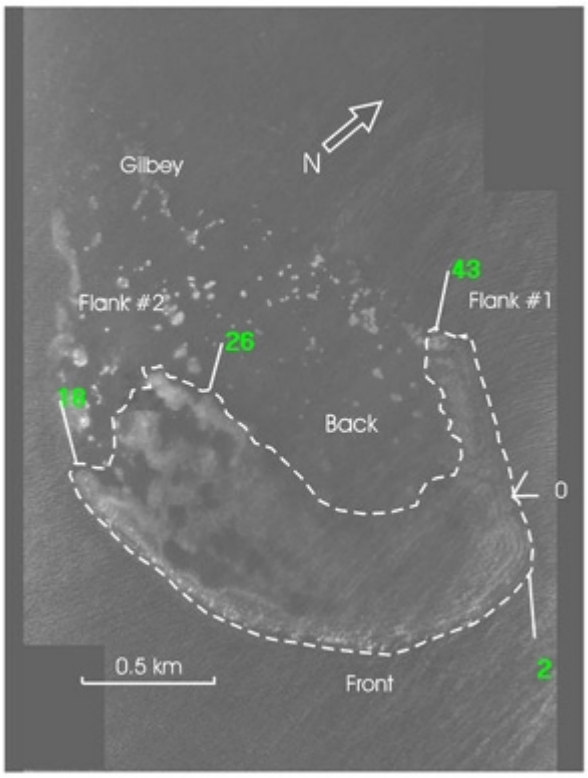
GILBEY

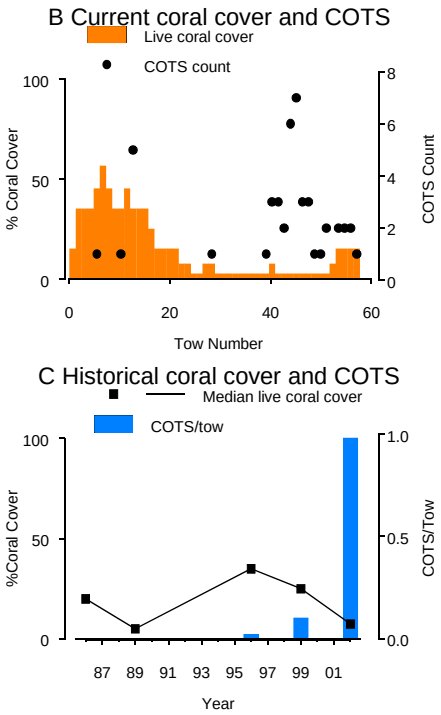
Surveyed August 2001.

This reef has been surveyed five times since 1986 when it was classified as Recovering from COTS activity. Reef-wide live coral cover declined and then recovered to a moderate level (10-30%) in 1996. Small numbers of COTS were recorded during surveys in 1996 and 1999. In 2002 there were large numbers of COTS and the reef has been reclassified as an Incipient Outbreak. Reef-wide live coral cover has declined to low levels (1-10%). No bleaching was observed in 2002 and white syndrome disease was restricted to a small number of scattered coral colonies.

Figure 4.69

A





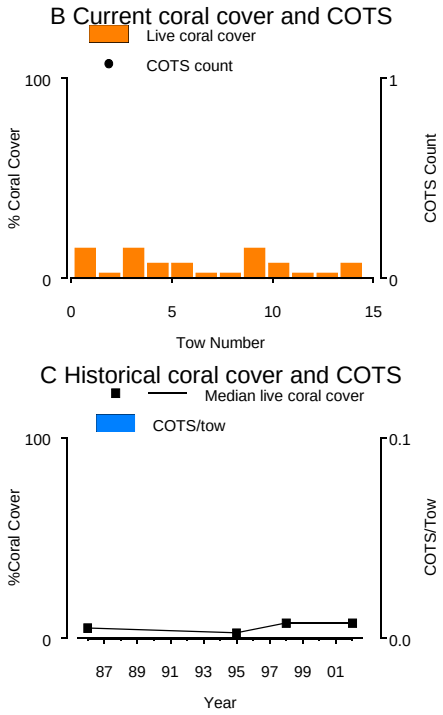
Gilbey (No. 17-057) is an outer shelf crescentic reef with an area of 6.6 sq.km.

JESSIE AND KENT IS'S

Surveyed November 2001.

This reef has been surveyed four times since 1986. Over this time reef-wide live coral cover has remained low (1-10%) with little or no change between survey years. The reef is currently classified as No Outbreak. Records of bleaching and coral disease on this reef in 2002 are not available.

Figure 4.70 A



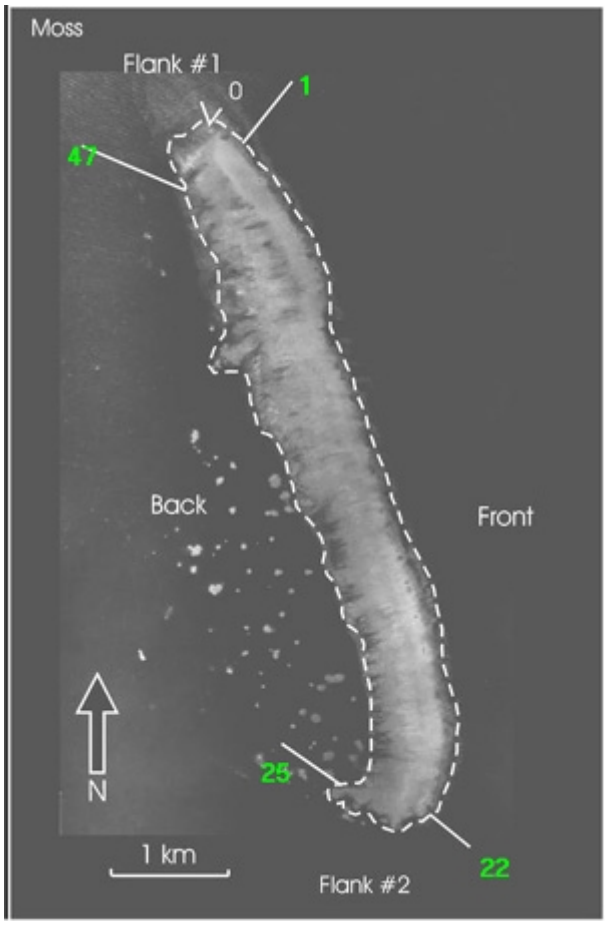
Jessie And Kent Is'S (No. 17-043) is an inner shelf fringing reef with an area of sq.km.

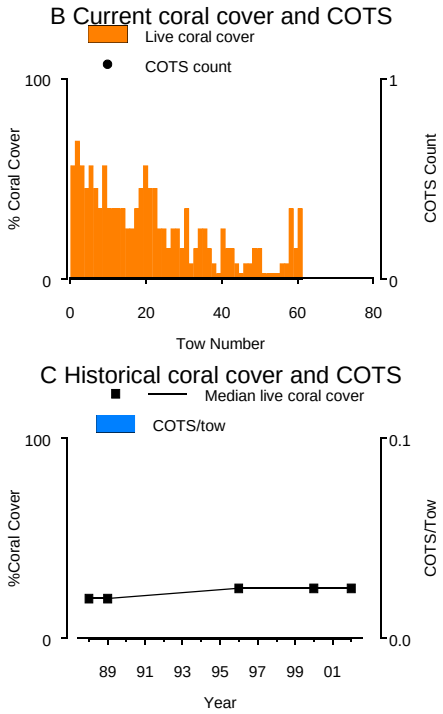
MOSS

Surveyed August 2001.

This reef has been surveyed five times since 1988 when it was classified as No Outbreak. There has been little change in reef-wide live coral cover which has remained at moderate levels (10-30%). No COTS have been observed on this reef during any survey and the reef remained classified as No Outbreak in 2002. No bleaching was observed and white syndrome disease and black band disease were restricted to a small number of scattered coral colonies.

Figure 4.71 A





Moss (No. 17-068) is an outer shelf ribbon reef with an area of 6.2 sq.km.

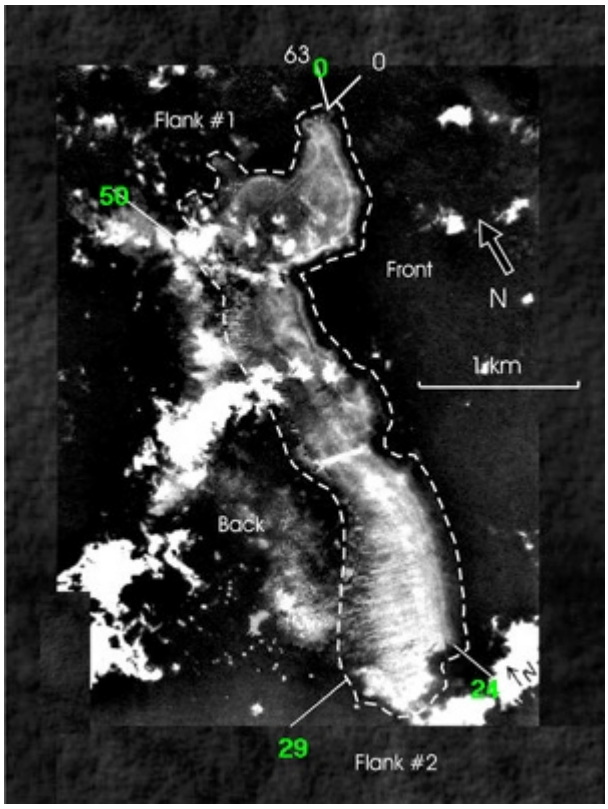
NOGGIN

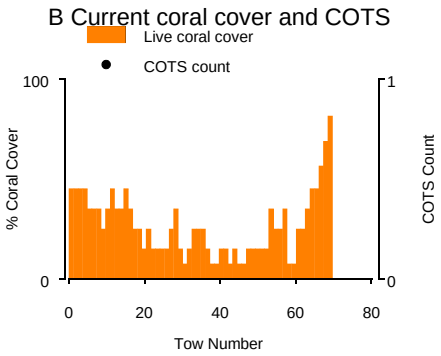
Surveyed November 2001.

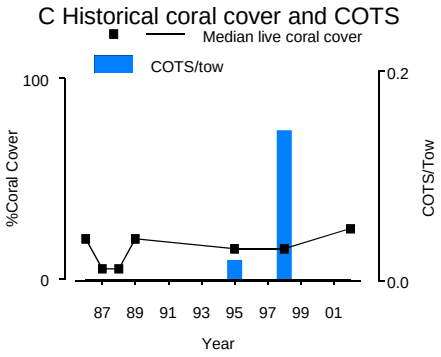
This reef has been surveyed by manta tow seven times since 1986. Reef-wide live coral cover has remained moderate (10-30%) with a slight increase in recent years. COTS have been observed on this reef during two surveys. In both instances they were at low densities that should not have caused significant coral mortality. Reef-wide live coral cover was moderate (10-30%) in 2002 and the reef is classified as No Outbreak. No bleaching was observed in 2002 and white syndrome disease was restricted to a small number of scattered coral colonies.

Figure 4.72

A







Noggin (No. 17-008) is an outer shelf crescentic reef with an area of 9.2 sq.km.

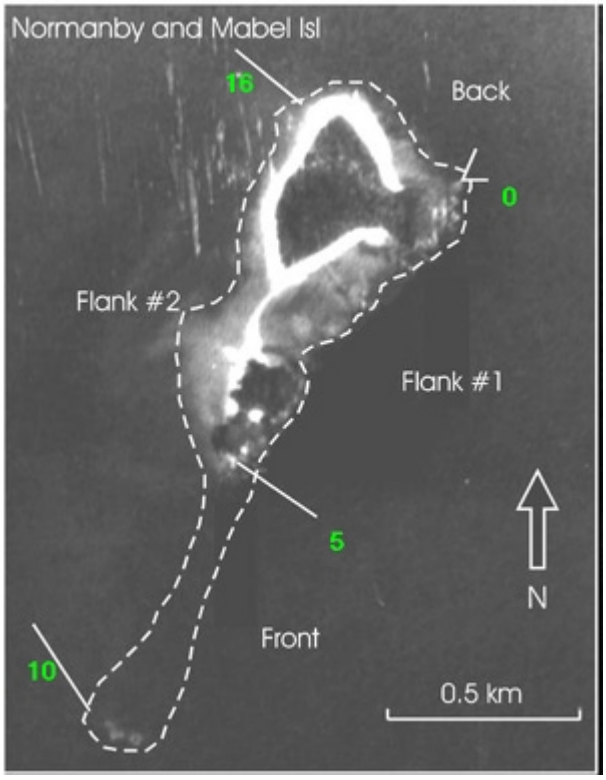
NORMANBY AND MABEL IS'S

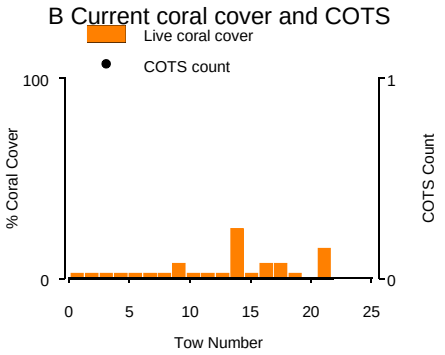
Surveyed November 2001.

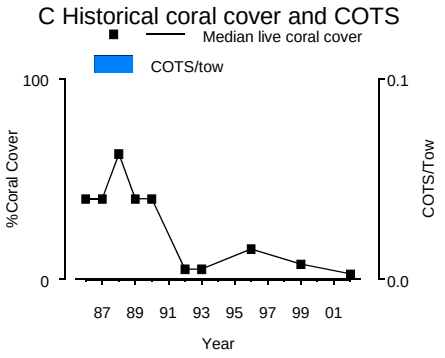
This reef has been sampled regularly since 1986. No COTS have been recorded in any surveys. Reef-wide live coral cover was initially high (30-50%) before a major decline between 1990 and 1992. The reasons for this drop in coral cover were uncertain but flooding from Cyclone Ivor (March 1990) may have been a factor. There was some recovery of reef-wide live coral cover up to 1996 before another period of decline. Reef-wide live coral cover was low (1-10%) in 2002 and the reef was classified as No Outbreak. No bleaching was observed and white syndrome disease was restricted to a small number of scattered coral colonies.

Figure 4.73

A







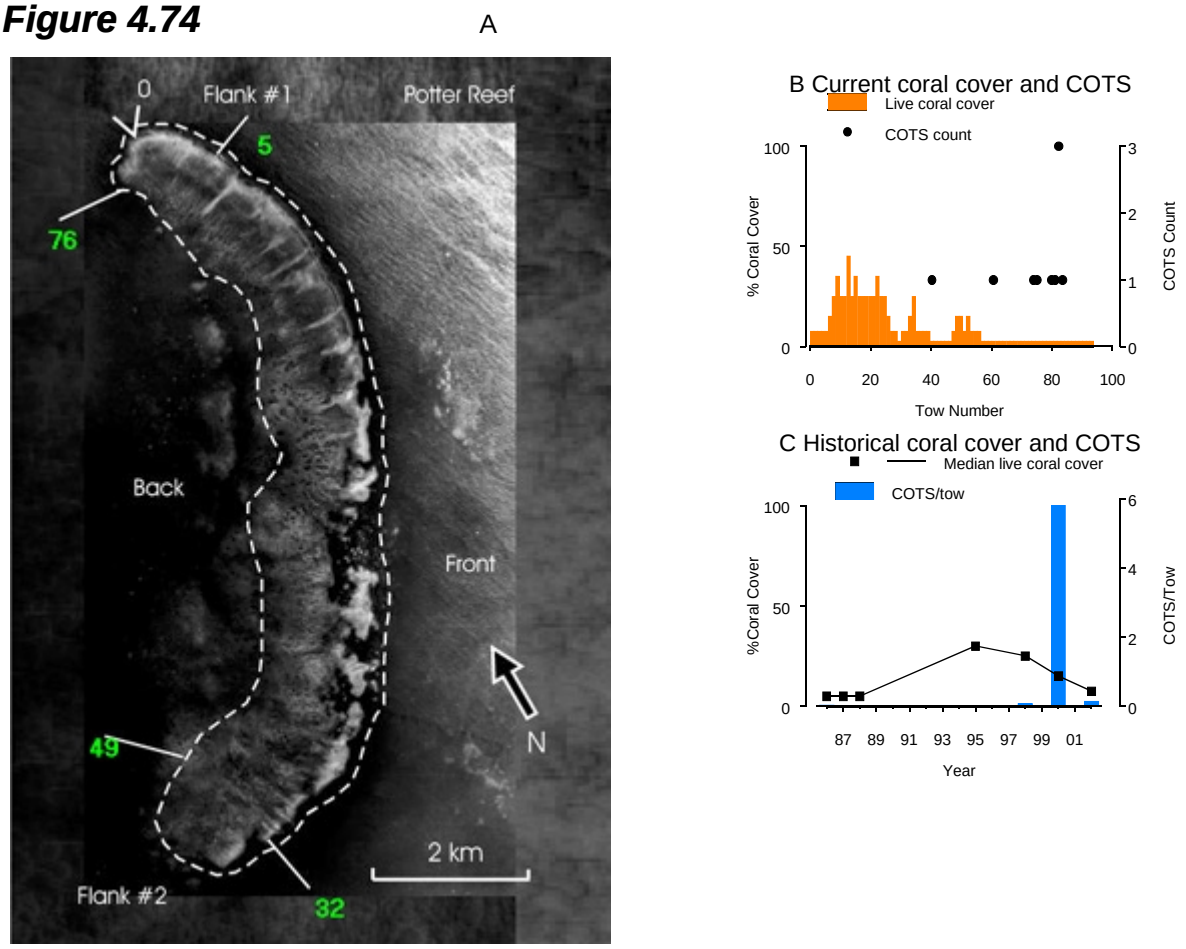
Normanby And Mabel Is'S (No. 17-012) is an inner shelf submerged reef with an area of .4 sq.km.

POTTER (A)

Surveyed November 2001.

This reef has been surveyed seven times since 1986 when it was classified as No Outbreak. Reef-wide live coral cover recovered from low to a moderate levels (10-30%) up until 1995, when small numbers of COTS were observed. Surveys in 2000 indicated large numbers of COTS and the reef was reclassified to an Active Outbreak. As a result of COTS activity reef-wide live coral cover has declined to the current low level (1-10%). Small numbers of COTS remain, but below outbreak levels and the reef was classified as Recovering in 2002. No bleaching was observed and white syndrome disease was restricted to small numbers of scattered coral colonies.

Figure 4.74



Potter (A) (No. 17-059) is an outer shelf submerged reef with an area of 15.7 sq.km.

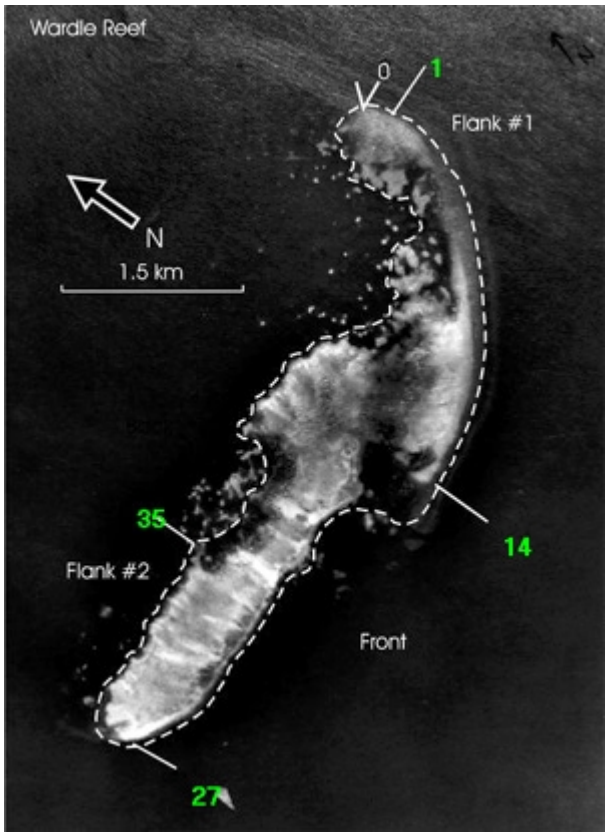
WARDLE

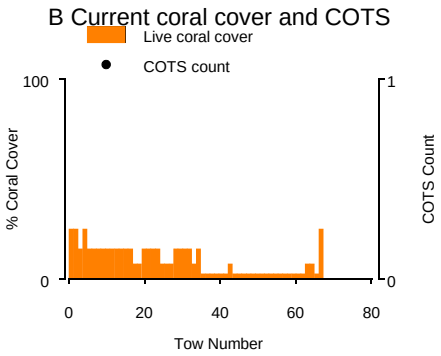
Surveyed November 2002.

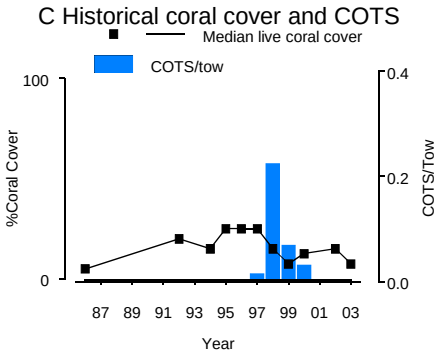
This reef has been surveyed eleven times since 1986, when it was classified as Recovering from COTS activity. There was a gradual recovery of reef-wide live coral cover to a moderate level (10-30%) in 1997. Incipient Outbreak levels of COTS were then recorded in 1998 and by 1999 coral cover had declined to a low level (1-10%). COTS numbers had also declined and the reef was reclassified as Recovering. Reef-wide live coral cover was low in 2003 and no COTS were recorded. No bleaching was seen and white syndrome disease was restricted to a small number of scattered coral colonies.

Figure 4.75

A







Wardle (No. 17-032) is an outer shelf crescentic reef with an area of 11.8 sq.km.

Townsville

Reef Pages

CHICKEN

Surveyed March 2003.

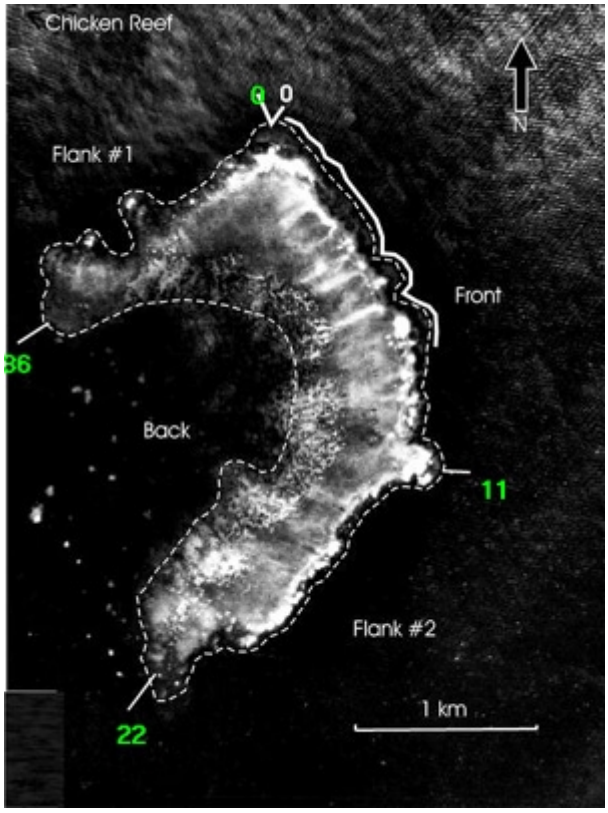
This reef has been surveyed extensively since 1986. Reef-wide live coral cover was initially high (30-50%) but dropped to a moderate level in 1989, possibly due to COTS which were present in some numbers. Median reef-wide live coral cover remained stable at moderate levels (10-30%) between 1989 and 2003. COTS numbers increased sharply in 2003 and the reef was reclassified from No Outbreak to Active Outbreak. Reef-wide live coral cover is expected to decline. White syndrome disease and coral bleaching affected a few scattered coral colonies in the 2003 surveys.

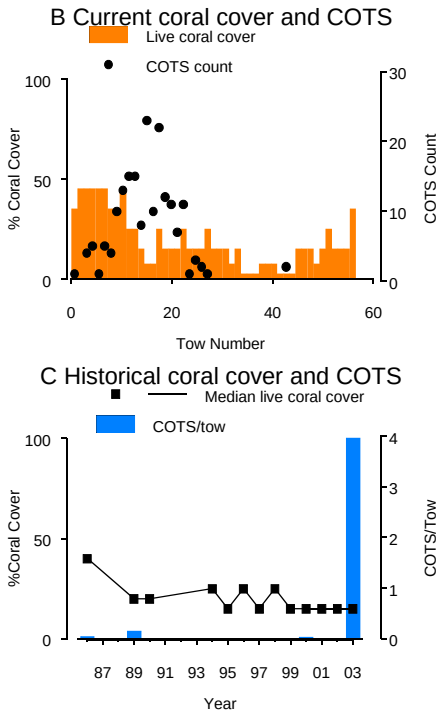
Detailed coral surveys on the north-eastern flank show that coral cover increased from approximately 30% when surveys began in 1993, to 43% in 1999. Coral cover was reduced to 37% in 2000 (possibly due to Cyclone Tessi) and decreased further to 28% in 2003 as a result of crown-of-thorns feeding activity. The observed changes in hard coral cover are mostly due to losses of *Acropora* spp. The soft coral community has been stable over the survey period. Very low levels of white syndrome have been recorded since 1999. SCUBA searches in 2003 recorded adolescent COTS at a density of 22/ha, adult COTS at 387/ha and *Drupella* spp. at 80/ha.

Notable trends in the reef fish community include a long term decline in two common species of surgeonfish (*Acanthurus nigrofuscus* and *Ctenochaetus striatus*). These species have shown declines over the last decade on many outer shelf reefs from Townsville north. The damselfish *Neopomacentrus azysron* also showed a general decline, though numbers have been relatively stable over the last four years. Numbers of parrotfish have tended to reflect changes in coral cover with the lowest abundance for the majority of common species coinciding with the highest coral cover in 1998 and 1999. Numbers of *Plectroglyphidodon lacrymatus* increased dramatically between 2002 and 2003 as they did at several other reefs in the region. Fluctuations in the damselfish genus *Pomacentrus* reflect changes in the numerically dominant species *P. lepidogenys*.

Figure 4.76

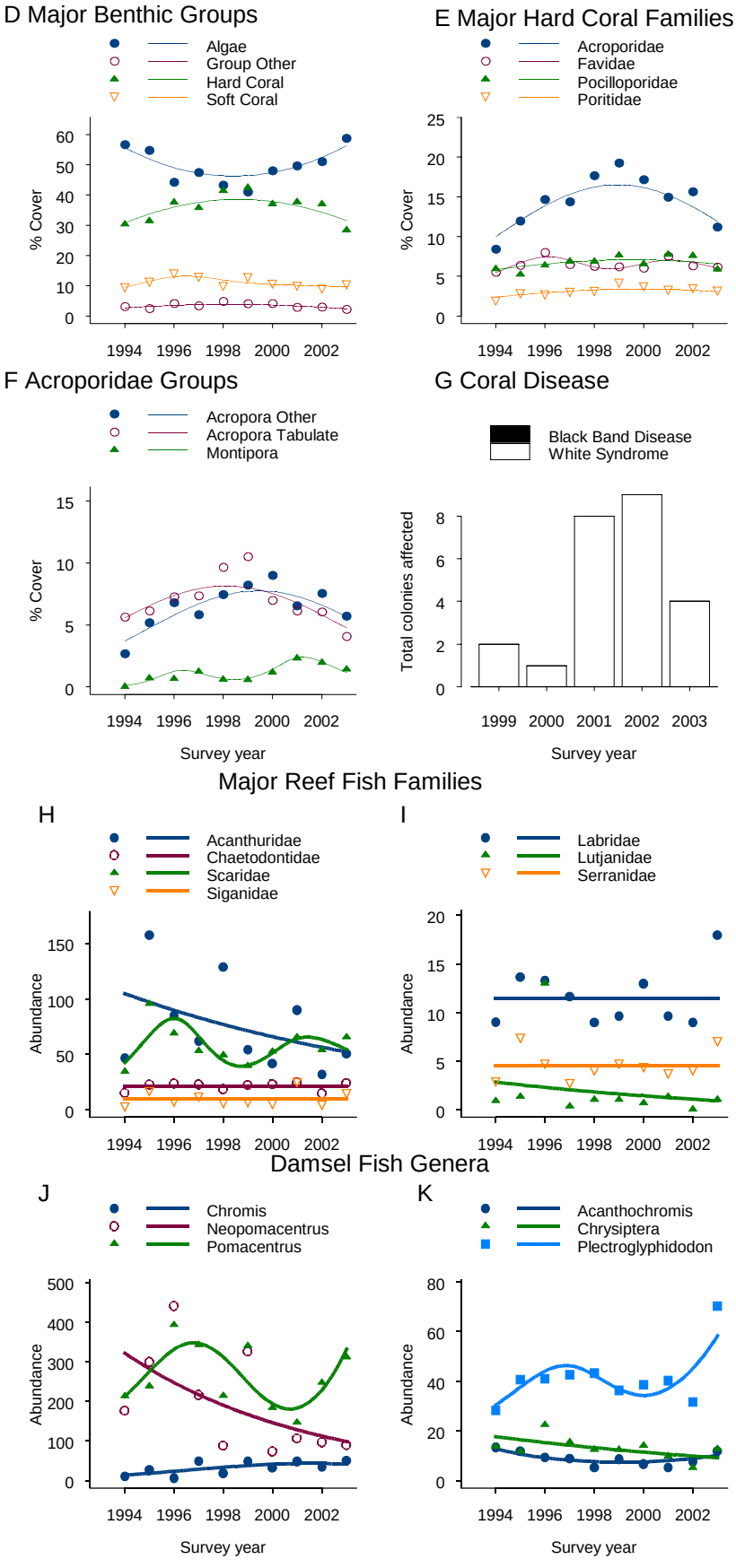
A





Chicken (No. 18-086) is an outer shelf crescentic reef with an area of 3.8 sq.km.

Figure 4.76 (Cont).



DAVIES

Surveyed March 2003.

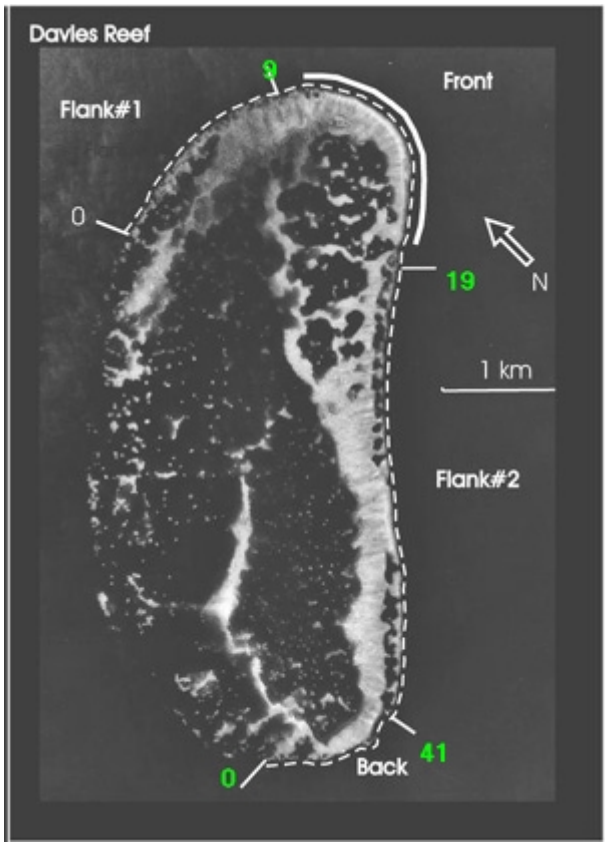
This reef has been surveyed extensively since 1986, when it was originally classified as No Outbreak. In 1988 the COTS numbers increased and the reef was classified as an Active Outbreak. COTS numbers subsequently peaked in 1990 and had declined by 1993 when the reef was reclassified as Recovering. Despite decreased numbers of COTS, median reef-wide live coral cover remained moderate and it was not until 1998 that there was a noticeable increase to a high level (30-50%). Small numbers of COTS were observed in 1997 and 1998 but well below levels that should affect reef-wide live coral cover. Since 1999 there has been a steady decline in coral cover to moderate levels (10-30%) in 2003. Small numbers of COTS were observed in 2003 and white syndrome disease and coral bleaching affected a few scattered coral colonies. The reef was classified as Recovering.

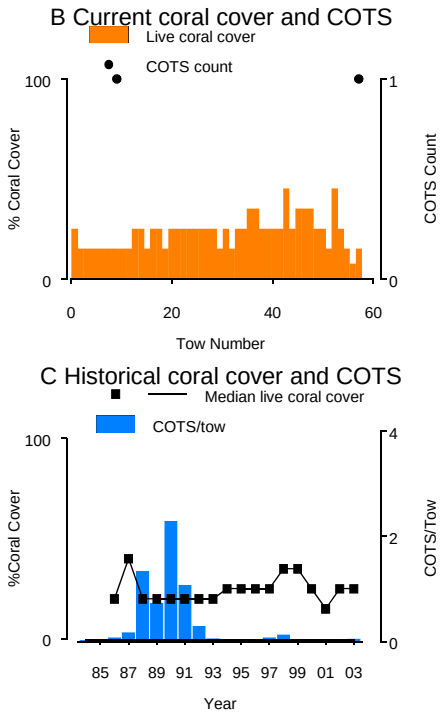
Detailed coral surveys since 1993 show that cover of hard coral on the north-east flank initially increased to 41% in 1998 and has been decreasing since then. In 2003 hard coral cover was 29%. The same trend occurs all the main hard coral families except for Poritidae which remained stable. The decline in hard coral is likely to be a result of multiple low level disturbances with COTS, bleaching and cyclones possible causes of mortality. Soft coral cover has not changed over the survey period and remains low at 2.5%. White syndrome disease has been observed at very low levels since 1999. *Drupella* spp. were recorded during SCUBA searches at a density of 300/ha.

There are no strong trends in reef fish abundance over the last decade. Recent declines in *Pomacentrus moluccensis* may reflect declines in cover of Acroporidae. There have been complementary increases in the less coral dependent *P. brachialis* and *P. wardi*. Patterns in the genus *Pomacentrus* are driven by the abundant *P. lepidogenys* which recruited in high numbers in 1995. Changes in abundance of the genus *Chrysiptera* resulted from similar recruitment pulses for *Chrysiptera rollandi* and *C. talboti*. *Neoglyphidodon* increased in numbers in the first and second surveys but abundance has been stable since.

Figure 4.77

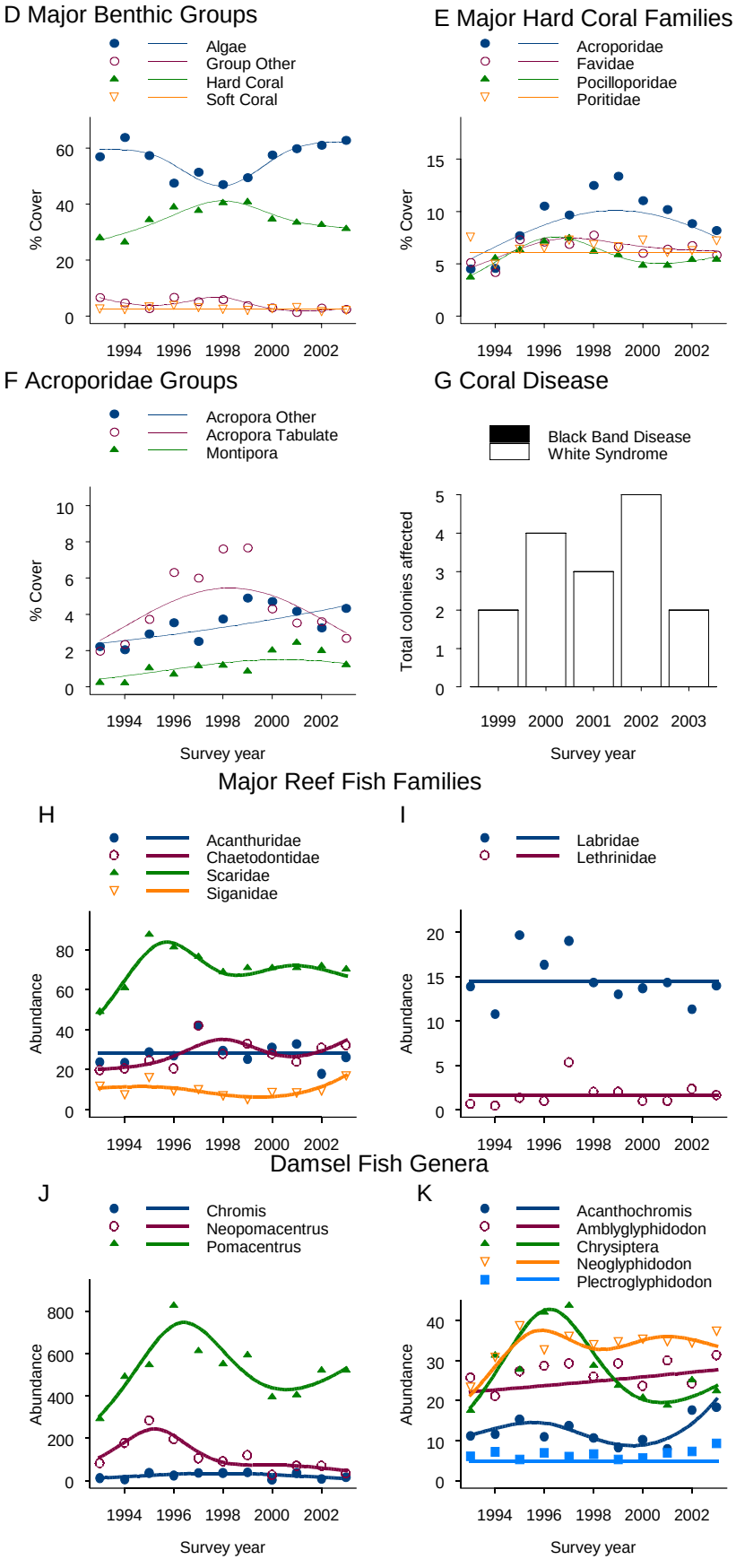
A





Davies (No. 18-096) is a middle shelf lagoonal reef with an area of 13.8 sq.km.

Figure 4.77 (Cont).



DIP

Surveyed March 2003.

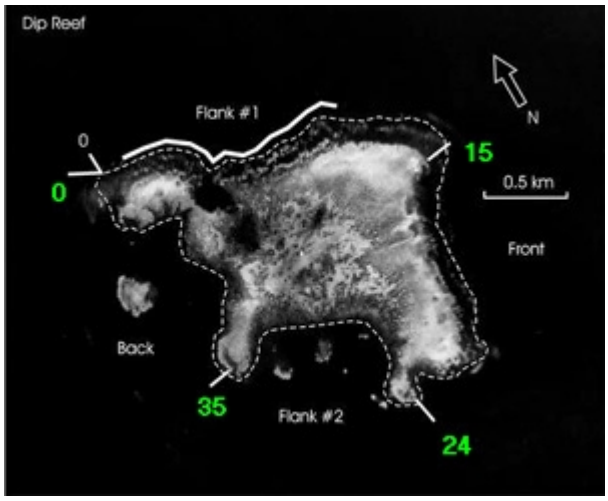
This reef has been surveyed extensively since 1984, when it was classified as No Outbreak. Surveys in 1986 revealed high COTS densities and the reef was reclassified as Active Outbreak. The reef was reclassified as Recovering in 1988. Median reef-wide live coral cover declined dramatically to a low (1-10%) level as a result of COTS activity between 1986 and 1988. From 1988 median reef-wide live coral cover recovered to moderate (10-30%) levels in 1993 and was maintained through to 2003. No COTS have been observed since 1986 and the reef remained classified as Recovering. White syndrome disease and coral bleaching affected a few scattered coral colonies during surveys in 2003.

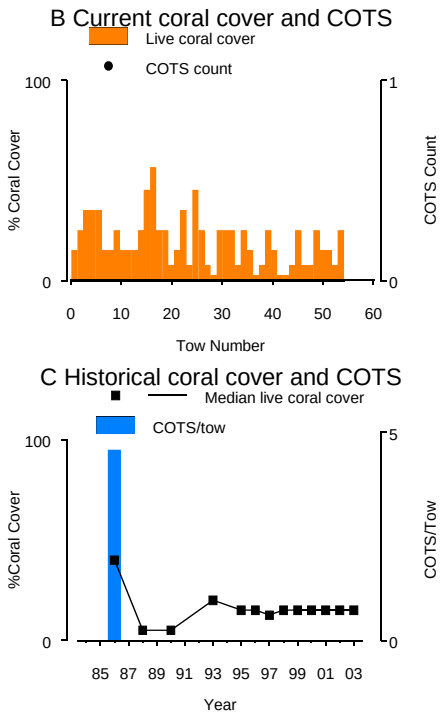
Detailed coral surveys on the northern flank of the reef show that the hard coral community has been relatively stable reaching a maximum of 30% in 1999, and declining slightly to 26% in 2003. No one family dominated the hard coral community however the Acroporidae include relatively high cover of Isopora spp. The decrease in tabulate *Acropora* in 2000 is likely to be due to Cyclone Tessi. The soft coral and algal communities have also been stable over the survey period. Very low levels of white syndrome have been recorded since 1999. *Drupella* spp. were observed during SCUBA searches at a density of 313/ha.

Notable trends in the fish community include declines over several years in the three numerically dominant species of Surgeonfish (Acanthuridae) *Acanthurus nigrofuscus, A. lineatus* and Ctenocheatus *striatus*. Species of wrasse (Labridae) and parrotfish (Scaridae) have shown variable abundance over the period of survey, though many species showed relatively high abundance in 2003. Within the damselfish fauna, *Chrysiptera rex* showed a steady decline between 1996 and 2002 then increased again in 2003. *Neopomacentrus azysron* has had very low abundance in the past two surveys relative to previous years. *Pomacentrus lepidogenys* drives the pattern for the genus with a decline in recent years reflecting a stabilizing of the population following a large recruitment pulse between 1998 and 1999.

Figure 4.78

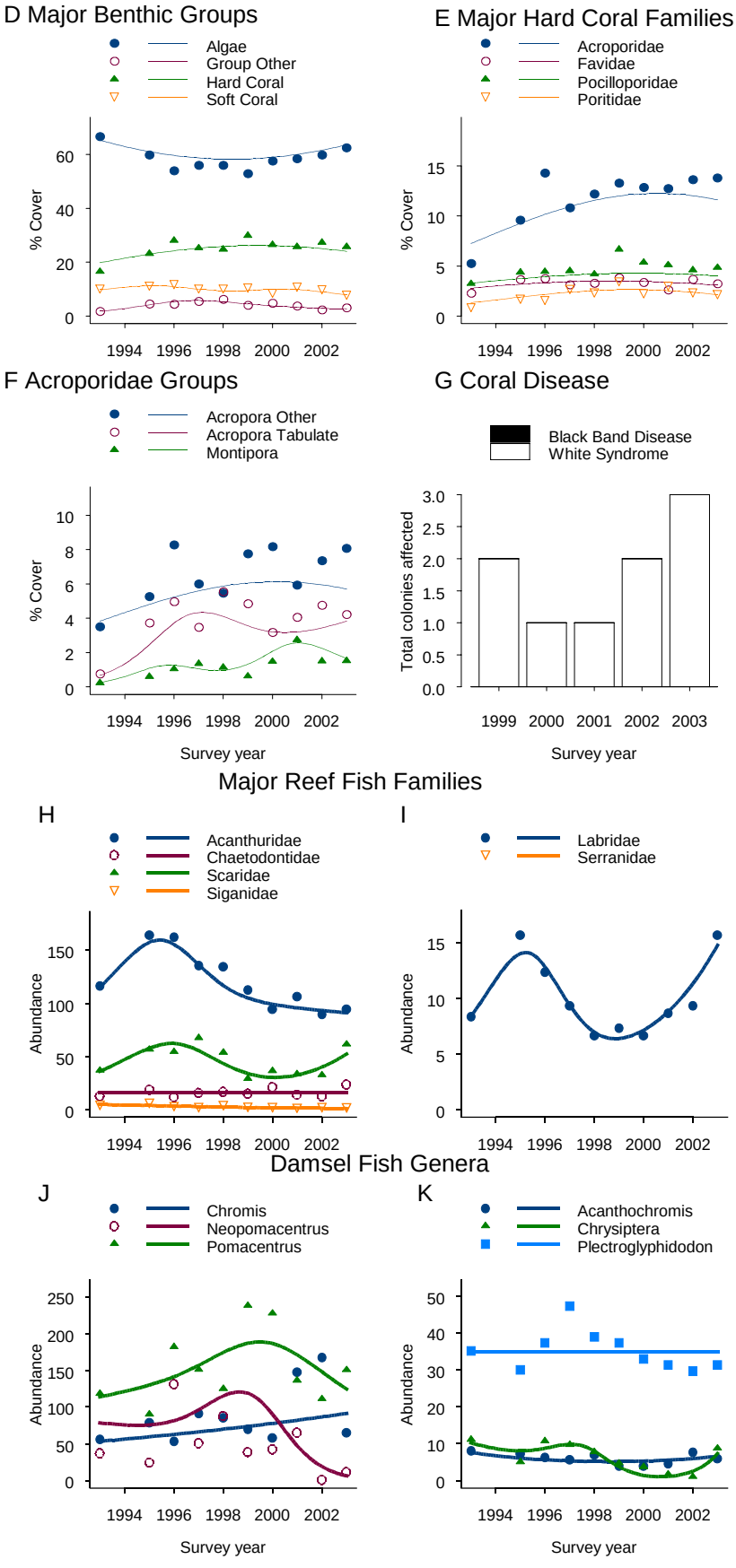
A





Dip (No. 18-039) is an outer shelf crescentic reef with an area of 5.6 sq.km.

Figure 4.78 (Cont).



HAVANNAH IS

Surveyed March 2003.

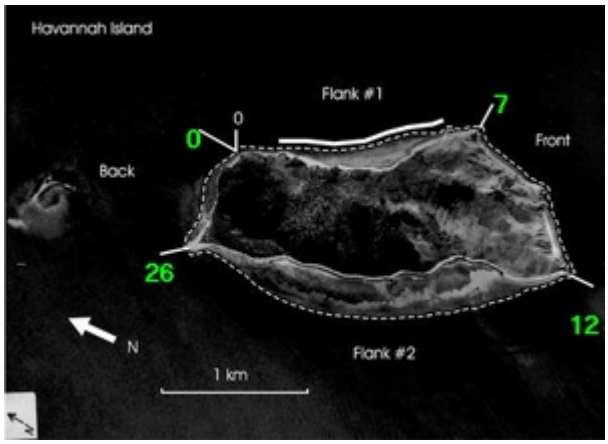
This reef has been surveyed ten times since 1987. Reef-wide live coral cover initially increased from moderate levels in 1987 to high levels by 1997. There was a sharp decrease in median reef-wide live coral cover due to extensive bleaching which was observed during the surveys in 1998. Reef-wide live coral cover continued to decline through to 1999. Surveys in 2003 indicated median reef-wide live coral cover remained very low (1-5%). No COTS have been recorded on this reef in manta tow surveys and the reef was classified as No Outbreak in 2003. No disease and only a low level of bleaching, restricted to a small number of scattered colonies, was recorded.

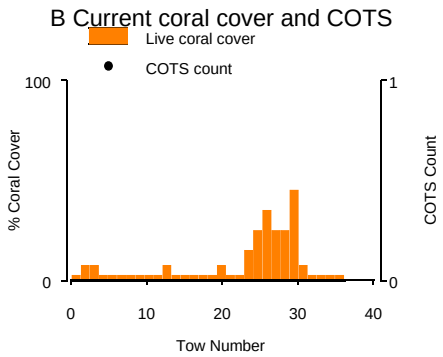
The results of detailed coral surveys show similar trends to the manta tow surveys. Cover of hard corals was initially dominated by branching and bottlebrush corals of the genus *Acropora* (35% cover). By 1999, cover of *Acropora* spp. had declined to 11% as a result of bleaching mortality. Since 1999 other disturbances have contributed to the further decline in hard coral. In 2000 Cyclone Tessi passed close to the reef and in 2001 small COTS were found during SCUBA searches. In 2003 one adolescent COTS was seen and *Drupella* spp. were observed at a density of 33.35/ha. Macro algae have increased in abundance with fleshy species now being the dominant life form at 59% cover. It is possible that the observed decline in soft corals since 2000 (mostly *Briareum* sp.) could be an artifact of the algal canopy reducing sampling efficiency from video tapes.

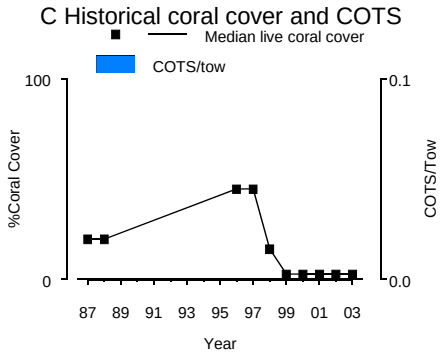
The decline in the coral community is strongly mirrored in the fish community. Of all species that had moderate abundance (more than an average of 1 per transect) during initial surveys only four were not markedly lower in 2003. These resilient species are *Pomacentrus wardi*, *Siganus doliatus*, *Cheilinus fasciatus* and *Acanthochromis polyacanthus*. No species showed comparative increases in abundance. This has resulted in the depauperate fish community observed in 2003.

Figure 4.79

A

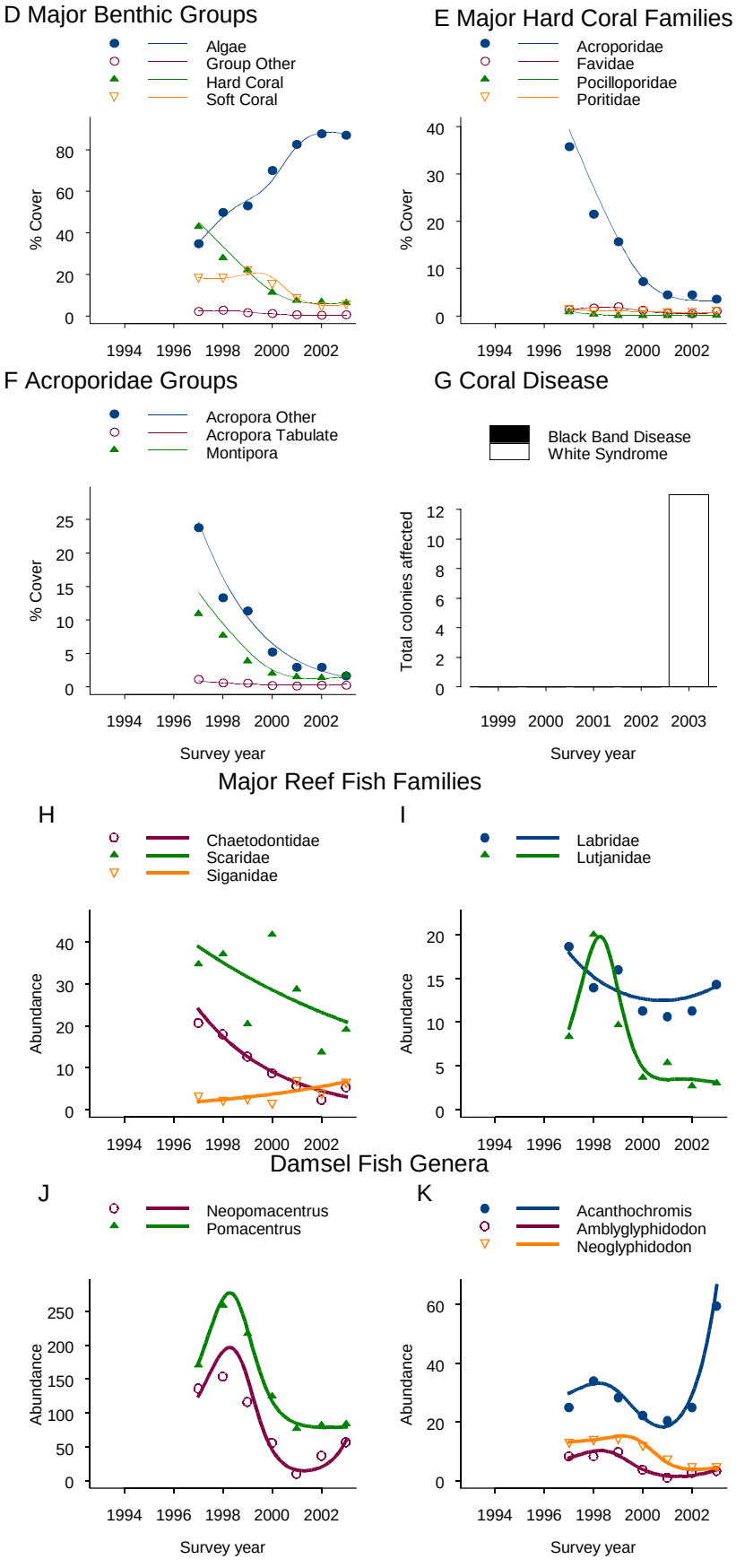






Havannah Is (No. 18-065) is an inner shelf fringing reef with an area of .3 sq.km.

