Appendix K

Statistical Analysis of the LTMP Survey Data

Analysis of Individual Reef Trends

Fish

Fish abundance data were collected using under water visual surveys. Initially, these surveys used transects that were 2 m wide for small site attached fish, and 10 m wide for larger mobile fish. These transects were found to be too wide and widths were decreased from 2 m to 1 m and 10 m to 5 m, prior to the third year of the survey.

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

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

where

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

δ represents the change in $\ell n(count + 1)$ between transects of different width,

x_{δ} is a dummy variable which takes on the value 1 for transects surveyed in the first two years of the study and 0 for the remaining transects,

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

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

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

and ε_{ijklm} is the error term

Coding of survey number

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

$$x_{ijklm} = (survey\ number - 3.5)$$

and

$$x_{ijklm} = (survey\ number - 6.0)$$

to allow direct estimation of β_{oijk} and β_{1ijk} at two different times during the survey period. When the survey number is centered around 3.5, the parameters β_{oijk} and β_{1ijk} represent the average value of the response over the period of the survey for reef *ijk* and the linear change in the response over the period of the survey for reef *ijk*, respectively. When the survey number is centered around 6, 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.

Correction factor for the change in transect width

The term δ represents the change in $\ell n(count + 1)$ due to the change in transect width. This change was assumed to be the same for all reefs at all sites for an individual taxon. This implies that the only difference between fish counts on transects of different widths was due to sampling error, and that there were no consistent regional differences.

Choosing a covariance structure

It was assumed that the errors were distributed as a multivariate normal with mean 0 and covariance structure Σ. The form of Σ was chosen as follows:

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

(a) independence

(b) compound symmetry

(c) first order autoregressive

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

(e) Toeplitz

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

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

Power

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

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

where

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

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

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

The average minimum detectable rate of change was tabulated on the logarithmic scale and can be converted to a rate of change on the count scale using Figure K1. To do this:

(1) estimate the mean abundance of fish per site for the reef of interest or the abundance of fish for the reef of interest in the last survey year (see appropriate reef page or Appendix H)

(2) find this value on the horizontal axis of Figure K1.

(3) draw a vertical line through this point until it intersects the two isopleths (or the margins of the figure) which bracket the minimal detectable rate of change of the taxa of interest (from Table K1)

(4) draw a horizontal line through each of these points until they intersect the left hand vertical axis

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

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

Larger fishes	MDD over 6 years	MDD (current)
Acanthuridae	0.30	0.79
Chaetodontidae	0.24	0.63
Labridae	0.27	0.73
Lethrinidae	0.44	1.16
Lutjanidae	0.40	1.05
Scaridae	0.33	0.88
Serranidae	0.39	1.03
Siganidae	0.42	1.12

Damselfishes	MDD over 6 years	MDD (current)
Acanthochromis	0.38	1.04
Amblyglyphidodon	0.23	0.65
Chromis	0.55	1.53
Chrysiptera	0.38	1.05
Neoglyphidodon	0.30	0.84
Neopomacentrus	0.69	1.90
Plectroglyphidodon	0.20	0.56
Pomacentrus	0.20	0.56