Figure 4.79 (Cont).



JOHN BREWER

Surveyed March 2003.

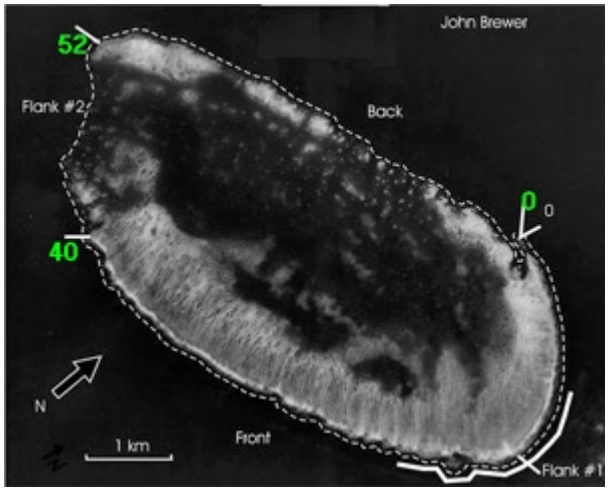
This reef has been surveyed extensively since 1984, when John Brewer Reef had extremely high COTS populations and the reef was classified as an Active Outbreak. COTS populations subsequently declined and in 1986 the reef was reclassified as Recovering. Median reef-wide live coral cover remained low (1-10%) through to 1990 before beginning to increase. Surveys in 1993 showed reef-wide live coral cover had increased to moderate (10-30%) levels and by 1998 reef-wide live coral cover was at high levels (30-50%). Surveys in 2001 recorded high COTS numbers and the reef was reclassified as Active Outbreak. COTS have remained at outbreak levels since this time and there has been a corresponding drop in coral cover to the current very low (1-5%) level. COTS numbers remain high and John Brewer Reef was classified as Active Outbreak in 2003. White syndrome disease and coral bleaching affected a few scattered coral colonies during surveys in 2003.

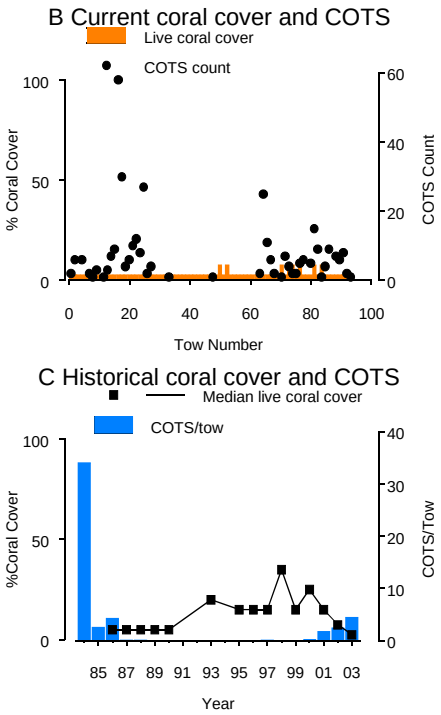
Sites on the north east flank have experienced multiple disturbances since 1997. In 1996 hard coral cover reached a maximum of 32%. Hard coral cover declined slightly in 1997 and this was attributed to the impact of Cyclone Justin on tabulate *Acropora*. A low level of coral bleaching was recorded in 1998 and 1999 and cover of hard corals did not increase significantly over these years. By 2003 total coral cover had declined dramatically to 2% as a result of crown-of-thorns feeding activity. The cover of soft corals also declined to 1%. The algal community was dominated by turf algae (68%). In 2003, 153 adult COTS were observed during SCUBA searches, at an average density of 1020/ha. It is noteworthy that this is the highest density of COTS ever recorded during routine SCUBA searches on any of the AIMS survey reefs. *Drupella* spp. were also observed at a density of 20/ha.

The rapid decline in coral cover over the last two years is yet to be reflected in the fish community. While the abundance of Acanthuridae, Labridae and several damselfish genera declined in concert with coral cover through to 2001, these families have generally increased in abundance through to 2003. It is noteworthy that the species showing increased abundance are not strongly associated with living coral. Whether their increases are a consequence of the rapid drop in coral cover or simply a reflection of high recruitment due to unrelated factors is unknown.

Figure 4.80

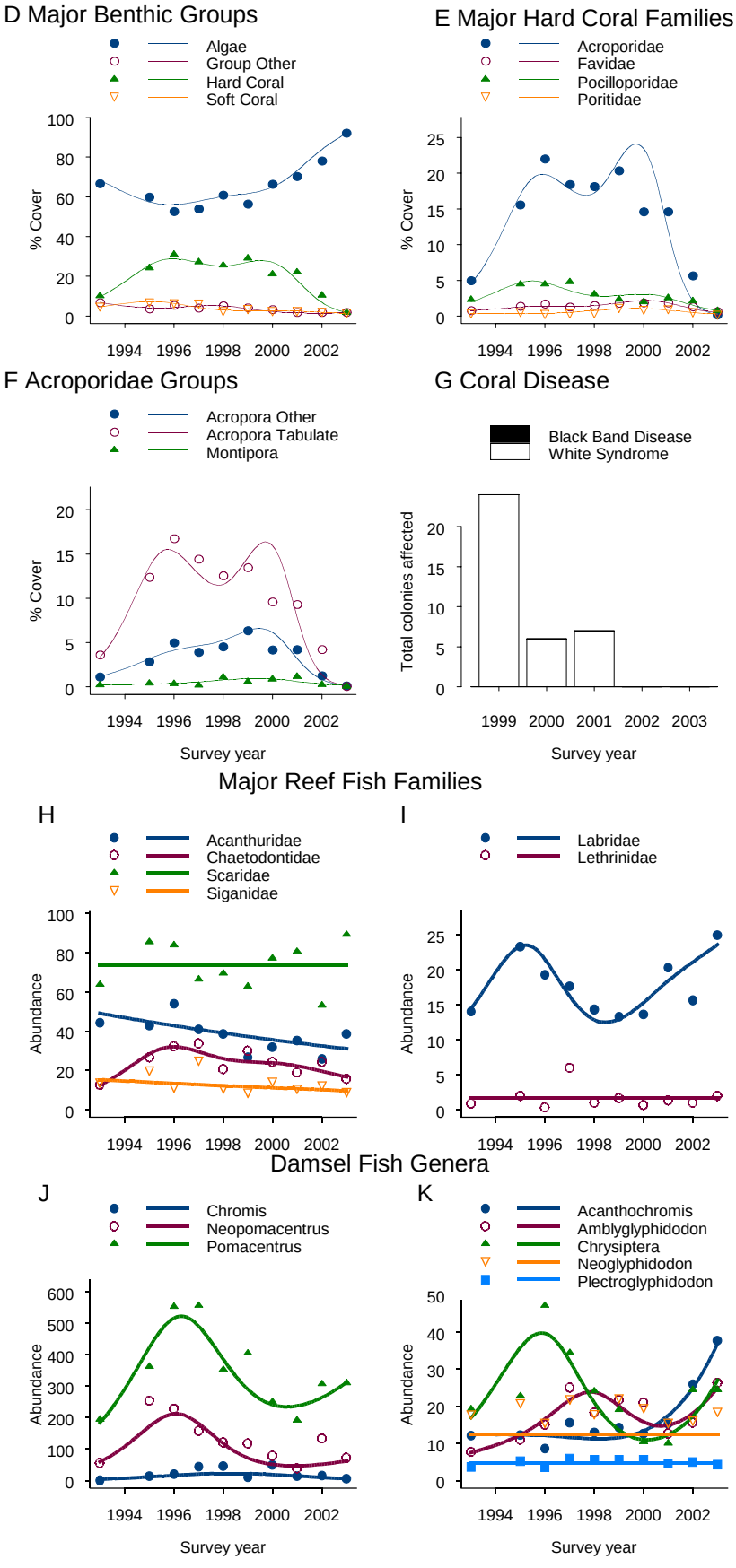
A





John Brewer (No. 18-075) is a middle shelf lagoonal reef with an area of 17.5 sq.km.

Figure 4.80 (Cont).



MIDDLE

Surveyed May 2003.

Manta tow surveys are not conducted on this reef due to poor underwater visibility.

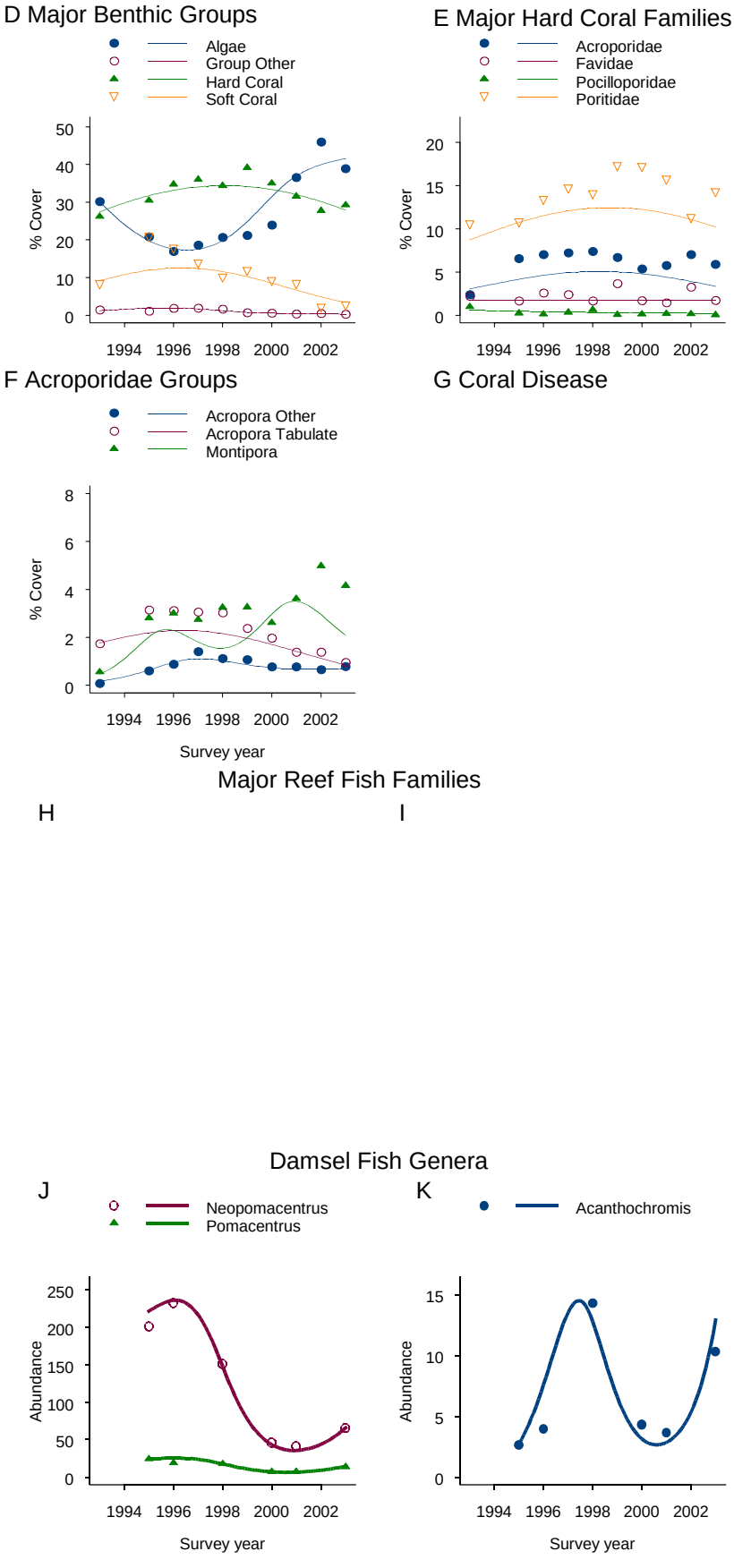
While there was widespread bleaching of both hard and soft corals in 1998, this caused only slight decreases in cover of these benthic groups. There has been a gradual decline in hard coral since 1999 and a significant decline in soft corals since 2002. The soft coral community was dominated by the family Alcyoniidae which have declined from a maximum cover of 12.5% during the survey period to 1% in 2003. Extensive bleaching, which was observed around Magnetic Island in 2002, is the probable cause of the decline.

Surveys of larger reef fishes are not conducted on this reef as visibility is typically too low. The damselfish fauna is dominated by just three species, *Pomacentrus wardi*, *Neopomacentrus bankieri* and *Acanthochromis polyacanthus*. Populations of these fishes have been variable over the period of survey and suggest recruitment to this reef is sporadic.

Figure 4.81 A

Middle (No. 19-011) is an inner shelf planar reef with an area of 1.2 sq.km.

Figure 4.81 (Cont).



MYRMIDON

Surveyed March 2003.

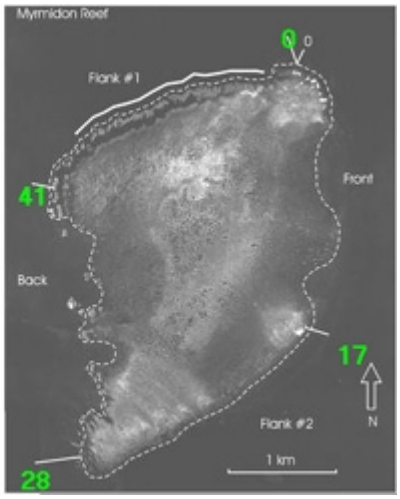
This reef has been surveyed extensively since 1988. Median reef-wide live coral cover remained at moderate levels (10-30%) through to 2003. COTS have only been observed once on this reef and in numbers too low to cause significant coral mortality. Myrmidon Reef was classified as No Outbreak in 2003. White syndrome disease and coral bleaching affected a few scattered coral colonies in 2003.

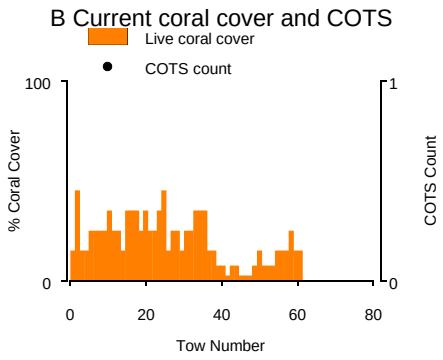
Detailed coral surveys on the northern flank of the reef show that hard coral cover increased until 1999 reaching a maximum of 39%. Hard coral cover decreased in 2000 (attributed to the influence of Cyclone Tessi in April 2000) and again in 2003 to 24%. It is clear that the most recent declines in the Acroporidae were due to bleaching. Declines in the Faviidae, to the lowest level of abundance since surveys began, were also attributed to bleaching. A small decline was also observed in Poritidae. The recent declines in soft coral abundance are probably also due to bleaching mortality. During the 2003 SCUBA searches, *Drupella* spp. were observed at a density of 580/ha.

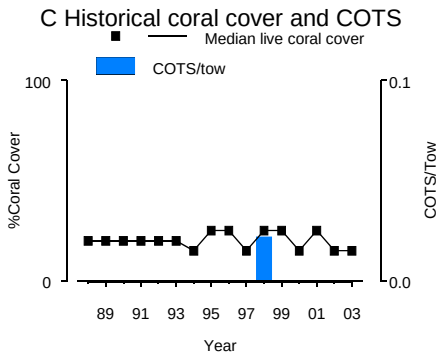
Within the larger reef fish fauna there have been few obvious trends over the period of survey with the exception of the parrotfish (Scaridae) where all five of the numerically dominant species reached the highest abundance in 2003. Several of the smaller damselfishes also showed this pattern. Numbers of *Acanthochromis polyacanthus* and *Plectroglyphidodon lacrymatus* showed marked increases between 2002 and 2003 and several species of *Chromis* also recorded their highest abundance in 2002 or 2003.

Figure 4.82

A

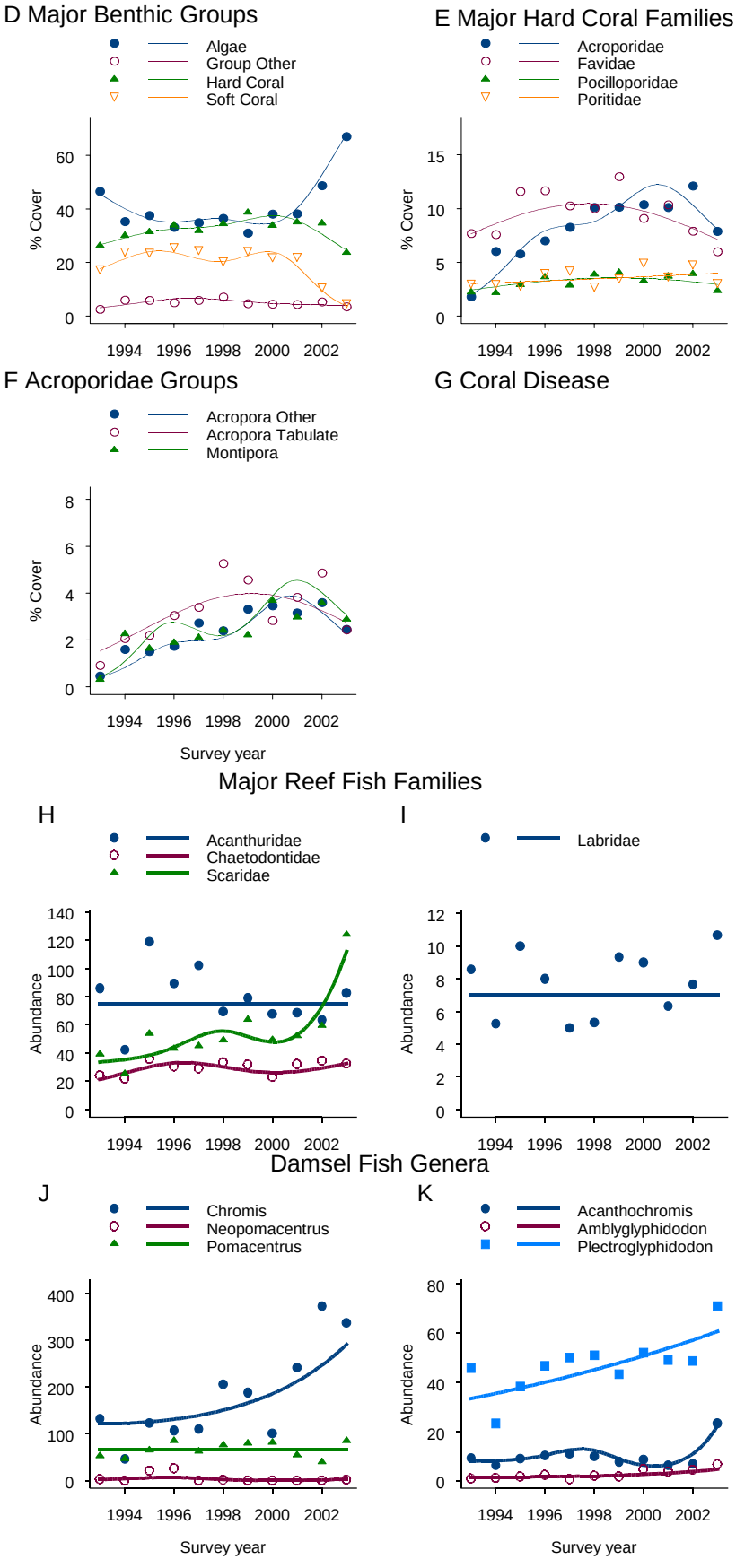






Myrmidon (No. 18-034) is an outer shelf planar reef with an area of 6.2 sq.km.

Figure 4.82 (Cont).



PANDORA

Surveyed March 2003.

Manta tow surveys are not conducted on this reef due to poor underwater visibility.

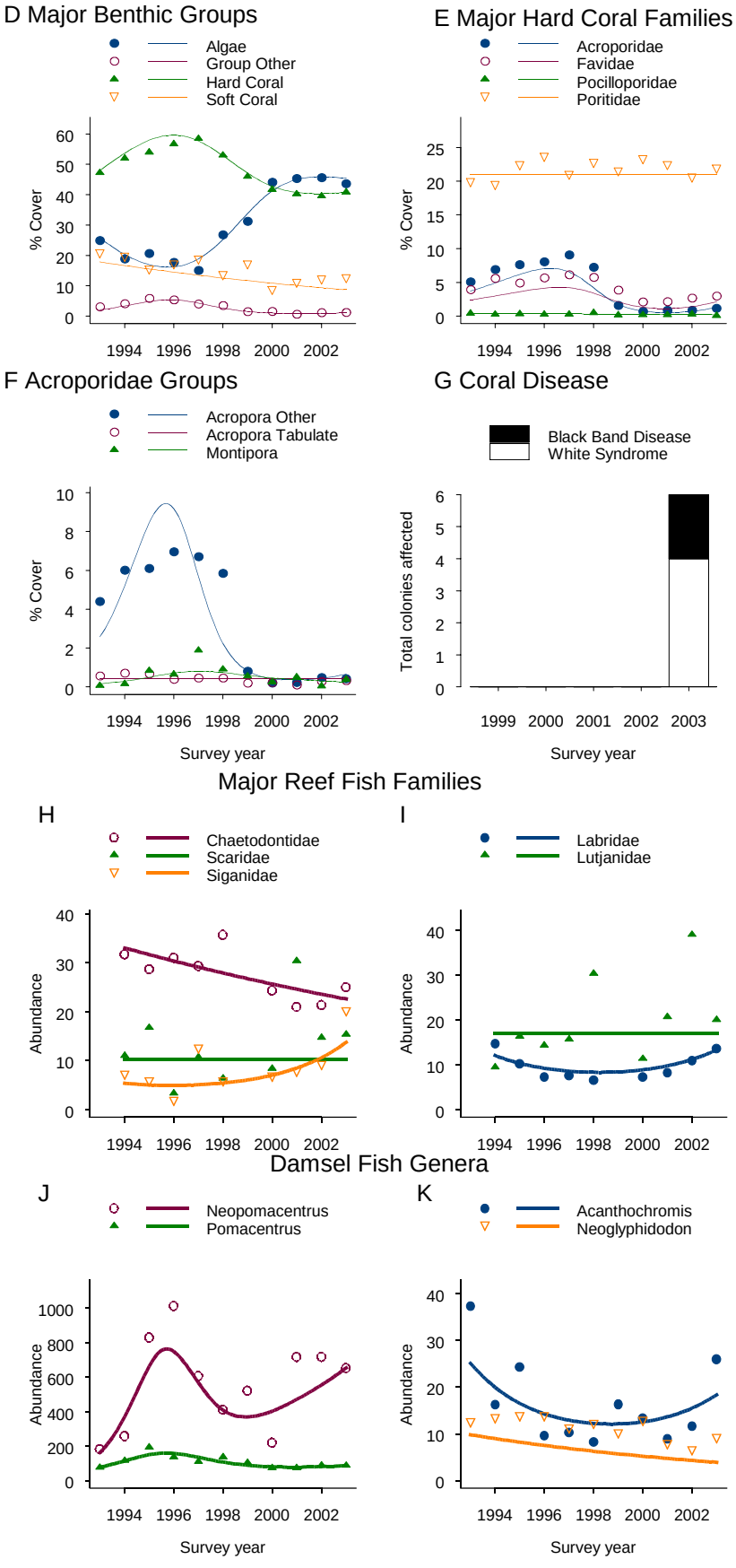
This reef has been surveyed annually since 1993 using visual census for fish and benthic video transects. Between 1993 and 1997 cover of hard coral increased by approximately 12% to a maximum cover of 60% in 1997. Moderate bleaching had affected all abundant hard and soft coral families during the surveys in January 1998. Following these surveys the Townsville region experienced a major flood event and approximately four weeks after these floods, around 80% of the corals on Pandora were bleached to a depth of around 10 metres (Devantier, Fabricius unpublished). Bleaching mortality reduced coral cover to 46% with Acroporidae being most affected. Cover dropped to below 1% and has not recovered. There have been further small declines in hard coral since, possibly due to the impact of Cyclone Tessi in 2000, with foliose corals *Echinopora* spp. and *Turbinaria* spp. being the most affected. Soft coral have been declining over the survey period with the largest decrease recorded following Cyclone Tessi. The density of corallivorous snails *Drupella* spp. was 86.7/ha in 2003.

The majority of fish species show variable or declining populations. Three of the four more common butterflyfishes (Chaetodontidae) show marked declines. Three of the four common damselfish of the genus *Pomacentrus* also show declines while one of these, *P. brachialis*, increased in abundance in 2003. *Acanthochromis* showed a similar pattern with a long-term decline followed by increased abundance in 2003. As on some other inshore reefs, *Siganus doliatus* populations have increased.

Figure 4.83 A

Pandora (No. 18-051) is an inner shelf planar reef with an area of .6 sq.km.

Figure 4.83 (Cont).



RIB

Surveyed March 2003.

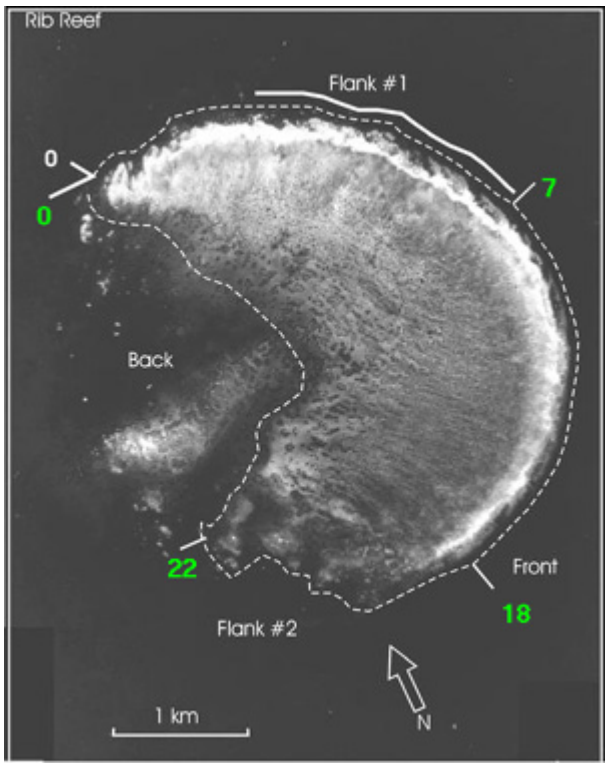
This reef has been surveyed extensively since 1987. A residual COTS population and large areas of old dead coral indicated that Rib Reef had been subject to high COTS populations before that. No COTS were observed in 1988 and the reef was classified as Recovering. Between 1990 and 1994, in the absence of COTS activity, median reef-wide live coral cover increased markedly from low to high levels (40-50%). Cover remained high through to 1998. In 1999 large numbers of COTS were observed and the reef was reclassified as Active Outbreak. Annual surveys through to 2003 showed that COTS numbers have remained at Active Outbreak levels with a corresponding drop in reef-wide live coral cover to a very low (1-15%) level. White syndrome disease and coral bleaching affected a few scattered coral colonies during surveys in 2003.

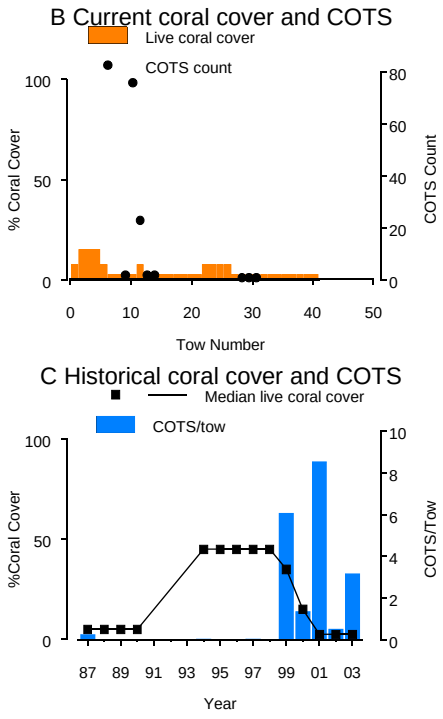
Detailed coral surveys since 1994 show that coral cover reached a maximum of 68% in 1996. A decrease in cover of hard coral in 1997 was attributed to the impact of Cyclone Justin on tabulate *Acropora* spp. Declines since 2000 can clearly be attributed to crown-of-thorns feeding activity. Hard coral cover in 2003 was 3%. Following Cyclone Justin, cover of soft corals declined to approximately half their original levels and no increase has been observed since this time. In 2003, the algal community was dominated by turf algae which were very abundant (72%). *Drupella* spp. have been recorded at densities of up to 1127/ha. on this reef (1999) but in 2003 SCUBA surveys found a density of only 7/ha. As *Drupella* spp. are corallivores it is not surprising that the very low coral cover observed in 2003 did not support a large population. Five adult COTS were observed during the SCUBA searches.

Abundant species of butterflyfish (Chaetodontidae) and the strongly coral associated damselfish, *Pomacentrus moluccensis* and *Chromis atripectoralis*, all declined since the peak in coral cover in 1996. Over this same period less coral dependent species, including *Acanthochromis polyacanthus*, *Amblyglyphidodon curacao*, *Pomacentrus lepidogenys*, *P. wardi*, *Plectroglyphidodon lacrymatus* and several species of parrotfish (Scaridae) increased in abundance. Increases in abundance of these less coral dependent species have been rapid over the last few years when coral cover has been very low.

Figure 4.84

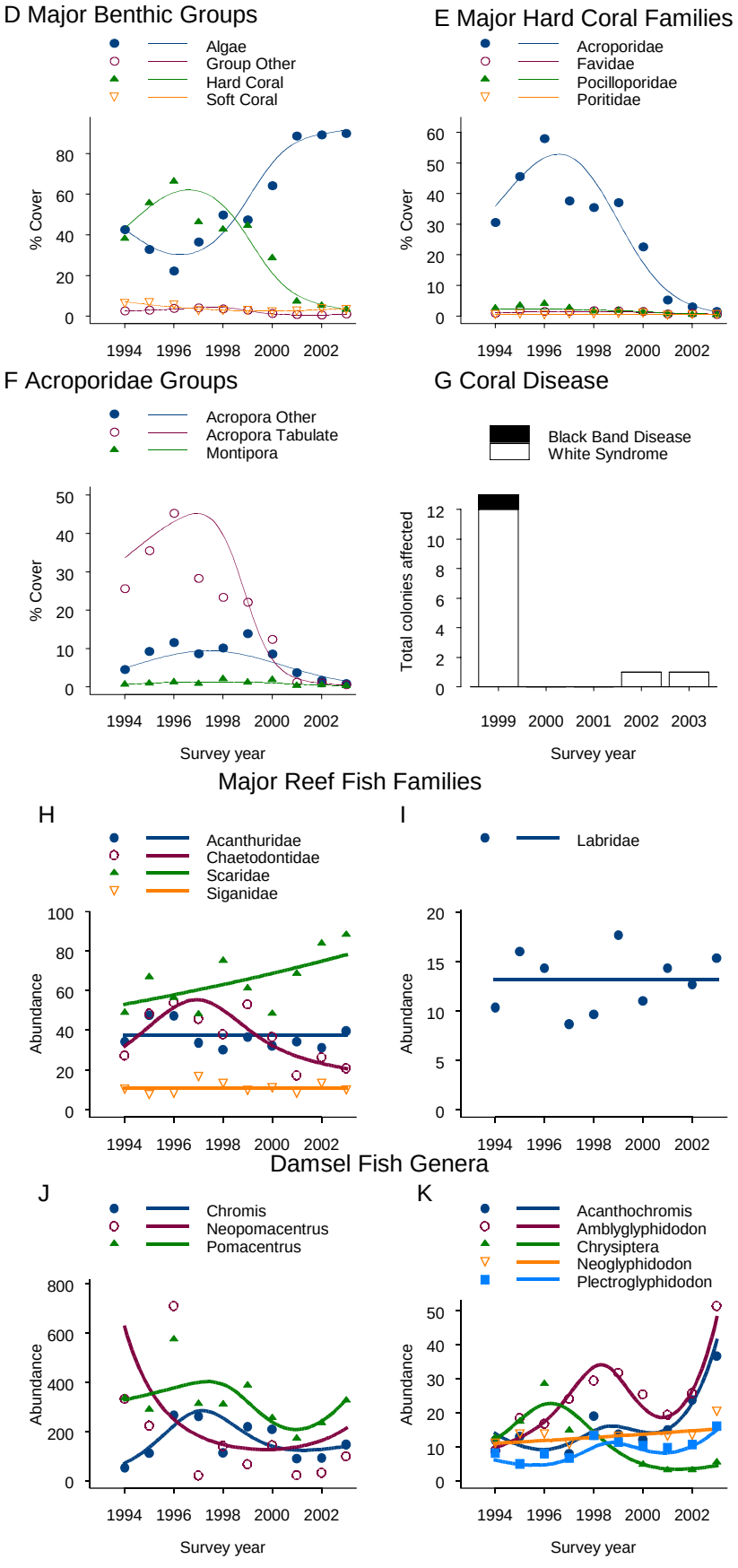
A





Rib (No. 18-032) is a middle shelf crescentic reef with an area of 5 sq.km.

Figure 4.84 (Cont).

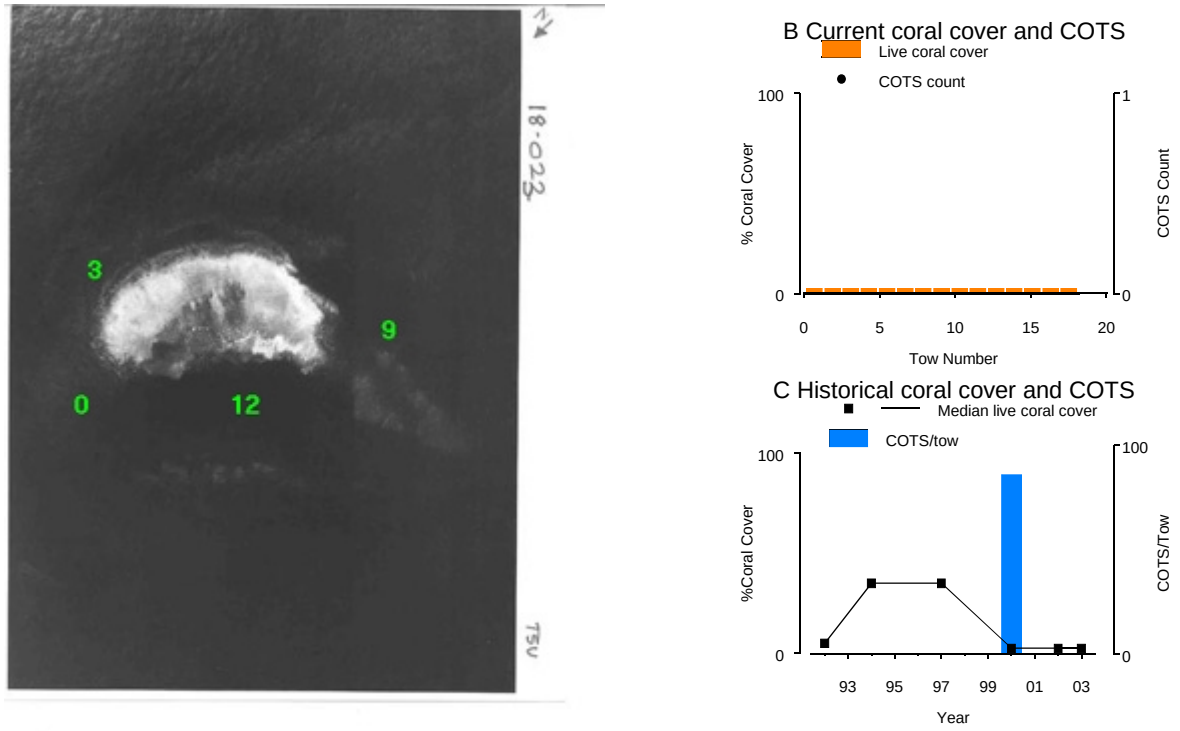


18023

Surveyed December 2002.

This reef has been surveyed six times since 1992. Reef-wide live coral cover was initially low (1-10%) and as there was no history prior to 1992, the reef was classified as No Outbreak. Reef-wide live coral cover subsequently increased to a high level (30-50%) in 1997. Surveys in 2000 revealed extremely high COTS densities and the reef was reclassified as an Active Outbreak. During the surveys an average of more than 85 COTS were observed for every two-minute manta tow. This is the highest density of COTS ever recorded on any reef since the AIMS broadscale surveys began in 1983. COTS feeding activity dramatically reduced the median reef-wide live coral cover from 30-40% in 1997 to less than 5% in 2002 when no COTS were seen and the reef was reclassified as Recovering. In 2003 median reef-wide live coral cover on this reef remained very low (1-5%) and no COTS were seen. No bleaching or signs of disease were recorded from this reef in 2003.

Figure 4.85



18023 (No. 18-023) is an outer shelf reef patches reef with an area of 3.1 sq.km.

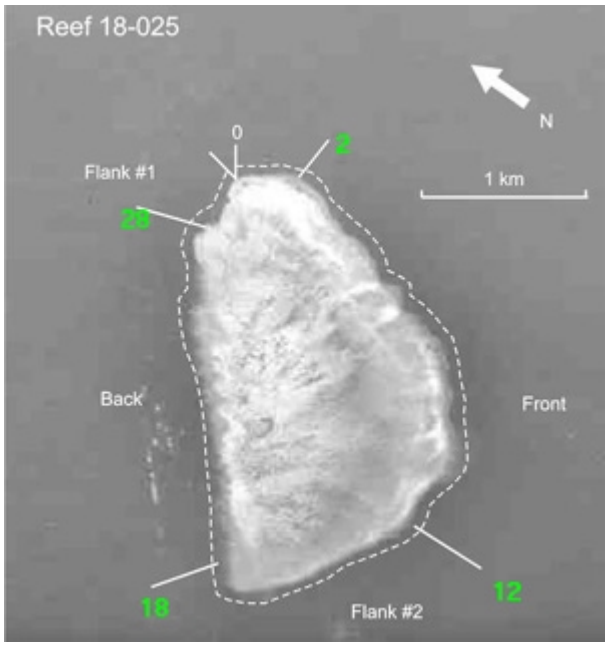
18025

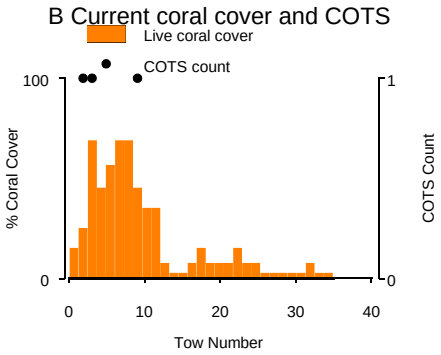
Surveyed February 2002.

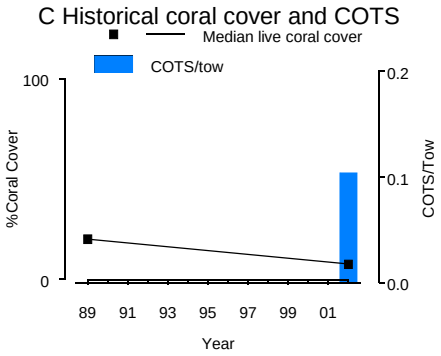
This reef has only been surveyed twice in 1989 and 2002. In 1989 this reef had moderate reef-wide live coral cover (10-30%). No COTS were observed and the reef was classified as No Outbreak. The most recent survey shows that coral cover is currently low (1-10%). Due to the gap between surveys, we can say very little about what has occurred in between. In 2002 there were large areas of long dead *Acropora* colonies, presumably resulting from COTS feeding activity a year or two previously. COTS were observed during surveys in 2002 but in numbers too low to affect overall coral cover. Reef 18025 was classified as No Outbreak.

Figure 4.86

A







18025 (No. 18-025) is a middle shelf reef patches reef with an area of 6.9 sq.km.

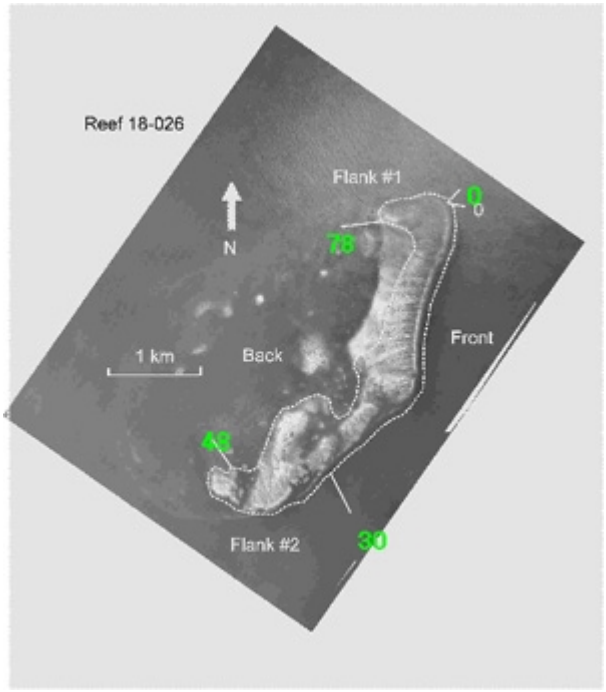
18026

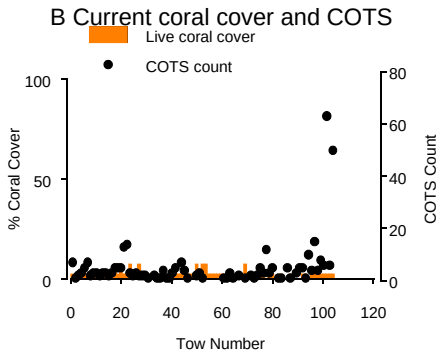
Surveyed February 2002.

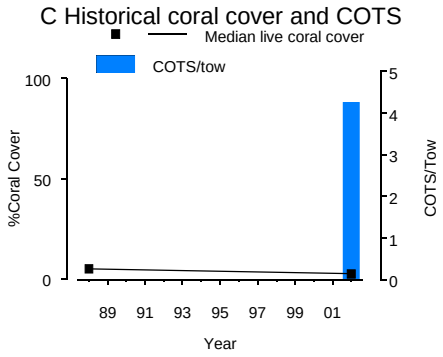
This reef has only been surveyed twice in 1988 and 2002. Reef-wide live coral cover was low (0-10%) in 1988. Although no COTS were observed large areas of dead coral indicated the reef had supported an Active Outbreak of COTS in the recent past and it was classified as Recovering. Reef-wide live coral cover was also low (1-10%) in 2002. Due to the long gap between surveys, we can say very little about what has occurred in between. There were large numbers of COTS in 2002 and the reef was reclassified as Active Outbreak.

Figure 4.87

A







18026 (No. 18-026) is a middle shelf crescentic reef with an area of 26.9 sq.km.

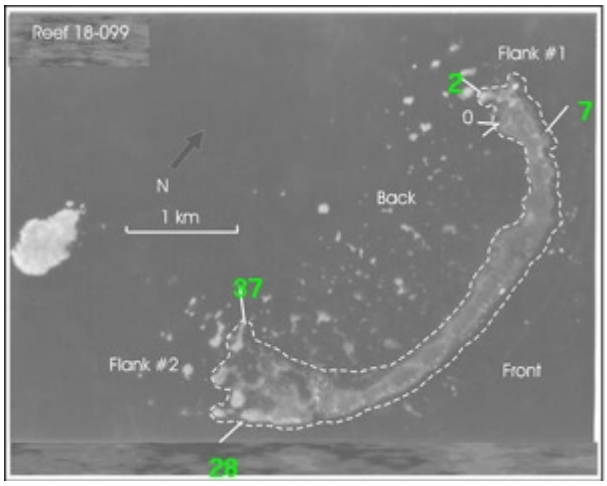
18099

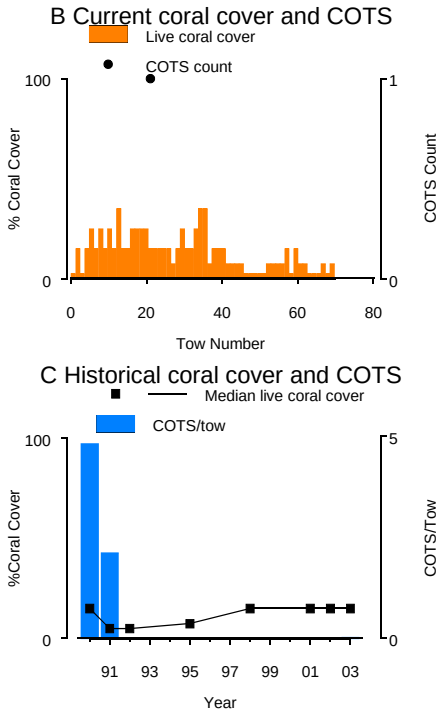
Surveyed March 2003.

This reef has been surveyed eight times since 1990. COTS numbers were high and reef-wide live coral cover was low in 1990 and the reef was classified as an Active Outbreak. No COTS were seen in 1992 and it was reclassified as Recovering. There was then a slow but steady increase in median reef-wide live coral cover to a moderate (10-20%) level in 2003. One COTS was recorded along with white syndrome disease and bleaching of a small number of scattered coral colonies. The reef was classified as Recovering in 2003.

Figure 4.88

A





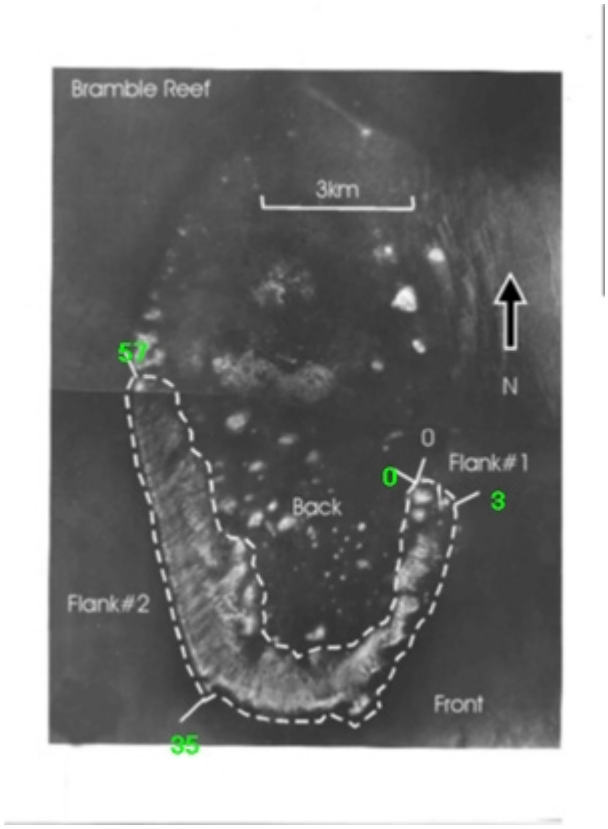
18099 (No. 18-099) is a middle shelf crescentic reef with an area of 12.5 sq.km.

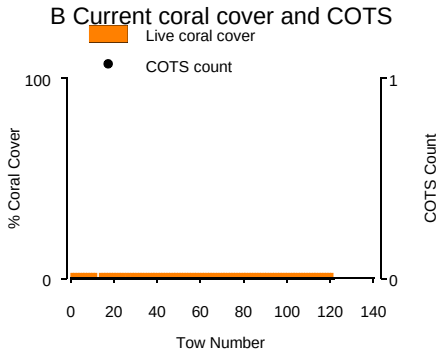
BRAMBLE

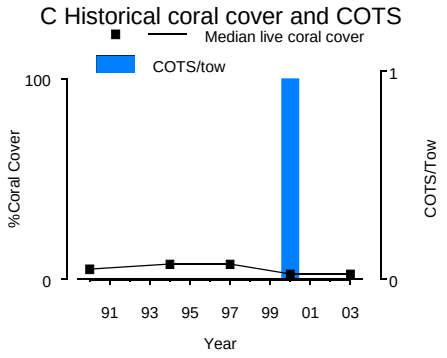
Surveyed December 2002.

Bramble Reef has been surveyed five times since 1990. There was evidence of COTS activity prior to the commencement of surveys so the reef was initially classified as Recovering. Recovery was slow and reef-wide live coral cover remained low (1-10%) until 1997 by which time there were extensive areas of moderate to high coral cover on the front and flanks of the reef. Incipient Outbreak levels of COTS were found in 2000. Median reef-wide live coral cover was very low (1-5%) and the patches of high coral cover were gone. No COTS were seen in 2003 but reef-wide live coral cover remained very low (1-5%). No bleaching or disease was recorded and the reef was reclassified as Recovering.

Figure 4.89 A







Bramble (No. 18-029) is a middle shelf crescentic reef with an area of 61.3 sq.km.

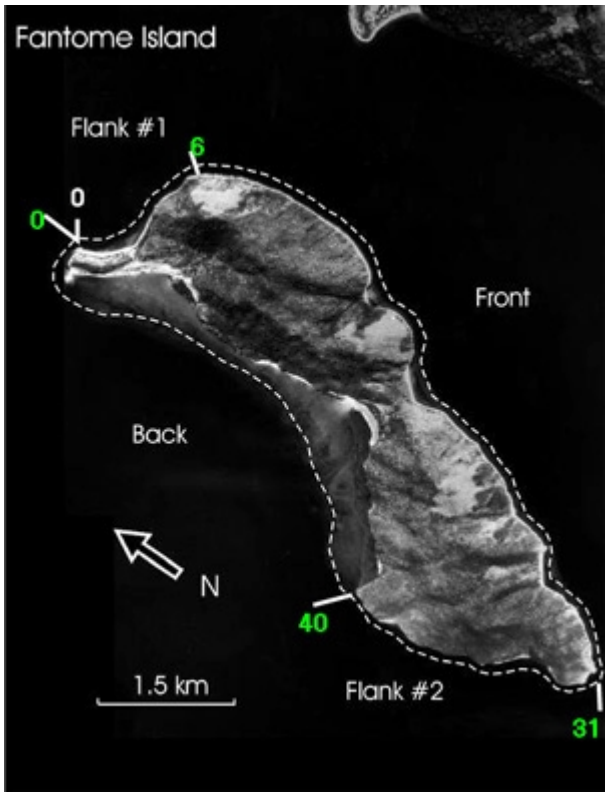
FANTOME IS

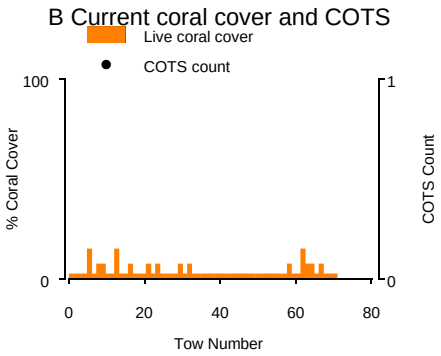
Surveyed December 2002.

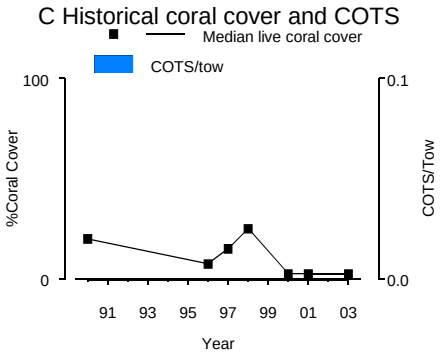
This reef has been surveyed seven times since 1990. Reef-wide live coral cover has varied between moderate and low over this time. No COTS have been recorded and the reef has remained classified as No Outbreak. Reef-wide live coral cover declined from moderate levels (10-30%) in 1998 to a low level in 2000, probably due to the coral bleaching event that severely affected reefs in this area in 1998. Reef-wide live coral cover remained low in 2003. No coral bleaching was observed and white syndrome disease was recorded from a small number of scattered colonies.

Figure 4.90

A







Fantome Is (No. 18-053) is an inner shelf fringing reef with an area of 1.9 sq.km.

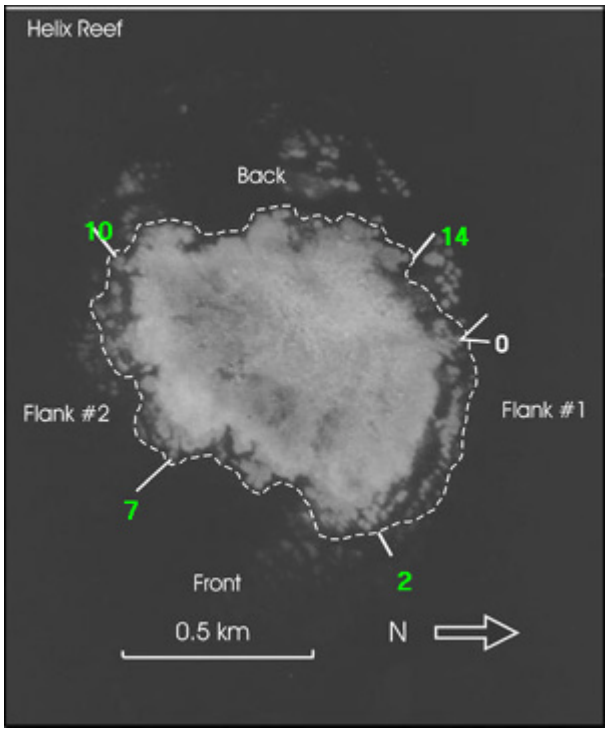
HELIX

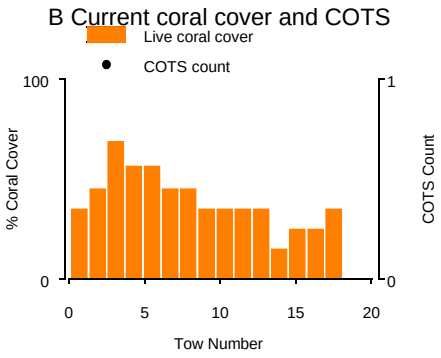
Surveyed March 2003.

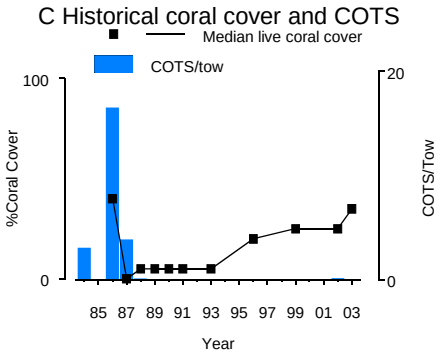
This reef has been surveyed regularly since 1984, when it was classified as an Active Outbreak. Median reef-wide live coral cover was initially high (30-50%) before rapidly declining to an extremely low level (0%) by 1997 due to intense COTS activity. Helix reef was reclassified as Recovering in 1998 and median reef-wide live coral increased (particularly in recent years) to a high level (30-50%) in 2003. No COTS were recorded in 2003 and the reef remained classified as Recovering. White syndrome disease and coral bleaching affected a few scattered coral colonies.

Figure 4.91

A







Helix (No. 18-076) is a middle shelf reef patches reef with an area of .6 sq.km.

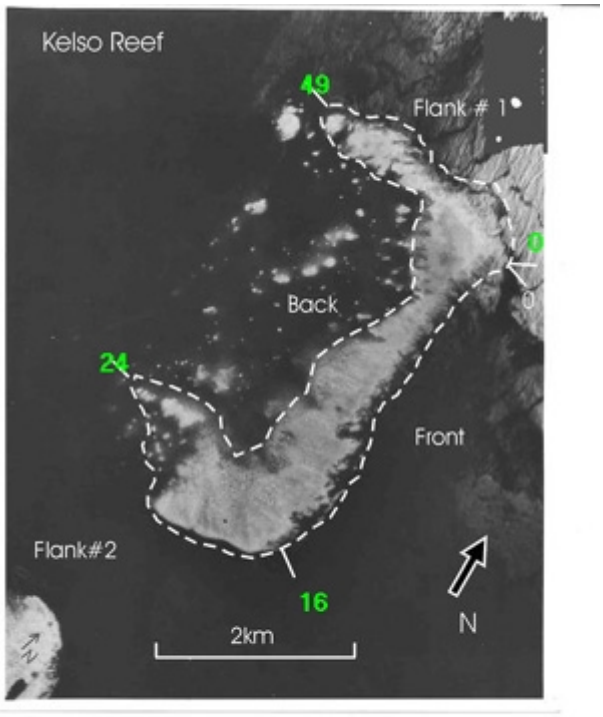
KELSO

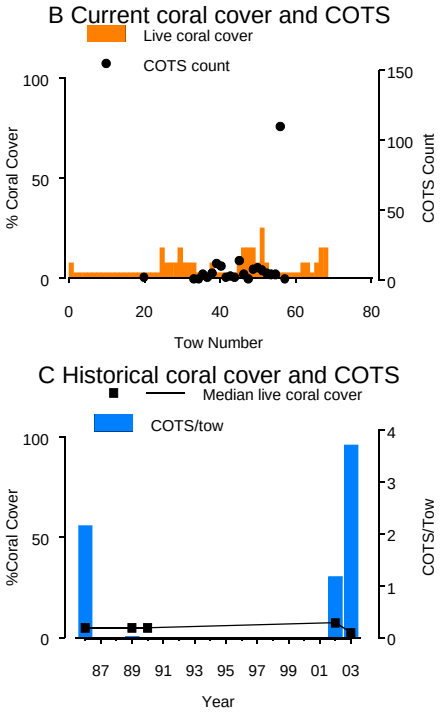
Surveyed November 2002.

This reef has been surveyed five times since 1986 with a long gap between 1990 and 2002. A large COTS population was present in the initial surveys and the reef was classified as Active Outbreak. Only one COTS was observed in 1989 and the reef was reclassified as Recovering. Median reef-wide live coral cover was low (1-10%), presumably as a result of COTS feeding activity. COTS were present again in high numbers at the next survey in 2002 and the reef was reclassified as Active Outbreak. Densities of COTS increased further in 2003. Reef-wide live coral cover was low in 2002 and 2003 but had probably reached at least moderate levels in the late 1990s as was the case on several other reefs in the region (eg John Brewer, Rib, Wheeler) that were more closely monitored. No bleaching or coral disease was recorded in 2003.

Figure 4.92

A





Kelso (No. 18-030) is a middle shelf crescentic reef with an area of 8.79 sq.km.

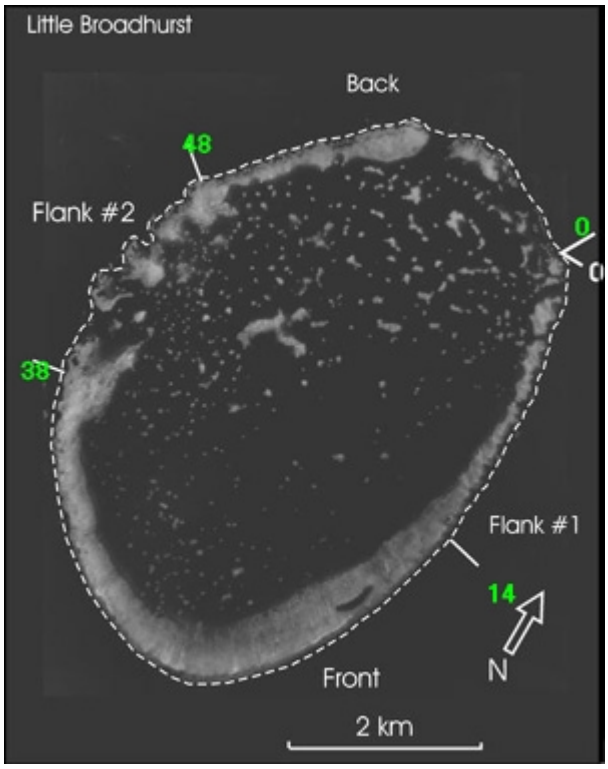
LITTLE BROADHURST

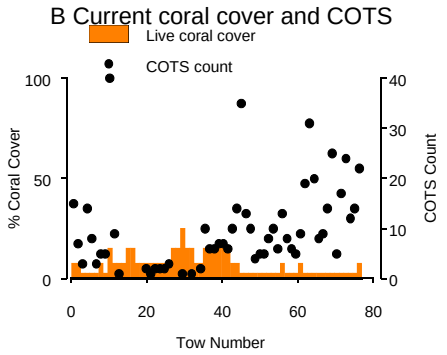
Surveyed March 2003.

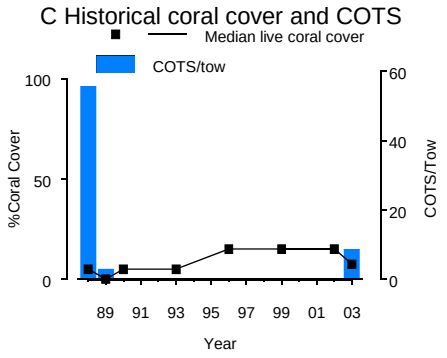
This reef has been surveyed periodically since 1988. Median reef-wide live coral cover was low (1-10%) in early surveys, COTS were extremely abundant and the reef was classified as Active Outbreak. By 1990 COTS densities had dropped dramatically and Little Broadhurst was considered to be Recovering. Reef-wide live coral cover increased and was at moderate (10-30%) levels from 1996 to 2002. COTS numbers increased in 2003 and the reef was reclassified to Active Outbreak. With the increase in COTS activity there was a decline in reef-wide live coral cover to low levels. White syndrome disease and coral bleaching affected a few scattered coral colonies during surveys in 2003.

Figure 4.93

A







Little Broadhurst (No. 18-106) is a middle shelf lagoonal reef with an area of 12.5 sq.km.

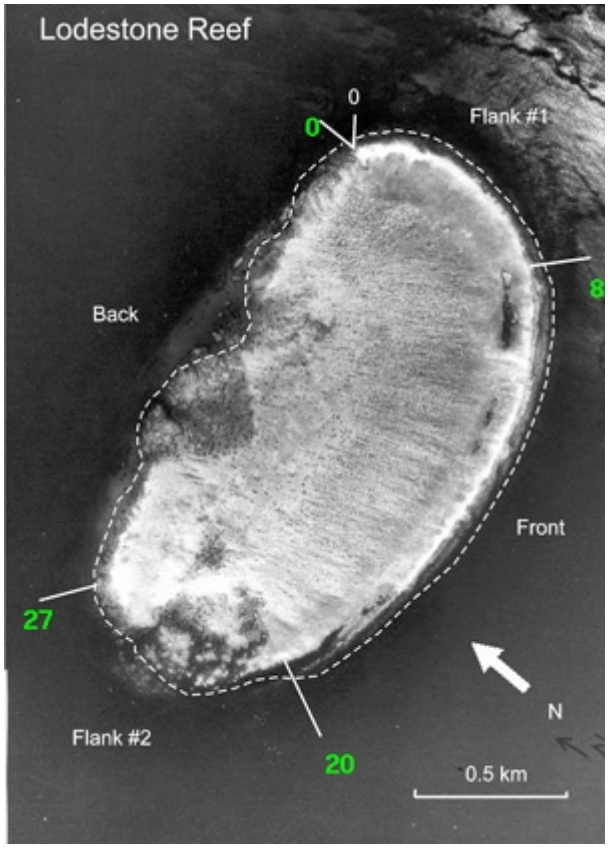
LODESTONE

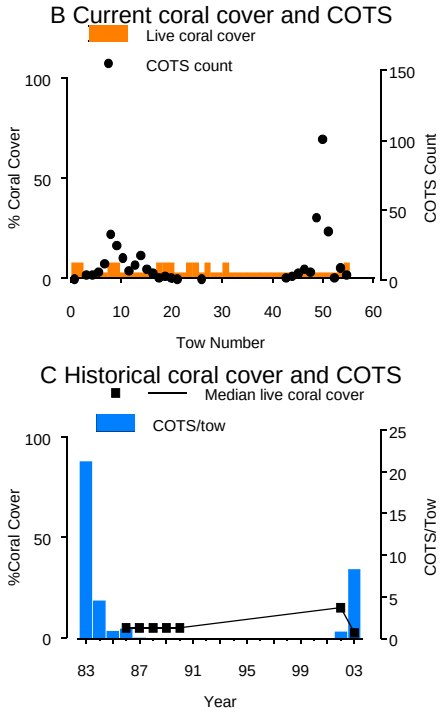
Surveyed April 1996.

This reef was surveyed frequently during the 1980s but was not surveyed between 1990 and 2002. In 1983 there were very large numbers of COTS and the reef was classified as Active Outbreak. This classification remained until 1987 when the reef was reclassified as Recovering. Reef-wide live coral cover had been reduced to a low (1-10%) level by COTS feeding activity. By 2002 median reef-wide live coral cover had increased to a moderate level (10-30%) but COTS numbers had reached Incipient Outbreak levels again. In 2003 COTS numbers had increased to be an Active Outbreak and reef-wide live coral cover had declined to very low levels (1-5%). No incidence of white syndrome disease and only low levels of coral bleaching were recorded during surveys in 2003.

Figure 4.94

A





Lodestone (No. 18-078) is a middle shelf planar reef with an area of 5 sq.km.

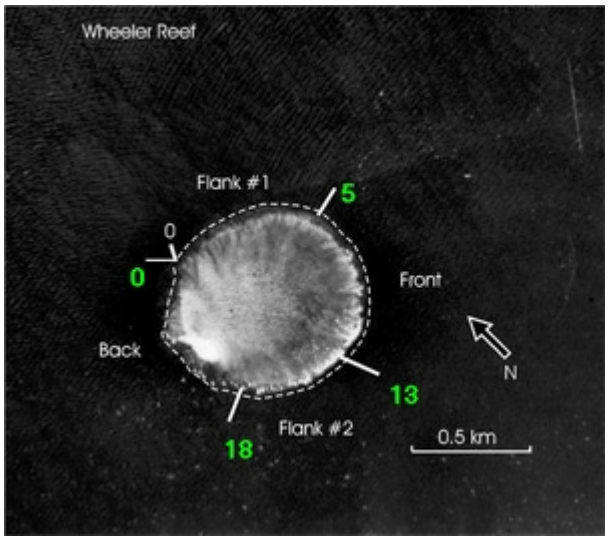
WHEELER

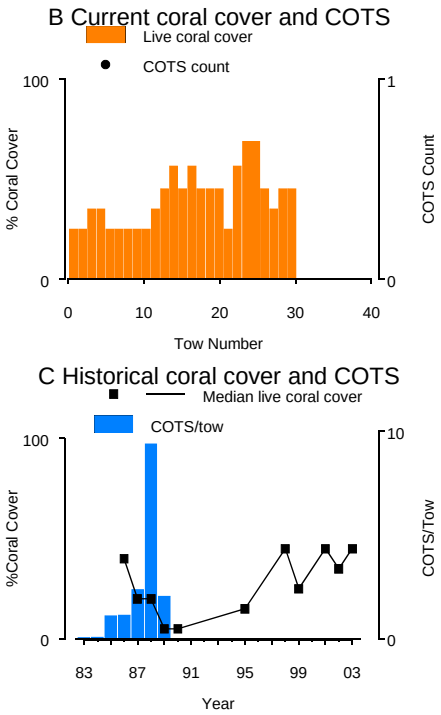
Surveyed March 2003.

This reef was first surveyed in 1983, when it was classified as No Outbreak. Active Outbreak levels of COTS were first observed in 1985 and remained through to 1989, with a peak in 1988. No COTS have been observed since 1990 and the reef was reclassified as Recovering in 1991. Median reef-wide live coral cover dropped from a high level (30-50%) in 1986 to a low level (1-10%) in 1988. It has since recovered to the high levels (30-50%) recorded in the early 1980s. White syndrome disease and coral bleaching affected a few scattered coral colonies during surveys in 2003.

Figure 4.95

A





Wheeler (No. 18-095) is a middle shelf planar reef with an area of 1.9 sq.km.

Cape Upstart

Reef Pages

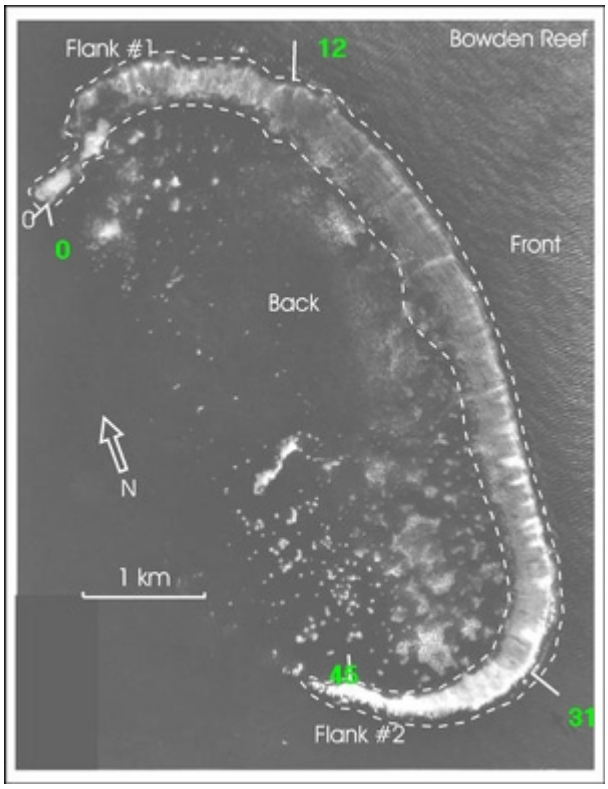
BOWDEN

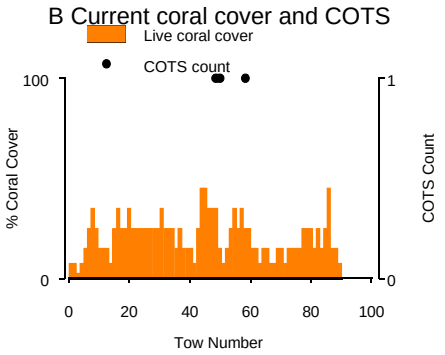
Surveyed November 2002.

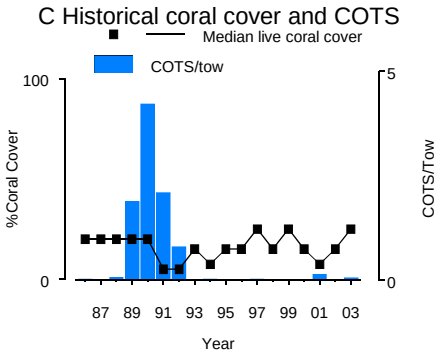
Bowden Reef has been surveyed annually since 1986. A major outbreak of COTS between 1989 and 1991 resulted in a sharp decline in reef-wide live coral cover from a moderate (10-30%) to a low level (1-10%). From 1993, COTS numbers remained very low and reef-wide live coral cover slowly increased. COTS were present in 2002 but they remained below outbreak levels. Manta tow surveys in 2003 indicated moderate reef-wide live coral cover and small numbers of COTS that would not be expected to cause significant coral mortality. Low levels of bleaching, white syndrome disease and black band disease were observed on a few scattered coral colonies during manta tow surveys in 2003.

Figure 4.96

A







Bowden (No. 19-019) is a middle shelf crescentic reef with an area of 9.4 sq.km.

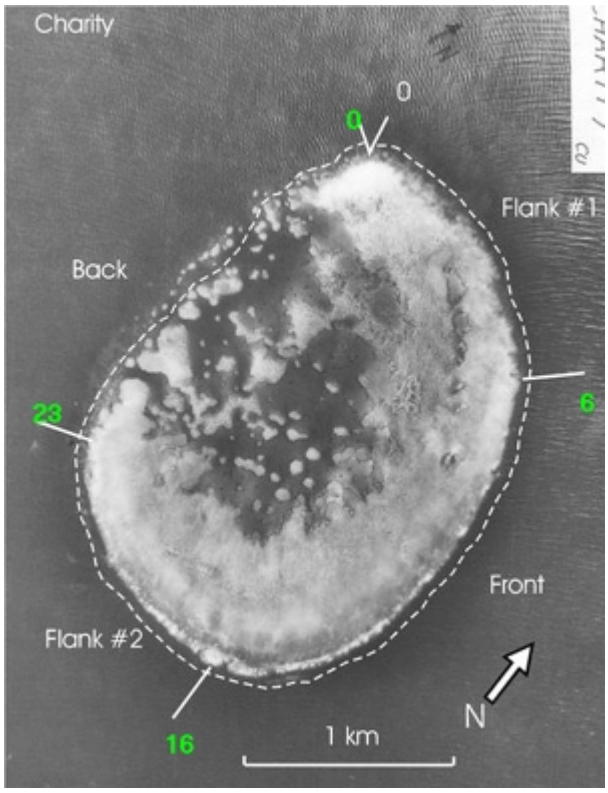
CHARITY

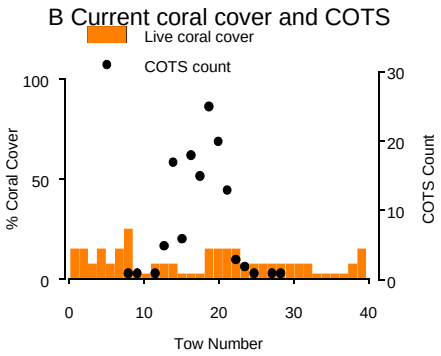
Surveyed December 2002.

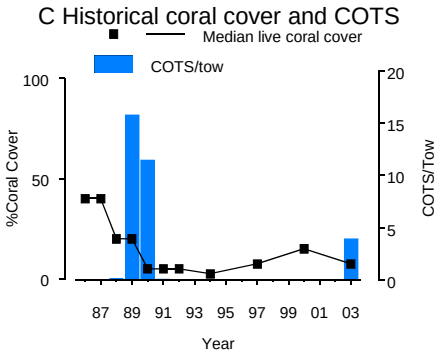
Charity Reef has been manta tow surveyed eleven times since 1986. Reef-wide cover of live coral was initially high (30-50%) but dropped to less than 10% in 1990 due to a COTS outbreak. Coral cover remained low (1-10%) until 1994 when it began to recover. No COTS were seen from 1992 until 2003. Reef-wide live coral cover reached moderate levels (11-30%) in 2000 but in 2003 there were outbreak densities of COTS again and coral cover had declined to a low level (1-10%). No bleaching was observed and white syndrome disease was restricted to a few scattered colonies.

Figure 4.97

A







Charity (No. 19-047) is a middle shelf crescentic reef with an area of 3.8 sq.km.

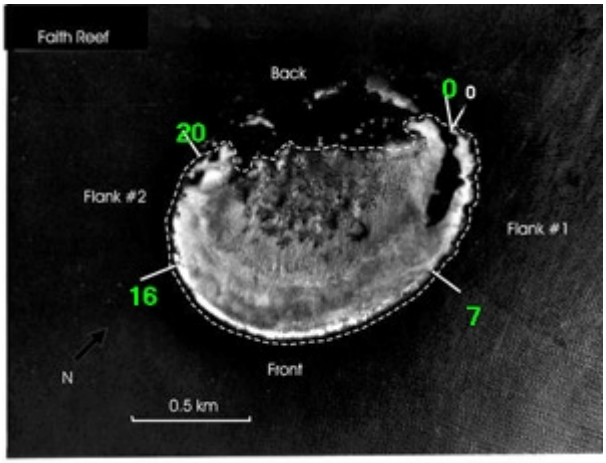
FAITH

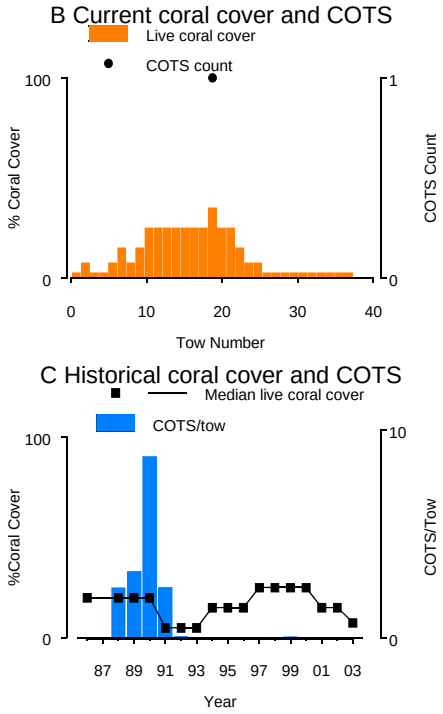
Surveyed December 2002.

Faith Reef has been surveyed frequently since 1986. Reef-wide live coral cover was moderate (10-30%) until 1990 when an outbreaking population of COTS reduced coral cover below 10%. Reef-wide live coral cover had recovered to former levels by 1997 and the reef was reclassified to No Outbreak. Reef-wide live coral cover has since declined to a low level (1-10%) in 2003 for unknown reasons. Small numbers of COTS were observed in 5 of the past 7 survey years though in numbers that were unlikely to impact on reef-wide live coral cover. Bleaching events in 1998 and 2002 may have contributed to the decline. No bleaching was seen in 2003 and white syndrome disease was restricted to a few scattered colonies. The reef remains classified as No Outbreak.

Figure 4.98

A





Faith (No. 19-044) is a middle shelf crescentic reef with an area of 3.8 sq.km.

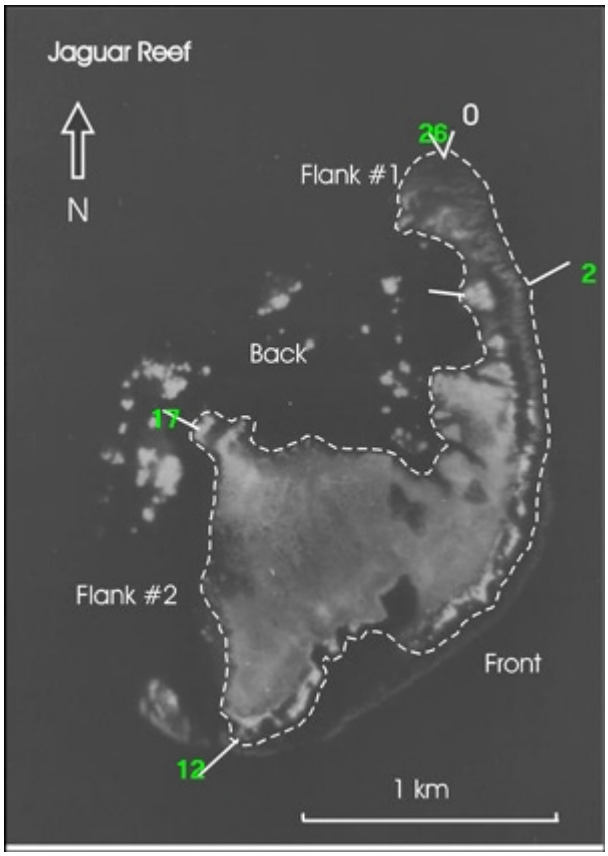
JAGUAR

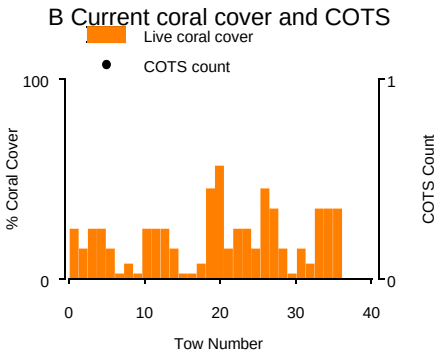
Surveyed August 2001.

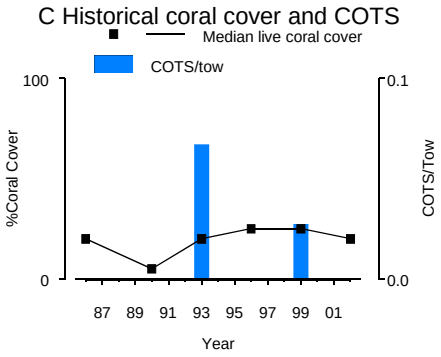
This reef has been surveyed six times since 1986. COTS have only been recorded on two of these occasions, both times in numbers too low to be considered a threat to reef-wide live coral cover. While reef-wide live coral cover declined between 1986 and 1990, it has since recovered to moderate levels (10-30%) where it appears to have stabilised. Jaguar Reef is currently classified as No Outbreak. No bleaching was observed and white syndrome disease was restricted to low numbers of individual colonies during manta tow surveys in 2002.

Figure 4.99

A







Jaguar (No. 18-120) is an outer shelf crescentic reef with an area of 3.8 sq.km.

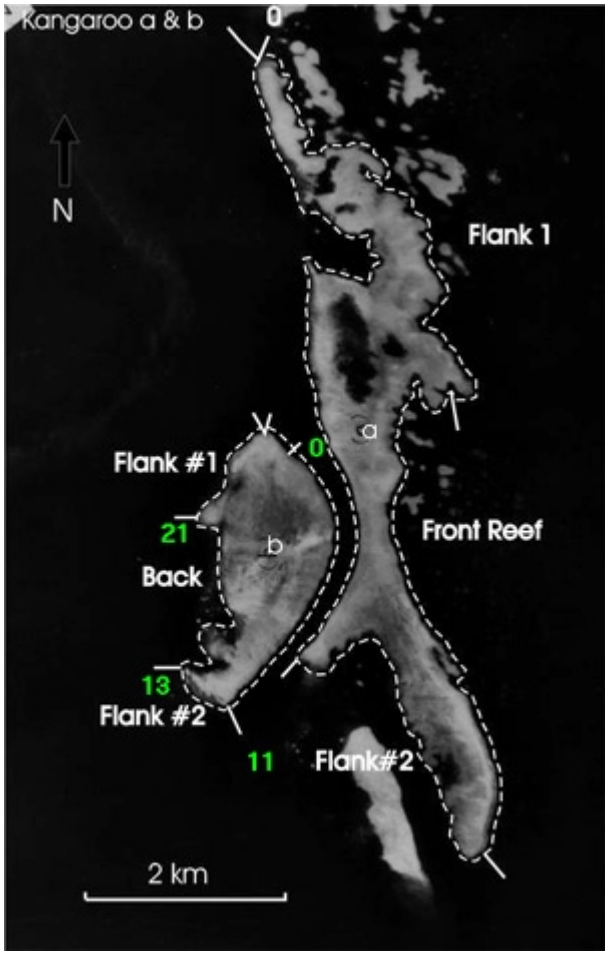
KANGAROO (A)

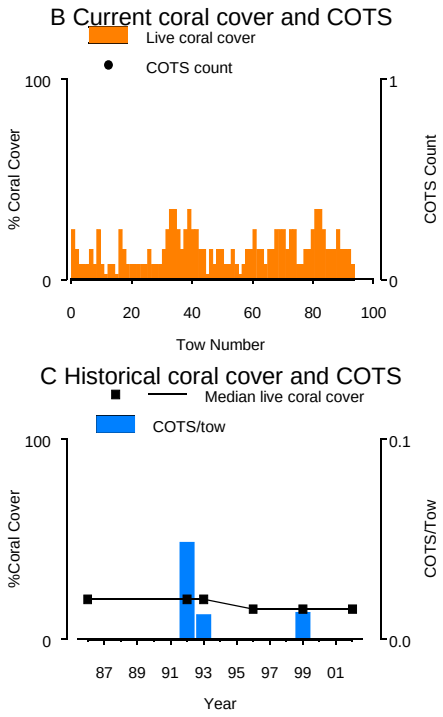
Surveyed August 2001.

This reef has been surveyed six times since 1986. While COTS have been recorded on a number of occasions they have generally been in numbers too low to be considered a threat to coral cover. Reef-wide live coral cover was moderate (10-30%) in 2002. The reef is currently classified as No outbreak. No bleaching was observed and white syndrome disease affected a few scattered colonies.

Figure 4.100

A





Kangaroo (A) (No. 19-063) is a middle shelf reef patches reef with an area of 30.6 sq.km.

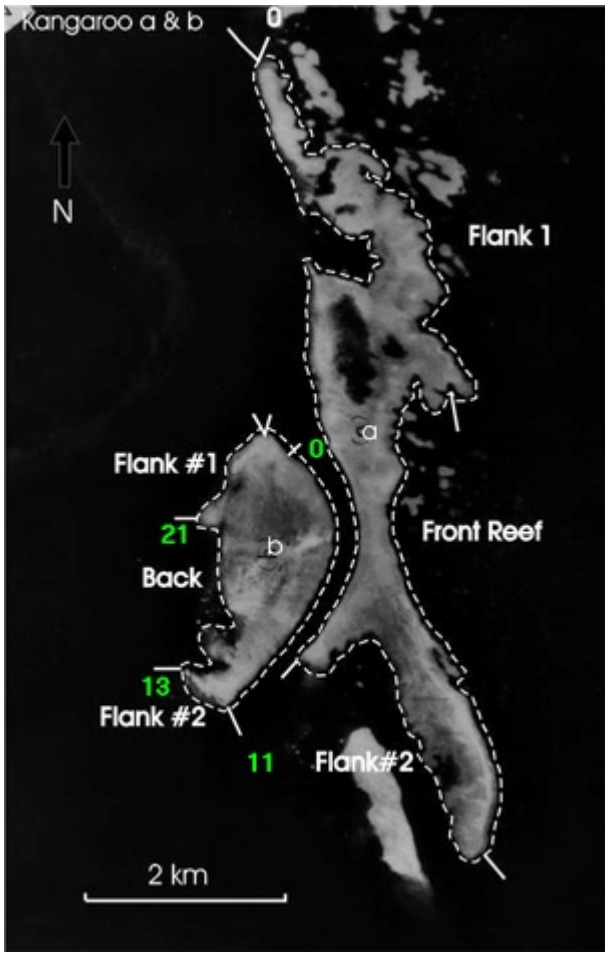
KANGAROO (B)

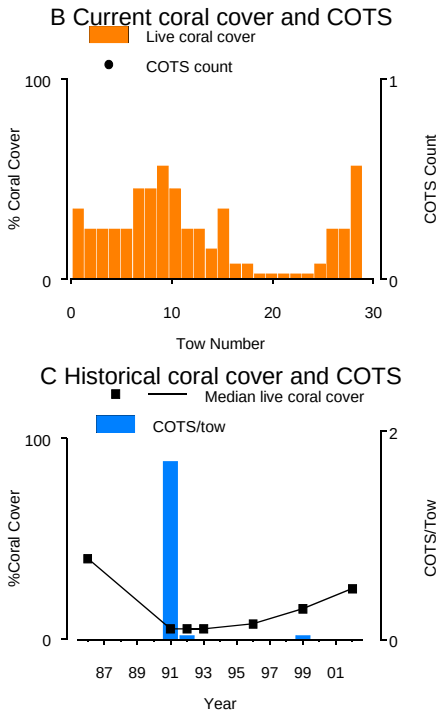
Surveyed August 2001.

This reef has been surveyed seven times since 1986. Reef-wide live coral cover was initially high (30-50%) but declined rapidly due to an outbreaking COTS population which peaked in 1991. Reef-wide live coral cover remained low until 1999 when there was evidence of recovery. COTS were recorded in 1999 but there were too few be considered a threat to coral cover. Recovery continued in 2002. Reef-wide live coral cover was moderate (10-30%) and Kangaroo Reef B was classified as Recovering. No bleaching was seen and white syndrome disease affected few scattered colonies.

Figure 4.101

A





Kangaroo (B) (No. 19-063) is a middle shelf reef patches reef with an area of 46.9 sq.km.

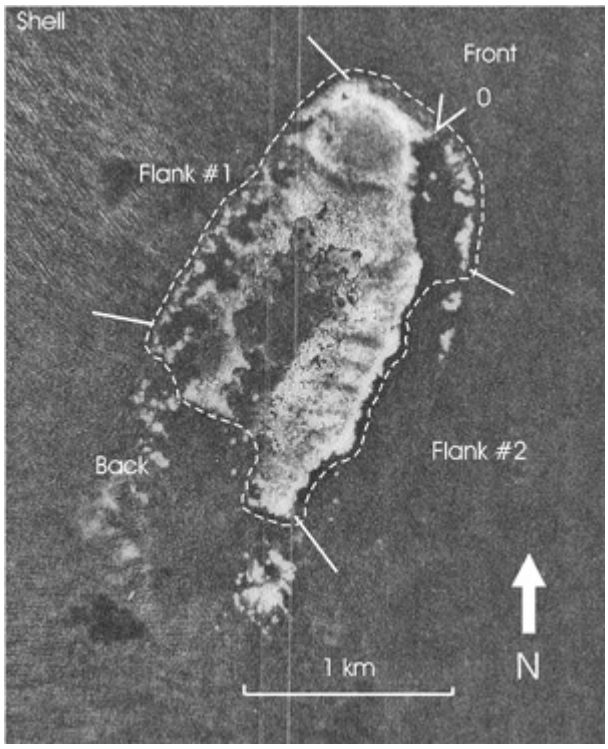
SHELL

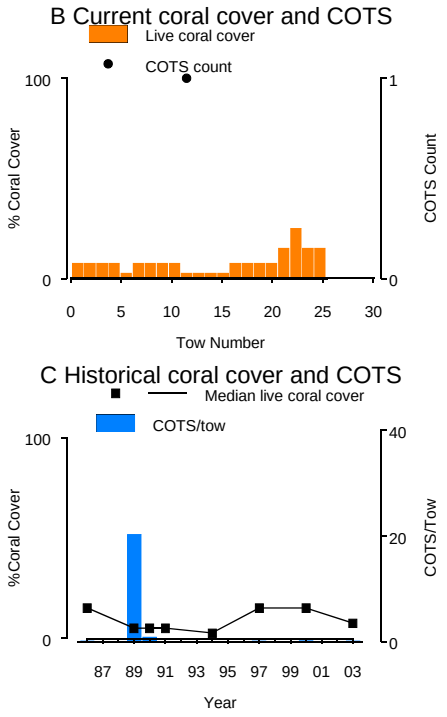
Surveyed December 2002.

Shell Reef has been surveyed eight times by manta tow since 1986. Initially reef-wide live coral cover was moderate (10-30%) but dropped to a low level (0-10%) in 1990 following a COTS outbreak in 1989 and 1990. The reef was classified as Recovering in 1991. From 1994, reef-wide live coral cover slowly increased to a moderate level in 1997 but has decreased in 2000 and 2003. COTS have been seen in the last two surveys but in numbers too few to affect reef-wide live coral cover. The reason for the decrease in reef-wide live coral cover is unknown. Shell Reef is currently classified as No Outbreak. No bleaching was observed in 2003 and white syndrome disease affected only a few scattered colonies.

Figure 4.102

A





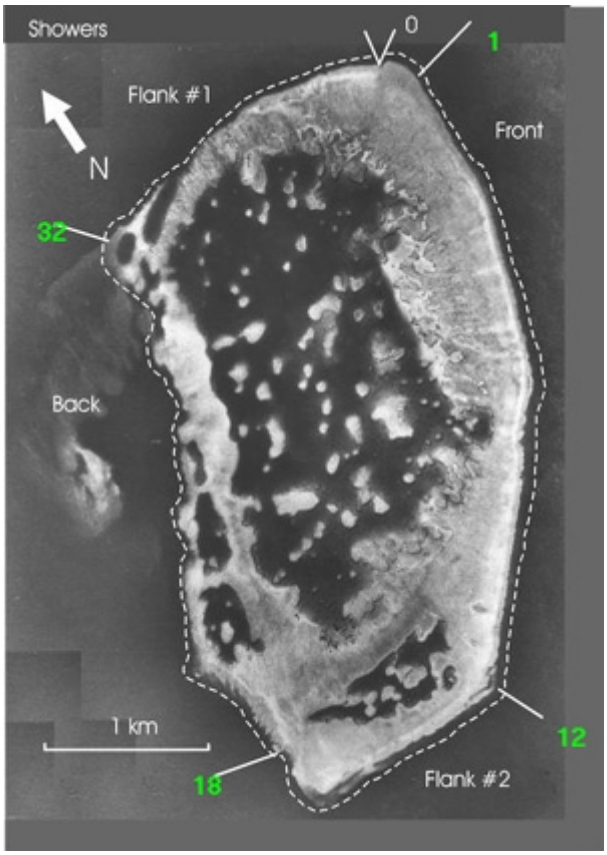
Shell (No. 19-028) is a middle shelf crescentic reef with an area of 2.5 sq.km.

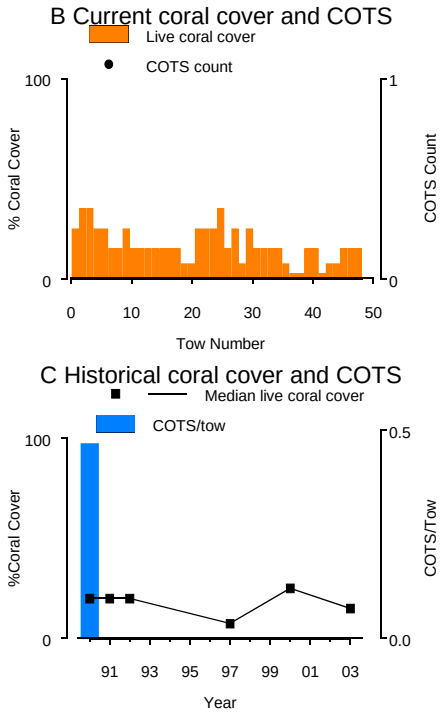
SHOWERS

Surveyed December 2002.

Showers Reef has been surveyed six times since 1990, when there was an Incipient Outbreak of COTS and reef-wide live coral cover was moderate (10-30%). Reef-wide live coral cover has remained moderate. No COTS were observed during surveys in 2003, coral cover was moderate and the reef was still classified as Recovering. No bleaching was recorded, but white syndrome disease and black band disease affected a few scattered coral colonies.

Figure 4.103 A





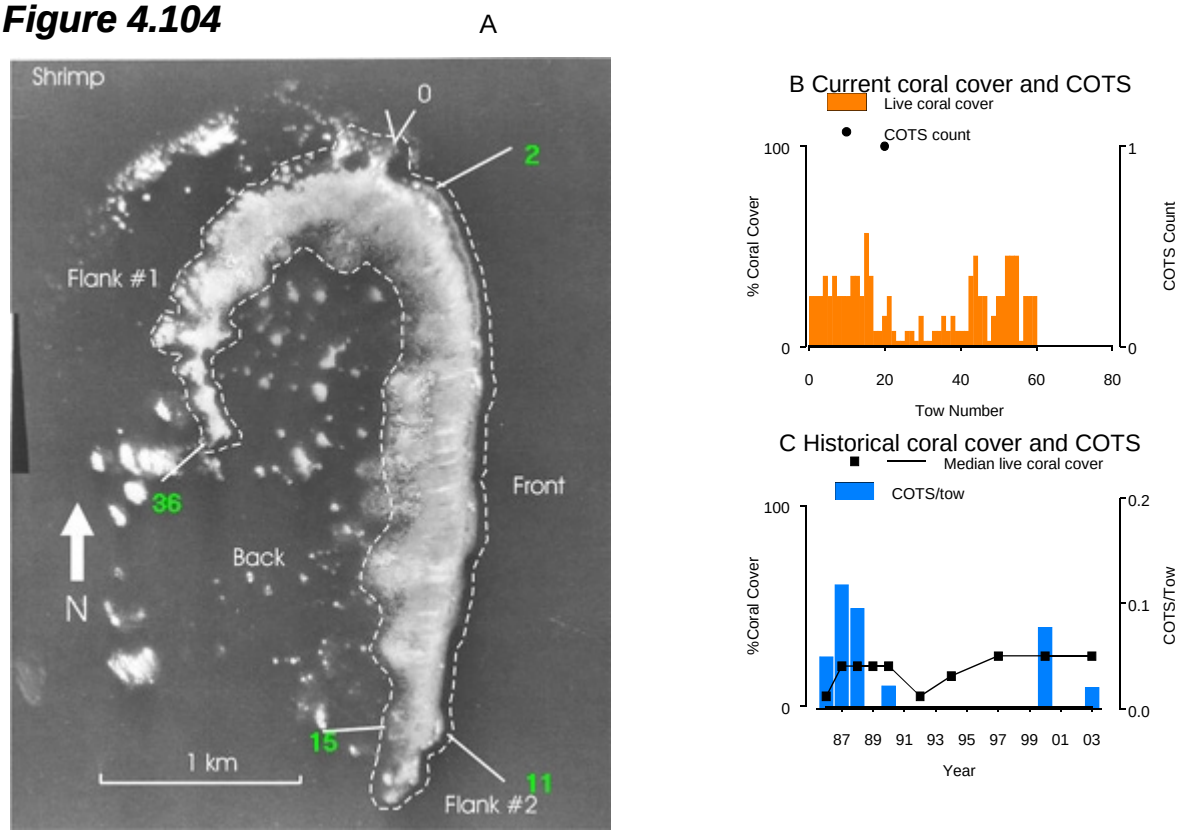
Showers (No. 19-076) is a middle shelf lagoonal reef with an area of 8.79 sq.km.

SHRIMP

Surveyed November 2002.

Shrimp Reef has been surveyed ten times since 1986. Reef-wide live coral cover was low initially (1-10%) but reached moderate levels (10-30%) in 1990 then declined to a low level by 1992. Limited COTS numbers were recorded during this period and the cause of this decline is unknown. Between 1992 and 2000, reef-wide live coral cover gradually increased, returning to moderate levels (10-30%). COTS were seen in 2000 but in numbers too few to affect reef-wide live coral cover. Small numbers of COTS were present in 2003 and reef-wide live coral was moderate. The reef was classified as No Outbreak. No bleaching was recorded in 2003 but white syndrome disease and black band disease affected a few scattered coral colonies.

Figure 4.104



Shrimp (No. 18-118) is a middle shelf crescentic reef with an area of 7.5 sq.km.

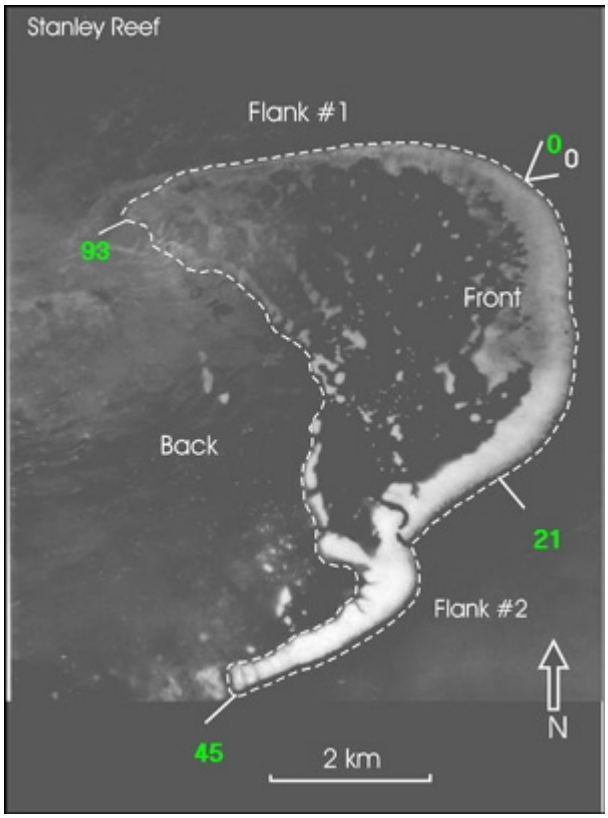
STANLEY

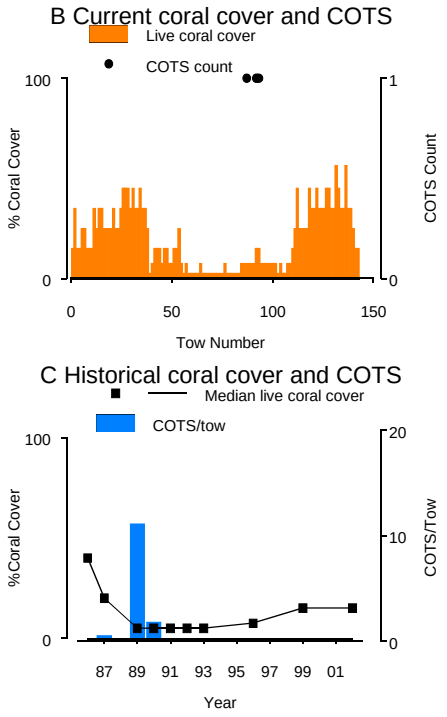
Surveyed November 2001.

This reef has been surveyed regularly since 1986 when reef-wide live coral cover was high (30-50%). Coral cover declined to a low level (1-10%) in 1989 due to a COTS outbreak which persisted until 1991.Reef-wide live coral cover increased gradually through the 1990s to a moderate level. COTS were recorded in 2002, but in numbers too few to affect reef-wide live coral cover which remained moderate (10-30%). Stanley Reef was still classified as Recovering. No bleaching was observed in 2002, but white syndrome disease was common (more than 10 colonies affected per two-minute tow) on the front and first flank of the reef.

Figure 4.105

A





Stanley (No. 19-045) is a middle shelf crescentic reef with an area of 58.1 sq.km.

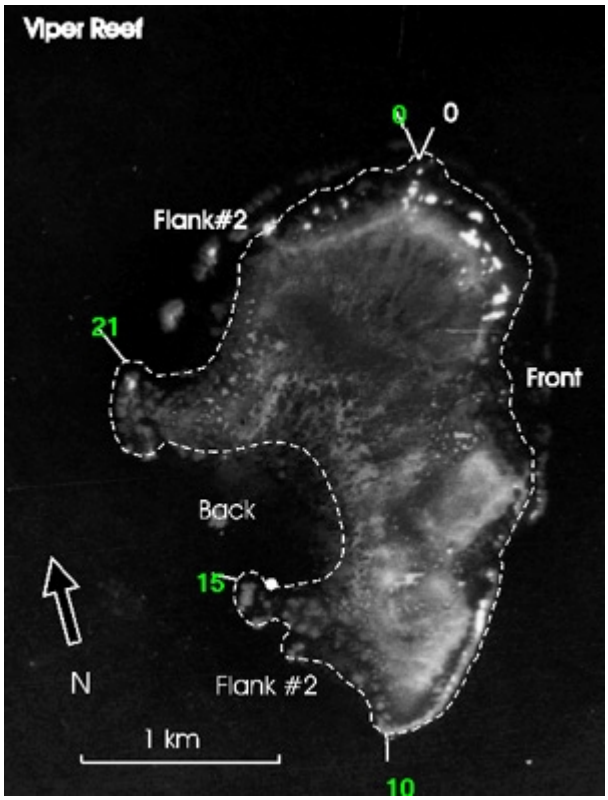
VIPER

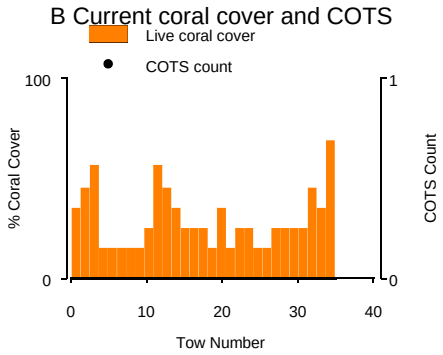
Surveyed August 2001.