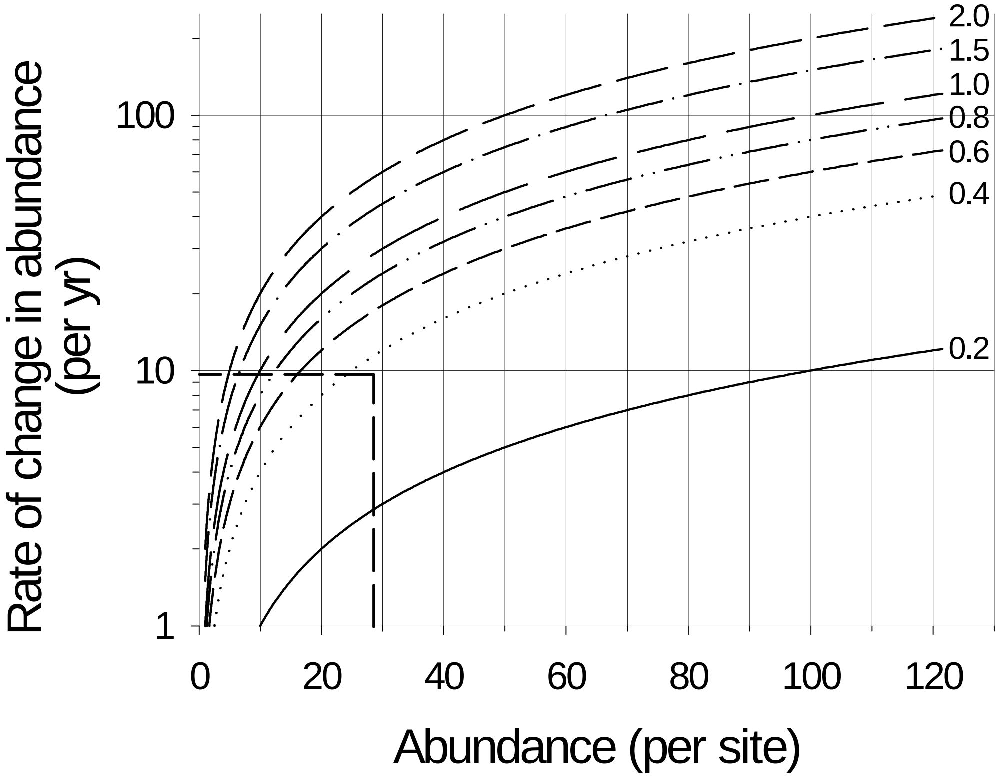

Figure K1: Relationship between mean abundance of fish per site and detectable rate of change in abundance for different values of minimum rate of change (MDD). Note detectable rate of change is given on a log scale. ***Interpretation:*** Drop-line gives an estimate of minimum detectable rate of change for overall trends in abundance of *Acanthochromis* on inshore reefs in the Whitsunday sector. From Appendix 5, mean abundance in 1996 was 86 fish per reef, thus the abundance per site was 86/3 = 28.6 (X axis). From Table K1, average minimum detectable rate of change over six years was 0.38. Using an interpolated MDD curve below that for MDD = 0.4, the estimated minimum detectable rate of change would be a gain or loss of about 10 fish annually.

transect recorded on videotape. Statistical analysis of these estimates differed from the analysis described for the fish taxa in the following ways:

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

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

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

(2) the statistical model is the same as the model used for the fish taxa analysis, but with the term representing the change in transect width (δ) removed.

(3) for the calculation of power: estimates of the level of cover are obtained from the appropriate reef page or Appendix G; Figure K2 is used in conjunction with Table K2.

Table K2: Average minimum detectable rate of change for percent cover of different taxa of benthic organisms based on means for sites on reefs. MDD over 6 years is the minimum detectable rate of change for the average trend, MDD (current) refers to the minimum detectable rate of change at the most recent survey. Note that these values are absolute: they apply to both positive and negative rates of change. These values are used in conjunction with Figure K2.

Taxon	MDD over 6 years	MDD (current)
Hard Corals	0.20	0.50
Acroporidae	0.38	0.96
Tabulate *Acropora* spp.	0.95	2.76
Other *Acropora* spp.	0.42	1.06
Montipora spp.	0.84	2.35
Faviidae	0.38	1.03
Pocilloporidae	0.48	1.26
Poritidae	0.60	1.57
Soft Corals	0.29	0.84
Algae	0.22	0.61