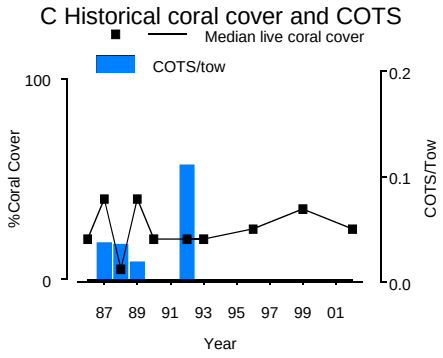
This reef has been surveyed regularly since 1986. COTS have been recorded on a number of occasions, particularly during the early years of survey, but always in numbers too low to affect reef-wide coral cover. Reef-wide live coral cover did decline in the late eighties for no clear reason. Cover increased to a moderate level (10-30%) in 2002. No COTS were observed and the reef was classified as No Outbreak. No bleaching was recorded in 2002 and white syndrome disease was present around the reef perimeter and common (affecting more than 10 colonies per two-minute tow) on the reef front where live coral cover was the highest.

Figure 4.106

A







Viper (No. 18-112) is an outer shelf crescentic reef with an area of 1.9 sq.km.

Whitsundays
Reef Pages

19131

Surveyed December 2002.

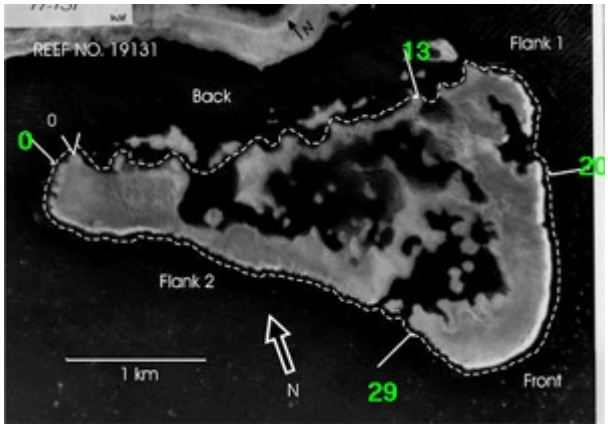
Reef 19131 has been surveyed by manta tow twelve times since 1989. Reef-wide live coral cover increased between 1989 and 1994 and was moderate (10-30%) until 1996. There was then a decline to a low level (1-10%) in 1999 which was most likely due to Cyclone Justin, which remained off the Whitsunday coast for an extended period in March 1997. Reef-wide live coral cover then increased to a moderate level in 2002. Surveys in 2003 recorded a decline to low cover(1-10%), most likely a result of coral bleaching 2002. The reef was classified as No Outbreak. No bleaching was seen in 2003 and white syndrome disease only affected a few scattered colonies.

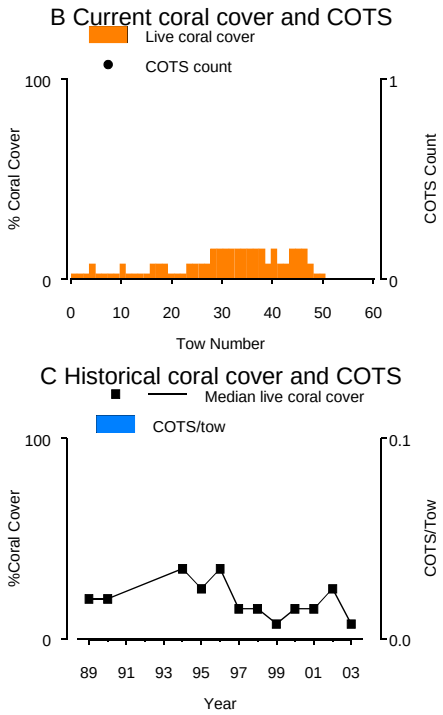
Detailed surveys reveal a gradual increase in hard coral cover until 1996 followed by a marked decline (approximately 25%) to 35% cover in 1997 correlating with Cyclone Justin. Hard corals in the family Acroporidae were most susceptible to this disturbance with large declines recorded in the genus *Montipora* and in tabulate *Acropora* spp. Hard coral cover remained stable until 2001, then increased to 41% in 2002. The 2003 survey recorded another decrease, which may be attributed to the bleaching event in 2002. Soft coral cover has been consistently low (approximately 1%). Algal cover has generally increased since 1989, complementing the changes in hard coral cover. Incidence of white syndrome disease increased in 2003 but was still at a low level. The density of corallivorous snails *Drupella* spp. was 40/ha in 2003.

Numbers of many fish taxa have fluctuated greatly over the 10-year study period, yet with a few exceptions (see below) there have been no prolonged increases or decreases. Some damselfish species (*Pomacentrus moluccensis*, *Chromis atripectoralis* and *C. nitida*) decreased dramatically in abundance after about 50% of hard coral was lost due to Cyclone Justin in March 1997. In 2003, numbers of these species remained very low. The loss of most branching coral may have caused a reduction in numbers of adults and of recruits since recruits and adults of the three species shelter preferentially in this habitat. As on the nearby Reef 19138, numbers of the damselfish *Acanthochromis polyacanthus* increased dramatically in 2003.

Figure 4.107

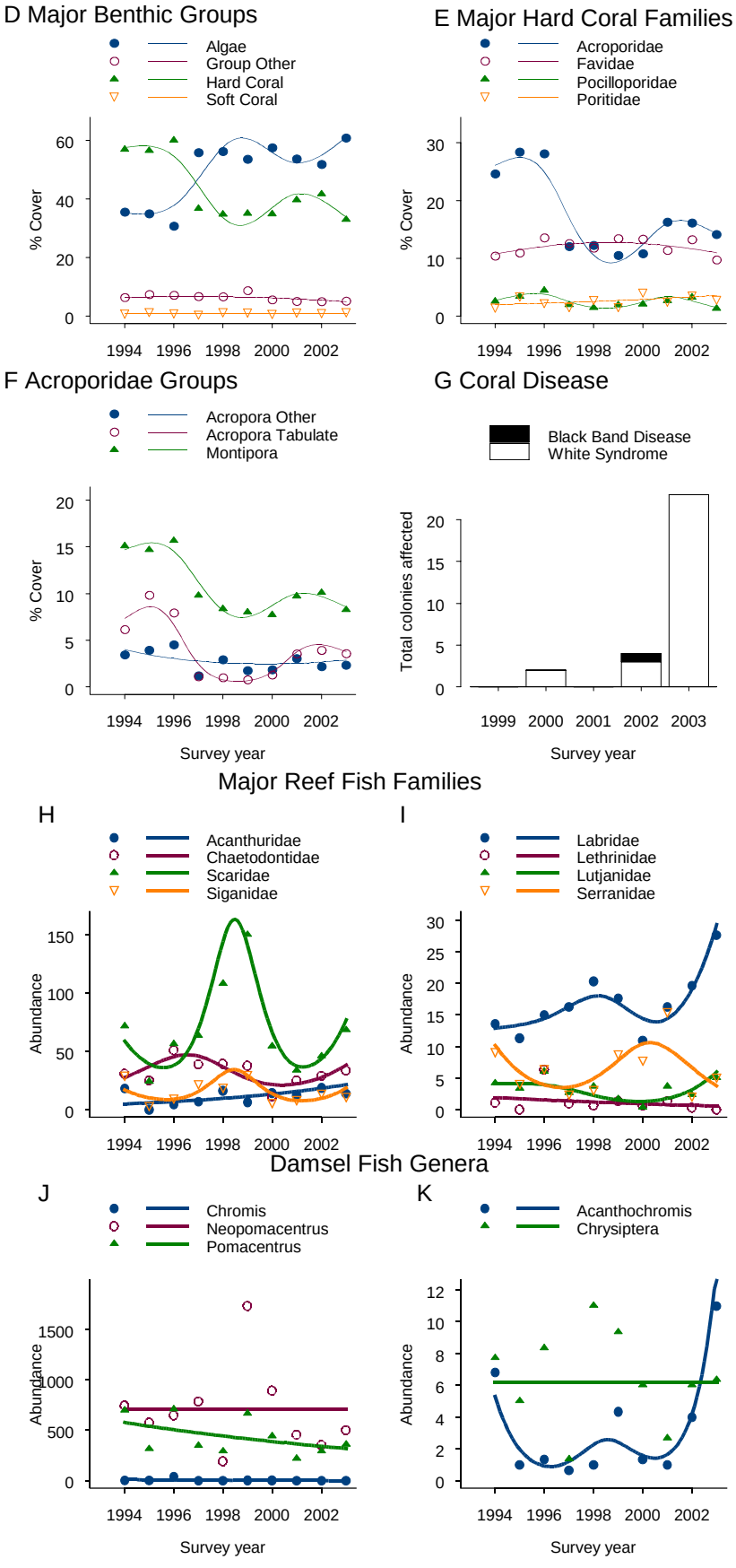
A





19131 (No. 19-131) is a middle shelf lagoonal reef with an area of 5.6 sq.km.

Figure 4.107 (Cont).



19138

Surveyed December 2002.

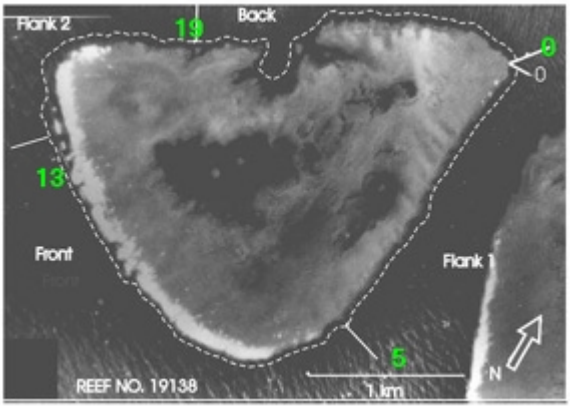
Reef 19138 has been surveyed by manta tow annually since 1990, when there were relatively high numbers of COTS and the reef was classified as an Incipient Outbreak. COTS numbers declined without a large affect on reef-wide live coral cover. Coral cover increased until 1995 before declining to a moderate level (10-30%). The decline was most likely due to the effect of Cyclone Justin, which remained off the Whitsunday coast for an extended period in March 1997. Reef-wide live coral cover remained moderate before declining once more in 2003. No COTS were recorded, so the most likely cause of decline is the coral bleaching in 2002. Reef-wide live coral cover was moderate (10-30%) and the reef was classified as Recovering in 2003. No bleaching was recorded and white syndrome disease only affected a few scattered coral colonies.

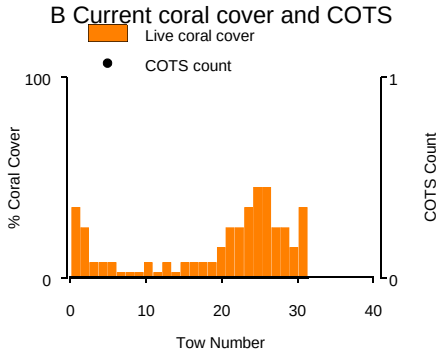
Detailed coral surveys on the southern flank of this triangular reef began in 1993. Hard coral cover increased to a maximum of 42% in 1996 before dropping sharply to 17% in 1997. Coral cover then increased slowly to about 23%. We attribute the decline in hard coral cover between 1996 and 1997 to the effects of Cyclone Justin. The family Acroporidae was most affected, declining from 23% cover in 1996 to 4% in 1997. This was mainly due to a decrease in tabulate life-forms within the genus *Acropora*. The density of corallivorous snails *Drupella* spp. was 13.3/ha in 2003.

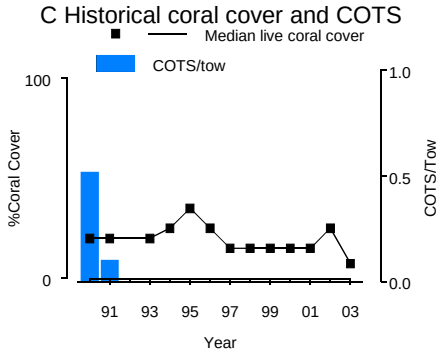
Numbers of many fish taxa have fluctuated greatly over the 10-year study period, but there have been few prolonged increases or decreases. Numbers of the commercially important coral trout (*Plectropomus leopardus*) have declined since surveys began; numbers in 2003 were at an 11-year low. Some damselfish species (*Pomacentrus moluccensis*, *Chromis atripectoralis* and *C. nitida*) decreased dramatically in abundance after about 50% of hard coral was lost due to Cyclone Justin in March 1997. In 2003, numbers of these species remained very low. The loss of most branching coral may have caused a reduction in numbers of adults and of recruits since recruits and adults of the three species shelter preferentially in this habitat. Numbers of the damselfish *Acanthochromis polyacanthus* had increased dramatically in 2003 at this reef and the two other middle shelf survey reefs in the Whitsunday sector.

Figure 4.108

A

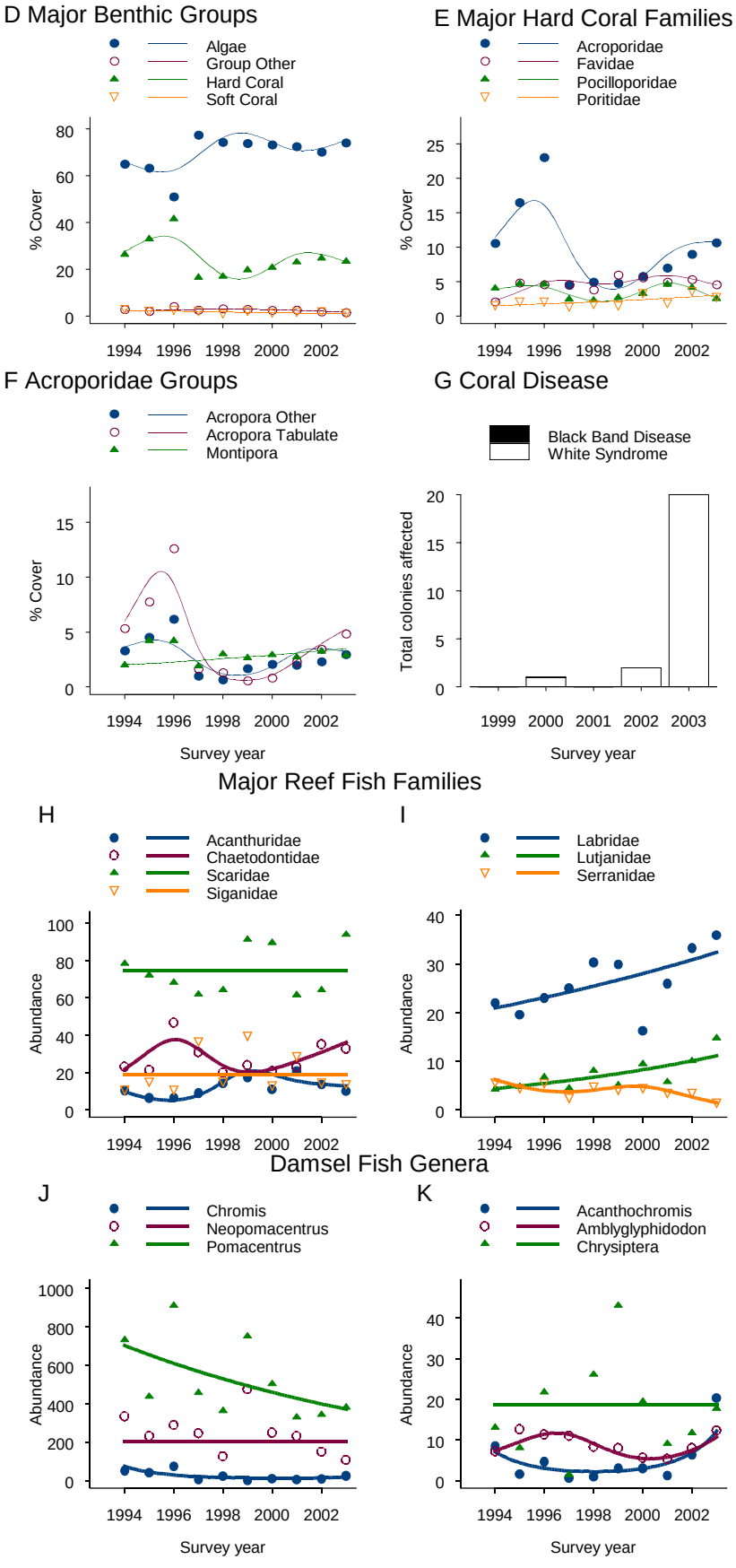






19138 (No. 19-138) is a middle shelf lagoonal reef with an area of 2.5 sq.km.

Figure 4.108 (Cont).



19159

Surveyed December 2002.

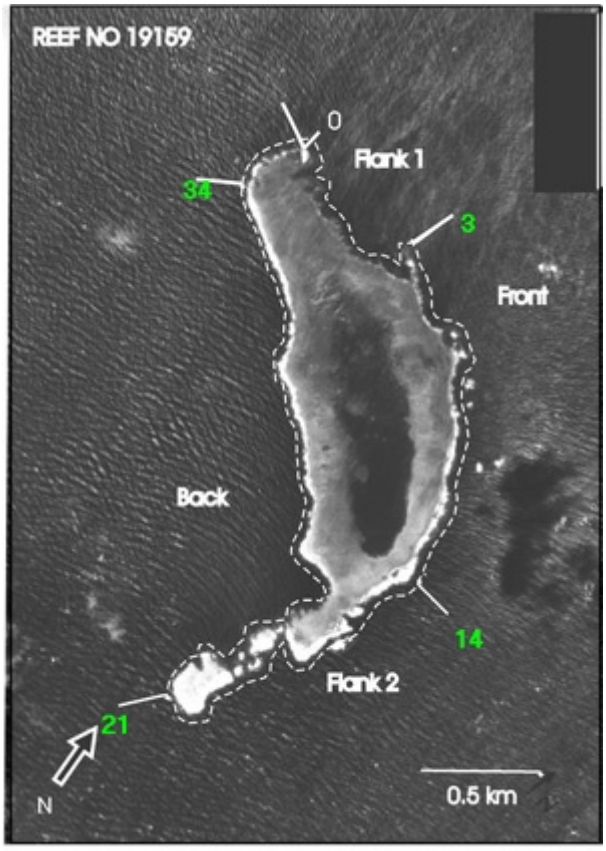
Reef 19159 was first surveyed by manta tow in 1986 when it was classified as No Outbreak with a high reef-wide live coral cover (30-50%). Reef-wide live coral cover remained relatively stable until 1997 when there was a sharp decline to a moderate level (10-30%), most likely due to Cyclone Justin. Despite initial signs of recovery in 1998, coral cover remained steady at a high level (30-50%) with 2003 manta tow surveys suggesting similar reef-wide live coral cover to recent years. Small numbers of COTS were recorded in 1999 and 2000. No bleaching was recorded in 2003 and white syndrome disease affected only a few scattered coral colonies.

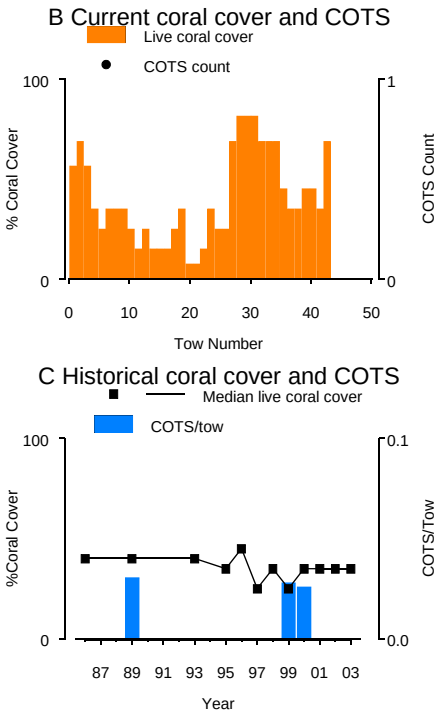
Intensive surveys of the north east flank show that hard coral cover has generally increased from 38% initially to 44.3% in 2003. Most of this is due to increases in life forms other than tabulate corals within the *Acropora* genus (e.g. bottle-brush, branching etc). The decrease in hard coral cover in 2000 may have been caused by non-outbreaking COTS populations in that year. A decline in the cover of soft coral was observed between 1996 and 1997. This is attributed to the effects of Cyclone Justin, which remained off the Queensland coast for an extended period in March 1997. Cover of soft coral has increased slightly since the disturbance (from approximately 14% to 17%), but has still not recovered to pre-cyclone levels (approximately 20% in 1992). Incidence of white syndrome disease increased in 2003 but was still low. The density of corallivorous snails *Drupella* spp. was 46.7/ha.

Numbers of large mobile fishes have often fluctuated from year to year but over the 12 year study period there have been no obvious long term trends. This may reflect the relatively stable state of the benthic community over the same period. Numbers of most damselfish species have also been stable. However, numbers of *Pomacentrus moluccensis* have declined since 1999, while a few *Chromis* species have increased in abundance and numbers of two larger damselfish species (*Amblyglyphidodon curacao* and *Acanthochromis polyacanthus*) increased dramatically in 2003.

Figure 4.109

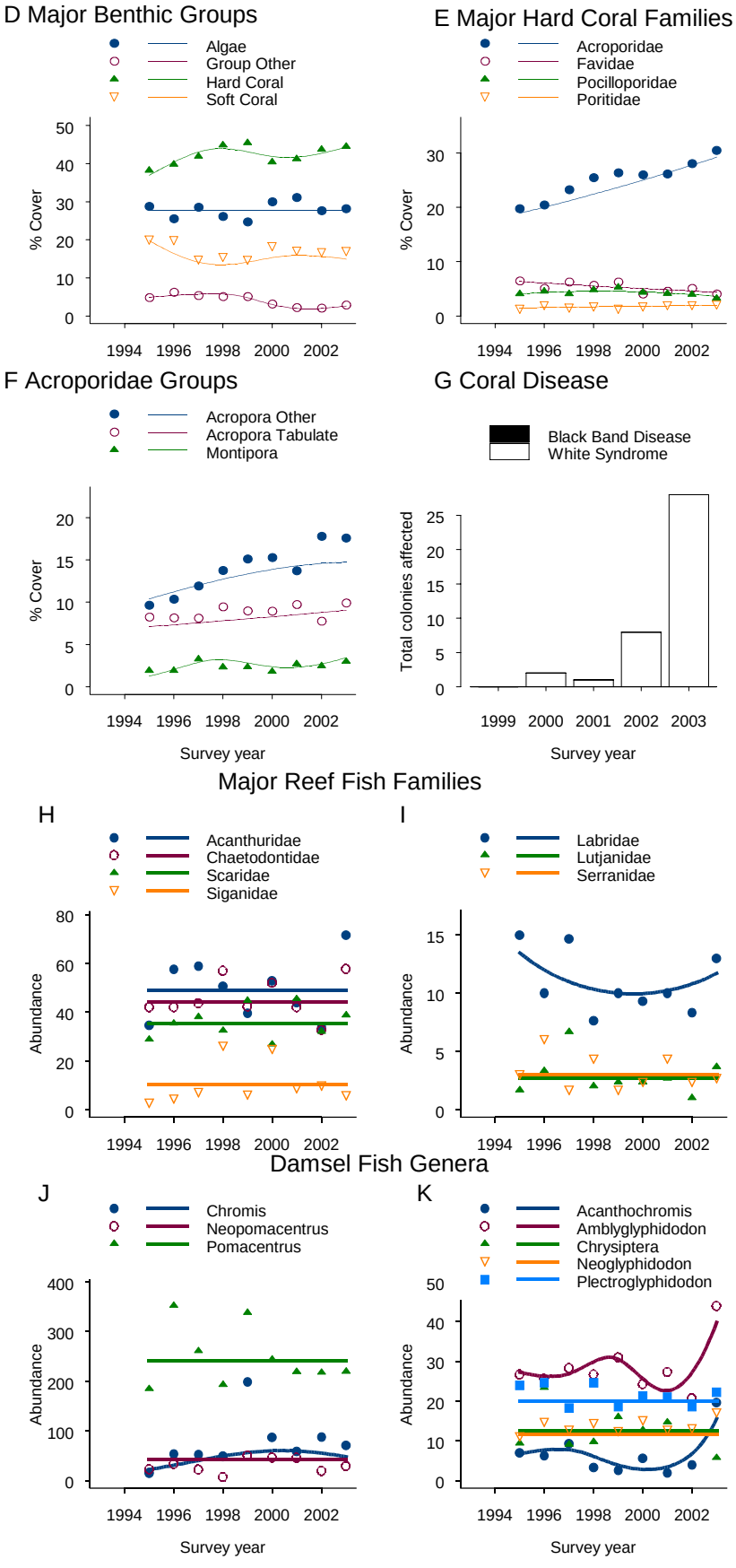
A





19159 (No. 19-159) is an outer shelf lagoonal reef with an area of 3.8 sq.km.

Figure 4.109 (Cont).



20104

Surveyed November 2002.

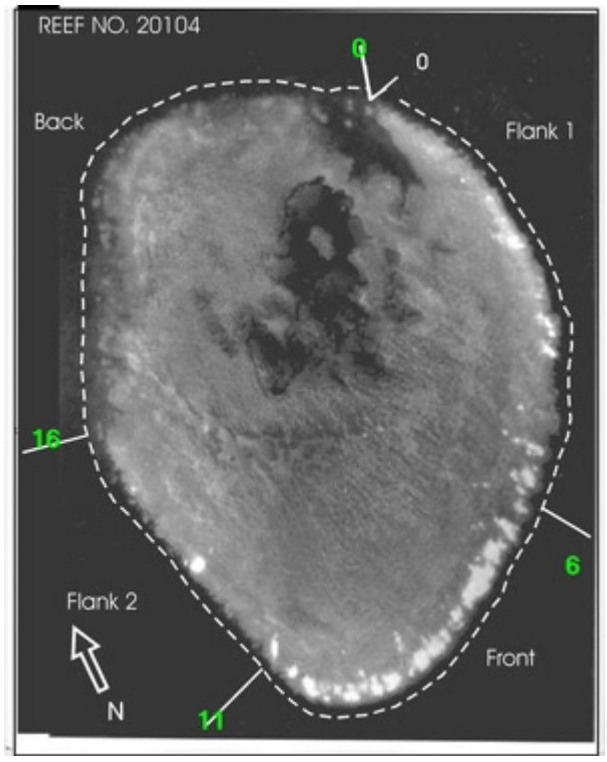
Reef 20104 has been surveyed fourteen times since 1989 when it was initially declared an Active Outbreak due to the presence of a large number of COTS. Reef-wide live coral cover declined to low levels (1-10%) in the early nineties. The reef was reclassified as Recovering from COTS in 1991. Reef-wide live coral cover then gradually increased to a moderate level (10-30%) in 2002. There was a setback in 1997, most likely as a result of the passage of Cyclone Justin just before the 1997 surveys. Reef-wide live coral cover declined once more in 2003. No COTS were recorded, so the most likely cause of the decline was the 2002 bleaching event. This reef was classified as Recovering in 2003. No bleaching was recorded and white syndrome disease was seen to only affect a few scattered colonies.

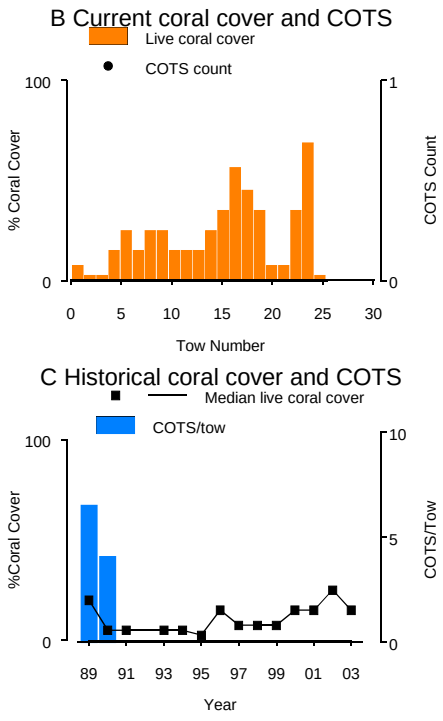
On the intensive survey sites, hard coral cover increased from 11.2% in the initial survey to 34.9% in 2003. This increase was mainly driven by the Acroporidae. The decrease in Acroporidae (especially tabulate life-forms of *Acropora*) in 1997 can be attributed to the effects of Cyclone Justin. The rapid increase in cover of tabulate *Acropora* spp. since then illustrates the fast growing nature of these corals. Soft coral cover remained relatively stable over the survey period. Algal cover decreased steadily from 73.8% in 1993 to 59.8% in 2003, with Halimeda spp. showing the biggest decrease. Incidence of white syndrome disease increased in 2003 but was still very low. The density of corallivorous snails *Drupella* spp. was 53.3/ha.

Although many fish species have fluctuated in abundance over the study period, few have shown long term trends. Two closely related butterflyfish species (*Chaetodon aureofasciatus* and *C. rainfordi*) increased in abundance as hard coral cover increased. Both species are closely associated with hard corals and *C. aureofasciatus* feeds predominantly on coral polyps. Numbers of the damselfish *Acanthochromis polyacanthus* had increased dramatically in 2003 at this reef and the two other middle shelf reefs surveyed in the Whitsunday sector.

Figure 4.110

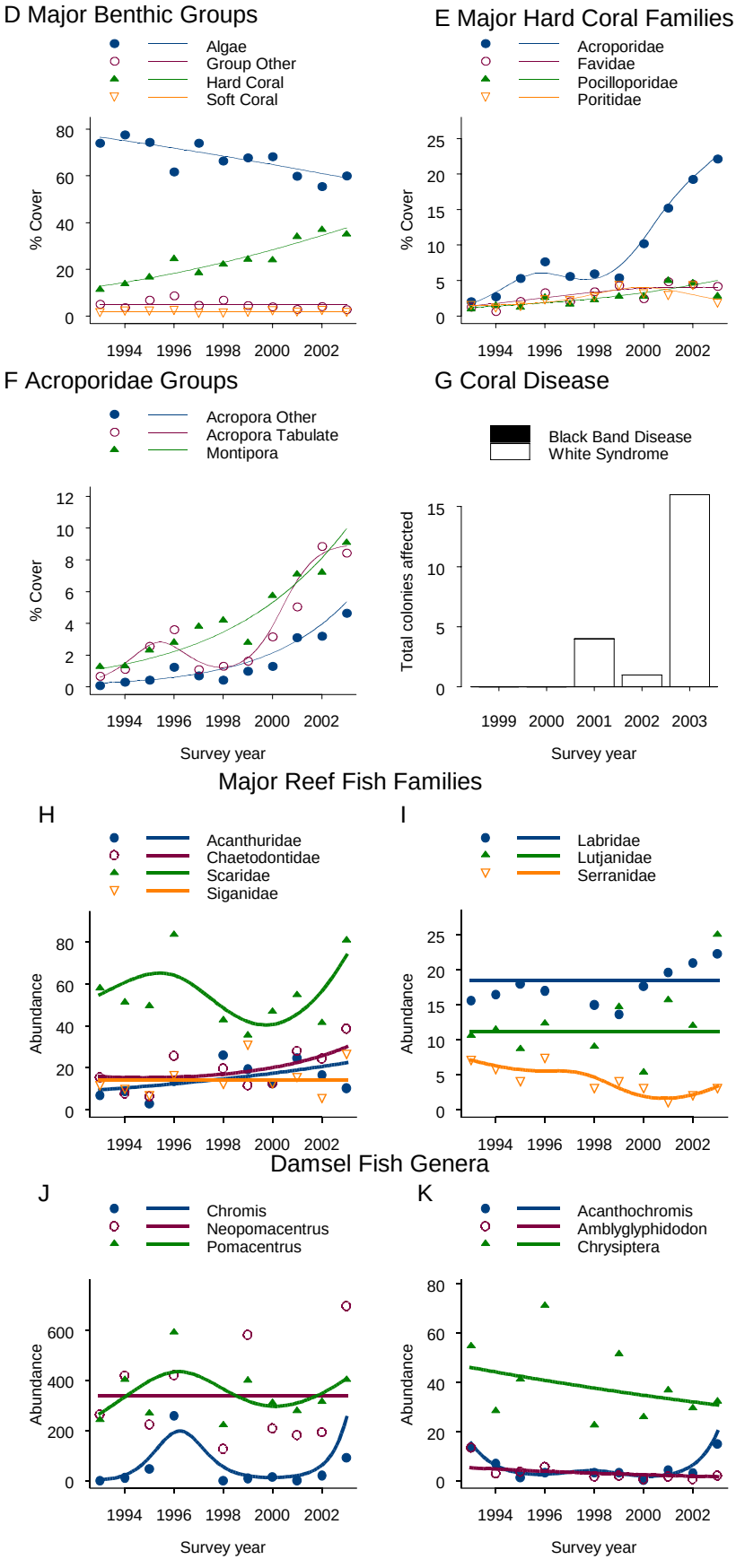
A





20104 (No. 20-104) is a middle shelf lagoonal reef with an area of 1.9 sq.km.

Figure 4.110 (Cont).



BORDER IS (A)

Surveyed December 2002.

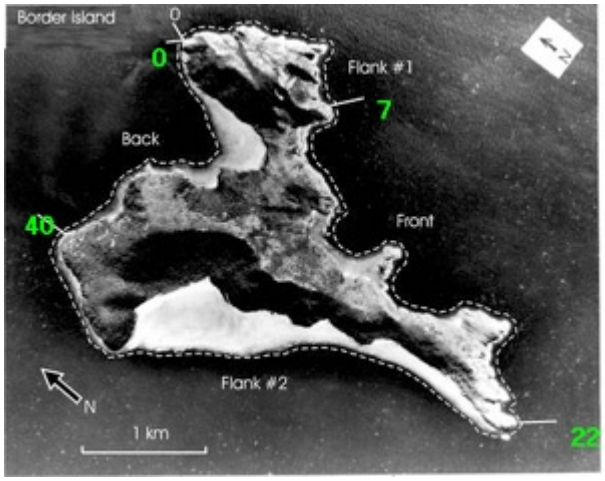
The fringing reef around Border Island A has been surveyed seven times by manta tow between 1995 and 2003. Reef-wide live coral cover remained moderate (10-30%). No COTS or coral bleaching was observed in 2003 and the reef was classified as No Outbreak. White syndrome disease was present but only affected a few scattered coral colonies.

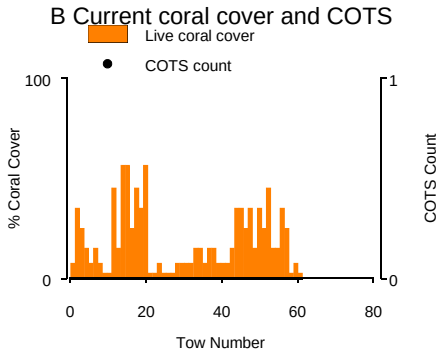
Cover of hard coral in the intensive survey sites has been stable over the survey period (on average 27.3%). Hard coral cover was dominated by the Poritidae, particularly *Goniopora* spp. Soft coral cover varied considerably between years, but cover has decreased since 2001 to its lowest level (22.2%) since 1994. The algal community was dominated by turfs. Algal cover was fairly stable until 2001 but then increased to a maximum for the survey period in 2003 (39%).

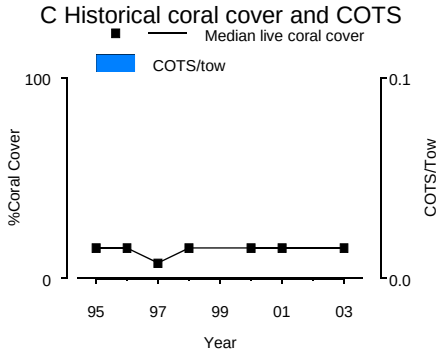
Numbers of most fish taxa were relatively stable. Although numbers have fluctuated over the 9-year study period there has been little tendency for prolonged increases or decreases. One exception may be the commercially important coral trout (*Plectropomus leopardus*). Numbers at Border Island have declined since 1994 and are currently stable but low. Evidence of fishing activity has been noted (i.e. presence of snagged lures and hooks) even though this reef has protected status (Marine Park A). Planktivorous damselfishes, *Chromis* spp. have increased in abundance since 1999, largely due to an influx of *C. nitida* in 2000 and *C. atripectoralis* in 2003. This increase in numbers of *Chromis* spp. occurred on all three inshore Whitsunday survey reefs.

Figure 4.111

A

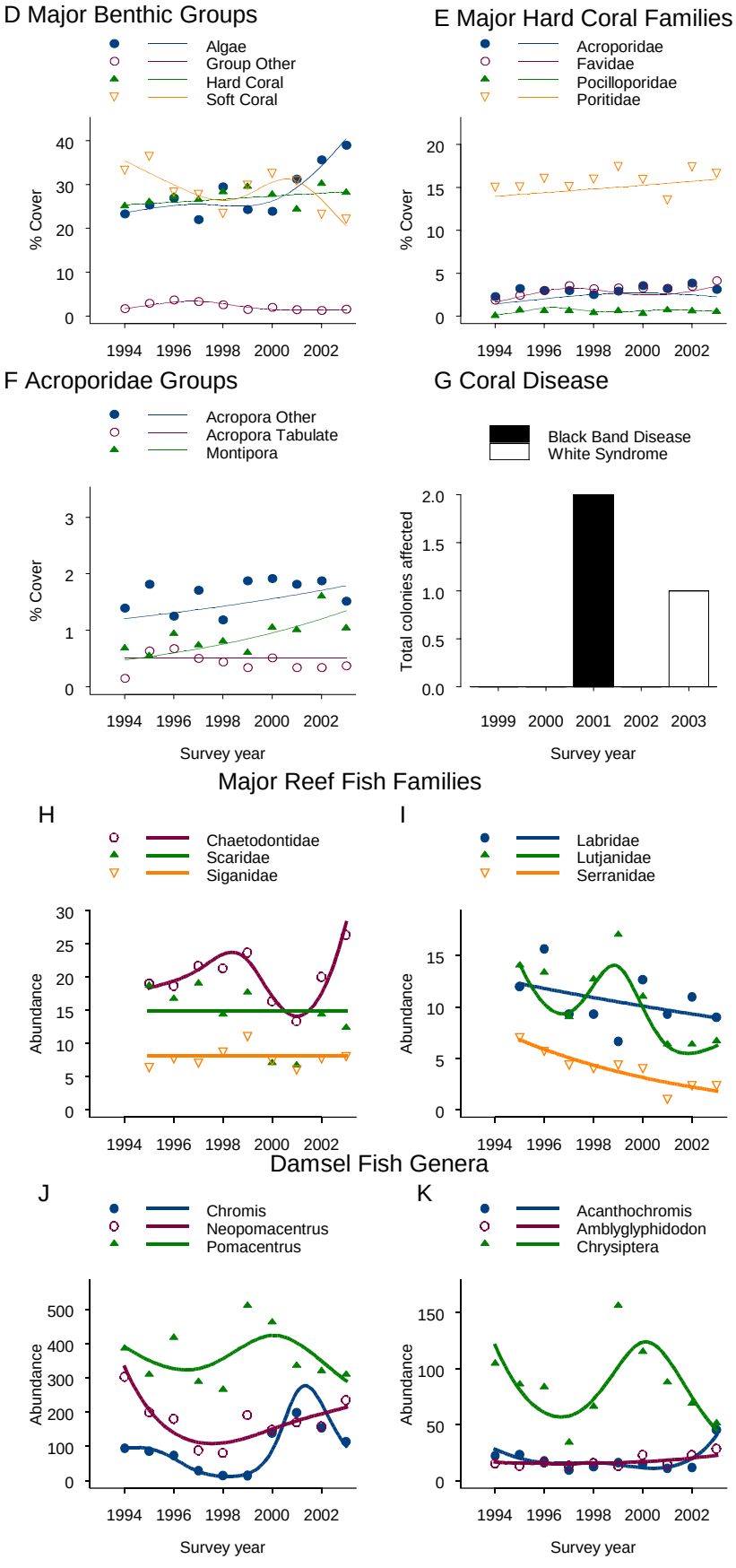






Border Is (A) (No. 20-067) is an inner shelf fringing reef with an area of 1.3 sq.km.

Figure 4.111 (Cont).



HAYMAN IS

Surveyed November 2002.

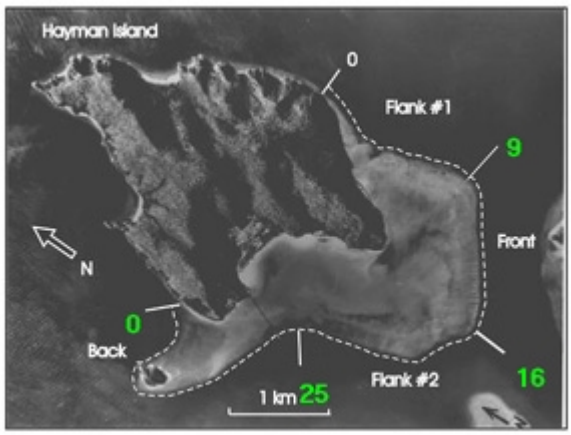
Hayman Island Reef has been surveyed by manta tow eleven times since 1990. Between 1990 and 1994 reef-wide live coral cover remained at moderate levels (10-30%) but declined in 1995. Coral cover has then increased gradually up to 2003. No COTS were found on reefs around Hayman Island in 2003 and it was again classified as No Outbreak. A few scattered coral colonies had bleached. No coral disease was recorded.

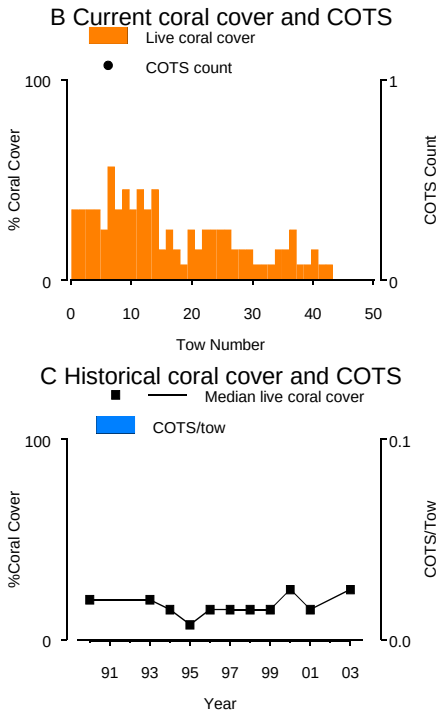
Intensive surveys on the southeastern flank record that mean hard coral cover has varied around 42%. The decrease in 1997 may be attributed to Cyclone Justin. Since then cover has increased to 46.5%. A small decrease in cover was observed in 2003, particularly in the Acroporidae. Hayman Island experienced high water temperatures in 2002 and the decrease was likely due to bleaching mortality. *Montipora* was the most abundant hard coral genus which, along with branching *Acropora* spp., drive trends in hard coral cover. The cover of algae has gradually increased over the survey period, with mean cover of 33%. White syndrome disease increased in 2003, but incidence is still low. The density of corallivorous snails *Drupella* spp. was 66.7/ha in 2003.

Numbers of most fish taxa have been relatively stable. Although numbers have fluctuated over the 11-year study period there have been few prolonged increases or decreases. Three species within the genus *Pomacentrus*: *P. moluccensis*, *P. brachialis* and *P. lepidogenys*, have declined slightly in abundance since surveys began in 1993, while numbers of another damselfish (*Chromis atripectoralis*) increased considerably in 2003 from very low numbers before. This increase in numbers of *Chromis* spp. has been a general pattern across the three inshore Whitsunday survey reefs over the last few years.

Figure 4.112

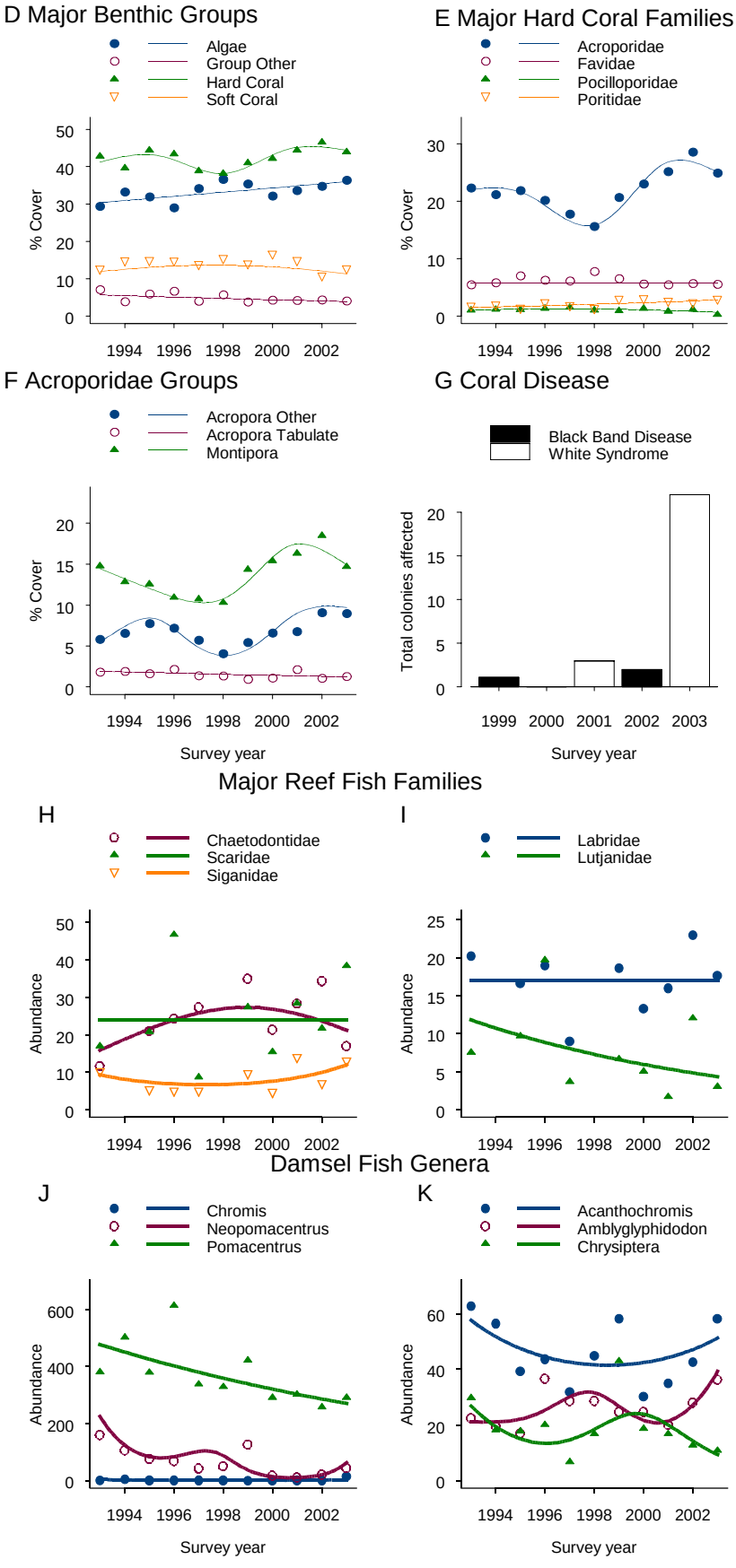
A





Hayman Is (No. 20-014) is an inner shelf fringing reef with an area of 3.8 sq.km.

Figure 4.112 (Cont).



HYDE

Surveyed November 2002.

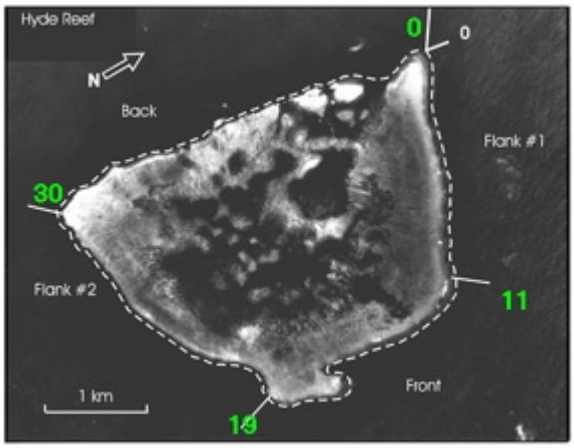
Hyde Reef has been surveyed thirteen times since 1986. Reef-wide live coral cover was moderate (10-30%) in 1986 and has changed little since. No COTS have been observed. Reef-wide live coral cover was high (30-50%) in 2003. No bleaching was recorded and white syndrome disease only affected a few scattered coral colonies.

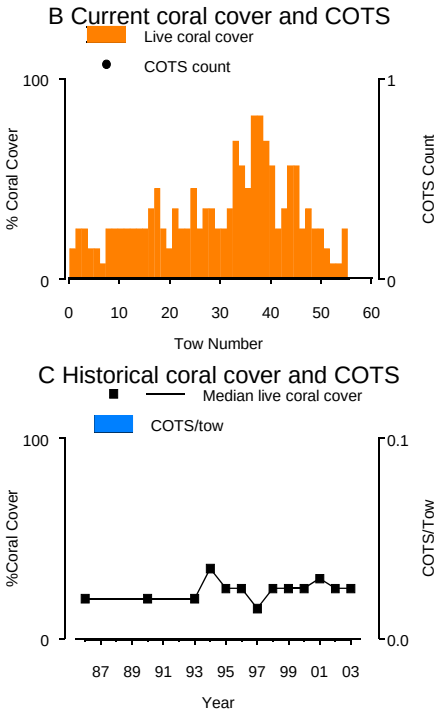
Surveys of the intensive study sites since 1993 show a stable hard coral cover of approximately 18%. Cover of soft corals has varied around a mean of approximately 45% and algal cover has fluctuated around 21%. The cover of sponges was also relatively high (about 10%). White syndrome disease occurred at very low levels in 2003.

Although numbers of most fish taxa have varied from year to year there has been little tendency for prolonged increases or decreases over the 10-year study period. This may reflect the relative stability of the benthos over the same period. Parrotfish (Scaridae) numbers have increased. Numbers of *Chrysiptera* spp. declined over the past few years, three of four *Chrysiptera* species were usually present up to 2000, but only *C. rex* was recorded after 2000. By 2003 numbers of this species were at the lowest levels since 1993.

Figure 4.113

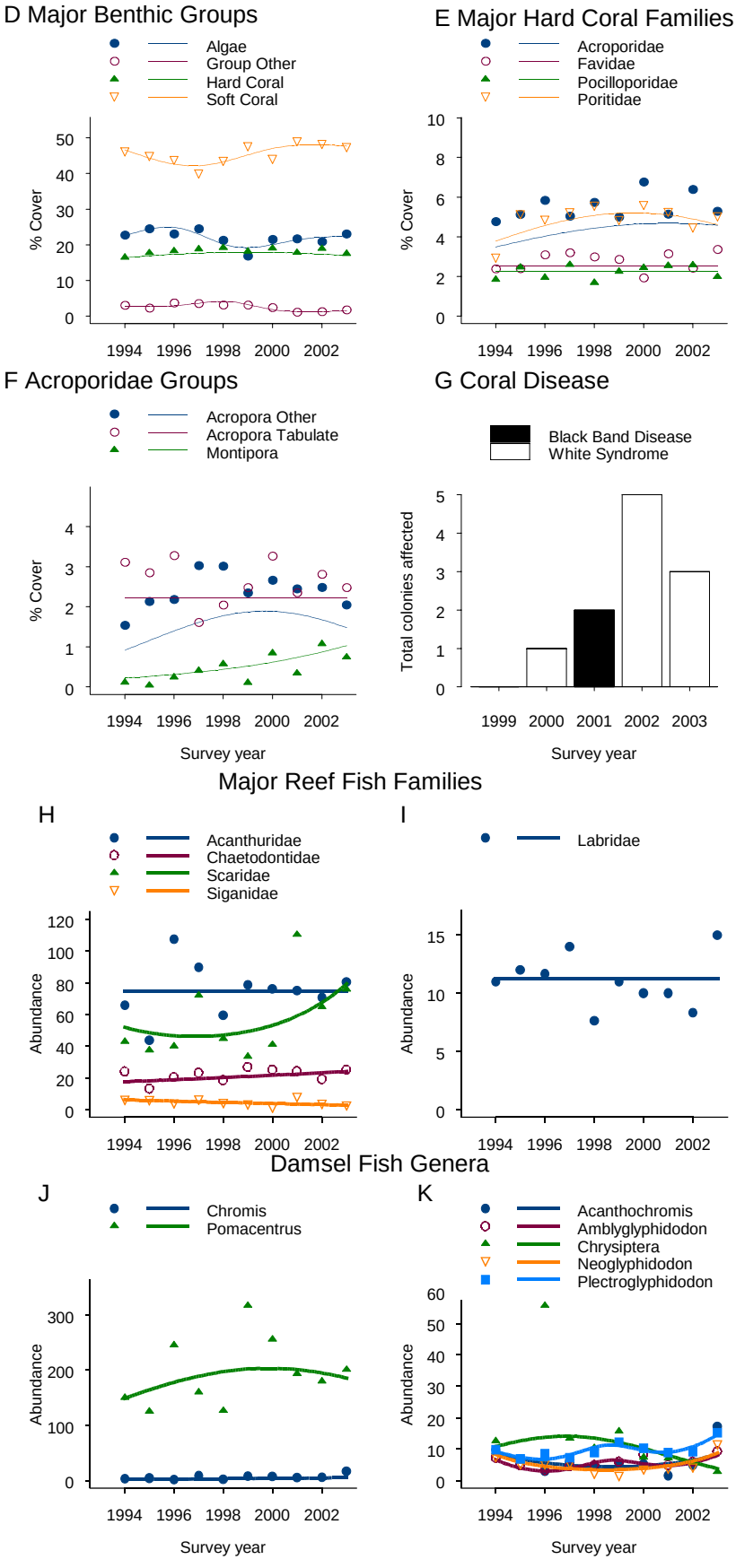
A





Hyde (No. 19-207) is an outer shelf lagoonal reef with an area of 12.5 sq.km.

Figure 4.113 (Cont).



LANGFORD AND BIRD IS'S

Surveyed November 2002.

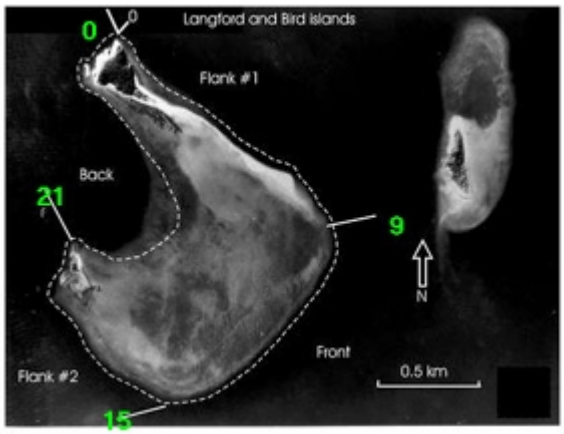
Langford and Bird Islands have been surveyed nine times by manta tow since 1990. Reef-wide live coral cover has generally increased from low levels (1-10%) in 1990 to moderate levels(10-30%) in 2000. Surveys in 2003 showed a decline in reef-wide live coral cover to low levels (1-10%). COTS were also recorded for the first time in 2003 but in very low numbers that should not affect reef-wide coral cover. The reef is currently classified as No Outbreak. No disease was recorded and only a few scattered coral colonies were bleached.

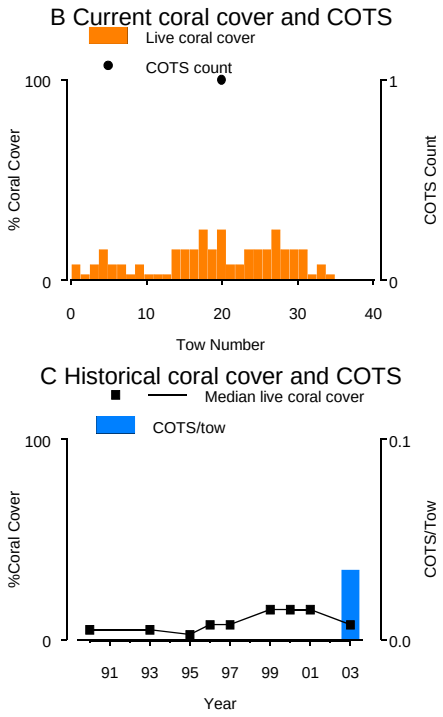
The intensive survey sites on the northeast flank include a lot of sandy substrate. Hard coral cover is relatively low and has increased gradually over the survey period (16.5% in 1993 to 21.7% in 2003). *Goniopora* and *Porites* are the most abundant genera. The cover of soft corals was fairly stable (19.5% on average) until a decrease in 2002, falling to 10.5% in 2003. This decrease is probably a result of bleaching mortality. The cover of algae has increase since 1999, reaching 46% in 2003. Incidence of white syndrome disease increased in 2003 but was still very low.

Abundance of most fish taxa were relatively stable. Although numbers have fluctuated over the 11-year study period there have been no prolonged increases or decreases. Abundance of two species of *Pomacentrus* (*P. moluccensis*, and *P. brachialis*) have declined slightly since surveys began in 1993, while a number of *Chromis* species (particularly *C. nitida*) increased in numbers over the past few years. The increase in numbers of *Chromis* was consistent across the other two inshore Whitsunday reefs. Numbers of *Acanthochromis polyacanthus* and *Amblyglyphidodon curacao* and *A. leucogaster* increased dramatically in 2003.

Figure 4.114

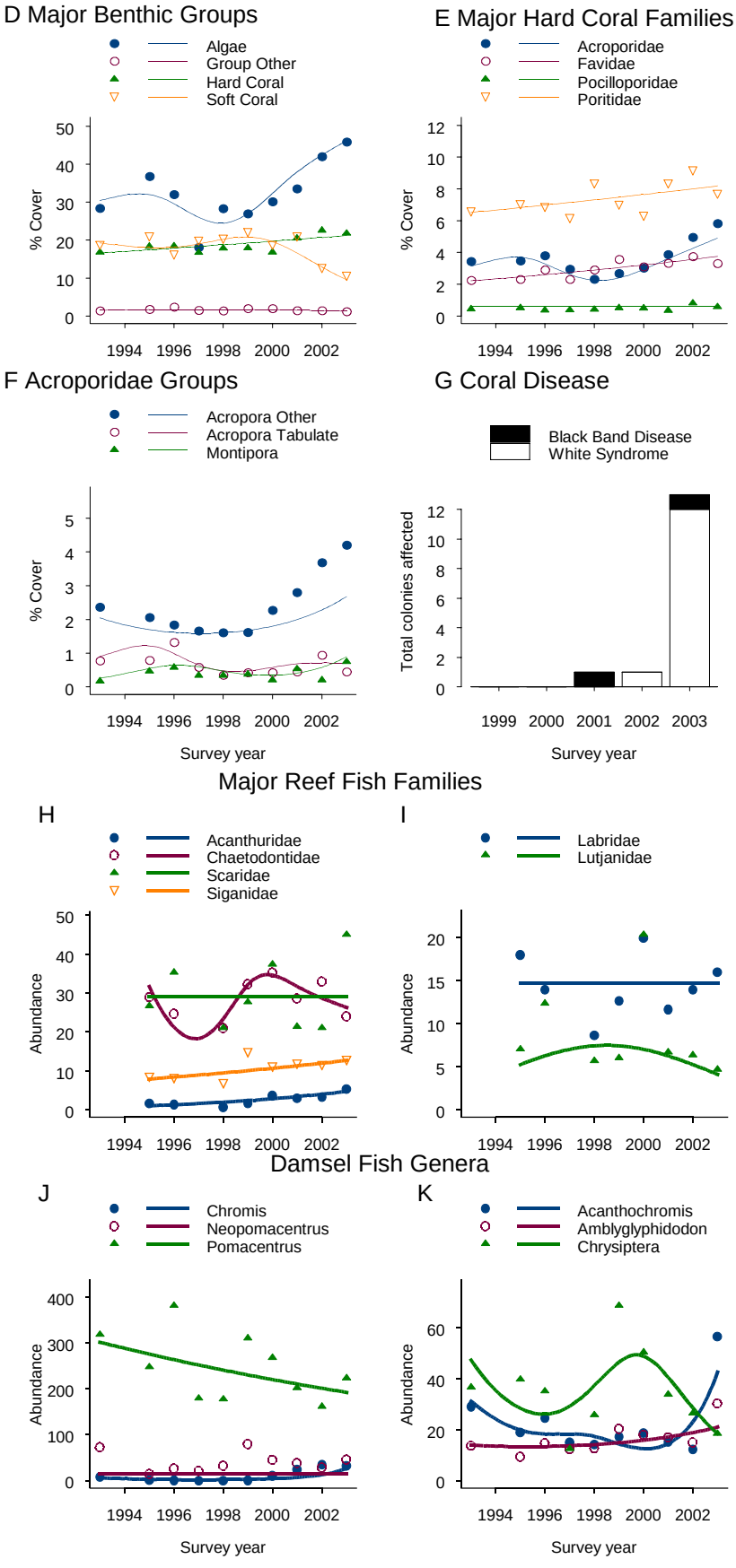
A





Langford And Bird Is'S (No. 20-019) is an inner shelf fringing reef with an area of 2.5 sq.km.

Figure 4.114 (Cont).



REBE

Surveyed November 2002.

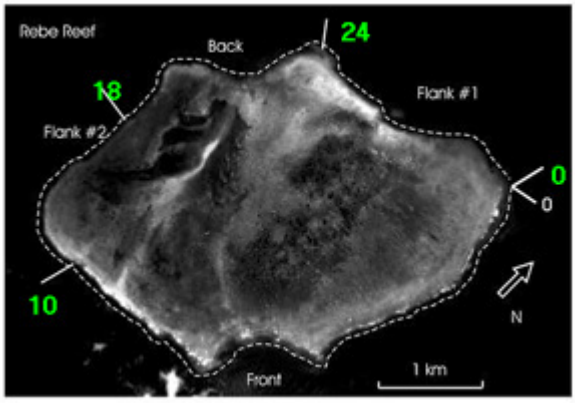
Rebe Reef has been surveyed eleven times since 1990 when it had a moderate reef-wide live coral cover (10-30%) and was classified as No Outbreak. Reef-wide live coral cover remained stable at a moderate level before entering a period of decline to a low level (1-10%) from 1994. No COTS were recorded, so the reason for this decline is unknown. Cyclone Celeste (1996) and Cyclone Justin (1997) may have played a part. Since 1997, reef-wide live coral cover has recovered to moderate levels (10-30%). There was slight decline in reef-wide live coral cover in 2003 possibly as a result of the 2002 bleaching event. This reef was still classified as No Outbreak. No bleaching was recorded in 2003 and white syndrome disease only affected a few scattered colonies.

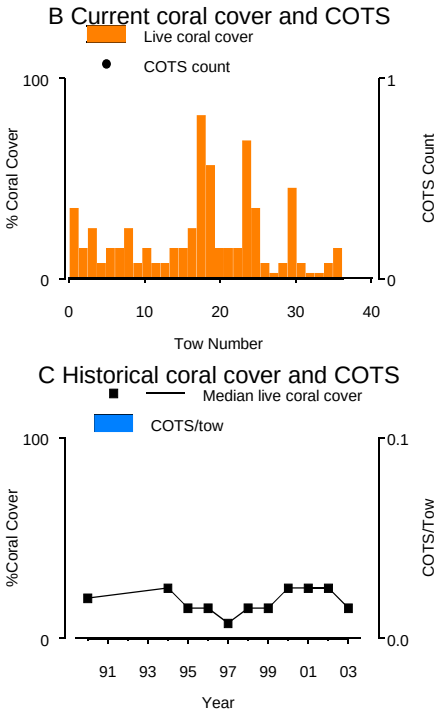
Intensive surveys on the southeastern flank show that hard coral cover remained relatively stable since 1994 at about 20%. In 2003 it was 18.7%. The cover of soft coral is relatively high and has been increasing over the survey period from 29.3% in 1994 to 44.6% in 2003. There has been a corresponding decrease in the cover of algae from 39.4% to 23.3%. Rebe reef has the greatest cover of sponges (12%) of any of our core survey reefs. The density of corallivorous snails *Drupella* spp. was 26.7/ha in 2003.

Although numbers of most fish taxa have varied from year to year there has been few prolonged increases or decreases over the 10 year study period. This may reflect the relative stability of the benthos over the same period. Numbers of the damselfish *Amblyglyphidodon curacao* have considerably increased since surveys began. Only one taxon, *Chrysiptera*, has shown a clear decline in numbers and richness. Three species were regularly recorded until 1999, after which only *C. rollandi* was observed, and by 2003 numbers of this species were the lowest recorded at this reef. As habitat and general fish assemblage structure appear to have remained relatively stable, it is possible that the supply of larval *Chrysiptera* has been minimal for some time.

Figure 4.115

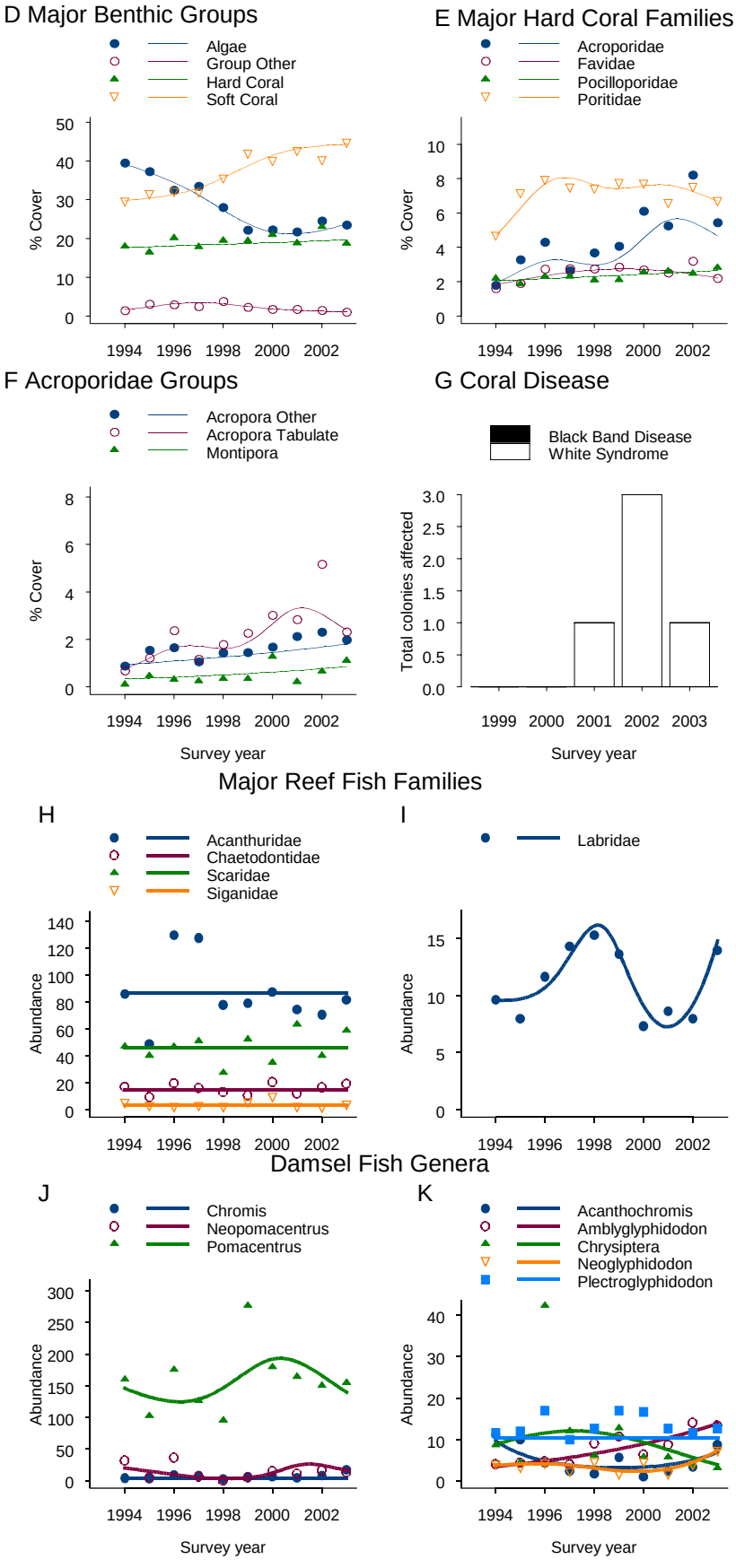
A





Rebe (No. 19-209) is an outer shelf planar reef with an area of 8.1 sq.km.

Figure 4.115 (Cont).



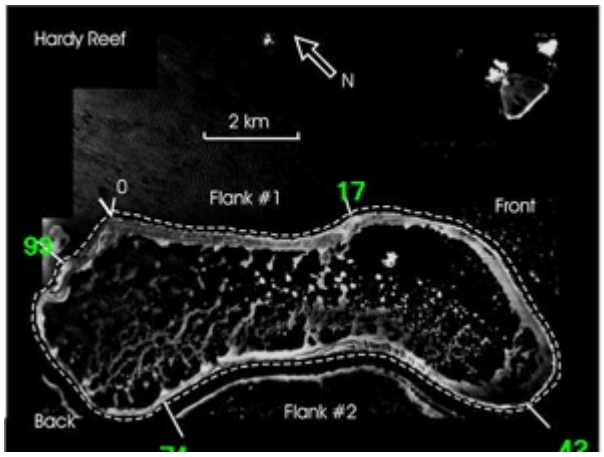
HARDY

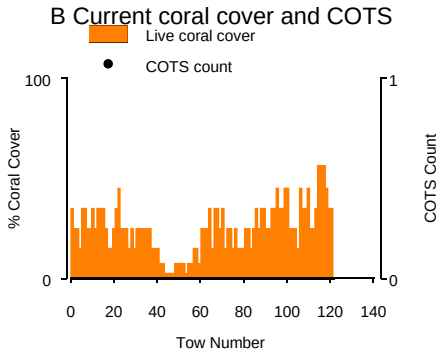
Surveyed December 2002.

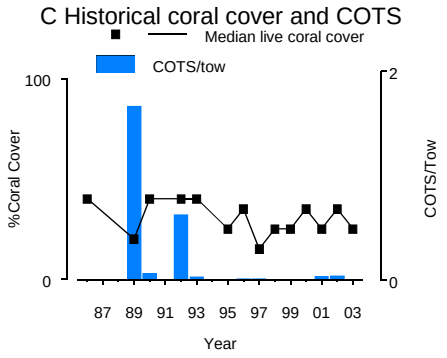
Hardy Reef was first surveyed in 1986 when it had high reef-wide live coral cover (30-50%) and was classified as No Outbreak. An outbreaking population of COTS developed between 1986 and 1989, resulting in a sharp decline in coral cover. The coral then recovered and reef-wide live coral cover remained high in subsequent years despite an Incipient Outbreak in 1992. Between 1993 and 1997 coral cover once again declined with a sharp drop recorded in 1997, most likely due to Cyclone Justin. Reef-wide live coral cover has increased gradually since 1997 to be moderate (10-30%) in 2003. No COTS or coral bleaching were observed in 2003 but a few scattered coral colonies had black band disease or white syndrome disease.

Figure 4.116

A







Hardy (No. 19-135) is a middle shelf crescentic reef with an area of 41.9 sq.km.

Pompey

Reef Pages

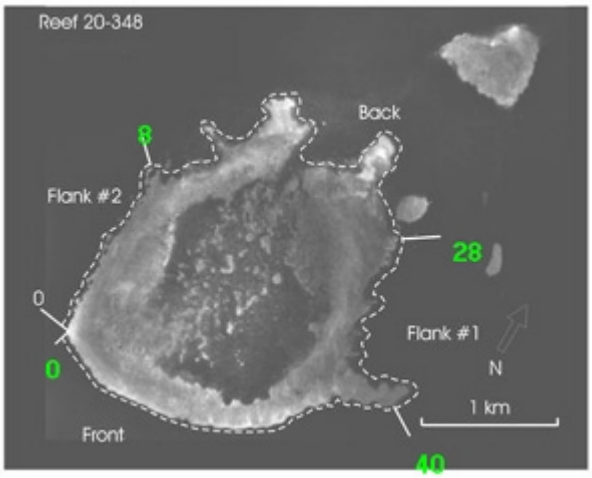
20348

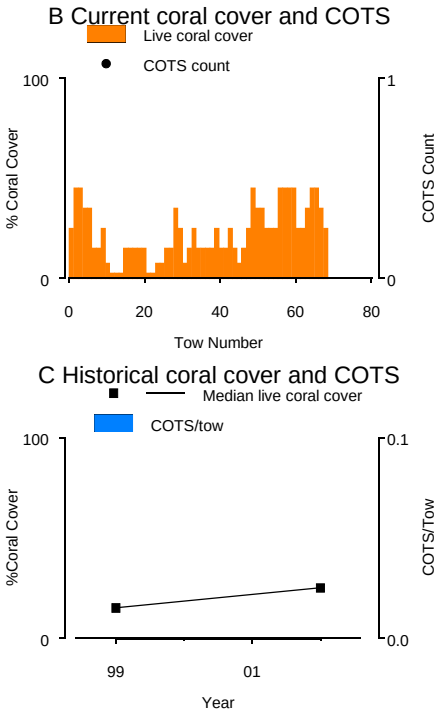
Surveyed August 2001.

This reef has been surveyed only twice, in 1999 and 2002. No COTS were observed in 2002, reef-wide live coral cover was moderate (10-30%) and the reef was classified as No Outbreak. No bleaching was recorded and white syndrome disease affected only a few scattered coral colonies.

Figure 4.117

A





20348 (No. 20-348) is a middle shelf lagoonal reef with an area of 12.5 sq.km.

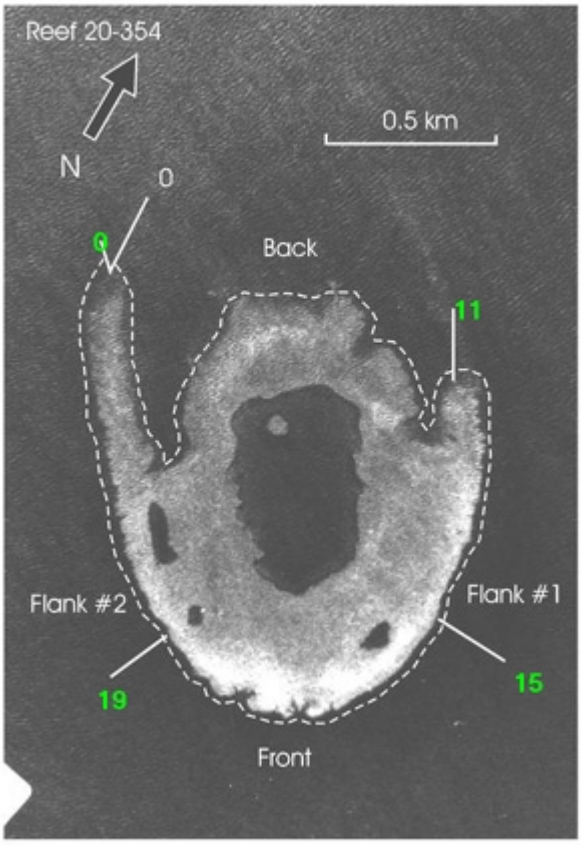
20354

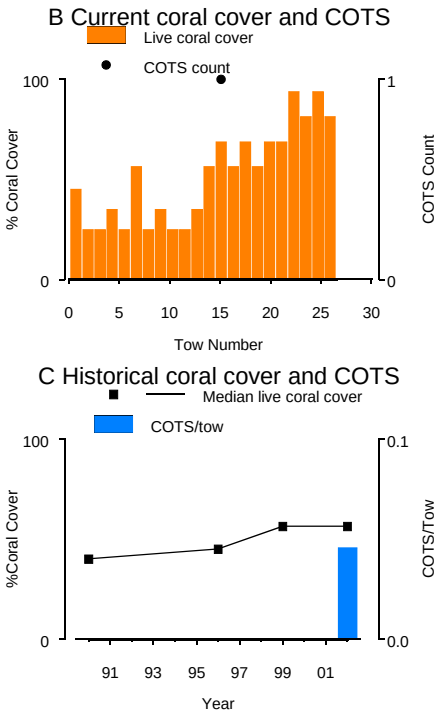
Surveyed August 2001.

This reef was surveyed four times between 1990 and 2002. Reef-wide live coral cover was initially high (30-50%) and increased to very high (50-75%) in 2002. A single COTS was recorded from this reef and it was classified as No Outbreak. No bleaching and a low incidence of white syndrome disease was recorded, affecting only a few scattered colonies.

Figure 4.118

A





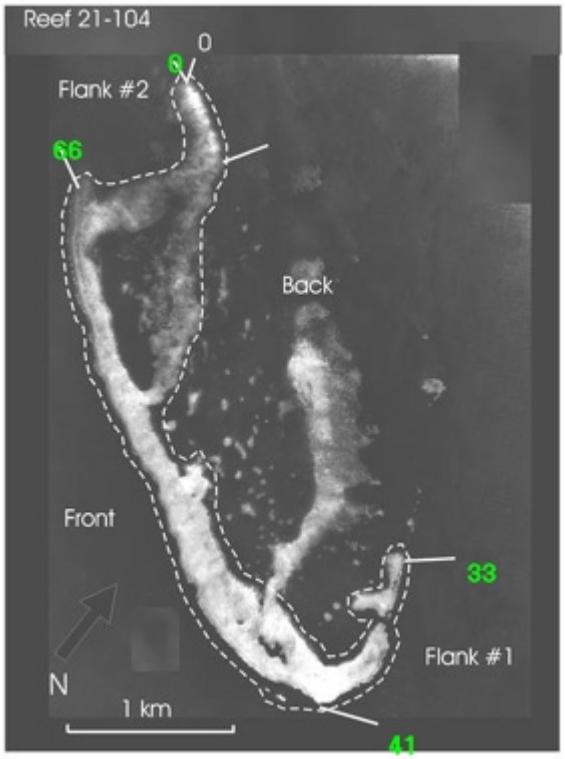
20354 (No. 20-354) is a middle shelf crescentic reef with an area of 2.5 sq.km.

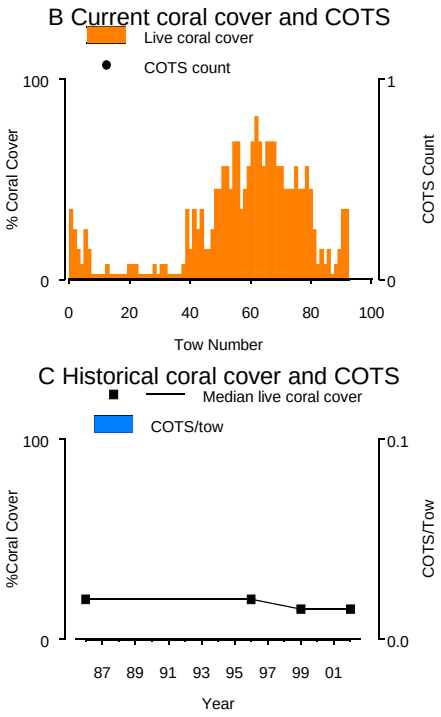
21104

Surveyed August 2001.

This reef was surveyed four times between 1986 and 2002. Over this time there was little change in reef-wide live coral cover, which remained at a moderate level (10-30%). No COTS have been recorded on any surveys and the reef was classified as No Outbreak in 2002. No bleaching and low levels of white syndrome disease and black band disease were recorded, affecting only a few scattered coral colonies.

Figure 4.119 A





21104 (No. 21-104) is a middle shelf lagoonal reef with an area of 15.6 sq.km.

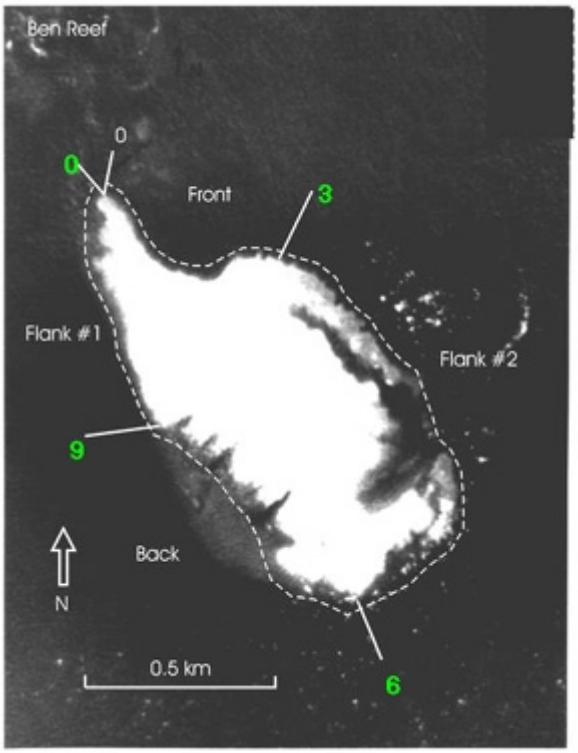
BEN

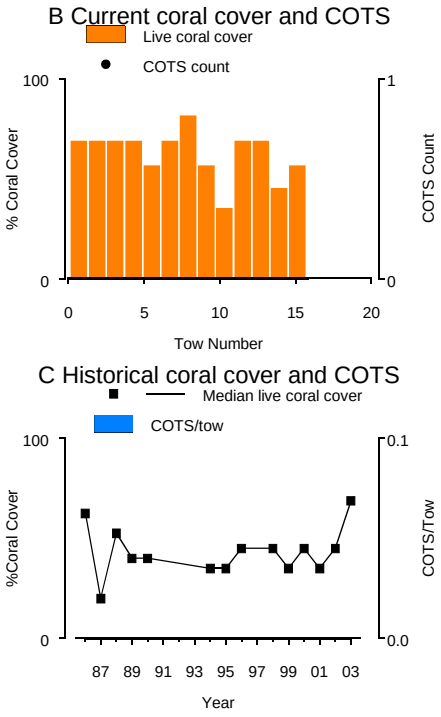
Surveyed November 2002.

Ben Reef has been surveyed fourteen times since 1986. Reef-wide live coral cover was initially very high (50-75%) but decreased to high levels (30-50%) during the 1990s then reached very high levels once more in 2003. No COTS have been recorded from this reef and it was classified as No Outbreak in 2003. No bleaching was observed and incidence of white syndrome disease was low, affecting only a few scattered coral colonies.

Figure 4.120

A





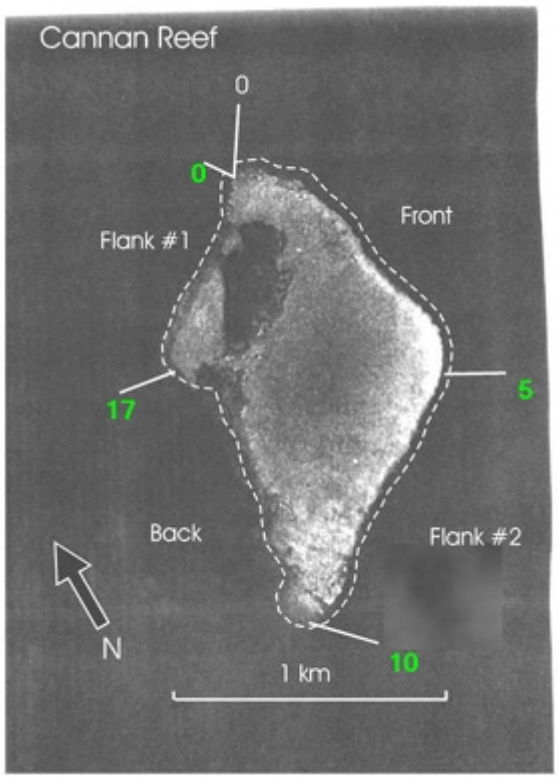
Ben (No. 20-113) is an outer shelf planar reef with an area of 1.2 sq.km.

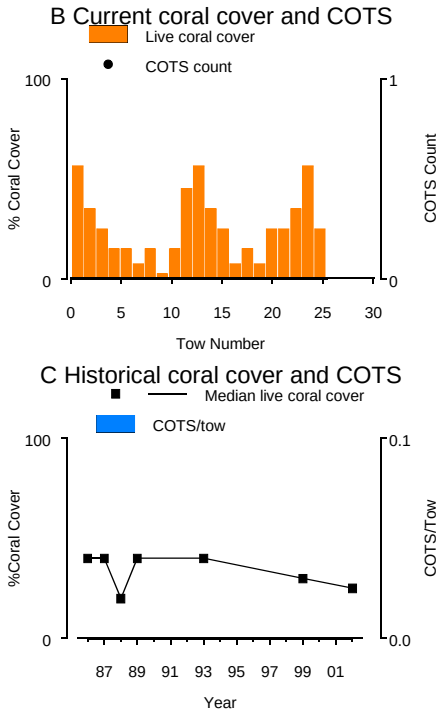
CANNAN

Surveyed August 2001.

This reef was surveyed seven times between 1986 and 2002. Reef-wide live coral cover was high (30-50%) initially but it decreased to be moderate (10-30%) in 2002. No COTS have been recorded, so the cause of the decline is unknown. The reef was classified as No Outbreak in 2002. No bleaching was recorded and there was evidence of white syndrome disease and black band disease affecting only a few scattered coral colonies.

Figure 4.121 A





Cannan (No. 20-144) is a middle shelf crescentic reef with an area of 0 sq.km.

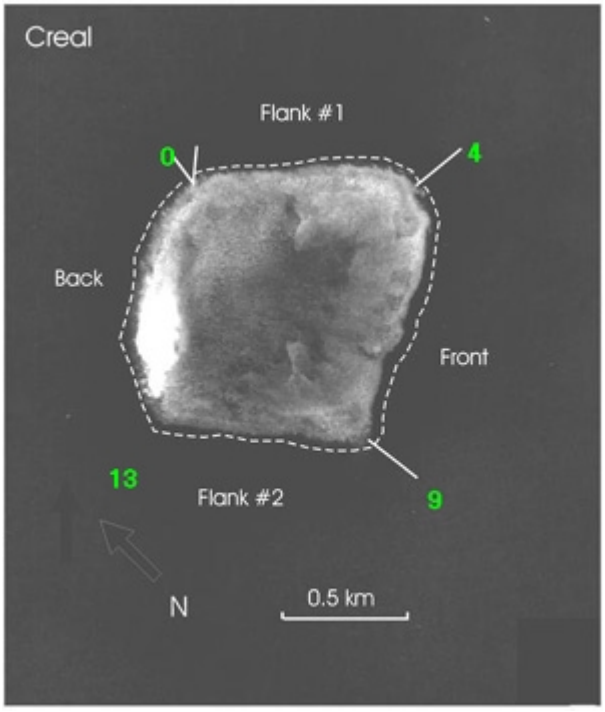
CREAL

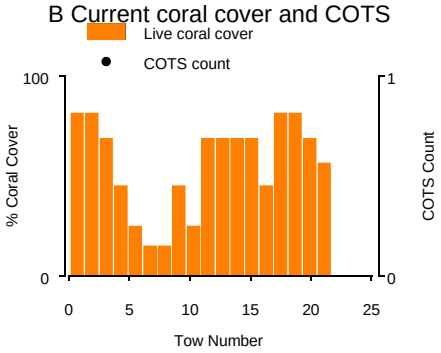
Surveyed September 2002.

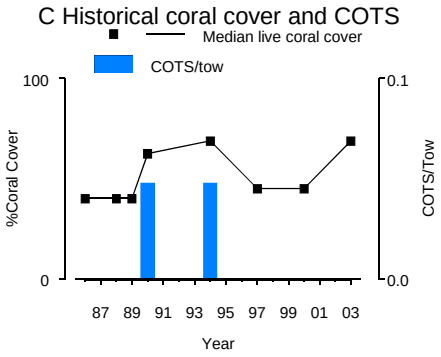
Creal Reef has been surveyed eight times since 1986. Reef-wide live coral cover was high (30-50%) in initial surveys. In 1990 coral cover dramatically increased despite a Non-Outbreaking population of COTS being present and stayed very high (50-75%) until 1994. Reef-wide live coral cover had then declined to previous levels around 30-50% by 1997 possibly due to Cyclone Justin and again increased to a very high level (50-75%) in 2003. No COTS were observed and the reef was classified as No Outbreak. A few scattered coral colonies were affected by bleaching and white syndrome disease in 2003.

Figure 4.122

A







Creal (No. 20-297) is a middle shelf planar reef with an area of 1.6 sq.km.

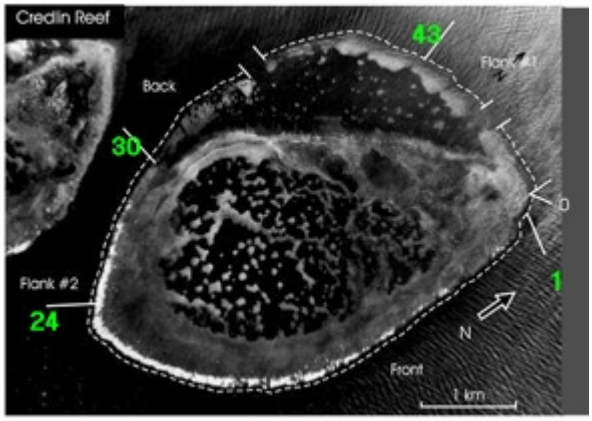
CREDLIN

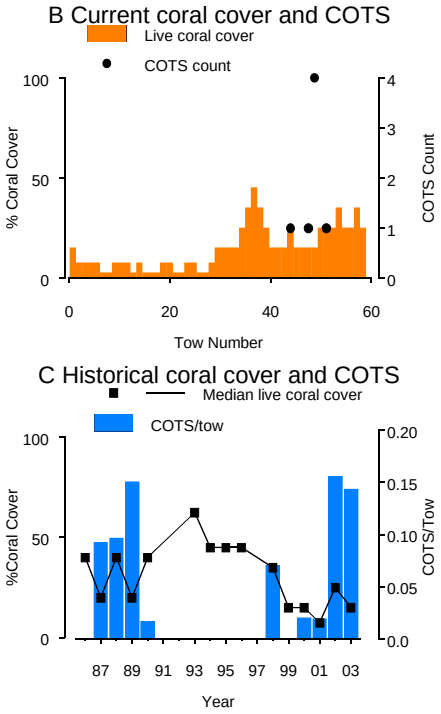
Surveyed September 2002.

Credlin Reef has been surveyed fifteen times since 1986 when it had high reef-wide live coral cover (30-50%) and no COTS. COTS were observed on this reef between 1987 and 1990, though in numbers too low to have an effect on overall coral cover. Reef-wide live coral cover peaked in 1993 at very high levels (50-75%), then declined to be low (1-10%) in 2001. The reasons for this decline were unclear, but cyclone Justin in 1997 may have contributed. COTS populations were observed in 1998 and 2000 to 2003 but below outbreak densities. There was a further decrease in 2003 which was almost certainly due to bleaching in 2002. A few scattered coral colonies were affected by bleaching, white syndrome and black band disease in 2003.

Figure 4.123

A





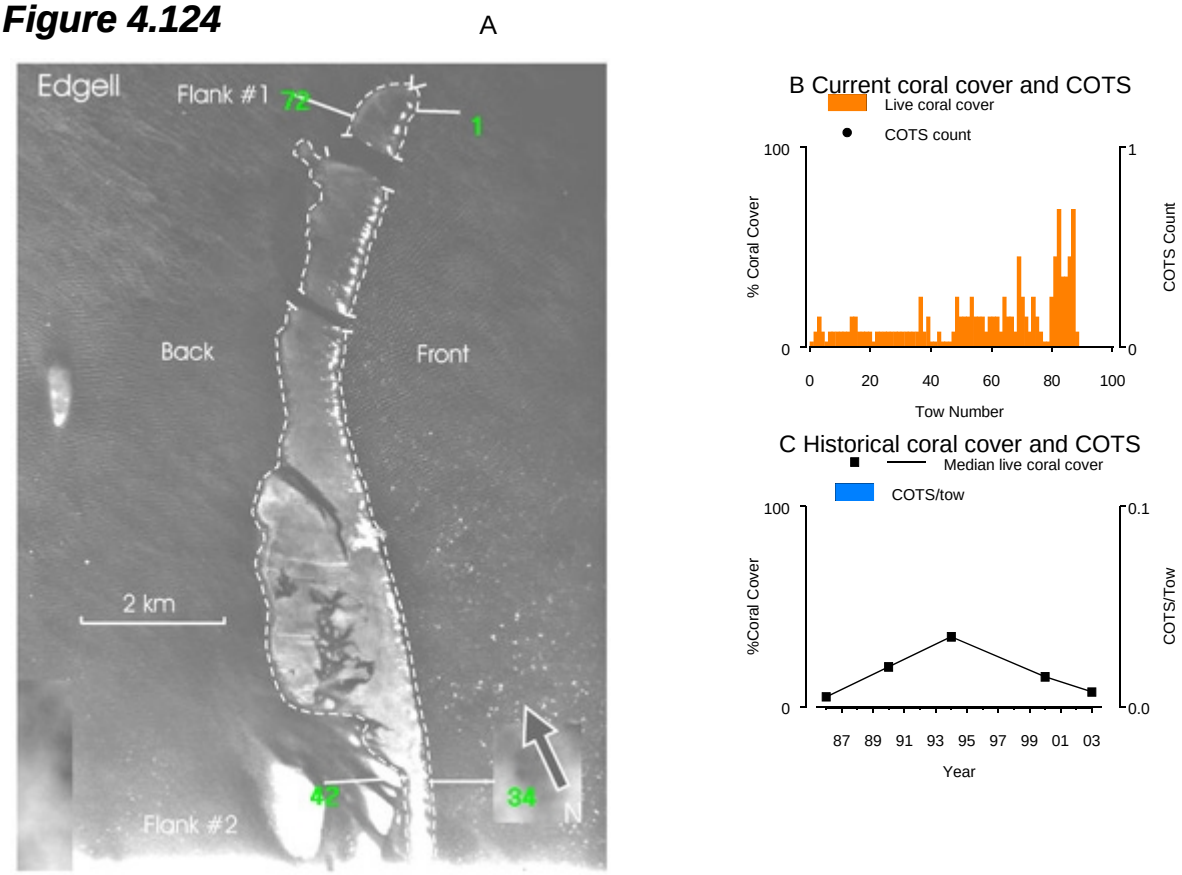
Credlin (No. 20-287) is a middle shelf lagoonal reef with an area of 9.4 sq.km.

EDGELL

Surveyed November 2002.

Edgell Reef has been surveyed five times by manta tow since 1986, when reef-wide live coral cover was low (1-10%) and no COTS were observed. Reef-wide live coral cover increased steadily to high levels (30-50%) by 1994, then declined to a low level (1-10%) in 2003. The causes of this decline are unknown. However the combined effects of Cyclone Justin, which affected reefs in the area in 1997, and the 2002 bleaching event may have contributed. Edgell Reef was classified as No Outbreak in 2003. No bleaching and a low incidence of white syndrome disease were recorded in 2003.

Figure 4.124



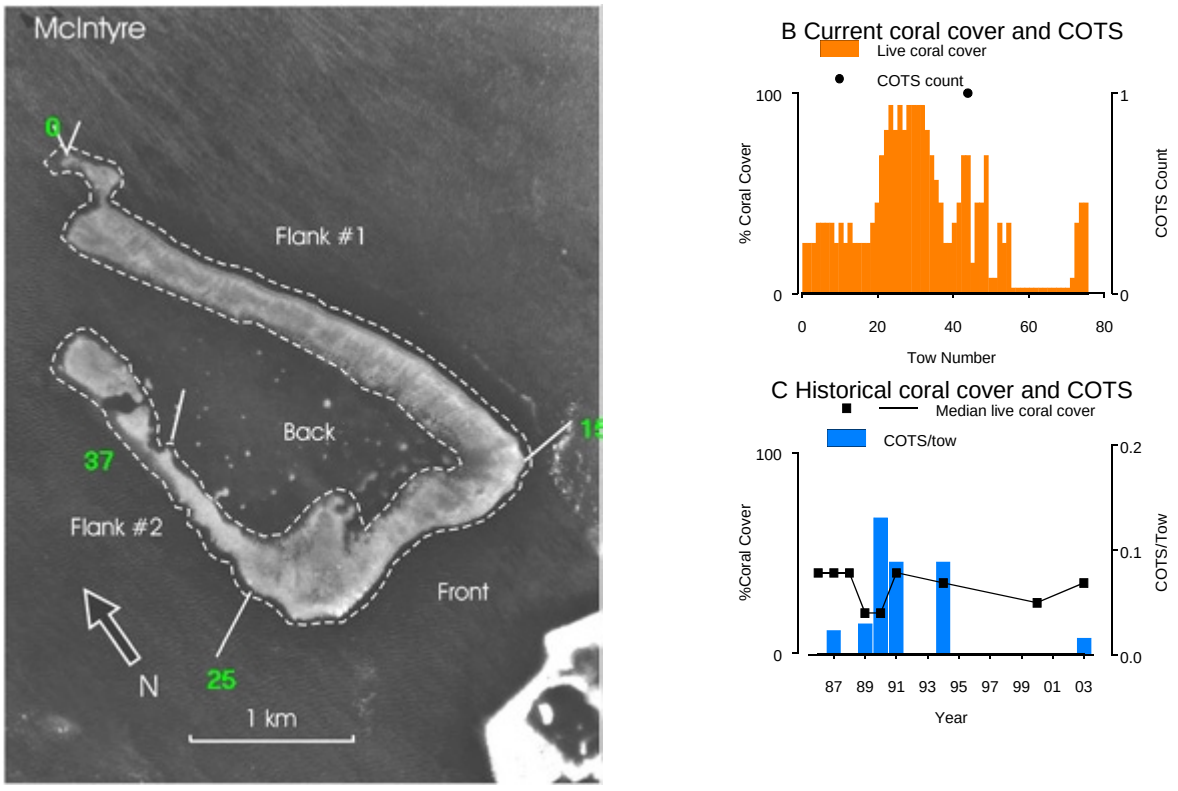
Edgell (No. 20-112) is a middle shelf reef patches reef with an area of 13.1 sq.km.

MCINTYRE

Surveyed November 2002.

McIntyre Reef was first surveyed in 1986, when there was high coral cover (30-50%) and no COTS were observed. This state remained until 1989 when reef-wide live coral cover decreased. Between 1989 and 1991 there was a non-outbreaking population of COTS, but reef-wide live coral cover increased and had regained 1986 levels by 1991. Despite the absence of COTS in all subsequent years except 1994, coral cover declined continuously to a moderate level by 2000. Cyclone Justin in 1997 may have contributed. Reef-wide live coral cover was high in 2003 and it was classified as No Outbreak, although a few COTS were recorded. No coral bleaching was observed. A few scattered colonies were affected by black band disease and white syndrome disease was common (>10 individual colonies per two-minute tow) on the front and flanks of the reef where coral cover was highest.

Figure 4.125



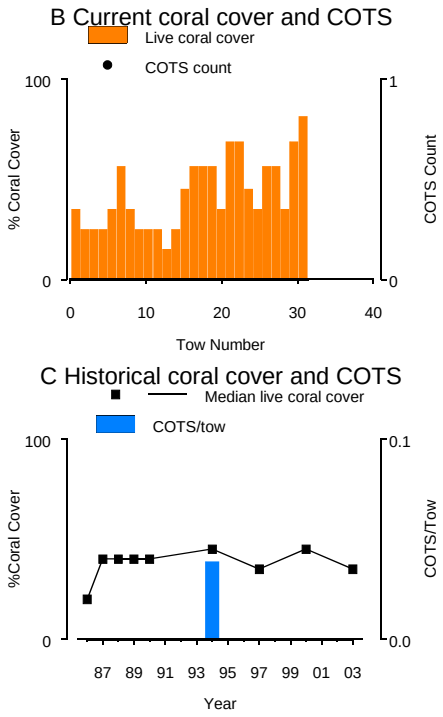
Mcintyre (No. 19-219) is a middle shelf lagoonal reef with an area of 8.79 sq.km.

PACKER

Surveyed September 2002.

Packer Reef was first manta tow surveyed in 1986 when reef-wide live coral cover was moderate (10-30%) and no COTS were seen. Reef-wide live coral cover then increased to a high level (30-50%) and remained high until 2003. COTS were detected once in 1994 at non-outbreaking levels. No bleaching or coral diseases were observed in 2003 and the reef remained classified as No Outbreak.

Figure 4.126 A



Packer (No. 20-145) is a middle shelf crescentic reef with an area of 1.6 sq.km.

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Swain

Reef Pages

21529

Surveyed September 2002.

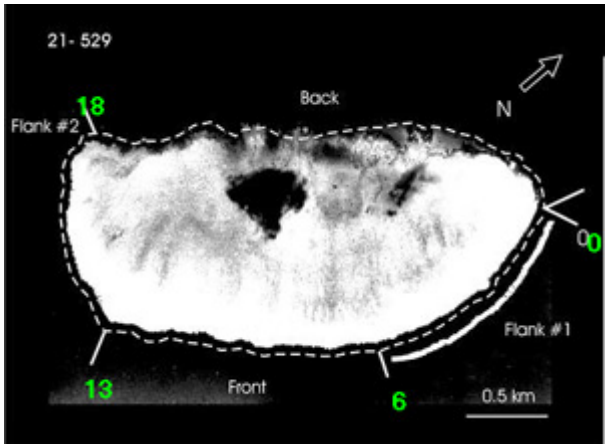
This reef has been surveyed extensively since 1993. Broadscale surveys over this period show that reef-wide live coral cover remained at moderate levels (10-30%) until 1997. From 1998 up until 2003 reef-wide live coral had increased steadily to very high values (50-75%). No COTS have been observed on this reef during any survey and it was classified as No Outbreak. Bleaching and white syndrome disease occurred at low levels affecting a few scattered coral colonies in 2003.

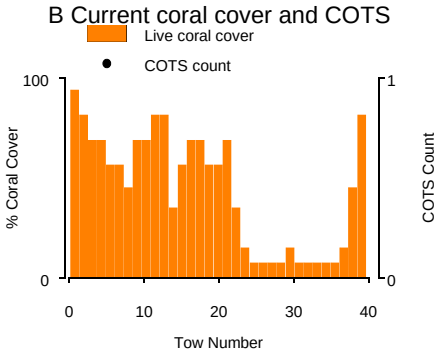
Detailed coral surveys showed that cover of hard coral has risen steadily over the survey period. Hard coral cover increased from an average of 29 % in 1995 to reach a maximum of 64% in 2002. In 2003 hard coral cover was 61%. Algal cover declined correspondingly, from 64% in 1995 to 33% in 2003. Soft coral cover has remained very low (< 2%) since surveys began. Changes in hard coral cover are largely due to increases in cover of bottlebrush and branching *Acropora* spp., and these taxa have remained dominant throughout this study. The density of corallivorous snails *Drupella* spp. was 46.7/ha in 2003.

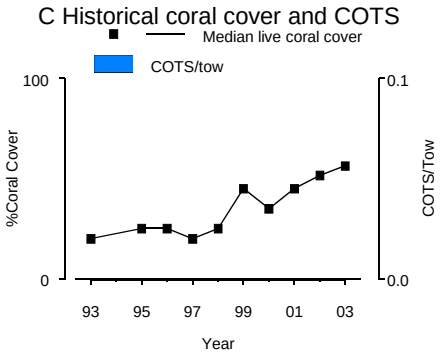
Although abundances of fishes have varied from year to year there has been little tendency for prolonged increases or decreases in any species over the 11 years of the study. One genus (*Pomacentrus*), tended to decline in abundance. In 2003, numbers of three *Pomacentrus* species, *P. wardi*, *P. brachialis* and *P. lepidogenys*, were at their lowest since surveys began and *P. coelestis* was absent in surveys for the first time.

Figure 4.127

A

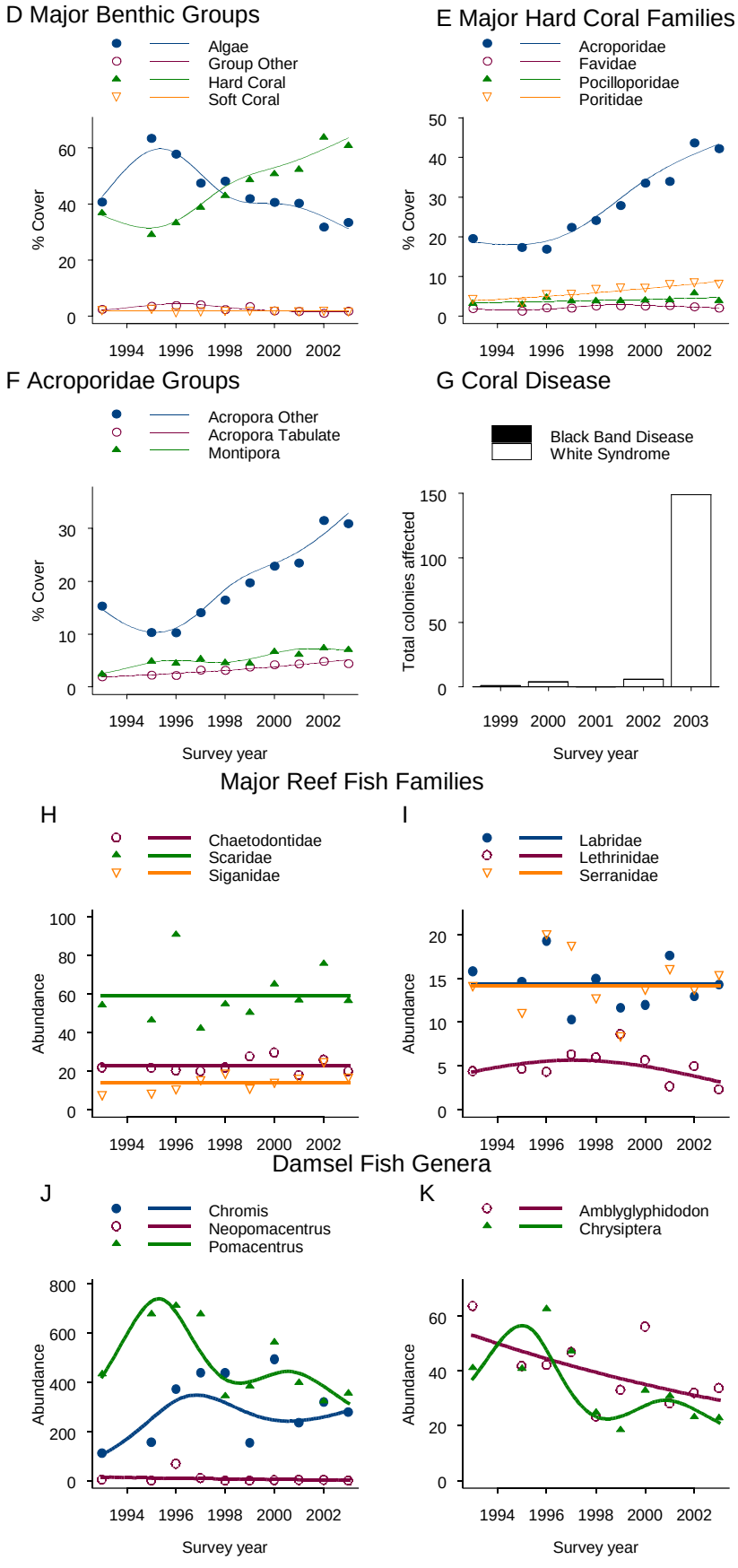






21529 (No. 21-529) is a middle shelf crescentic reef with an area of 6.3 sq.km.

Figure 4.127 (Cont).



22088

Surveyed December 2002.

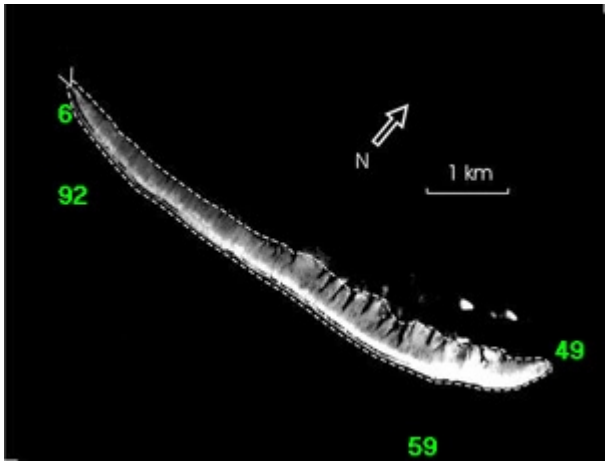
This reef has been surveyed extensively since 1993 when COTS numbers were high. This reef was classified as having an Incipient Outbreak until 1997 and reef-wide live coral cover dropped from a high level (30-50%) in 1993 to a low level (1-10%) by 1997. The reef was reclassified as Recovering from then on. No COTS were observed on this reef after 1997 and there has been a steady recovery in reef-wide live coral cover to moderate (10-30%) in 2003. A few scattered coral colonies were affected by bleaching and white syndrome disease.

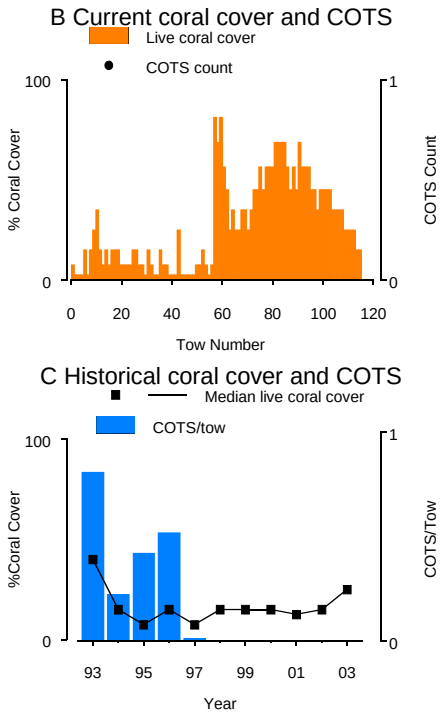
Cover of hard corals in the intensive survey sites decreased to a low of 17.4% in 1997, coinciding with high COTS numbers. After 1998 hard coral cover increased to 47% in 2003. There has been a steady increase in the abundance the families Acroporidae and Poritidae. Acroporidae is currently the most abundant family of hard corals on this reef with an average cover of 22.6%. The cover of algae decreased correspondingly, averaging 35.2% in 2003. While soft coral abundance was low, there had been a gradual increase in cover. The density of corallivorous snails *Drupella* spp. was 6.7/ha in 2003.

Although year to year variation in abundance was common there was little tendency for prolonged increases or decreases in most taxa. The decrease in numbers of Acanthuridae was largely driven by *Ctenochaetus* spp and is similar to that recorded at Chinaman Reef, where coral cover has increased similarly. This genus also decreased in abundance on outer shelf reefs in the Cooktown / Lizard Is sector as hard coral cover reached high levels. The increase in numbers of Chaetodontidae reflected an influx of a coral-associated species, *C. rainfordi*. Although the genus *Pomacentrus* appears stable in a long-term sense, numbers of one species (*P. wardi*) have declined dramatically to an 11 year low in 2003 as also occurred at Chinaman Reef.

Figure 4.128

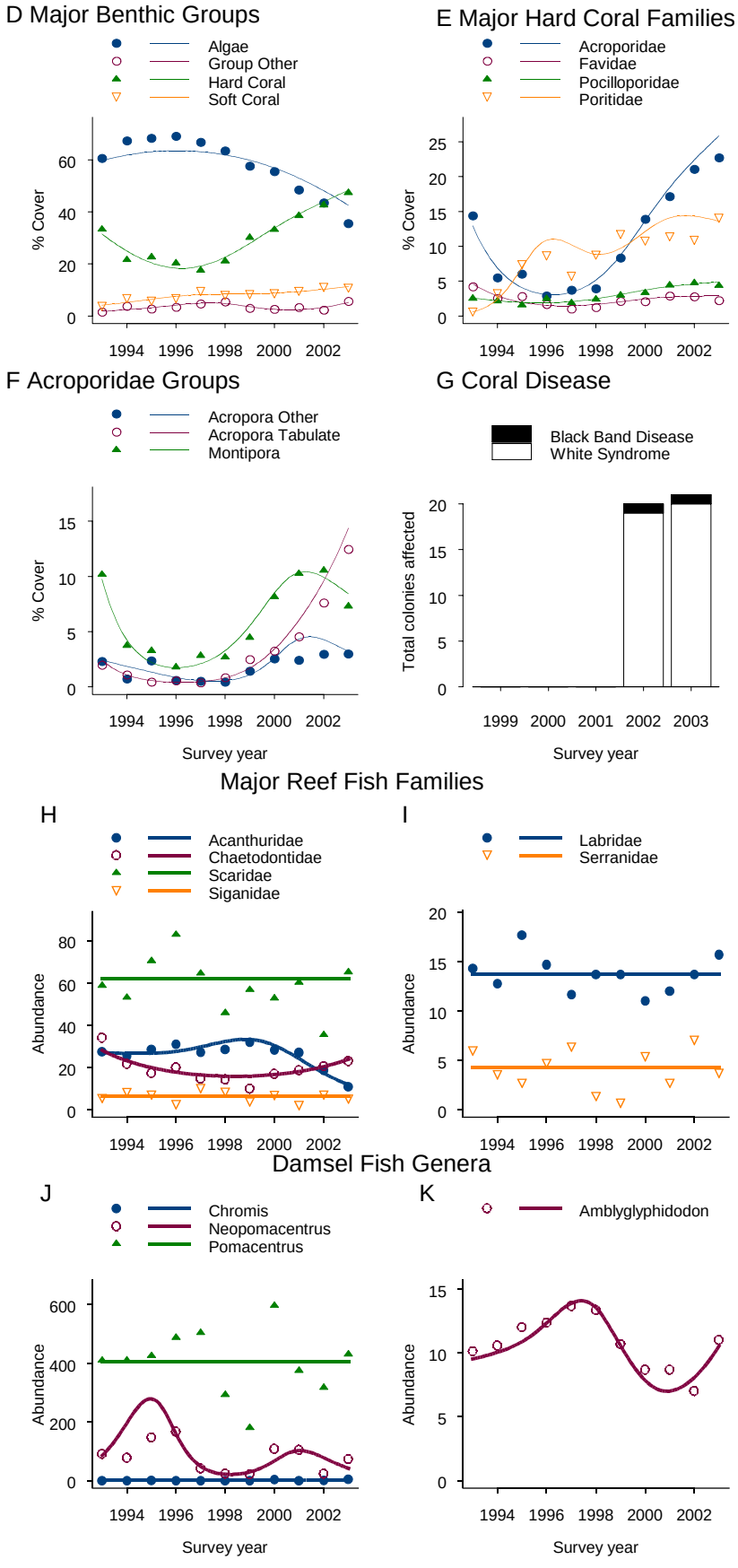
A





22088 (No. 22-088) is an inner shelf ribbon reef with an area of 14.4 sq.km.

Figure 4.128 (Cont).



CHINAMAN

Surveyed September 2002.

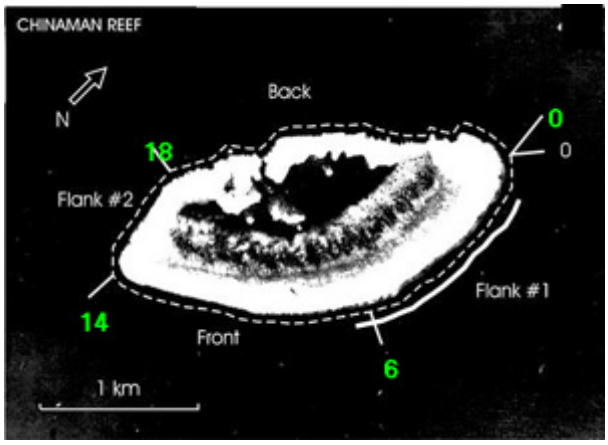
This reef has been surveyed extensively since 1986. Although COTS have been recorded regularly during manta tow surveys, the reef was only classified as an Active Outbreak in 1998. Over the period of survey reef-wide live coral cover has fluctuated. There was a notable drop in coral cover between 1988 and 1990 which coincides with similar declines on reefs in the Capricorn Bunker sector. Storm damage is considered the most likely cause. From 1990 reef-wide live coral cover increased reaching high levels (30-50%) in 1999. Since then there has been an Active Outbreak of COTS that caused a decline in reef-wide live coral cover to low levels (1-10%). A few scattered coral colonies were affected by bleaching or white syndrome disease in 2003.

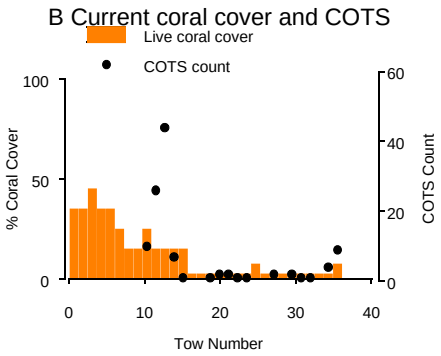
Hard coral cover increased from approximately 22% initially to 44% in 2003 in the intensive survey sites on the northeastern flank. The increase was mainly driven by Acroporidae, particularly tabulate *Acropora* spp. Algal cover decreased correspondingly since 1993. Declines in soft coral occurred following the 1998 and 2002 summers and were probably due to bleaching mortality. The soft coral community was dominated by Xeniidae and cover was moderately high at 26 % in 2003. The density of corallivorous snails *Drupella* spp. was 33.3/ha in 2003.

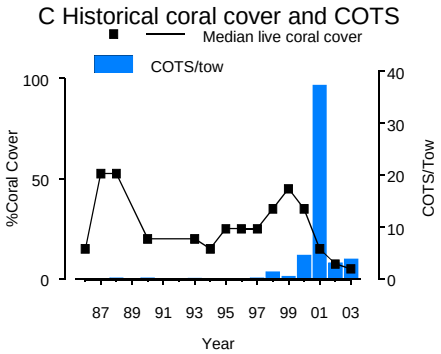
Although year to year variation in abundance was common there was little tendency for prolonged increases or decreases in most taxa. The decrease in numbers of Acanthuridae was largely driven by *Ctenochaetus* species. Similar declines occurred on Reef 22088, where coral cover increased similarly. This genus also decreased in abundance on outer shelf reefs in the Cooktown / Lizard Is sector as hard coral cover reached high levels. The increase in numbers of Chaetodontidae was due to an increase in the coral-associated species, *C. rainfordi* and *C. trifascialis*. Although the genus *Pomacentrus* appears stable in the long-term, numbers of one species, *P. wardi*, have declined to an 11 year low in 2003 as was also the case at Reef 22088.

Figure 4.129

A

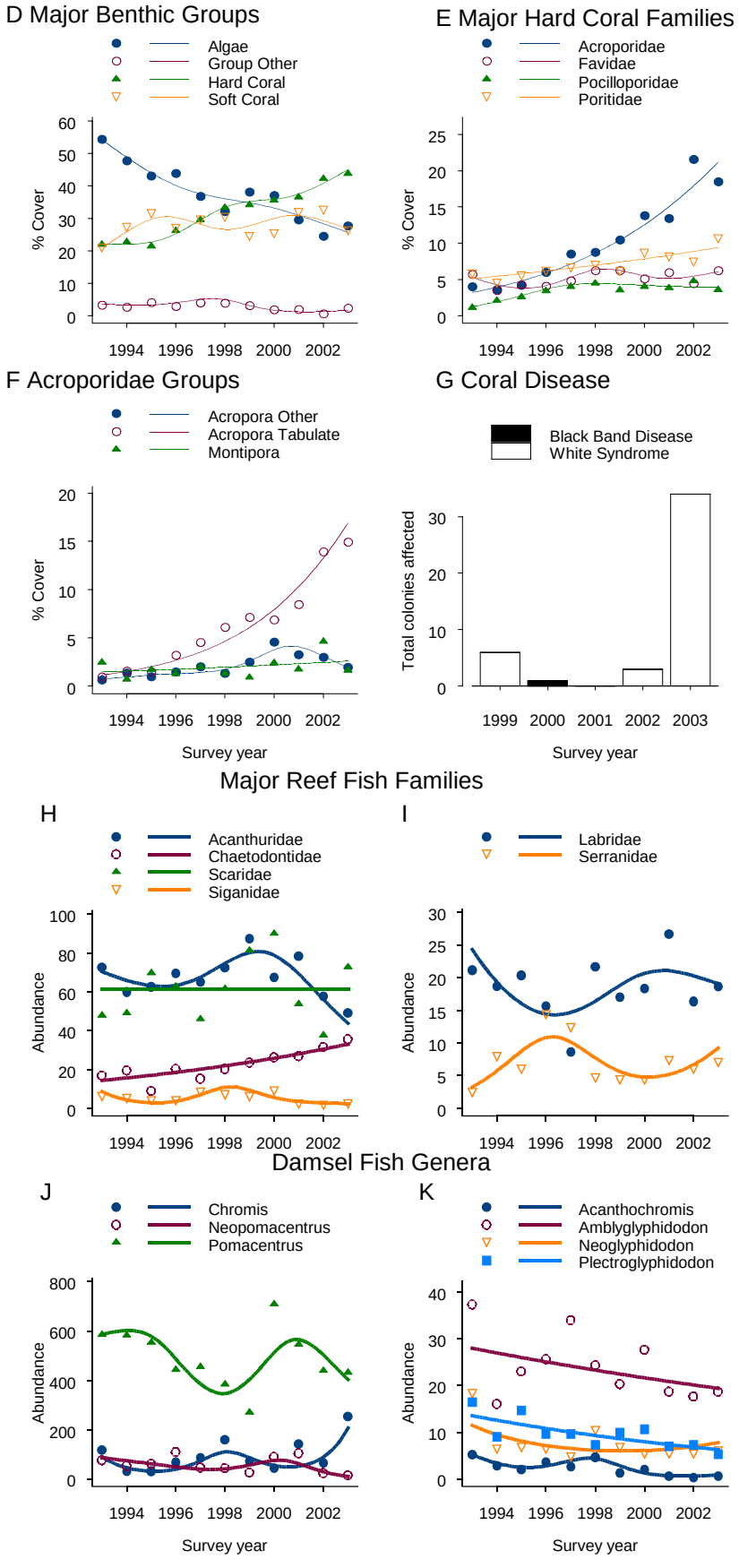






Chinaman (No. 22-102) is a middle shelf lagoonal reef with an area of 3.1 sq.km.

Figure 4.129 (Cont).



EAST CAY

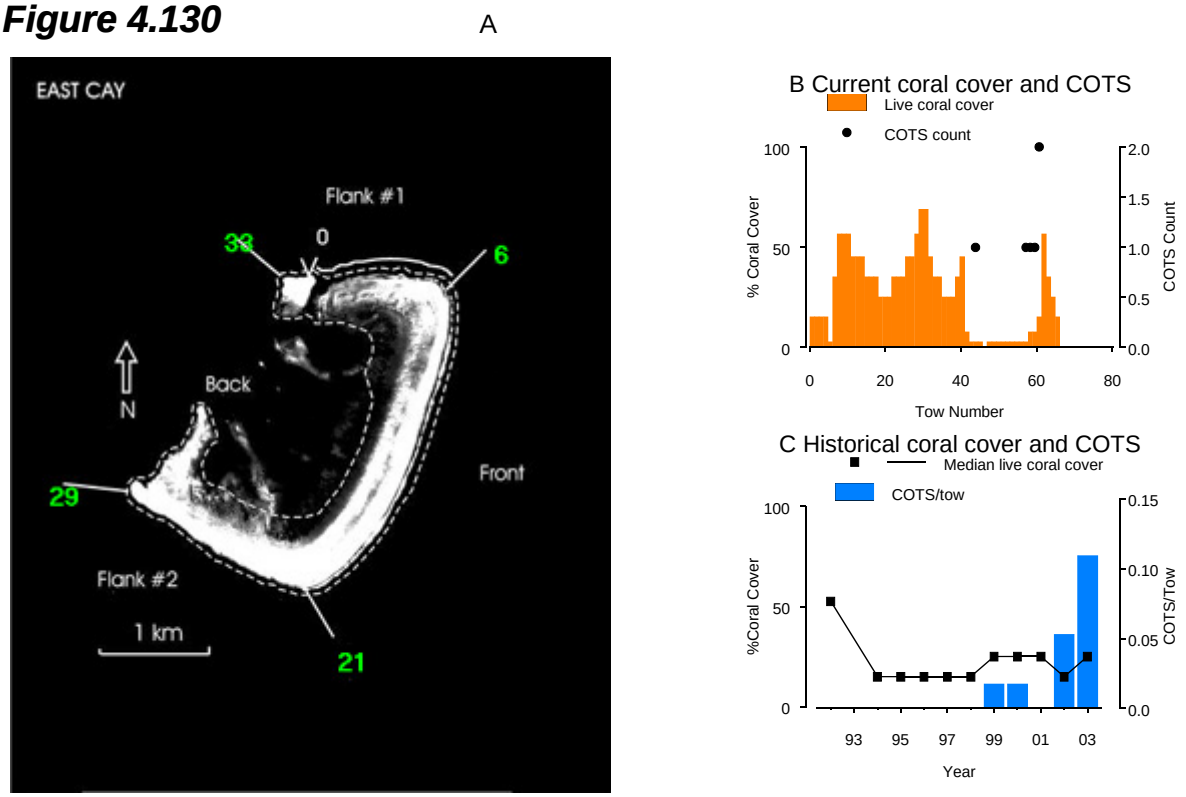
Surveyed September 2002.

This reef has been surveyed regularly since 1992 when reef-wide live coral cover was high (30-50%). Coral cover dropped to moderate levels (10-30%) in 1994 for unknown reasons and cover remained moderate to 2003. COTS have been recorded sporadically but below outbreak densities. Low numbers of COTS were observed on this reef during manta tow surveys in 2003 and the reef was classified as No Outbreak. A few scattered coral colonies were affected by bleaching or white syndrome disease in 2003.

Hard coral cover at the intensive survey sites increased gradually after 1994 and average 21.7% in 2003. Turfing algae and soft corals were the dominant benthic groups, averaging 41.5% and 22.7% respectively. There were small declines in cover of several hard coral families and a large decline in cover of Xeniidae soft corals. High sea surface temperatures were recorded in the summer of 2002 and bleaching mortality was the likely cause. The cover of sponges was the highest in the Swain sector.

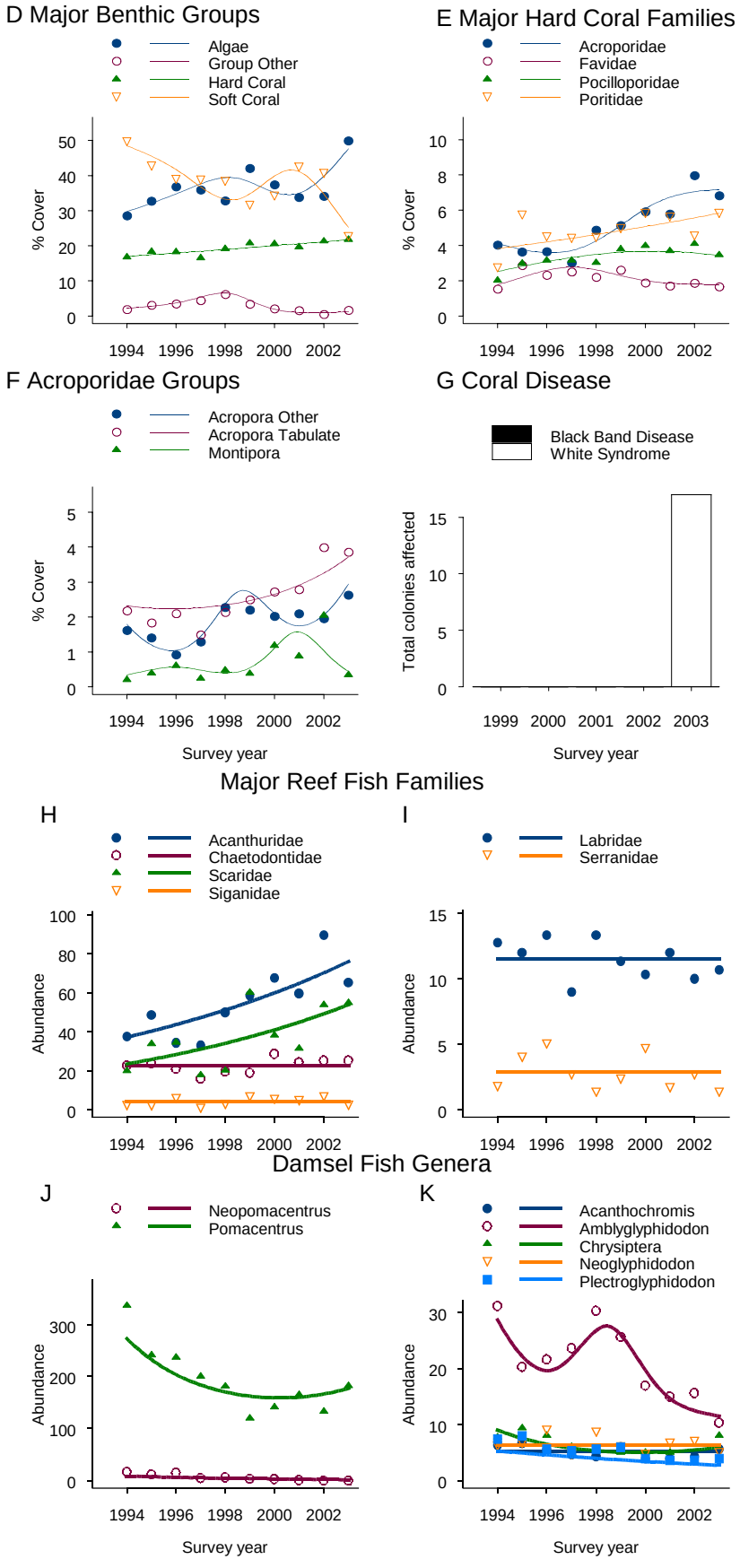
Among reef fishes, Acanthuridae and Scaridae increased in abundance while damselfishes declined over the survey period. Declines in numbers of *Pomacentrus* spp were driven largely by one species, *P. lepidogenys*. Numbers of this species were stable from 1999 to 2003. Abundance of another small damselfish species, *Neopomacentrus azysron*, decreased over the period and the species was not recorded after 2001. Numbers of a larger damselfish species, *Amblyglyphidodon curacao*, declined steadily from 1998. The reasons for these declines are unknown but successful recruitment events may be sporadic in this region.

Figure 4.130



East Cay (No. 21-305) is an outer shelf crescentic reef with an area of 6.3 sq.km.

Figure 4.130 (Cont).



GANNET CAY

Surveyed September 2002.

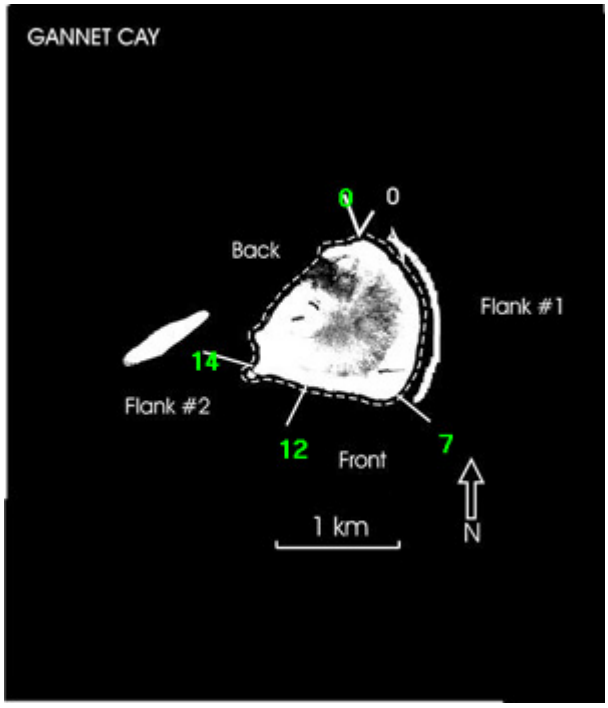
This reef has been surveyed extensively using manta tow since 1986. COTS have been present at Outbreak levels at fifteen of eighteen surveys. As a result, reef-wide live coral cover has declined dramatically from the extremely high levels (75-100%) in the 1980s. While there was some recovery between 1995 and 1997 when COTS were below outbreak levels, recent increases in COTS numbers, particularly in 2001, have seen reef-wide live coral cover drop to the lowest level (median cover less than 5%) so far in 2003. COTS numbers remain high and the reef is classified as Active Outbreak. No bleaching or coral disease was recorded in 2003.

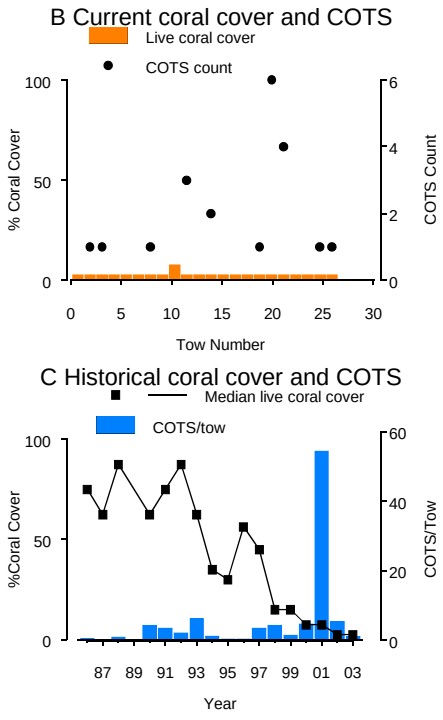
Surveys of the intensive study sites since 1993 show a steady decline in hard coral cover. Cover of hard corals was 60% in the first year of survey but has declined consistently to a low of approximately 4% cover in 2003. This decline is mostly due to the loss of branching *Acropora* colonies. Cover of Pocilloporidae has also decreased slightly. Algal cover has shown a corresponding increase in cover (32% in 1993 to 86% in 2003), due largely to an increase in turf algae. Soft coral cover has increased overall from 3% at to 9%. The density of corallivorous snails *Drupella* spp. was 40/ha in 2003.

The decline in hard coral cover from over 60% to under 10% over the 11 year study period has almost certainly affected some fish taxa. Two coral associated butterflyfish (Chaetodontidae), *Chaetodon rainfordi* and *C. aureofasciatus*, have decreased in abundance over the study period. The damselfish, *Pomacentrus moluccensis* (Pomacentridae) was initially abundant but has declined; this species lives among small branching corals. *Chromis atripectoralis*, another coral dependent damselfish, was not recorded in surveys for the first time in 2003. One of the few taxa to have increased in numbers is the parrotfish (Scaridae). However, there is high inter-annual variability in abundance among parrotfish species and *Scarus niger* is the only species to have shown a monotonic increase in abundance. Numbers of the snapper *Lutjanus carponotatus* (Lutjanidae), and the commercially important coral trout, *Plectropomus leopardus* (Serranidae), were at an 11-year low in 2003, although coral trout numbers were also low in 1998. Though Gannet Cay is a protected zone, signs of illegal fishing (snagged hooks and line) have been observed during surveys.

Figure 4.131

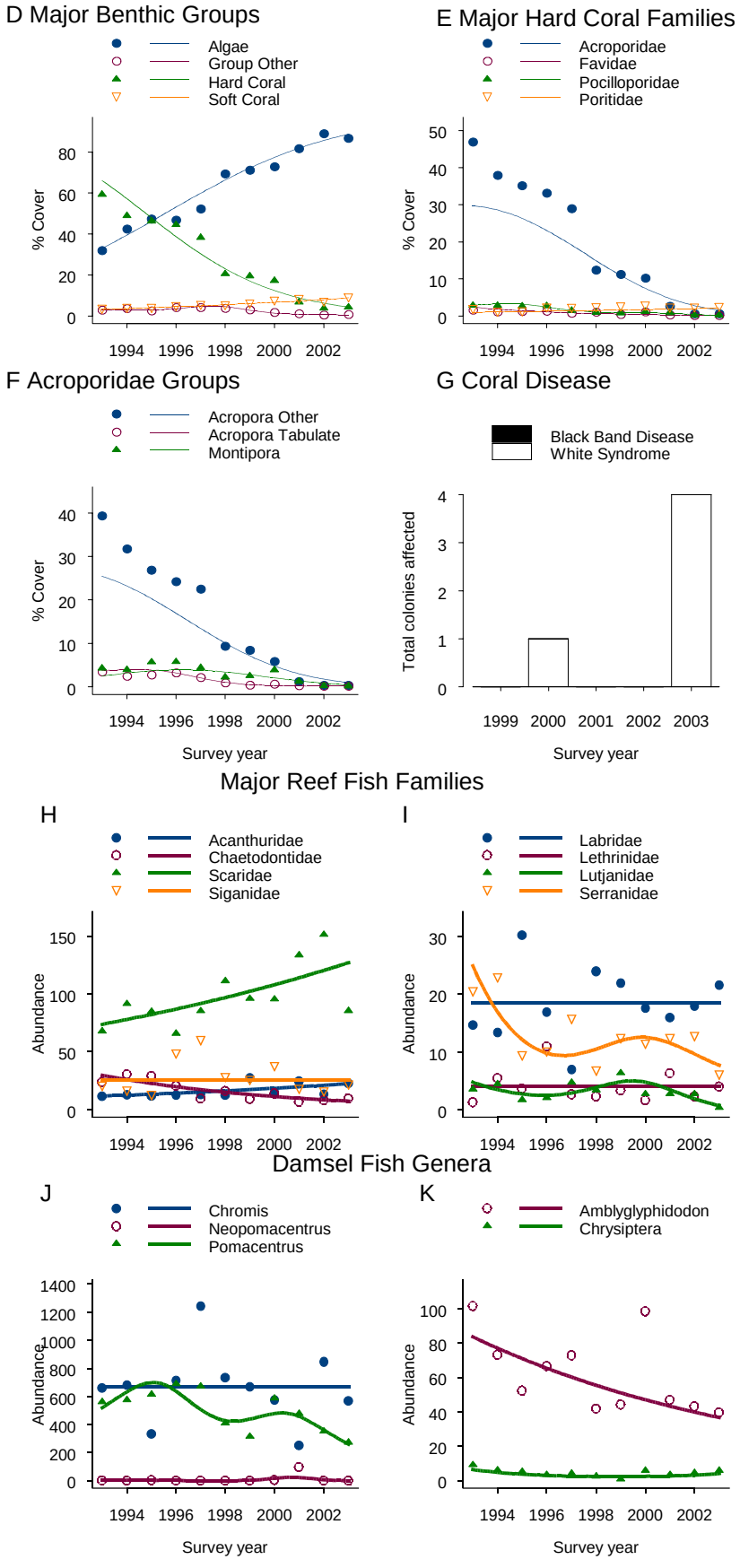
A





Gannet Cay (No. 21-556) is a middle shelf planar reef with an area of 1.2 sq.km.

Figure 4.131 (Cont).



HORSESHOE

Surveyed September 2002.

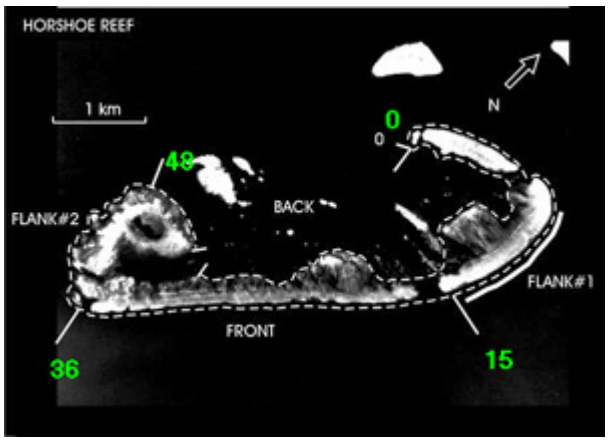
Originally surveyed in 1986, this reef has been surveyed regularly since 1991. There was an Incipient Outbreak of COTS in 1986 but COTS numbers dropped below outbreak levels until 1995. There was a small increase in reef-wide live coral cover up until 1995. COTS activity then increased, peaking in 1998 and again in 2003, with a corresponding decline in reef-wide live coral cover. In 2003 reef-wide coral cover was the lowest yet recorded (1-10%) and reef was classified as Active Outbreak. A few scattered coral colonies were affected by bleaching or white syndrome disease in 2003.

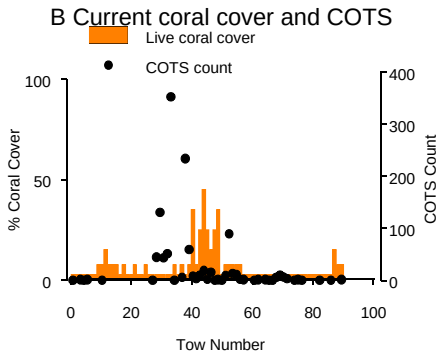
The detailed benthic surveys on the northeastern flank of this reef show that hard coral cover increased until 1997. Coinciding with a large number of COTS in 1998, coral cover then declined to average 10.7% in 2003. This decline in cover was due mainly to decreases in the cover of *Acropora* and *Montipora* spp. at one site. This pattern is typical for COTS related mortality as the starfish aggregate and feed initially on their preferred prey (e.g. species of *Acropora* and *Montipora*). The cover of soft corals remained reasonably stable, fluctuating around a mean of 5%. The abundance of algae increased after 1997 and was 81% in 2003. The density of corallivorous snails *Drupella* spp. was 173.3 /ha.

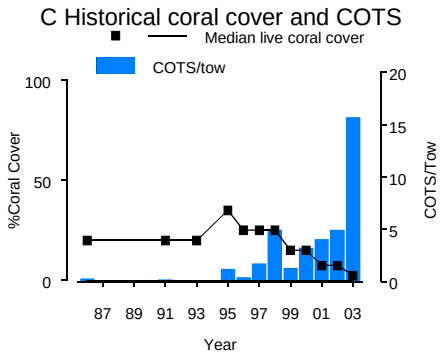
The decline in coral cover since 1995 has almost certainly affected some fish taxa. Two coral-associated butterflyfish (Chaetodontidae), *Chaetodon rainfordi* and *C. plebeius*, have decreased in abundance. The damselfish, *Pomacentrus moluccensis* (Pomacentridae) was initially abundant but has declined; this species lives among small branching corals. Two other *Pomacentrus* species (*P. lepidogenys* and *P. wardi*) were previously abundant and were also very low in abundance in 2003, although these species are not directly dependent on coral. Numbers of the commercially important coral trout, *Plectropomus leopardus* (Serranidae), were at an 11-year low in 2003 but similarly low numbers have been recorded in 1993 and 1999. Numbers of larger mobile fish within three families (Acanthuridae, Scaridae and Labridae) have generally increased over the study period. Acanthuridae and Scaridae are herbivores and it is tempting to attribute these increases to the greater availability of algae, though increased algal cover has not always led to greater herbivore abundance elsewhere.

Figure 4.132

A

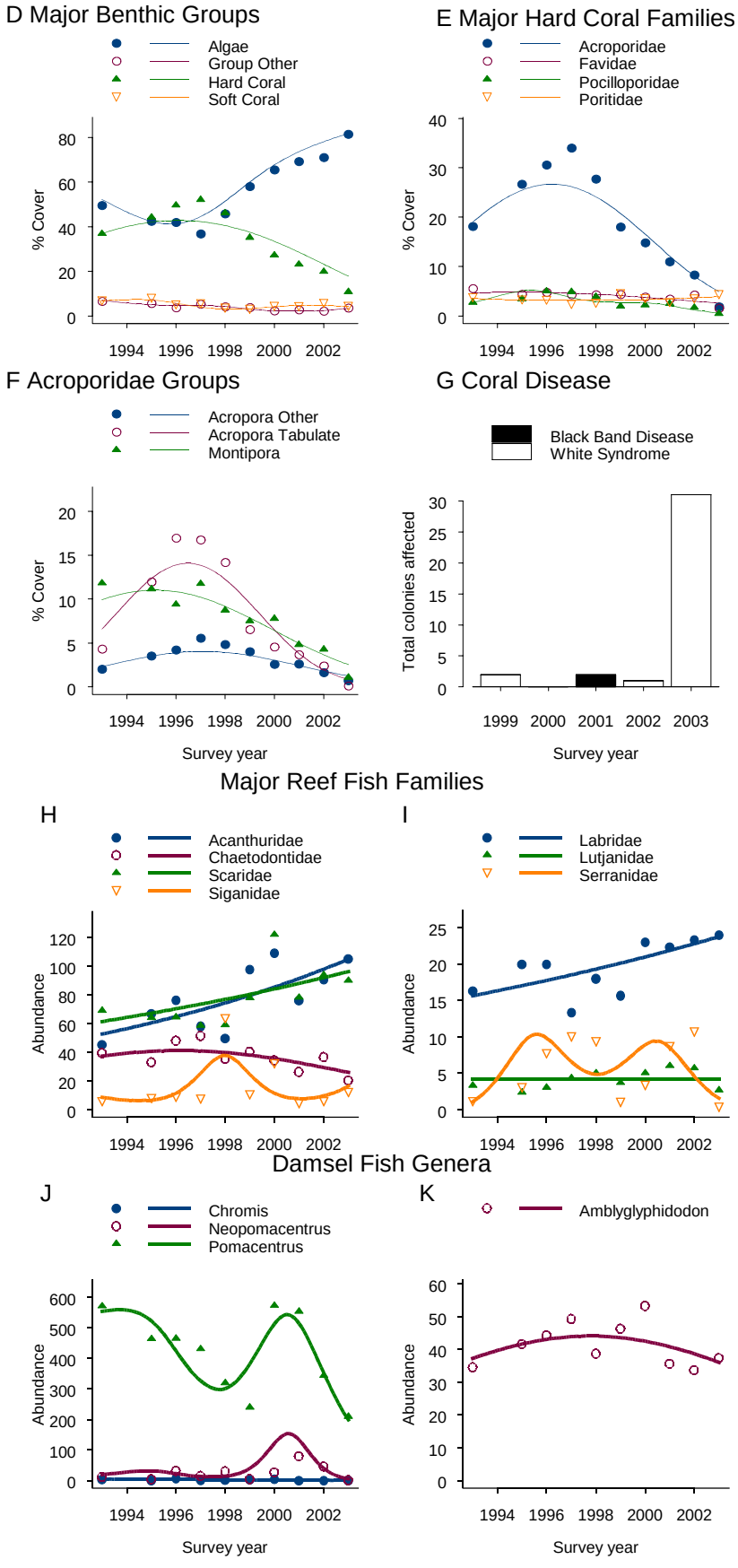






Horseshoe (No. 22-104) is a middle shelf crescentic reef with an area of 12.5 sq.km.

Figure 4.132 (Cont).



TURNER CAY

Surveyed September 2002.

Manta tow surveys have been conducted on this reef annually since 1994. Over this time, reef-wide live coral cover gradually increased to high levels (30-50%), peaking in 1999. Reef-wide live coral cover remained at this level until COTS numbers increased dramatically in 2001 and the reef was reclassified as an Active Outbreak. The Active Outbreak persisted to 2003 and reef-wide live coral cover declined to a low level (1-10%). No bleaching was recorded in 2002 and the incidence of white syndrome disease was low, affecting a few scattered coral colonies.

Cover of hard corals on the intensive survey sites had increased to 33% in 1999 but then declined particularly in 2002 and 2003 with hard coral cover being at its lowest level (13.6%) since surveys started. This corresponds to a dramatic increase in the number of COTS. Most of the corals that were lost were Acroporidae, though the Faviidae and Pocilloporidae have also declined. Abundance of soft corals is high on this reef, currently averaging 25.5%. Soft coral cover has decreased by 11% since 1994, though cover increased slightly in the 2000 and 2001 surveys. Algal cover remained stable around 33%, though algal cover rose sharply in 2002 and 2003. This was been due to turf and coralline algae.

Fish assemblages in general were fairly stable over the study period. Numbers of three coral-associated butterflyfishes (Chaetodontidae), *Chaetodon rainfordi*, *C. melannotus* and *C. trifascialis*, decreased substantially after 2002 when the large outbreak of crown-of-thorns starfish began to reduce live coral cover. Numbers of these three species in 2003 were the lowest in 10 years. Abundance patterns for damselfish *Pomacentrus* spp. followed the disproportionately abundant *P. lepidogenys*. Numbers of *P. wardi* were at a 10-year low in 2003 and *P. coelestis* was not recorded for the first time. Another damselfish species, *Neopomacentrus azysron* declined in abundance after 1996 (as occurred at East Cay) and was present in very low numbers in 2003. We suspect that successful recruitment events for small site attached damselfishes may be sporadic in this region. Although numbers of larger mobile fish within the family Scaridae fluctuated from year to year, numbers have increased generally over the surveys. The increase in abundance of *Chromis* in 2002 was due to an influx of *C. nitida*.

Figure 4.133

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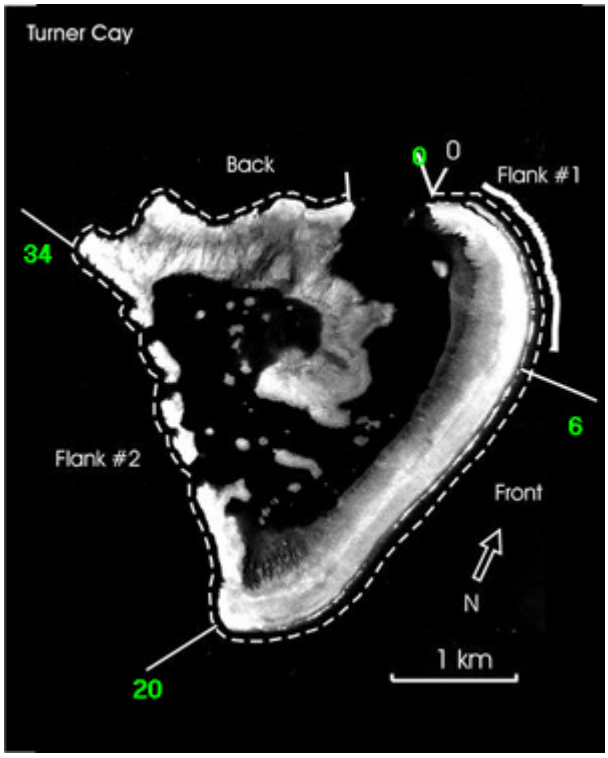
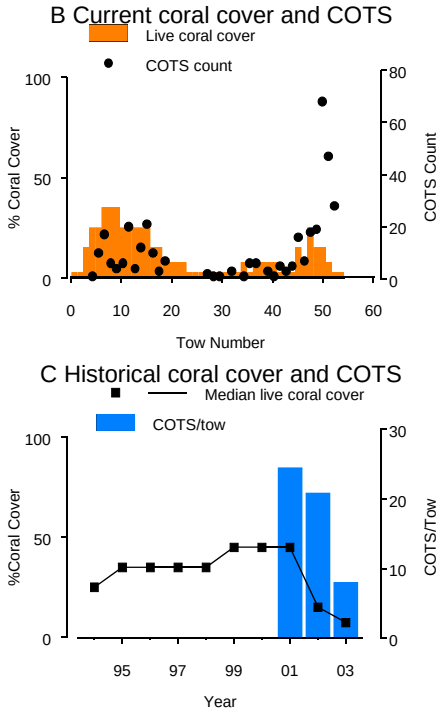
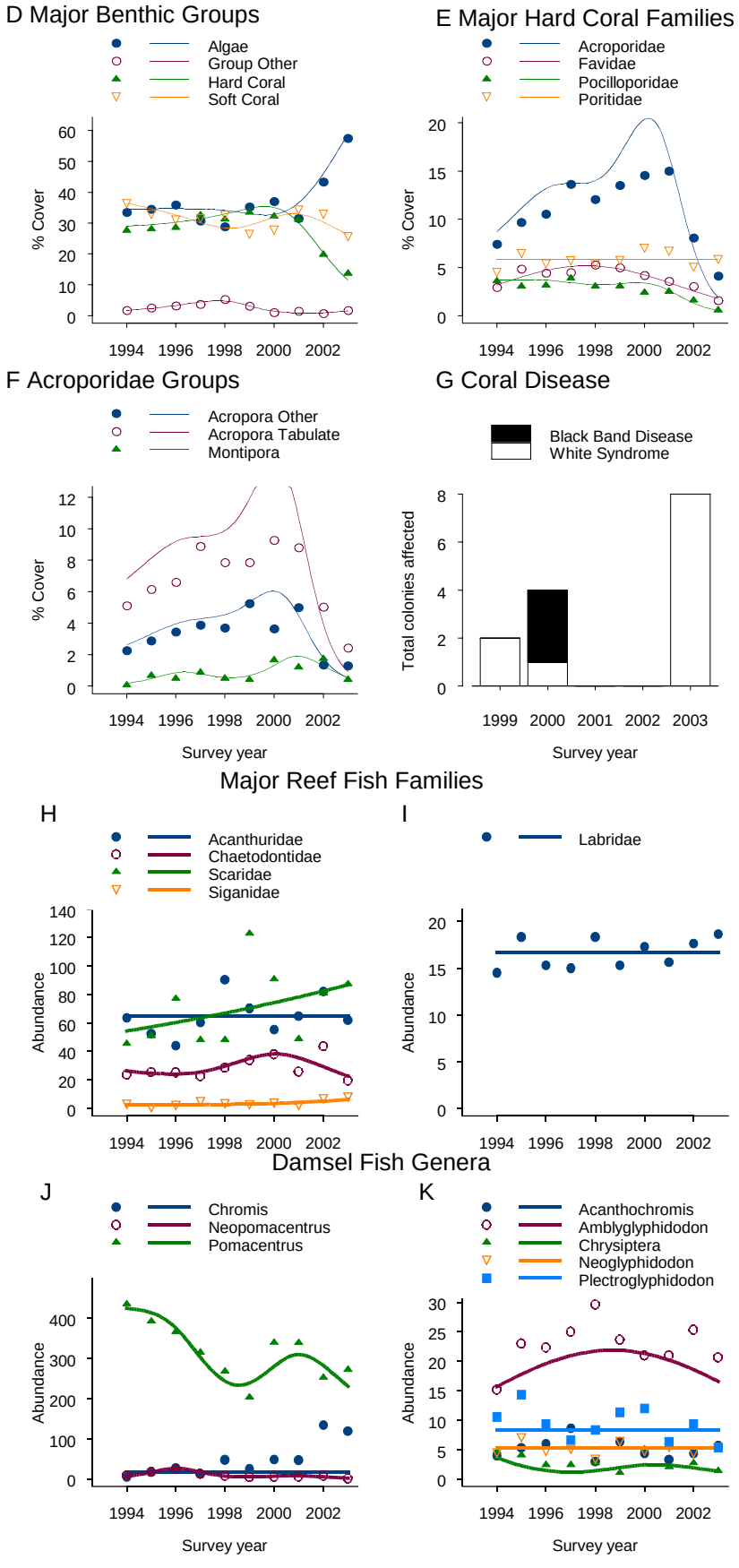




Turner Cay (No. 21-562) is an outer shelf lagoonal reef with an area of 5 sq.km.

Figure 4.133 (Cont).



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Capricorn Bunker

Reef Pages

BROOMFIELD

Surveyed September 2002.

This reef has been surveyed using manta tow since 1986. Reef-wide live coral cover dropped dramatically between 1988 and 1990. Evidence suggests strong weather in the region during this time may have partly influenced this decline. Since 1993 reef-wide coral cover has slowly increased to a high level (30-50%). No COTS have been recorded on this reef during manta tow surveys and it was classified as No Outbreak in 2003. For most of the reef perimeter bleaching and white syndrome disease were at low levels (restricted to a few dispersed coral colonies) in 2003. However, white syndrome disease was relatively common (more than 10 colonies per two-minute tow) on the first flank of Broomfield Reef where coral cover was the highest.

Intensive surveys on the northeastern flank of the reef show a dramatic increase in hard coral cover from 10% in 1993 to 56% in 2002. Hard coral cover did not increase between 2002 and 2003 but remained stable at 56% cover. Tabulate *Acropora* spp. occupied 35% of the substrate in 2003, in stark contrast to 0% in 1993. Another 13% is occupied by other *Acropora* lifeforms. Historical records indicate that dominance by tabulate *Acropora* spp. is typical for reefs in this region, as is very low cover of soft corals (<1%). The cover of algae has decreased with corresponding increase in hard coral. Cover of algae is now moderate at approximately 36%. The lack of an increase in hard coral cover between 2002 and 2003 is possibly due to increasing levels of white syndrome disease recorded on this reef. A total of 315 colonies were affected by white syndrome in 2003, up from 21 in 2002. The density of corallivorous snails *Drupella* spp. was 13.3/ha in 2003.

Hard coral cover provides most of the topographic complexity on the flat gently sloping reef bases characteristic of the exposed Capricorn Bunker reefs. Judging by the low numbers of fish present when surveys began in 1993, we presume that the removal of most hard coral during the late 1980's created a relatively featureless environment that was unsuitable for sustaining large fish populations. However abundance of many species of large mobile fish from the families Acanthuridae, Scaridae, Chaetodontidae and Labridae, increased dramatically after 1994 and closely tracked increases in hard coral cover. Damselfishes have shown less dramatic changes with the exception of *P. coelestis*, a species that preferentially recruits to bare or rubble substrate. *P. coelestis* flourished during the time of low coral cover and dominated the damselfish community, with peak numbers recorded in 1996. Numbers subsequently declined and had stabilized by 1998. Most damselfish species have displayed slow or minimal changes, due possibly to the slower recovery of fine scale habitat (small branching corals, crevices etc) necessary to sustain high numbers and diversity of these relatively site-attached species.

Figure 4.134

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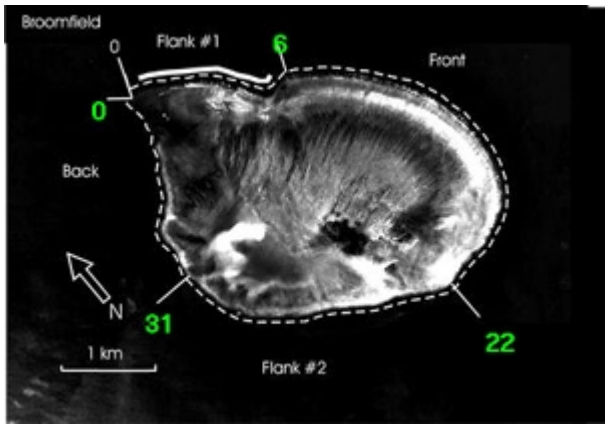
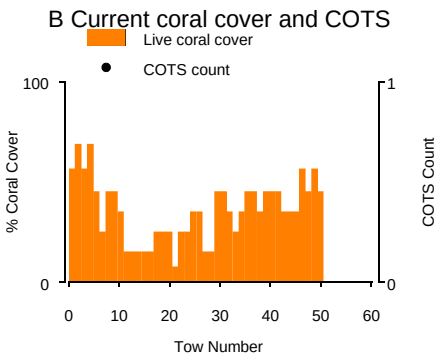
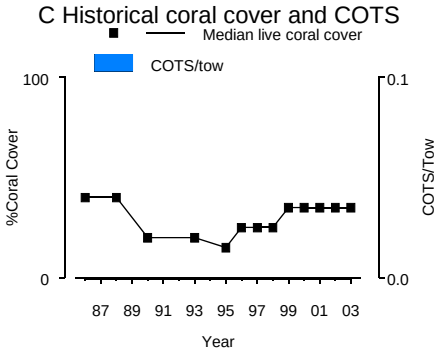
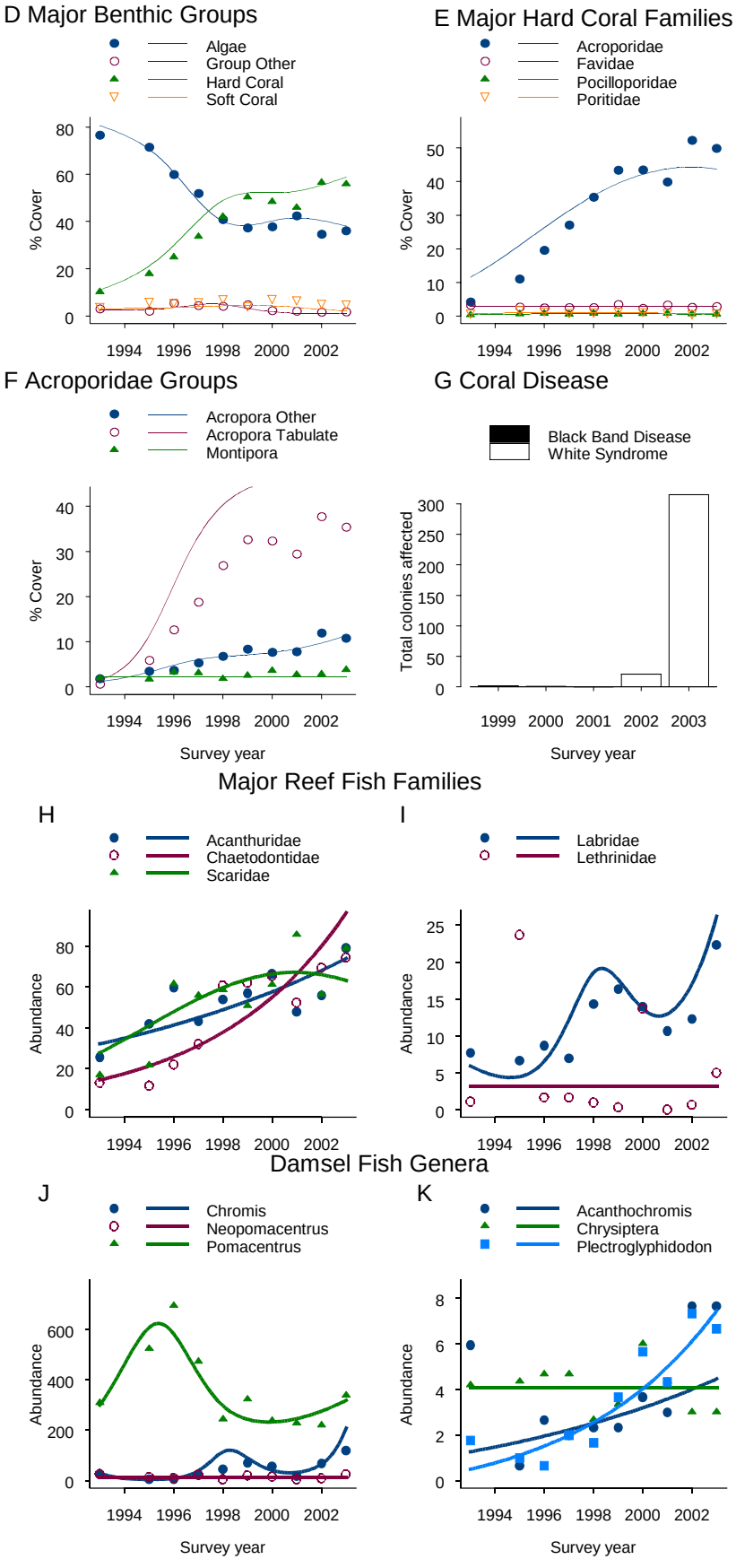






Broomfield (No. 23-048) is an outer shelf planar reef with an area of 21.3 sq.km.

Figure 4.134 (Cont).



LADY MUSGRAVE IS

Surveyed September 2002.

This reef has been surveyed extensively since 1986. Reef-wide live coral cover fell dramatically between 1988 and 1990, apparently due to strong weather. Coral cover continued to decline until 1993 before recovering. Although COTS have been recorded on this reef on several occasions, there have been too few to affect reef-wide live coral cover. Reef-wide live coral cover was very high (50-75%) in 2003 and the reef was classified as No Outbreak. No bleaching was recorded and white syndrome disease was at low levels over most of the reef perimeter (restricted to a few dispersed coral colonies) but was common (more than 10 colonies per two-minute tow) on the first flank of Lady Musgrave Island Reef where coral cover was the highest.

Intensive surveys on the northern flank of the reef show that hard coral cover has increased dramatically from less than 5% in 1993 to a very high level of 75% in 2003. Cover of tabulate *Acropora* spp. has increased dramatically from 0% in 1993 to 67% a decade later. Another 7% of cover can be attributed to other *Acropora* lifeforms. Historical records indicate that dominance by tabulate *Acropora* spp. is typical for reefs in this region. Soft coral cover is low at less than 1%. The cover of algae decreased from 94% in 1993 to 23% in 2003. This decline in cover of algae corresponds to the increasing hard coral cover. White syndrome disease was recorded at low levels for 3 years before a dramatic increase in 2003, when 343 colonies were affected by white syndrome in the intensive surveys, up from 37 in 2002. This is the highest number of colonies affected by white syndrome ever recorded from any reef of the GBR. Despite this relatively high level of disease, hard coral cover still increased. The density of corallivorous snails *Drupella* spp. was 20/ha in 2003.

Hard coral cover provides most of the topographic complexity on the flat gently sloping reef bases characteristic of the exposed Capricorn Bunker reefs. Judging by the low numbers of fish present when surveys began in 1993, we presume that the removal of most hard coral during the late 1980s created a relatively featureless environment unsuitable for sustaining large fish populations. Abundance of many species of large mobile fish from the Acanthuridae, Scaridae, Chaetodontidae, Labridae and Lutjanidae increased after 1994 and closely tracked the increases in hard coral cover. Damselfishes have shown more variable changes. *Pomacentrus coelestis*, a species that preferentially recruits to bare or rubble substrate, flourished during the time of low coral cover and dominated the damselfish community, with maximum numbers recorded in 1996. Numbers subsequently declined and had stabilized by 1998. Some damselfishes (*Pomacentrus lepidogenys*, *P. bankanensis* and two *Plectroglyphidodon* species) increased consistently over the period, while a number of *Chromis* species had only returned in any numbers in 2003.

Figure 4.135

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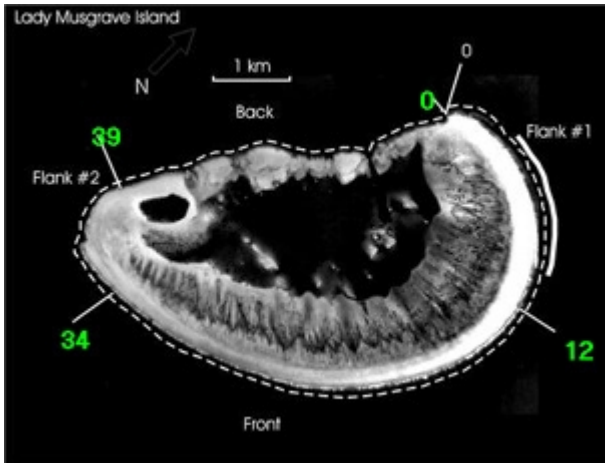
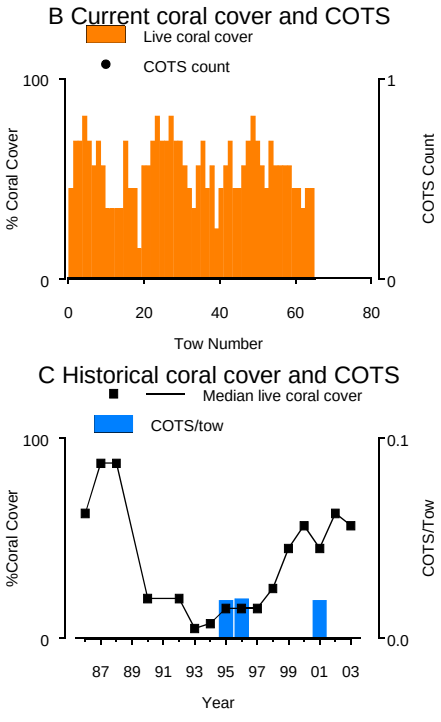
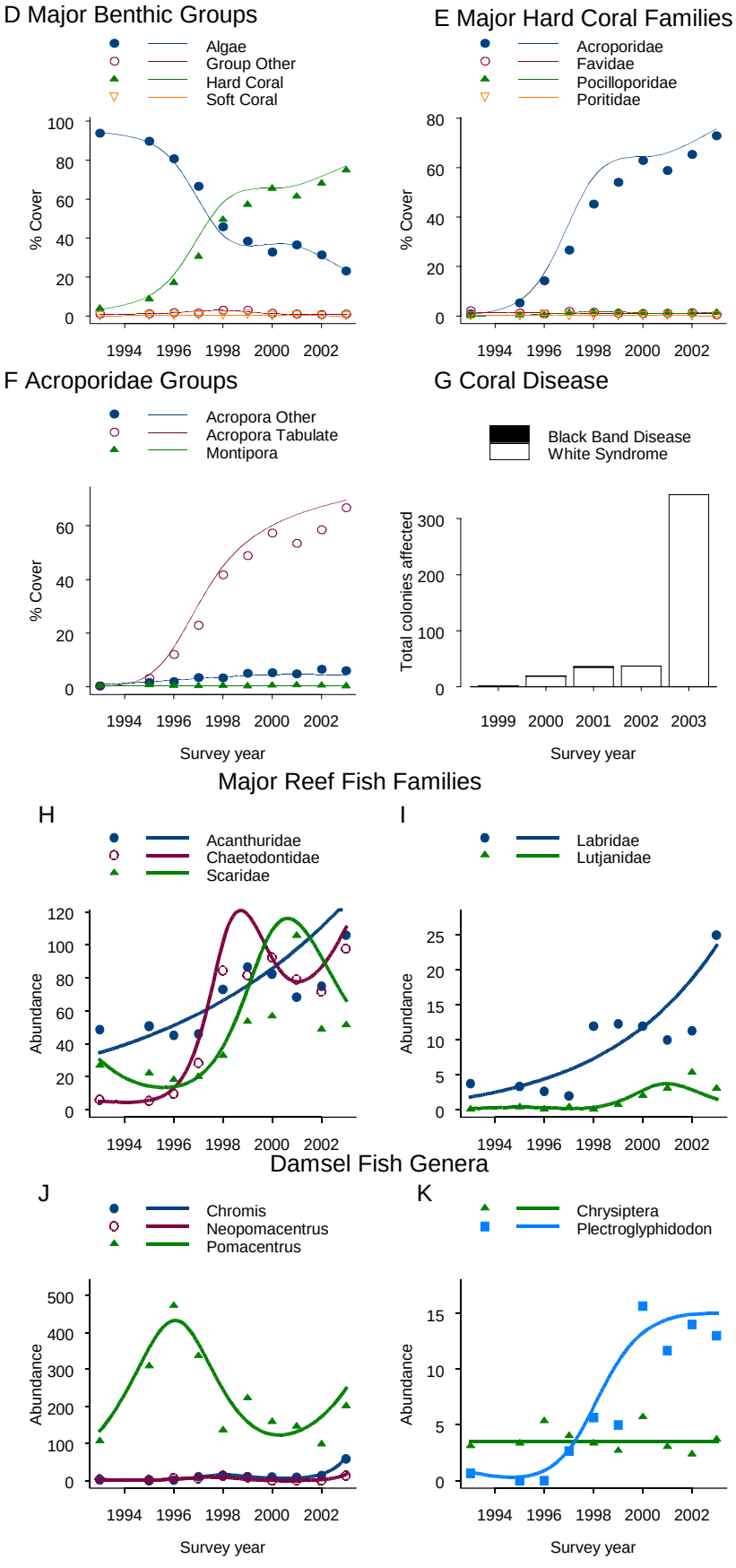




Lady Musgrave Is (No. 23-082) is an outer shelf lagoonal reef with an area of 12.5 sq.km.

Figure 4.135 (Cont).



ONE TREE IS

Surveyed September 2002.

This reef has been surveyed extensively since 1986. Reef-wide live coral cover dropped dramatically between 1988 and 1990, apparently caused by strong weather. Reef-wide live coral cover increased slowly after 1990 to reach high levels (30-50%) in 2003. No COTS have been recorded on this reef and it was classified as No Outbreak in 2003. Bleaching and white syndrome disease were at low levels for most of the reef perimeter (affecting a few dispersed coral colonies) in 2003. However white syndrome disease was common (more than 10 colonies per two-minute tow) where coral cover was the highest on the front of One Tree Island Reef.

Intensive surveys on the northeastern flank show that coral cover has increased from less than 5% in 1993 to 76% in 2003. Tabulate *Acropora* spp. make up 66% of that cover, a dramatic increase from 0% in 1993. Another 8.5% of cover can be attributed to other *Acropora* lifeforms. The cover of algae declined from 77% in 1993 to 20% in 2003. Cover of soft corals remained low (4%) since surveys began. White syndrome disease increased dramatically from 17 affected colonies in 2002 to 336 affected colonies in 2003. This relatively high level of disease had no apparent impact on hard coral cover. The density of corallivorous snails *Drupella* spp. was 6.7/ha in 2003.

Hard coral cover provides most of the topographic complexity on the flat gently sloping reef bases characteristic of the exposed Capricorn Bunker reefs. Judging by the low numbers of fish present when surveys began in 1993, we presume that the removal of most hard coral during the late 1980s created a relatively featureless environment unsuitable for sustaining large fish populations. Numbers of most large mobile fish taxa increased after 1994 and often tracked increases in hard coral cover. Numbers of Lethrinidae were highly variable over time. *Pomacentrus coelestis*, a damselfish species that preferentially recruits to bare or rubble substrate, flourished during the time of low coral cover and dominated the damselfish community, peaking in 1994. Numbers have subsequently declined while most other *Pomacentrus* species have increased in abundance. While most damselfishes have increased in abundance, some increased steadily while others (e.g. *Plectroglyphidodon* sp and *Chromis* spp.) only reappeared in numbers later in the survey period. Such differences in recovery rate are likely linked to the slower recovery of fine scale habitat (small branching corals, crevices etc) necessary to sustain high numbers and diversity of relatively site attached damselfish species.

Figure 4.136

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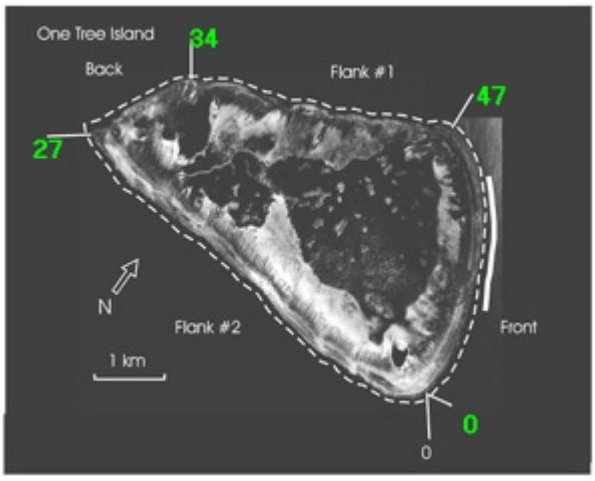
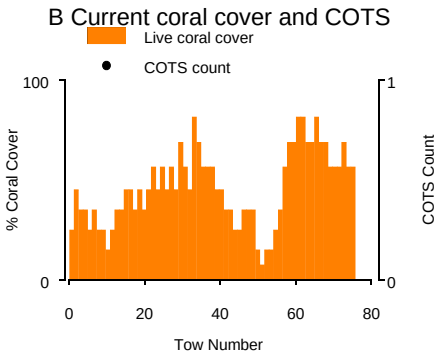
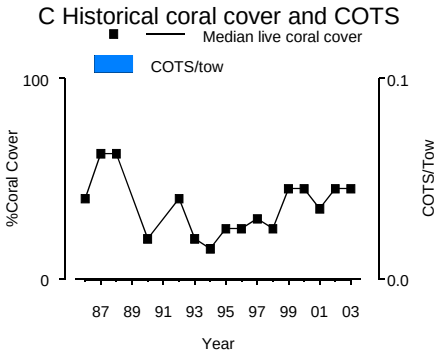
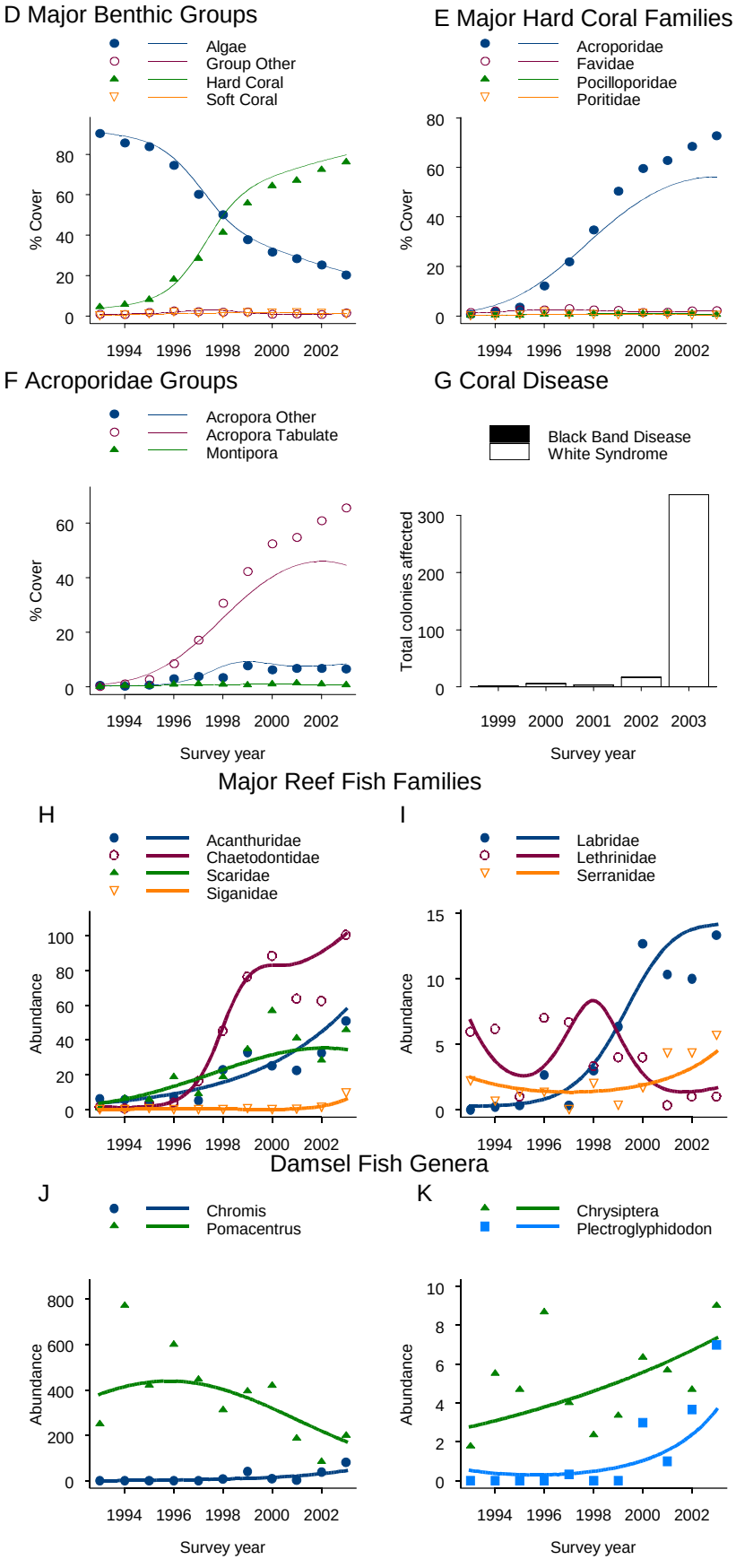






One Tree Is (No. 23-055) is an outer shelf lagoonal reef with an area of 18.09 sq.km.

Figure 4.136 (Cont).



WRECK IS

Surveyed September 2002.

This reef has been surveyed nine times since 1993. While reef-wide live coral cover has always been moderate, it has increased in recent years. Reef-wide live coral cover was high (30-50%) in 2003. No COTS have been recorded on this reef and it is currently classified as No Outbreak. Bleaching and white syndrome disease were at low levels reef-wide, affecting only a few dispersed coral colonies in 2003. However, white syndrome was common (more than 10 colonies per two-minute tow) on the first and second flanks of Wreck Island Reef where coral cover was the highest.

Intensive surveys on the northeastern flank show that hard coral cover increased dramatically from about 15% in 1993 to 72% in 1999. Since 1999 cover has fluctuated but shown a slow decline. Hard coral cover averaged 60% in 2003, down 12% since 1999. Tabulate *Acropora* spp. made up 47% of the total cover in 2003, up from 0% in 1993. Algal cover declined dramatically as cover of hard coral increased up until 1999. Cover of algae was 19% in 1999 and 32% in 2002. Soft coral cover was relatively high for reefs in this sector, averaging 5% in 2003, but reached 9-13% cover prior to 1999. Increasing levels of white syndrome was the most likely cause of the slight decline in hard coral cover. White syndrome increased to 77 affected colonies on the intensive survey sites in 2002 and increased again to 221 affected colonies in 2003. The density of corallivorous snails *Drupella* spp. was 6.7/ha in 2003.

Hard coral cover provides most of the topographic complexity on the flat gently sloping reef bases characteristic of the exposed Capricorn Bunker reefs. Judging by the low numbers of fish present when surveys began in 1993, we presume that the removal of much hard coral during the late 1980s created a relatively featureless environment unsuitable for sustaining large fish populations. However, numbers of most large mobile fish taxa increased after 1994 and often tracked increases in hard coral cover. *Pomacentrus coelestis*, a damselfish species that preferentially recruits to bare or rubble substrate, flourished during the time of low coral cover and dominated the damselfish community, peaking in 1996. Numbers then declined and had stabilized by 1999. Most other *Pomacentrus* species increased in abundance over the same period. The genera *Neopomacentrus* and *Chrysiptera* were stable over the study period, while *Chromis* spp. and *Plectroglyphidodon* spp. increased in abundance. Recovery rates in the damselfishes varied considerably. This pattern is likely linked to the slow recovery of fine scale habitat (small branching corals, crevices etc) necessary to sustain high numbers and diversity of relatively site attached damselfish species.

Figure 4.137

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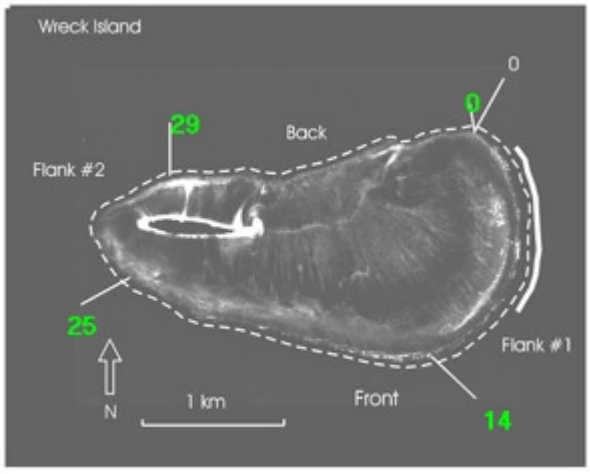
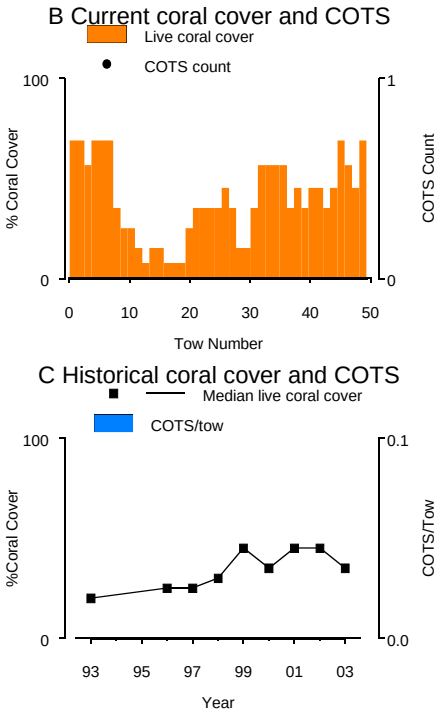
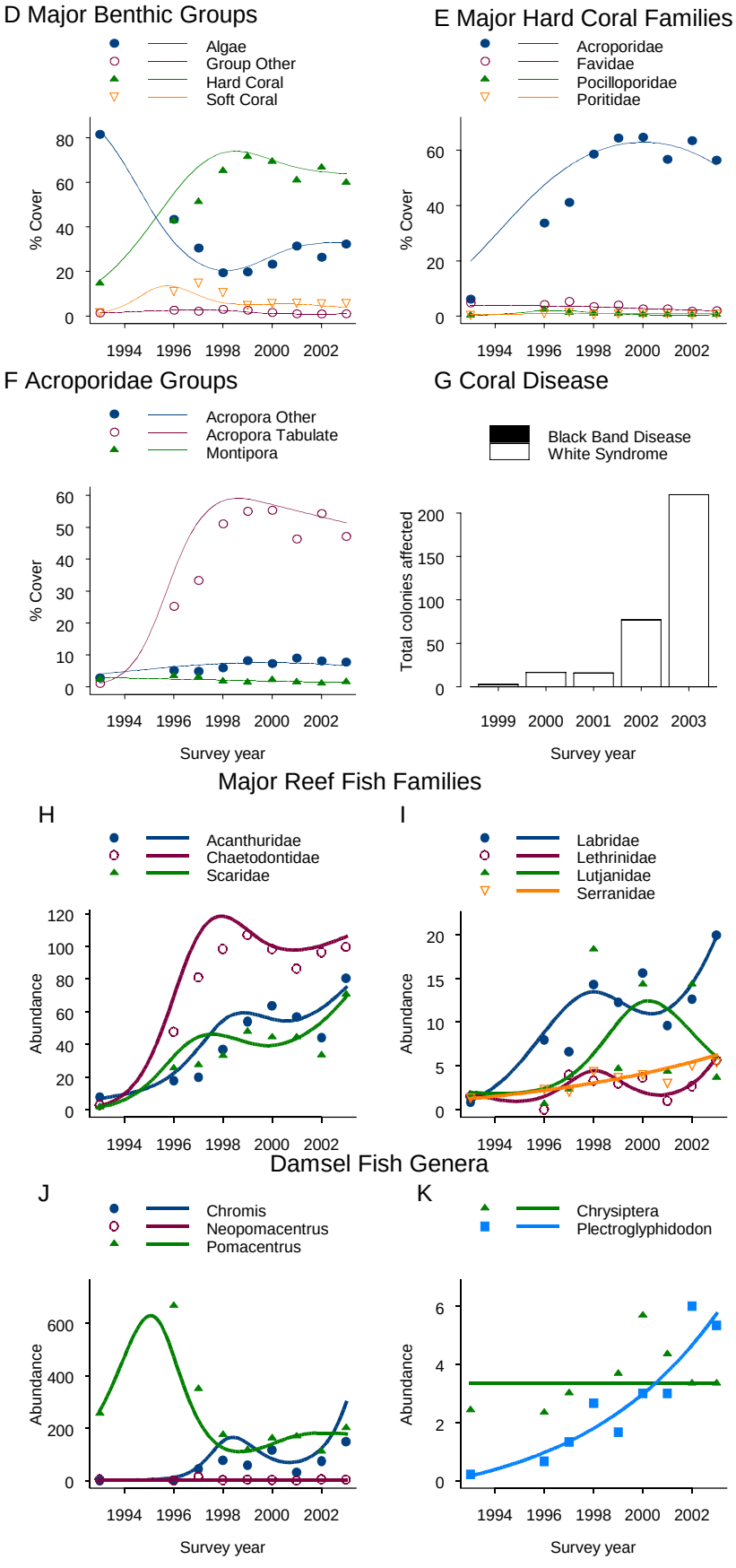




Wreck Is (No. 23-051) is an outer shelf planar reef with an area of 6.3 sq.km.

Figure 4.137 (Cont).



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5. References

Abdo D, Burgess S, Coleman G and Osborne K (2003) Surveys of benthic reef communities using underwater video. Long-term Monitoring of the Great Barrier Reef, Standard Operational Procedure No. 9, Australian Institute of Marine Science, Townsville, Qld. 48 pp.

Akaike H (1973) Information theory as an extension of the maximum likelihood principle. In: Petrov BN and Csaki F (eds) *Second International Symposium on Information Theory*. Akademiai Kiado, Budapest.

Bainbridge SJ, Bass DK and Miller IR (1994) Broadscale surveys of crown-of-thorns starfish and corals on the Great Barrier Reef 1992-1993. AIMS COTS Report Number 1, Australian Institute of Marine Science, Townsville, Qld. 137pp.

Baker VJ and Coleman G (2000) A guide to the Reef Monitoring database. Long-term Monitoring of the Great Barrier Reef, Standard Operational Procedure No. 5, Australian Institute of Marine Science, Townsville, Qld. 72pp.

Bass DK and Miller IR (1996) Crown-of-thorns starfish and coral surveys using the manta tow and scuba search techniques. Long-term Monitoring of the Great Barrier Reef, Standard Operational Procedure No. 1, Australian Institute of Marine Science, Townsville, Qld. 38pp.

Burnham KP and Anderson DR (1998) Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York.

Done TJ (1982) Patterns in the distribution of coral communities across the central Great Barrier Reef. *Coral Reefs* 1: 95-107.

Engelhardt U, Miller I, Lassig B, Sweatman H and Bass D (1997) Crown-of-thorns starfish (*Acanthaster planci*) populations in the Great Barrier Reef World Heritage Area: Status report 1995-96. In: Wachenfeld D, Oliver J and Davis K (eds) *State of the Great Barrier Reef World Heritage Area Workshop*. Proceedings of a technical workshop held in Townsville, Qld, 27-29 November 1995. (GBRMPA Workshop Series 23). Great Barrier Reef Marine Park Authority, Townsville, Qld. 158-184.

English S, Wilkinson C and Baker V (eds) (1997) Survey Manual for Tropical Marine Resources. 2nd edition. Australian Institute of Marine Science, Townsville, Qld. 402pp.

Fernandes L (1991) Development of a more robust method for determining the status of individual reefs with respect to outbreaks of crown-of-thorns starfish *Acanthaster planci*. Report to Great Barrier Reef Marine Park Authority, Townsville, Qld. 47pp.

Halford AR and Thompson AA (1996) Visual census surveys of reef fish. Long-term Monitoring of the Great Barrier Reef, Standard Operational Procedure No 3, Australian Institute of Marine Science, Townsville, Qld. 24 pp.

Laird HM and Ware JH (1982) Random-effects models for longitudinal data. *Biometrics* 38: 963-974.

Lassig BR and Engelhardt U (1995) COTS Comms. *Reef Research* 5(1): 18-23.

McCullagh P and Nelder JA (1989) Generalized Linear Models. 2nd edition. Chapman & Hall, London. 511pp.

Miller IR and Müller R (1997) A quality control procedure for observer agreement of manta tow benthic cover estimates. *Proc 8th Int Coral Reef Symp*, Panama 2: 1475-1478.

Moran PJ and De'ath G (1992) Estimates of the abundance of the Crown-of-Thorns starfish *Acanthaster planci* in outbreaking and non-outbreaking populations on reefs within the Great Barrier Reef. *Marine Biology* 113: 509-516.

Oliver J, De'ath G, Done T, Williams D, Furnas M and Moran P (eds) (1995) Long-term Monitoring of the Great Barrier Reef: Status Report Number 1, Australian Institute of Marine Science, Townsville, Qld. 121pp.

Pinheiro JC and Bates DM (2000) Mixed-effects models in S and S-Plus. Springer-Verlag, New York.

S-Plus 2000 for Windows (2000) Insightful Corp. Seattle, WA.

Sweatman H (ed) (1997) Long-term Monitoring of the Great Barrier Reef: Status Report Number 2, Australian Institute of Marine Science, Townsville, Qld. 161pp.

Sweatman H, Bass D, Cheal A, Coleman G, Miller I, Ninio R, Osborne K, Oxley W, Ryan D, Thompson A and Tompkins P (1998) Long-term Monitoring of the Great Barrier Reef: Status Report Number 3, Australian Institute of Marine Science, Townsville, Qld. 303pp.

Sweatman H, Cheal A, Coleman G, Delean S, Fitzpatrick B, Miller I, Ninio R, Osborne K, Page C and Thompson A (2001) Long-term Monitoring of the Great Barrier Reef: Status Report Number 5, Australian Institute of Marine Science, Townsville, Qld. 106pp.

Sweatman H, Cheal A, Coleman G, Fitzpatrick B, Miller I, Ninio R, Osborne K, Page C, Ryan D, Thompson A and Tompkins P (2000) Long-term Monitoring of the Great Barrier Reef: Status Report Number 4, Australian Institute of Marine Science, Townsville, Qld. 117pp.

Williams DM (1982) Patterns in the distribution of fish communities across the central Great Barrier Reef. *Coral Reefs* 1: 35-43.

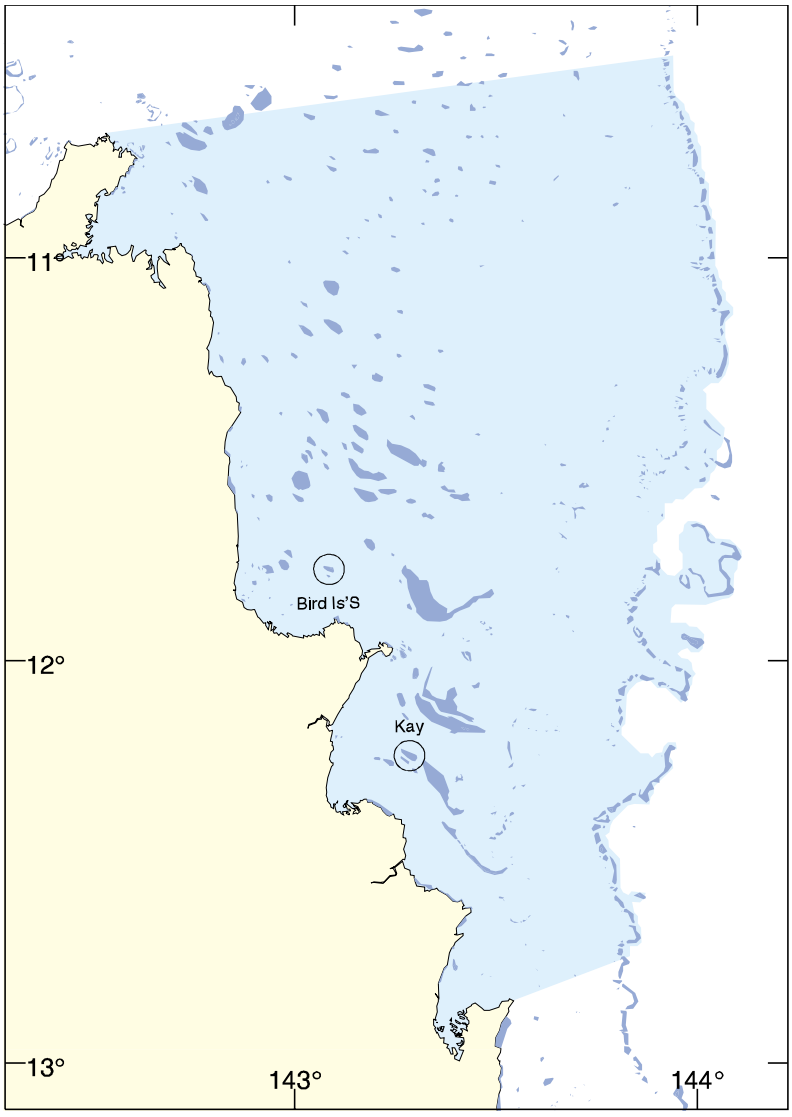
Zar JH (1984) Biostatistical Analysis. 2nd edition. Prentice – Hall, Inc. Englewood Cliffs, New Jersey. 718pp.

6. Appendices

Appendix A

Location of reefs surveyed in 2003 and the types of surveys taken.

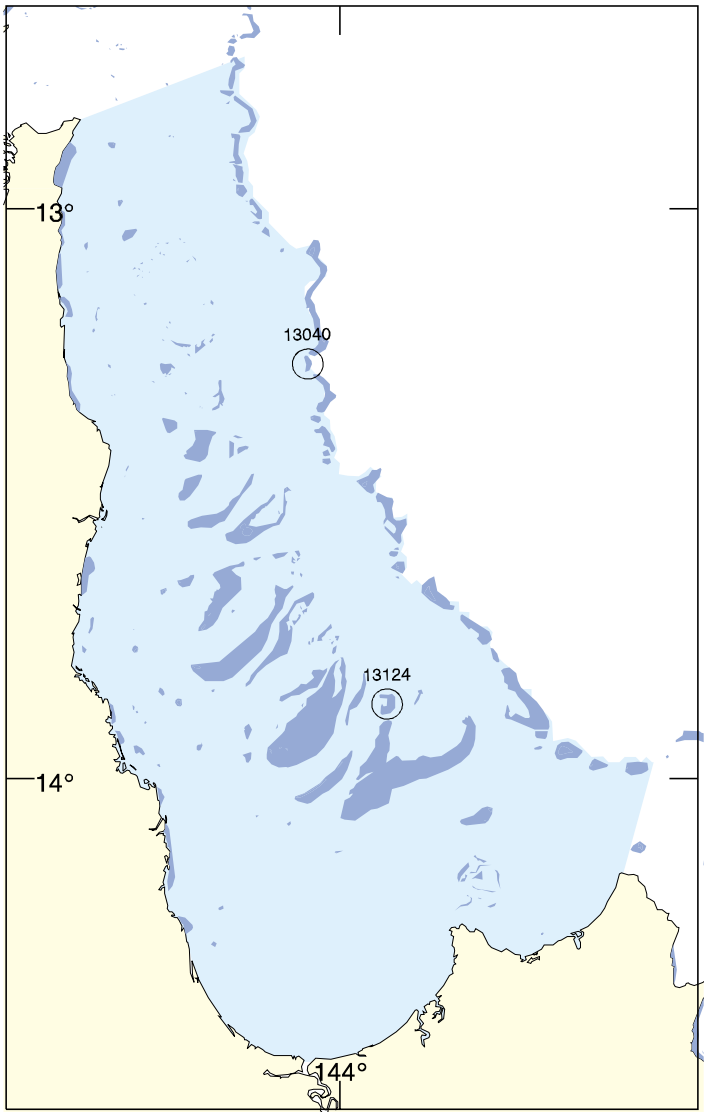
Cape Grenville Sector



- Fish and Benthos

○ Manta Tow

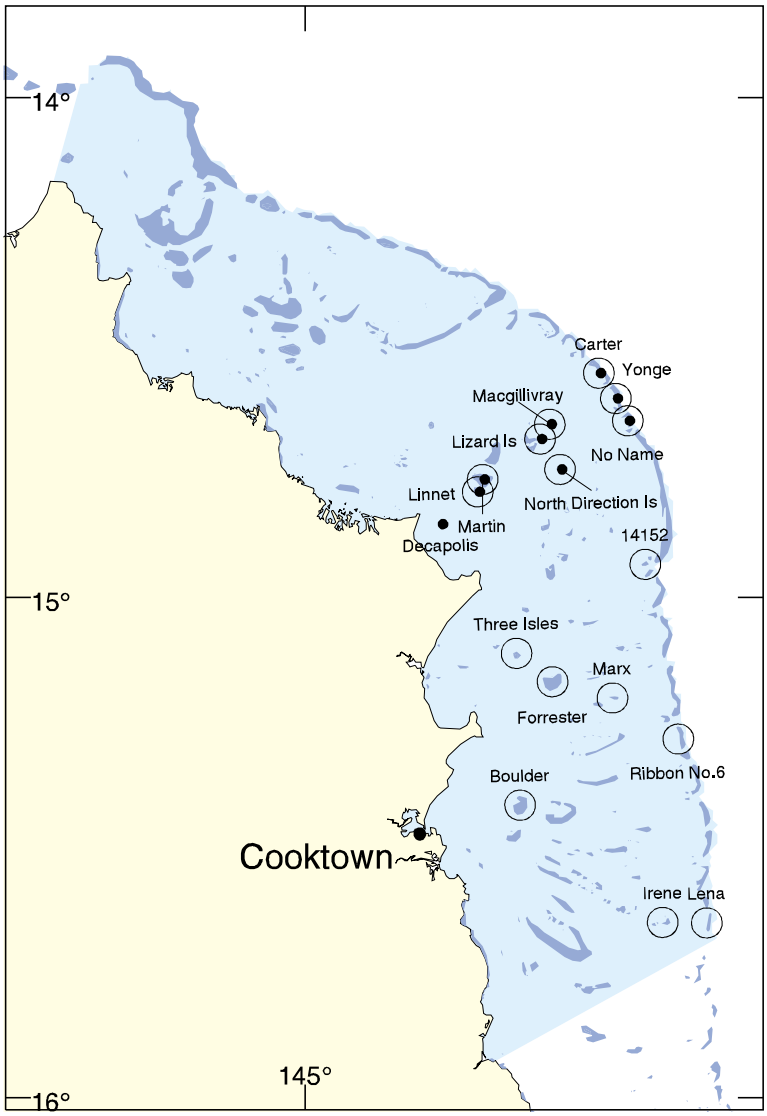
Princess Charlotte Bay Sector



- Fish and Benthos

○ Manta Tow

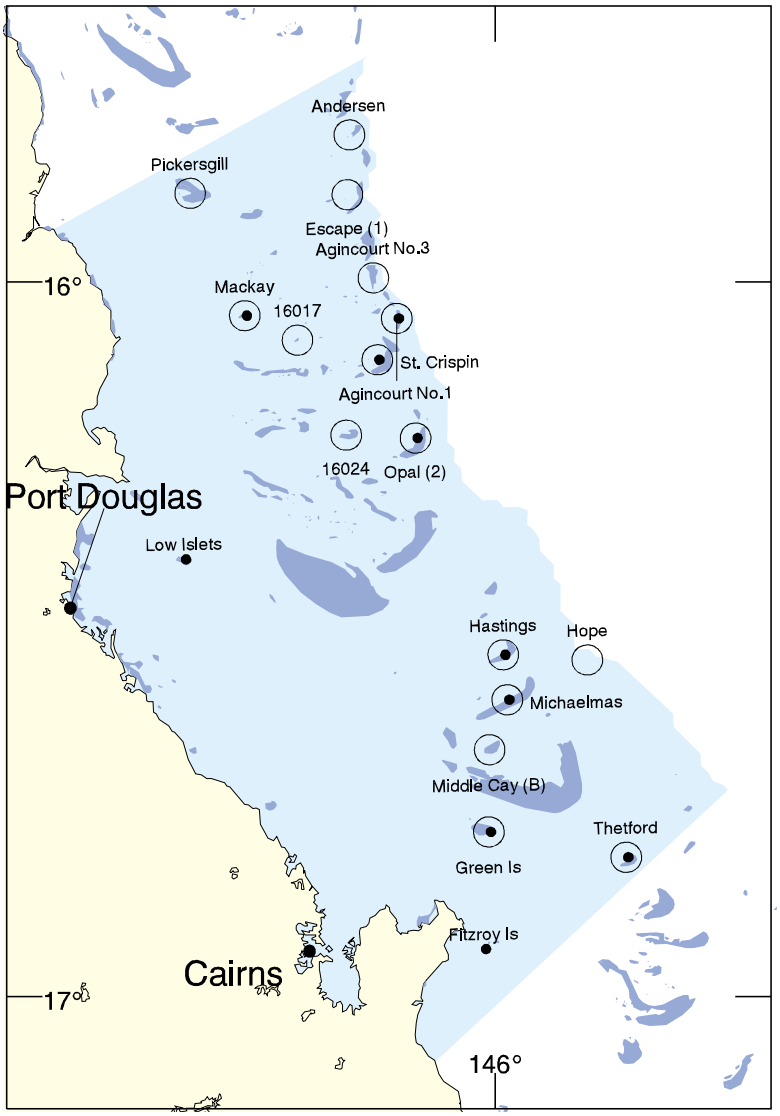
Cooktown / Lizard Island Sector



- Fish and Benthos

○ Manta Tow

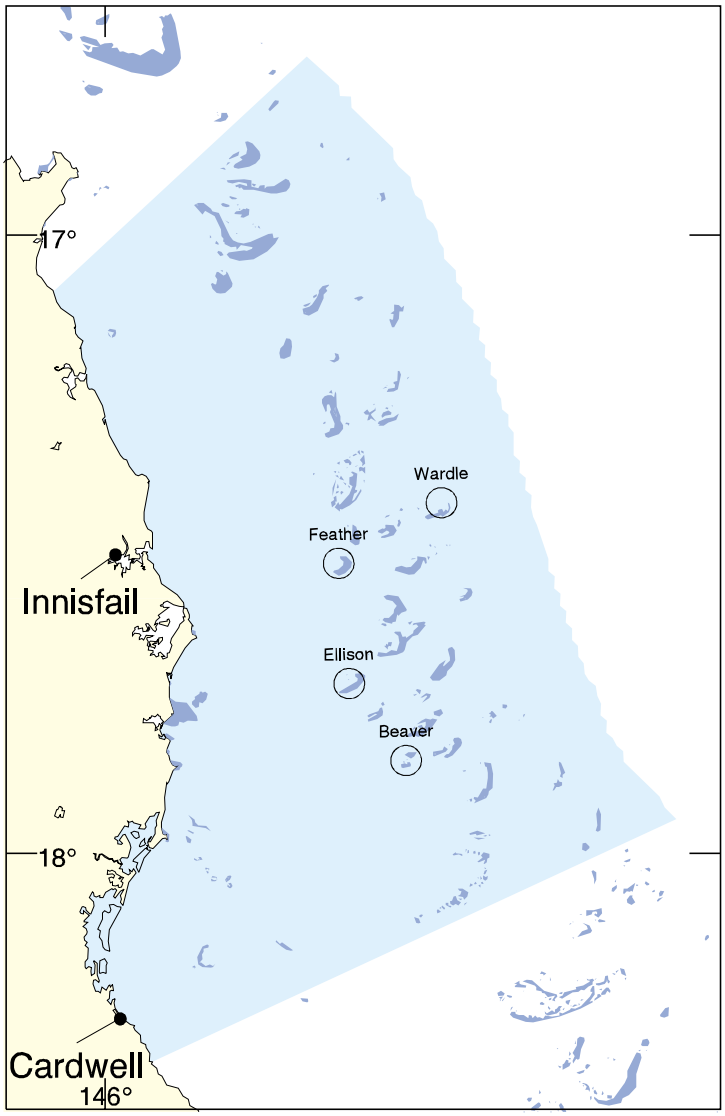
Cairns Sector



- Fish and Benthos

○ Manta Tow

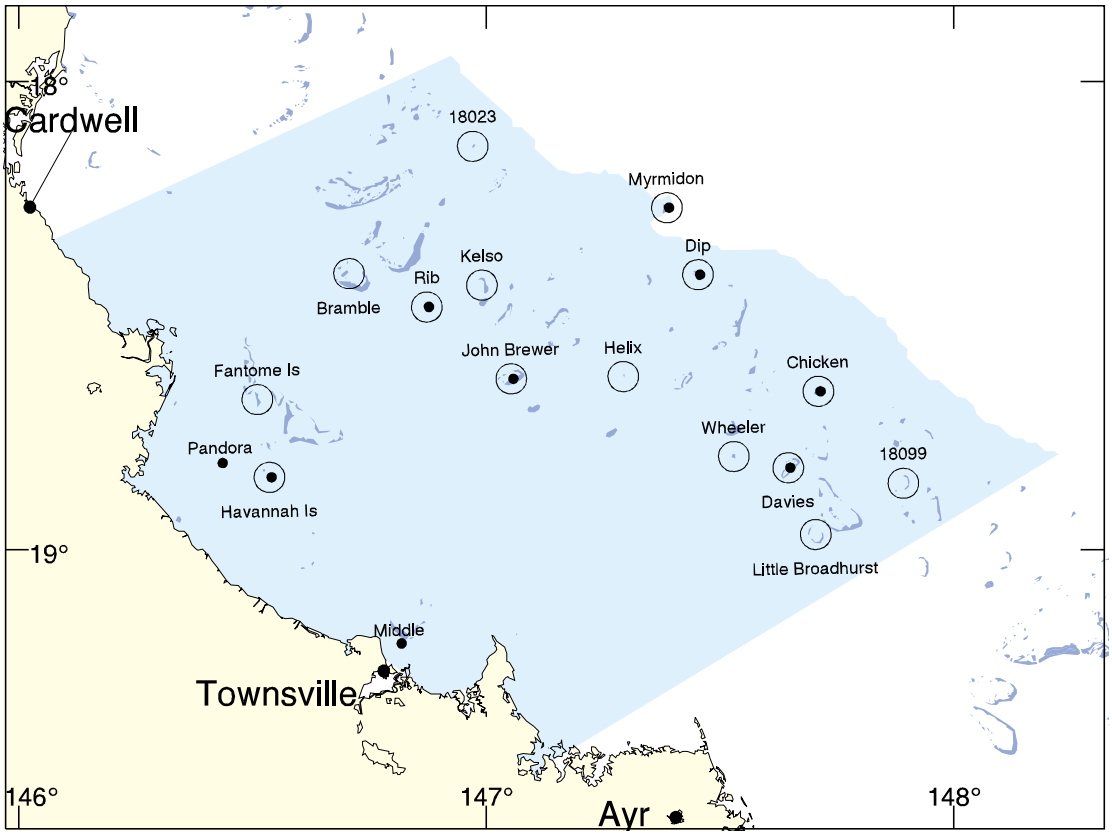
Innisfail Sector



- Fish and Benthos

○ Manta Tow

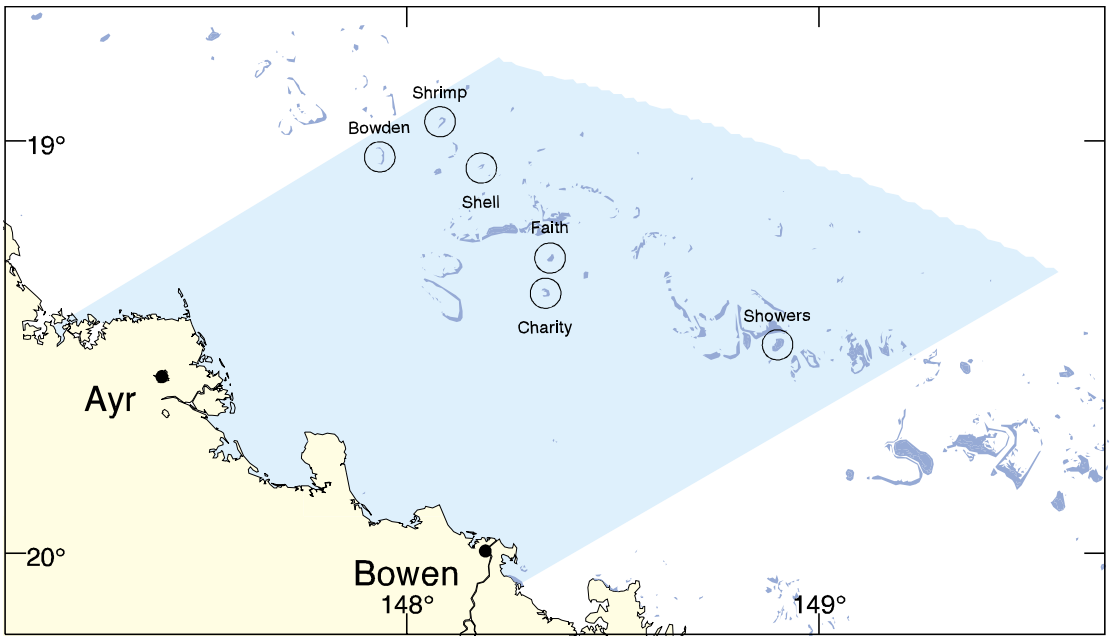
Townsville Sector



- Fish and Benthos

○ Manta Tow

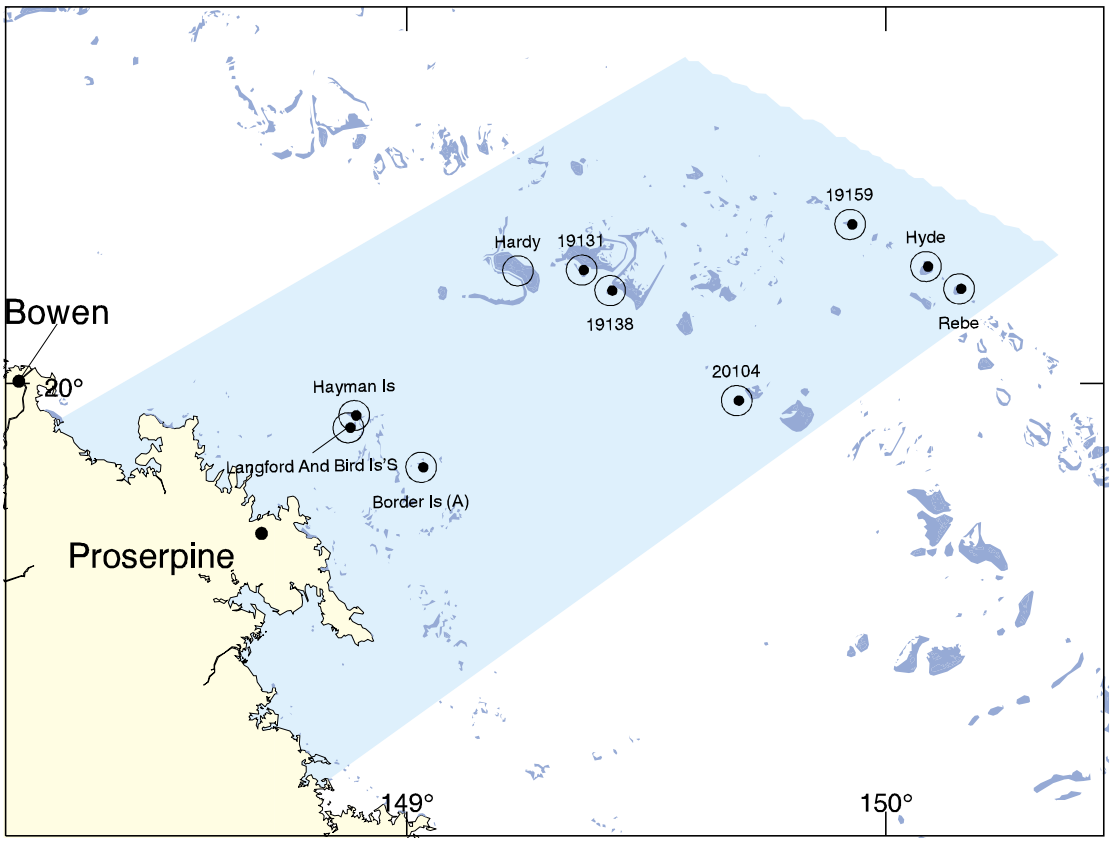
Cape Upstart Sector



- Fish and Benthos

○ Manta Tow

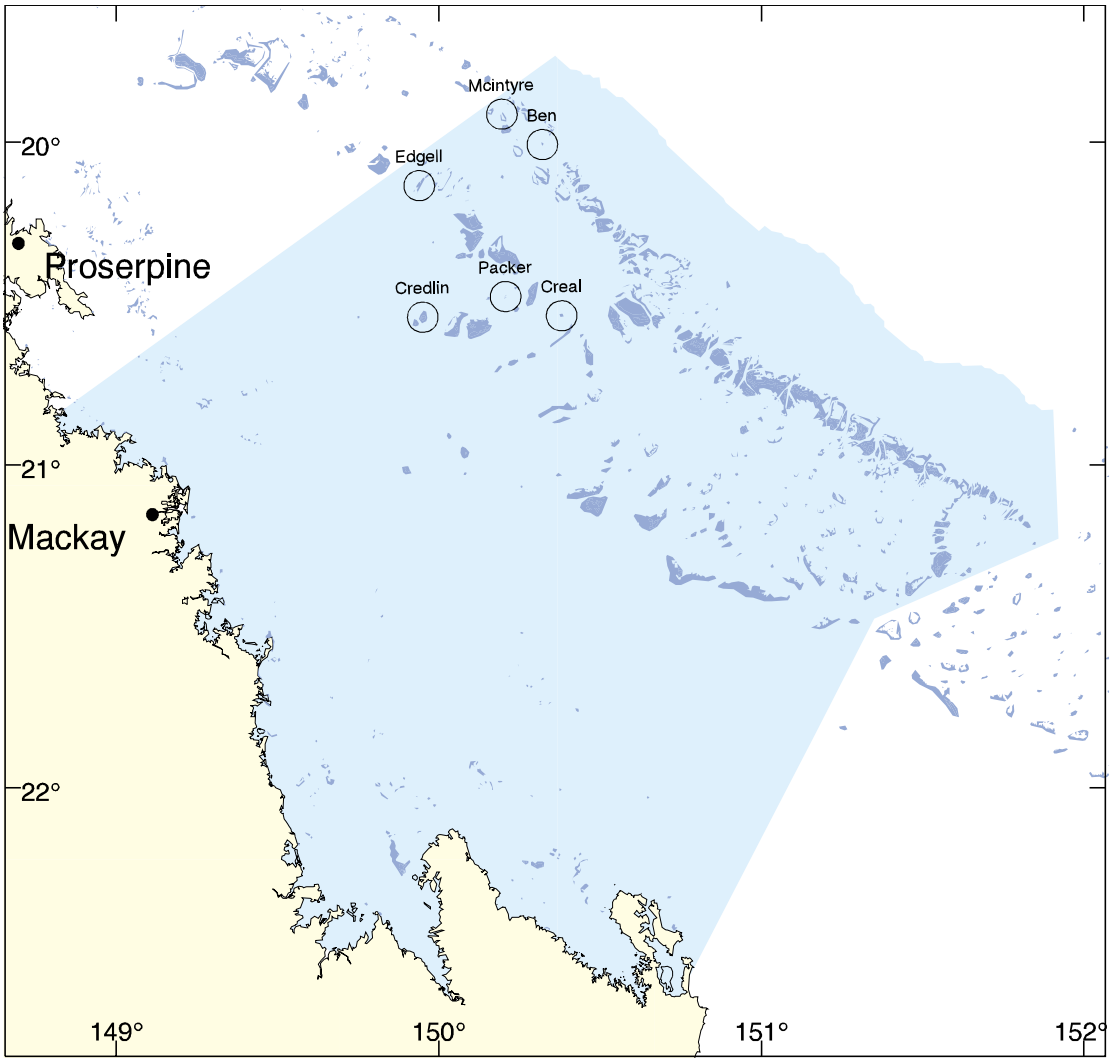
Whitsunday Sector



- Fish and Benthos

○ Manta Tow

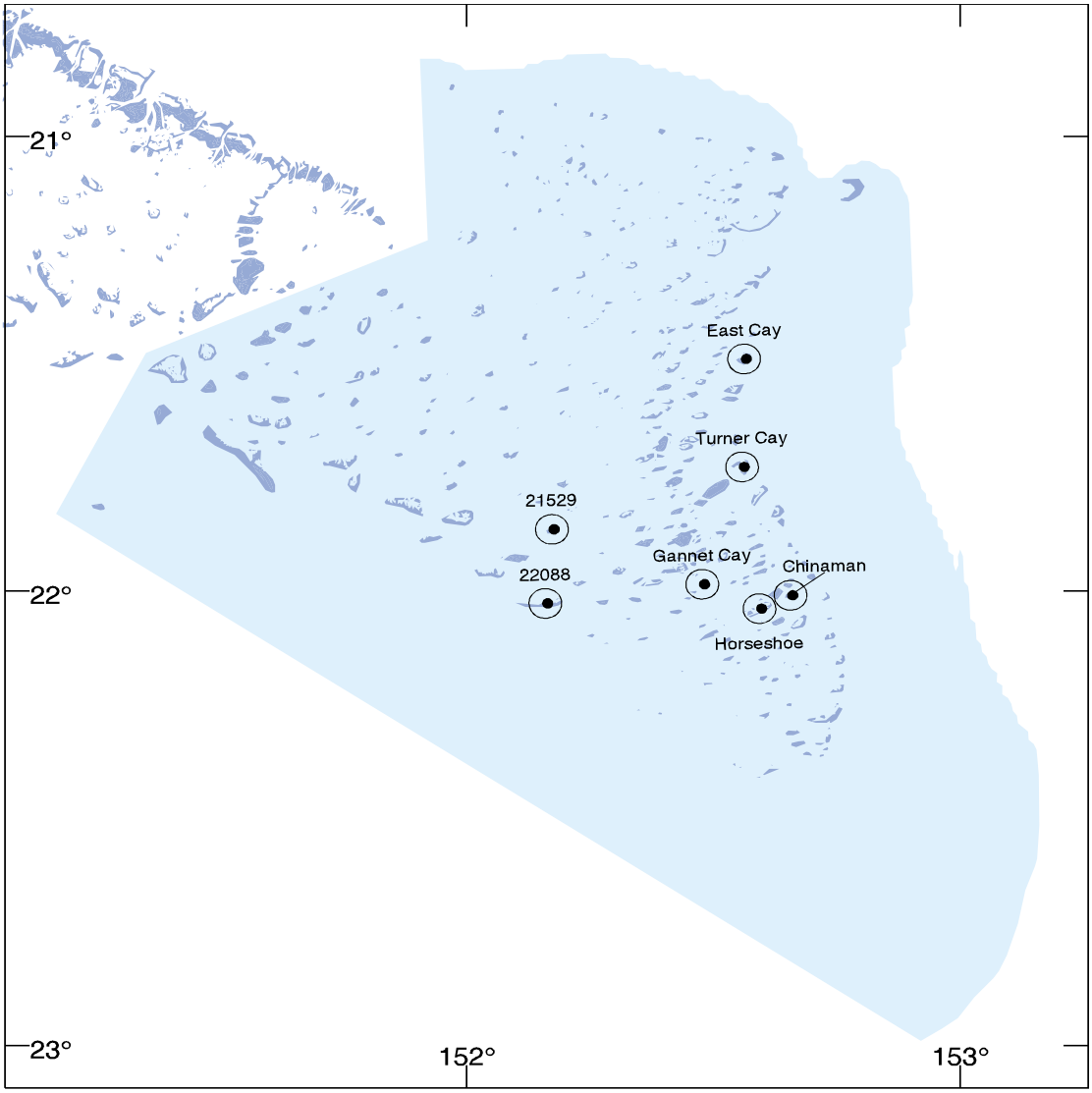
Pompey Sector



- Fish and Benthos

○ Manta Tow

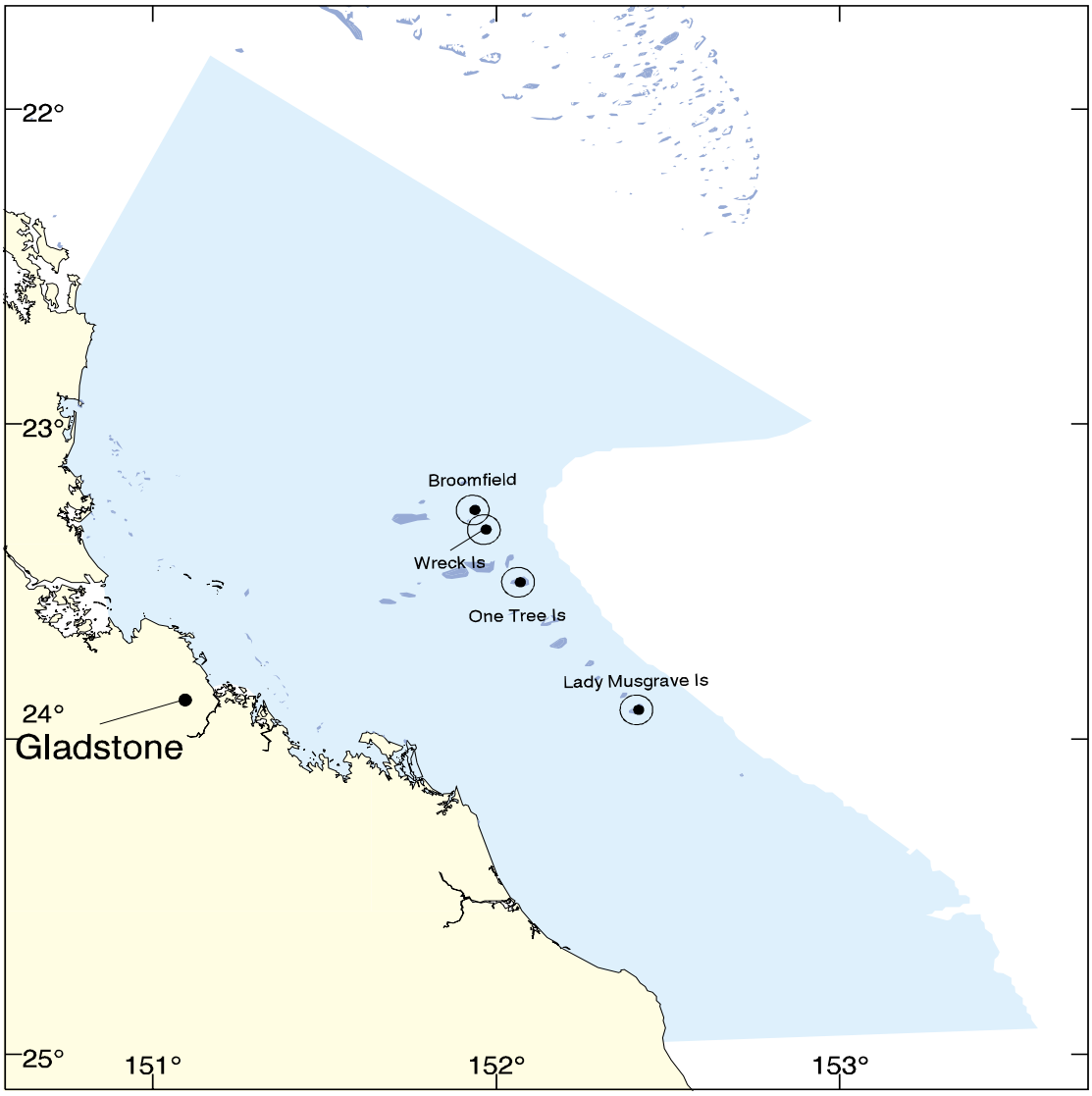
Swain Sector



- Fish and Benthos

○ Manta Tow

Capricorn Bunker Sector



- Fish and Benthos

○ Manta Tow

Appendix B

Summary of reefs surveyed in 2003. 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
				2003
Cape Grenville	Inshore	11167	Bird Is's	M
		12010	Kay	M
Princess Charlotte Bay	Middle Shelf	13124	13124	M
Princess Charlotte Bay	Outer-Shelf	13040	13040	M
Cooktown / Lizard Is	Inshore	14123	Martin	MBF
		14126	Linnet	MBF
		14131	Decapolis	BF
		15005	Three Isles	M
		15012	Boulder	M
Cooktown / Lizard Is	Middle Shelf	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	14137	Carter	MBF
		14138	Yonge	MBF
		14139	No Name	MBF
		14152	14152	M
		15032	Ribbon No.6	M
		15085	Lena	M
Cairns	Inshore	16028	Low Islets	BF
		16049	Green Is	MBF
		16054	Fitzroy Is	BF
Cairns	Middle 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.3	M
		15099	Agincourt No.1	MBF
		16019	St. Crispin	MBF
		16025	Opal (2)	MBF
		16058	Hope	M

Sector	Shelf Position	Reef ID	Reef Name	Year Surveyed
				2003
Innisfail	Middle Shelf	17034	Feather	M
		17044	Ellison	M
		17051	Beaver	M
Innisfail	Outer-Shelf	17032	Wardle	M
Townsville	Inshore	18051	Pandora	BF
		18053	Fantome Is	M
		18065	Havannah Is	MBF
		19011	Middle	Bf
Townsville	Middle Shelf	18029	Bramble	M
		18030	Kelso	M
		18032	Rib	MBF
		18075	John Brewer	MBF
		18076	Helix	M
		18095	Wheeler	M
		18096	Davies	MBF
		18099	18099	M
		18106	Little Broadhurst	M
Townsville	Outer-Shelf	18023	18023	M
		18034	Myrmidon	MBF
		18039	Dip	MBF
		18086	Chicken	MBF
Cape Upstart	Middle 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	Middle 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	Middle Shelf	19219	Mcintyre	M
		20112	Edgell	M
		20145	Packer	M
		20287	Credlin	M
		20297	Creal	M
Pompey	Outer-Shelf	20113	Ben	M

Sector	Shelf Position	Reef ID	Reef Name	Year Surveyed
				2003
Swain	Middle 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

C1. List of large, mobile fish species that would be counted on 5m wide transects

Acanthuridae

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 unicornis
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 meyeri
Chaetodon ornatissimus
Chaetodon pelewensis
Chaetodon plebeius
Chaetodon punctatofasciatus
Chaetodon rafflesii
Chaetodon rainfordi
Chaetodon reticulatus
Chaetodon speculum
Chaetodon trifascialis
Chaetodon trifasciatus
Chaetodon ulietensis
Chaetodon unimaculatus
Chaetodon vagabundus
Chelmon rostratus
Forcipiger flavissimus
Forcipiger longirostris
Hemitaurichthys polylepis

Labridae

Cheilinus fasciatus
Cheilinus undulatus
Choerodon fasciatus
Coris gaimard
Epibulus insidiator
Gomphosus varius
Halichoeres hortulanus
Hemigymnus fasciatus
Hemigymnus melapterus

Lethrinidae

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

Lutjanidae

Lutjanus adetii
Lutjanus argentimaculatus
Lutjanus biguttatus
Lutjanus bohar
Lutjanus boutton
Lutjanus carponotatus
Lutjanus fulviflammus
Lutjanus fulvus
Lutjanus gibbus
Lutjanus kasmira
Lutjanus lemniscatus
Lutjanus lutjanus
Lutjanus monostigma
Lutjanus quinquelineatus
Lutjanus rivulatus
Lutjanus russellii
Lutjanus sebae
Lutjanus semicinctus
Lutjanus vitta
Macolor (grouped)

Scaridae

Bolbometopon muricatum
Calotomus carolinus
Cetoscarus bicolor
Chlorurus bleekeri
Chlorurus gibbus
Chlorurus japanensis
Chlorurus sordidus
Hipposcarus longiceps
Scarus altipinnis
Scarus chameleon
Scarus dimidiatus
Scarus flavipectoralis
Scarus forsteni
Scarus frenatus
Scarus ghobban
Scarus globiceps
Scarus longipinnis
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 spinus
Siganus vulpinus

Zanclidae

Zanclus cornutus

C2. List of damselfish species that would be counted on 1m 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 retrofasciata
Chromis ternatensis
Chromis vanderbilti
Chromis viridis
Chromis weberi
Chromis xanthochira
Chromis xanthura
Chrysiptera flavipinnis
Chrysiptera rex
Chrysiptera rollandi
Chrysiptera talboti
Dascyllus aruanus
Dascyllus reticulatus
Dascyllus trimaculatus
Dischistodus melanotus
Dischistodus perspicillatus
Dischistodus prosopotaenia
Dischistodus pseudochrysopoecil
Hemiglyphidodon plagiometopon
Neoglyphidodon melas
Neoglyphidodon nigroris
Neoglyphidodon polyacanthus
Neopomacentrus azysron
Neopomacentrus bankieri
Neopomacentrus cyanomos
Plectroglyphidodon dickii
Plectroglyphidodon johnstonianu
Plectroglyphidodon lacrymatus
Pomacentrus adelus
Pomacentrus amboinensis
Pomacentrus australis
Pomacentrus bankanensis
Pomacentrus brachialis
Pomacentrus chrysurus
Pomacentrus coelestis
Pomacentrus grammorhynchus
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 gascoynei
Stegastes nigricans

Appendix D

Status of crown-of-thorns starfish in each sector on the Great Barrier Reef for survey year 2003.

D. Status of crown-of-thorns starfish (COTS) in each sector in 2003. 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
Cape Grenville	2	0	0	0 (0)	3-/4+ (3- to 4+)	51.76 ± 15.3	0	0	100
Princess Charlotte Bay	2	0.01	1	1 (50)	2-/2+ (2- to 2+)	24.62 ± 6.63	0	0	100
Cooktown / Lizard Island	16	0.01	8	4 (25)	2+ (1+/2- to 3-)	23.96 ± 1.63	0	31.25	68.8
Cairns	16	0	0	0 (0)	2- (1- to 4+)	18.17 ± 3.78	0	56.25	43.8
Innisfail	4	0	0	0 (0)	1- (1- to 1+)	4.251 ± 1.71	0	100	0
Townsville	25	3.18	3668	15 (60)	1+ (1- to 3+)	14.00 ± 2.13	40	44	16
Cape Upstart	6	0.54	136	5 (83)	1+/2- (1+ to 2+)	14.51 ± 2.31	16.67	33.33	50
Whitsunday	10	0.002	1	1 (10)	2- (1+ to 3-)	21.90 ± 3.04	0	20	80
Pompey	6	0.03	8	2 (33)	3- (1+ to 4+)	37.90 ± 8.30	0	0	100
Swain	7	4.71	1676	5 (71)	1+ (1- to 4-)	18.75 ± 5.49	57.14	14.29	28.6
Capricorn Bunker	4	0	0	0 (0)	3-/3+ (3- to 4-)	44.1 ± 4.24	0	0	100

Appendix E

Percentage cover of selected groups of benthic organisms recorded from each region in 2003 Survey.

Figures are regional means.

CL = Cooktown / Lizard Is, CA = Cairns, TO = Townsville, WH = Whitsunday, SW = Swain, CB = Capricorn Bunker. I= Inshore, M = Middle shelf, O = Outer shelf

Sector	Shelf	Hard Coral	Soft Coral	Algae	Acroporidae	Favidae	Pocilloporidae	Poritidae	*Acropora* Tabulate	*Acropora* Other	*Montipora*
CL	I	31.1	4.6	50.7	11.3	4.6	3.9	4.8	3.3	5.4	2.5
CL	M	20.1	8.6	59.3	2.9	4.1	1.9	7.4	0.6	1.5	0.6
CL	O	55.0	4.4	37.6	44.1	1.4	6.3	1.5	27.9	14.3	1.8
CA	I	7.7	9.6	71.4	0.7	0.3	0.3	4.5	0.0	0.1	0.5
CA	M	18.7	13.8	62.3	8.2	2.9	3.1	1.3	4.8	2.5	0.9
CA	O	26.6	29.8	39.8	17.3	1.5	4.5	2.3	7.9	8.8	0.6
TO	I	25.4	6.7	56.4	3.5	1.8	0.0	12.3	0.5	0.9	2.1
TO	M	10.9	2.3	82.2	2.7	2.2	1.8	2.4	0.8	1.5	0.4
TO	O	25.8	7.5	62.6	10.9	5.1	4.3	2.8	3.5	5.4	1.9
WH	I	31.2	15.0	40.3	11.2	4.3	0.4	9.0	0.7	4.9	5.5
WH	M	30.3	1.2	64.7	15.5	6.1	2.2	2.4	5.6	3.3	6.7
WH	O	26.8	36.2	24.7	13.7	3.2	2.7	4.6	4.9	7.2	1.6
SW	M	33.3	10.3	52.7	17.1	2.3	2.4	7.9	6.3	7.3	3.4
SW	O	17.6	24.1	53.5	5.4	1.6	2.0	5.8	3.1	1.9	0.4
CB	O	66.6	2.8	27.7	62.8	1.7	0.7	0.4	53.6	7.6	1.6

Appendix F

Summary counts of the different fish taxa recorded from each region in 2003 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 2003 survey.

CL = Cooktown / Lizard Is, CA = Cairns, TO = Townsville, WH = Whitsunday, SW = Swain, CB = Capricorn Bunker. I= Inshore, M = Middle shelf, O = Outer shelf

Sector	Shelf	Acanthuridae	Chaetodontidae	Labridae	Lethrinidae	Lutjanidae	Scaridae	Serranidae	Siganidae	Zanclidae
CL	I	67	117	47	3	36	102	7	82	1
CL	M	109	81	64	10	20	134	12	42	3
CL	O	379	180	46	18	79	182	6	5	19
CA	I	51	31	39	0	62	83	4	51	1
CA	M	201	90	45	6	50	167	1	16	3
CA	O	250	117	51	16	15	217	1	13	5
TO	I	3	46	42	1	35	52	8	40	0
TO	M	105	69	54	5	2	247	4	36	2
TO	O	228	80	44	8	6	250	8	17	5
WH	I	10	67	43	0	14	96	7	33	0
WH	M	34	105	86	2	45	242	9	50	0
WH	O	234	102	42	7	7	173	5	11	5
SW	M	113	65	57	4	5	221	19	34	7
SW	O	192	68	44	2	1	213	5	16	13
CB	O	238	279	61	9	8	185	13	10	3

F2. Number of damselfishes recorded in the regions in the 2003 survey.

CL = Cooktown / Lizard Is, CA = Cairns, TO = Townsville, WH = Whitsunday, SW = Swain, CB = Capricorn Bunker. I= Inshore, M = Midle 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	77	69	0	135	37	5	0	8	355	1	1388	0	0	0
CL	M	50	74	3	126	186	56	4	11	114	22	1220	0	0	0
CL	O	61	2	1	1314	26	21	0	0	1	129	291	0	0	1
CA	I	21	41	0	5	42	3	1	21	62	1	329	0	0	0
CA	M	37	42	1	282	33	20	9	21	226	101	730	0	0	29
CA	O	47	10	2	415	27	18	0	4	65	104	377	0	0	1
TO	I	96	6	0	0	0	0	0	13	775	0	183	0	0	1
TO	M	93	109	6	170	52	2	11	76	205	30	1153	0	0	6
TO	O	41	7	5	455	22	24	0	2	104	173	546	0	0	33
WH	I	161	95	0	162	80	2	0	4	324	0	822	0	0	1
WH	M	46	17	1	118	56	1	0	0	1303	0	1138	0	0	22
WH	O	46	67	2	105	11	8	1	35	42	50	574	0	0	2
SW	M	6	84	3	665	19	0	0	6	54	4	1017	0	0	3
SW	O	17	47	2	180	14	0	0	16	2	14	680	0	0	13
CB	O	8	3	0	307	14	8	0	1	34	24	701	0	0	3

Appendix G

Mean Percentage cover of selected groups of benthic organisms recorded from each reef in 2003 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	54.8	19.5	4.7	5.6	2.8	3.0	5.0	1.9	2.9	0.7
CL	Linnet	14126	I	39.8	51.0	5.4	19.1	9.7	6.4	6.9	4.9	10.3	3.8
CL	Decapolis	14131	I	57.4	22.9	3.8	9.2	1.2	2.4	2.4	3.0	3.0	3.2
CL	Macgillivray	14114	M	52.6	20.1	5.8	1.4	3.5	1.2	10.5	0.2	0.6	0.6
CL	Lizard Is	14116	M	61.9	15.7	17.7	2.2	4.4	2.5	4.5	0.5	0.6	0.9
CL	North Direction I	14143	M	63.3	24.6	2.2	5.0	4.3	1.8	7.3	1.2	3.4	0.4
CL	Carter	14137	O	38.4	55.9	3.0	46.9	1.7	5.4	0.5	31.1	13.9	2.0
CL	Yonge	14138	O	37.3	57.0	3.6	45.0	1.6	6.4	2.0	28.0	15.0	1.9
CL	No Name	14139	O	37.2	52.1	6.7	40.5	1.1	7.0	2.1	24.7	14.1	1.6
CA	Low Islets	16028	I	75.8	10.9	7.2	1.0	0.7	0.0	6.3	0.0	0.0	0.9
CA	Green Is	16049	I	74.7	5.0	5.2	0.6	0.3	0.4	2.8	0.1	0.1	0.4
CA	Fitzroy Is	16054	I	63.7	7.1	16.4	0.4	0.0	0.4	4.4	0.0	0.1	0.3
CA	Mackay	16015	M	66.1	23.1	3.2	4.0	4.9	2.1	2.1	1.2	1.6	1.2
CA	Hastings	16057	M	61.4	25.0	9.5	14.0	3.3	5.1	1.2	8.9	4.5	0.5
CA	Michaelmas	16060	M	41.3	22.9	29.9	14.1	3.1	3.6	0.6	9.2	3.3	1.7
CA	Thetford	16068	M	80.4	3.8	12.7	0.7	0.2	1.4	1.1	0.1	0.4	0.2
CA	Agincourt No.1	15099	O	34.8	36.7	26.2	25.7	1.4	7.5	1.0	13.9	11.4	0.3
CA	St. Crispin	16019	O	38.2	24.1	33.3	12.2	2.1	3.6	4.6	7.2	4.0	1.0
CA	Opal (2)	16025	O	46.4	19.1	30.1	14.1	0.9	2.4	1.2	2.6	11.0	0.3
TO	Pandora	18051	I	43.5	40.7	12.3	1.1	2.9	0.0	21.8	0.3	0.4	0.4
TO	Havannah Is	18065	I	86.8	6.2	5.4	3.5	0.9	0.1	0.9	0.2	1.6	1.7
TO	Middle	19011	I	38.8	29.2	2.4	5.8	1.7	0.0	14.2	0.9	0.8	4.1
TO	Rib	18032	M	89.6	3.2	3.2	1.4	0.3	0.3	0.6	0.5	0.7	0.2
TO	John Brewer	18075	M	91.8	1.6	1.4	0.1	0.5	0.7	0.1	0.0	0.1	0.0
TO	Davies	18096	M	64.0	29.1	2.4	7.0	6.1	4.7	6.7	2.0	4.0	1.0
TO	Myrmidon	18034	O	66.8	23.6	4.6	7.8	5.9	2.3	3.0	2.4	2.4	2.9
TO	Dip	18039	O	62.3	25.6	7.7	13.7	3.2	4.8	2.1	4.2	8.0	1.5
TO	Chicken	18086	O	58.6	28.3	10.3	11.1	6.1	5.9	3.1	4.0	5.6	1.4
WH	Hayman Is	20014	I	36.3	43.9	12.3	24.8	5.4	0.2	2.7	1.2	8.9	14.7
WH	Langford & Bird	20019	I	45.7	21.7	10.5	5.8	3.3	0.5	7.7	0.4	4.2	0.7
WH	Border Is (A)	20067	I	38.9	28.2	22.2	3.0	4.1	0.5	16.6	0.4	1.5	1.0
WH	19131	19131	M	60.7	32.9	1.1	14.0	9.6	1.2	2.7	3.5	2.3	8.2
WH	19138	19138	M	73.7	23.3	1.0	10.5	4.5	2.5	2.7	4.8	2.9	2.8
WH	20104	20104	M	59.8	34.9	1.6	22.1	4.1	2.8	1.8	8.4	4.6	9.1
WH	19159	19159	O	28.0	44.3	16.9	30.4	4.0	3.2	2.0	9.9	17.5	3.0
WH	Hyde	19207	O	22.9	17.4	47.2	5.3	3.3	2.0	5.0	2.5	2.0	0.7
WH	Rebe	19209	O	23.3	18.7	44.6	5.4	2.2	2.8	6.7	2.3	2.0	1.1
SW	21529	21529	M	33.2	60.7	1.4	42.1	1.9	3.8	8.0	4.3	30.8	7.0
SW	Gannet Cay	21556	M	86.3	4.1	8.7	0.4	0.0	0.2	2.3	0.0	0.2	0.1
SW	22088	22088	M	35.2	47.3	10.7	22.6	2.2	4.3	14.0	12.4	2.9	7.3
SW	Chinaman	22102	M	27.5	43.8	26.1	18.4	6.2	3.5	10.6	14.9	1.9	1.6
SW	Horseshoe	22104	M	81.1	10.7	4.3	1.8	1.5	0.4	4.3	0.1	0.6	1.1
SW	East Cay	21305	O	49.8	21.7	22.7	6.8	1.6	3.4	5.8	3.8	2.6	0.3
SW	Turner Cay	21562	O	57.2	13.6	25.5	4.0	1.5	0.5	5.8	2.4	1.2	0.4
CB	Broomfield	23048	O	35.9	55.8	4.7	49.7	2.7	0.5	0.6	35.3	10.7	3.7
CB	Wreck Is	23051	O	32.1	59.8	5.6	56.2	1.8	0.4	0.7	47.0	7.7	1.5
CB	One Tree Is	23055	O	20.1	76.1	1.0	72.6	2.0	0.5	0.3	65.5	6.4	0.7
CB	Lady Musgrave Is	23082	O	22.8	74.8	0.0	72.7	0.4	1.4	0.0	66.6	5.9	0.2

Appendix H

Summary counts of the different fish taxa recorded from each reef in 2003 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 2003 survey.

Sector	Reef	Reef ID	Shelf	Acanthuridae	Chaetodontidae	Labridae	Lethrinidae	Lutjanidae	Scaridae	Serranidae	Siganidae	Zanclidae
CL	Martin	14123	I	115	134	53	7	40	125	4	47	0
CL	Linnet	14126	I	82	179	68	0	35	162	4	147	2
CL	Decapolis	14131	I	4	39	19	2	32	19	14	53	0
CL	Macgillivray	14114	M	147	64	68	13	34	138	7	33	4
CL	Lizard Is	14116	M	123	87	47	11	19	133	17	52	1
CL	North Direction I	14143	M	56	91	77	7	7	131	11	41	3
CL	Carter	14137	O	458	184	53	10	86	144	3	0	22
CL	Yonge	14138	O	333	185	40	14	54	191	6	4	19
CL	No Name	14139	O	345	170	44	29	98	211	8	11	16
CA	Low Islets	16028	I	31	25	37	0	106	53	5	76	0
CA	Green Is	16049	I	114	37	46	1	48	172	5	51	2
CA	Fitzroy Is	16054	I	7	32	35	0	33	23	3	26	0
CA	Mackay	16015	M	32	69	40	12	31	79	2	23	3
CA	Hastings	16057	M	266	128	42	6	12	116	0	10	3
CA	Michaelmas	16060	M	208	113	33	1	148	126	2	15	3
CA	Thetford	16068	M	298	51	66	5	7	345	0	14	3
CA	Agincourt No.1	15099	O	202	125	37	27	24	152	0	17	7
CA	St. Crispin	16019	O	266	138	73	7	4	320	2	9	5
CA	Opal (2)	16025	O	282	87	42	15	16	178	1	12	4
TO	Pandora	18051	I	1	75	41	2	60	46	8	60	0
TO	Havannah Is	18065	I	4	16	43	0	9	57	7	19	0
TO	Rib	18032	M	119	63	46	3	4	264	4	30	3
TO	John Brewer	18075	M	116	47	75	6	1	267	3	26	2
TO	Davies	18096	M	79	97	42	5	2	210	6	51	0
TO	Myrmidon	18034	O	248	98	32	6	7	371	1	4	8
TO	Dip	18039	O	285	71	47	14	8	184	2	5	6
TO	Chicken	18086	O	152	72	54	4	3	196	21	43	2
WH	Hayman Is	20014	I	7	51	53	1	9	115	7	38	0
WH	Langford & Bird	20019	I	16	72	48	0	14	135	7	38	0
WH	Border Is (A)	20067	I	6	79	27	0	20	37	7	24	0
WH	19131	19131	M	42	101	83	0	15	204	15	31	0
WH	19138	19138	M	30	98	108	2	44	281	4	40	0
WH	20104	20104	M	31	116	67	3	75	242	9	79	0
WH	19159	19159	O	215	173	39	9	11	116	8	17	8
WH	Hyde	19207	O	242	76	45	4	6	227	6	7	3
WH	Rebe	19209	O	246	58	42	8	5	176	2	10	5
SW	21529	21529	M	1	60	43	7	4	169	46	49	0
SW	Gannet Cay	21556	M	69	29	65	12	1	256	18	64	7
SW	22088	22088	M	33	69	47	0	3	195	11	15	9
SW	Chinaman	22102	M	148	107	56	0	8	218	21	7	4
SW	Horseshoe	22104	M	315	61	72	0	8	269	1	36	13
SW	East Cay	21305	O	196	76	32	0	0	164	4	7	17
SW	Turner Cay	21562	O	187	59	56	3	1	262	6	24	8
CB	Broomfield	23048	O	237	223	67	15	5	236	12	6	0
CB	Wreck Is	23051	O	242	299	60	17	11	212	16	4	1
CB	One Tree Is	23055	O	153	301	40	3	5	137	17	29	8
CB	Lady Musgrave Is	23082	O	318	293	75	2	9	154	7	1	3

H2. Number of damselfishes recorded in the reefs in the 2003 survey.

Sector	Reef	Reef ID	Shelf	*Acanthochromis*	*Amblyglyphidodon*	*Chromis*	*Chrysiptera*	*Neoglyphidodon*	*Neopomacentrus*	*Plectroglyphidodon*	*Pomacentrus*
CL	Martin	14123	I	41	51	111	61	7	143	0	1393
CL	Linnet	14126	I	181	152	295	50	17	679	4	2421
CL	Decapolis	14131	I	9	4	0	1	1	242	0	351
CL	Macgillivray	14114	M	70	62	202	152	9	46	29	909
CL	Lizard Is	14116	M	50	78	102	148	10	257	11	2072
CL	North Direction I	14143	M	29	81	75	257	15	39	27	680
CL	Carter	14137	O	40	4	1307	15	0	0	125	185
CL	Yonge	14138	O	82	0	1499	41	0	0	163	259
CL	No Name	14139	O	61	1	1135	21	0	2	98	429
CA	Low Islets	16028	I	22	19	1	21	20	97	0	374
CA	Green Is	16049	I	22	62	13	94	10	58	2	477
CA	Fitzroy Is	16054	I	20	41	1	11	34	30	0	137
CA	Mackay	16015	M	51	141	24	77	79	42	6	664
CA	Hastings	16057	M	42	11	390	15	0	183	139	704
CA	Michaelmas	16060	M	11	3	606	14	3	608	160	838
CA	Thetford	16068	M	43	11	109	25	0	69	99	712
CA	Agincourt No.1	15099	O	48	0	316	27	1	2	121	370
CA	St. Crispin	16019	O	60	30	370	20	5	4	75	465
CA	Opal (2)	16025	O	32	1	560	33	6	190	115	295
TO	Pandora	18051	I	78	7	0	1	27	1960	0	260
TO	Havannah Is	18065	I	179	10	0	0	13	170	0	249
TO	Middle	19011	I	31	0	0	0	0	196	0	40
TO	Rib	18032	M	110	154	440	16	61	297	48	977
TO	John Brewer	18075	M	113	79	20	73	55	217	13	927
TO	Davies	18096	M	55	94	50	67	112	101	28	1556
TO	Myrmidon	18034	O	70	20	1014	3	0	7	213	254
TO	Dip	18039	O	18	0	197	26	4	35	94	451
TO	Chicken	18086	O	36	0	153	38	1	269	211	933
WH	Hayman Is	20014	I	175	109	45	32	5	131	0	870
WH	Langford & Bird	20019	I	170	91	98	55	3	137	0	669
WH	Border Is (A)	20067	I	137	85	344	153	5	703	0	926
WH	19131	19131	M	33	8	3	19	0	1499	0	1070
WH	19138	19138	M	61	37	76	53	0	322	0	1140
WH	20104	20104	M	45	6	275	96	0	2088	0	1203
WH	19159	19159	O	59	132	213	17	51	88	67	657
WH	Hyde	19207	O	52	28	51	8	34	0	46	602
WH	Rebe	19209	O	26	40	52	9	21	39	38	463
SW	21529	21529	M	11	101	835	68	3	0	1	1060
SW	Gannet Cay	21556	M	11	119	1709	17	4	0	0	813
SW	22088	22088	M	1	33	15	3	2	219	0	1291
SW	Chinaman	22102	M	2	56	765	0	18	45	16	1293
SW	Horseshoe	22104	M	5	112	0	7	4	4	2	627
SW	East Cay	21305	O	17	31	0	24	15	0	12	546
SW	Turner Cay	21562	O	17	62	360	4	16	3	16	814
CB	Broomfield	23048	O	23	1	358	9	1	77	20	1012
CB	Wreck Is	23051	O	9	5	448	10	1	11	16	598
CB	One Tree Is	23055	O	0	0	245	27	0	7	21	591
CB	Lady Musgrave Is	23082	O	0	6	178	11	1	39	39	601

Appendix I

Statistical Analysis of the Survey Data

Analysis of reef trends [Section 4]

Temporal trends in percent cover of benthic groups and families and abundance of fish families were examined at each reef within each Sector/Shelf region using linear mixed-effects models. Estimated trends and observed means for each measure were plotted against survey year to provide a visual presentation of temporal patterns.

Benthic cover analyses

Estimates of percent cover for the benthic groups are obtained by point sampling a 50 m transect recorded on videotape. The response at each site (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 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).

Fish abundance analyses

Counts of fish abundance are obtained from 50 m transects adjacent to the benthic vdeo surveys. The response at each site (summed counts over 5 transects) is transformed to the natural logarithm of the observed count ($log(y + 1)$) after adding 1 to account for zeros in the data.

Mixed-effects models

Linear mixed-effects models (Laird and Ware 1982, Pinheiro and Bates 2000), which extend the linear model to include random effects to account for correlation among observations on the same sampling unit, were used to examine the relationship

between the response and time (i.e. survey year). The response, y_i, for the i^{th} sampling unit is expressed as:

$$y_i = X_i\beta + Z_i b_i + \varepsilon_i, \quad i = 1,...,M,$$
$$b_i \sim N(0,\Sigma), \quad \varepsilon_i \sim N(0,\sigma^2 I)$$

where X_i and Z_i are known fixed-effect and random-effect regressor matrices, β are the fixed-effects, b_i are the random-effects, and ε_i is the within-sampling-unit error with a spherical Gaussian distribution, $N(0,\sigma^2 I)$. The random-effects and within-sampling-unit errors are assumed independent between sampling units and within sampling units. The distribution of the random-effects is characterised by the variance-covariance matrix Σ.

The model chosen to describe the response (y_{ijklm}) represents the empirical logit of percent cover of a particular benthic group, or the log of abundance of a particular fish family, recorded on site *l* for the k^{th} reef in the ij^{th} region at time (*m*) as:

$$y_{ijklm} = f(x_{ijklm}) + b_{ijkl} + \varepsilon_{ijklm}$$

where $f(x_{ijklm})$ represents the fixed-effects as some function of the response for the l^{th} site at the k^{th} reef in the ij^{th} region at survey time *m*, b_{ijkl} represents the random-effects (i.e. random intercepts) for individual reefs and ε_{ijklm} is the within-sampling unit error. The random intercepts form for the random-effects in the model results in a scalar variance estimate for between sampling unit variation. The assumption that the variance of the ε_i is equal to $\sigma^2 I$ can be relaxed to allow within-sampling unit correlation structures. The errors were assumed to conform to a multivariate normal distribution with mean 0 and covariance structure Σ. To account for temporal correlation within sampling units, models were fitted with and without a continuous autoregressive covariance structure (Pinheiro and Bates 2000). The structure was assumed to be homogeneous for all reefs.

Form of the fixed-effects component

The following forms for the fixed-effects relationship between the response and survey year were examined:

$$\text{Constant - } y_{ijklm} = \beta_{0ijk} + \varepsilon_{ijklm},$$

$$\text{Linear - } y_{ijklm} = \beta_{0ijk} + \beta_{1ijk} x_{ijklm} + \varepsilon_{ijklm},$$

$$\text{Quadratic - } y_{ijklm} = \beta_{0ijk} + \beta_{1ijk} x_{ijklm} + \beta_{2ijk} x_{ijklm}^2 + \varepsilon_{ijklm},$$

$$\text{Natural spline - } y_{ijklm} = s_{ijk}(x_{ijklm}) + \varepsilon_{ijklm},$$

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,
s_{ijk} represents a natural spline, with specified degrees of freedom, in the response for
the k^{th} reef in the ij^{th} region,
x_{ijklm} is the survey number for the l^{th} site, k^{th} reef in the ij^{th} region at time m, and
ε_{ijklm} is the error term.

Natural splines are flexible, smooth and nonlinear functions of the explanatory variables which represent the relationship with the response. Natural splines 'smooth' the relationship by dividing the data along the x-axis into regions separated at user-defined breakpoints and fitting polynomial regressions to each group constrained to be continuous (i.e. 'smooth') at the breakpoints. The degree of flexibility (i.e. the smoothness) is determined by the number of breakpoints as defined by the degrees of freedom of the spline.

A set of models containing each of the fixed effects structures described were defined as an *a priori* candidate set of models. The candidate set included models with natural splines with either three or four degrees of freedom. The set of models examined accounted for temporal correlation within sampling units by fitting models for each fixed effects structure both with and without a continuous autoregressive correlation structure.

Model selection

The 'best' approximating model among the set of candidate models outlined above was determined using Akaike's Information Criteria (AIC) (Akaike 1973, Burnham and Anderson 1998). The criterion is defined as:

$$AIC = -2\log(L(\hat{\theta} \mid y)) + 2K$$

where $L(\hat{\theta} \mid y)$ represents the likelihood of the model parameters, $\hat{\theta}$, given the data, y, and K represents the number of parameters in the model. The AIC value is then a measure of the goodness-of-fit of the model to the data penalised by the number of

parameters in the model. This is equivalent to the tradeoff between bias and variance which is implicit in the principle of parsimony that aims to select a model with the smallest number of parameters which adequately represents the data.

The model from the set of candidate models which minimises AIC was subsequently used for inference.

Coding of the survey year

To estimate average and current trends in the response the data were analysed using the survey year coded both as:

$$x_{ijklm} = \left(survey\ year - 1997.5\right)$$

and

$$x_{ijklm} = \left(survey\ year - 2003\right)$$

to allow direct estimation of β_{oijk} and β_{1ijk} at two different times during the survey period. When the survey year is centered around 1997.5, the parameters β_{oijk} and β_{1ijk} represent the average value of the response over the last eleven years for reef *ijk* and the linear change in the response over the period of the surveys for reef *ijk*, respectively. When the survey year is centered around 2003, 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. These estimates were then used to summarise the average and current changes in the response at the Sector level for GBR-wide summaries.

Statistical computing

The S-Plus (2000) statistical software (Insightful Corp., Seattle, WA) was used for all analyses. The `lme` function was used to fit the linear mixed-effects models described for the benthic cover and fish abundance analyses.