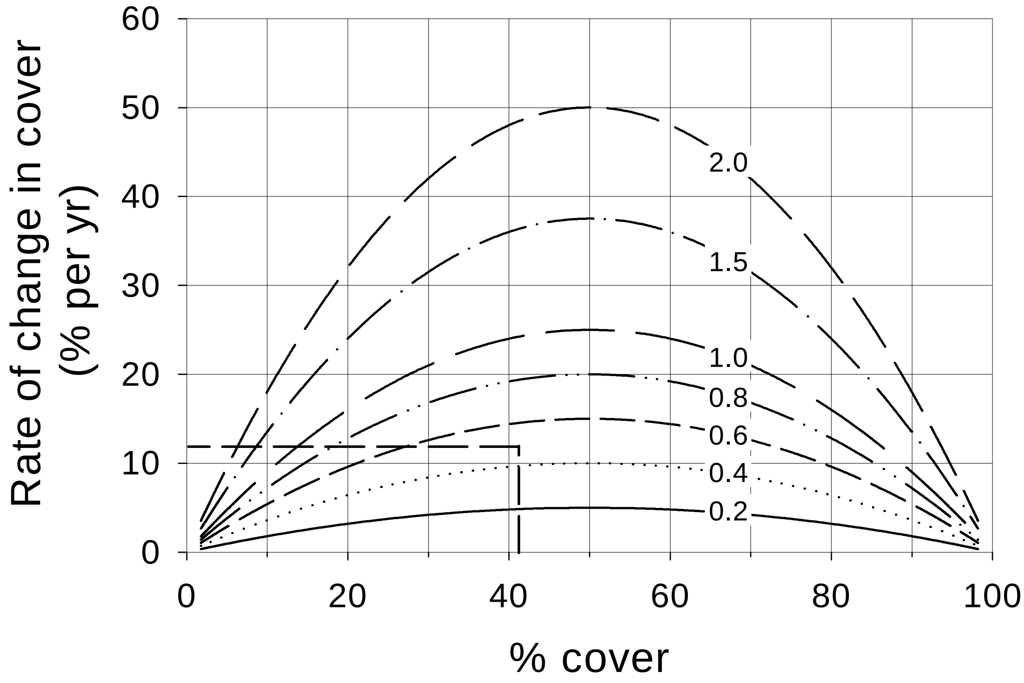

Figure K2: Relationship between cover of benthic taxa per site and detectable rate of change in percent cover for different values of minimum detectable difference (MDD) in rate of change. ***Interpretation:*** Drop-line gives an estimate of minimum detectable rate of change for the current trend in hard corals on Davies Reef (Townsville sector). From Appendix 4, mean percent cover in 1998 was 41.9 (X axis). From Table K2, the average minimum detectable rate of change is 0.50. Using an interpolated MDD curve between those for MDD = 0.4 and MDD = 0.6, the estimated minimum detectable rate of change would be a gain or loss of about 12% cover annually.

Analysis of regional trends

Fish abundance and benthic cover data

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

(1) reef means were used instead of site means for the benthic cover analysis

(2) reef means of $\ell n(count+1)$ were used instead of $\ell n(count+1)$ for the fish count data

(3) covariance structures which were heterogeneous across shelf position were considered.

(4) for the calculation of power: estimates of the benthic cover or fish abundance are obtained from Appendices E or F; Tables K3 and K4 are used instead of Tables K1 and K2.

Table K3: Average minimum detectable rate of change for abundances of different reef fish taxa based on **regional** means for sites on reefs. MDD over 6 years is the minimum detectable rate of change for the average trend, MDD (current) refers to the minimum detectable rate of change at the most recent survey. Note that these values are absolute; they apply to both positive and negative rates of change. These values are used in conjunction with Figure K1.

Larger fishes	MDD over 6 years	MDD (current)
Acanthuridae	0.27	0.53
Chaetodontidae	0.21	0.46
Labridae	0.18	0.38
Lethrinidae	0.36	0.85
Lutjanidae	0.32	0.99
Scaridae	0.23	0.54
Serranidae	0.29	0.73
Siganidae	0.32	0.92

Damselfishes	MDD over 6 years	MDD (current)
Acanthochromis	0.36	0.66
Amblyglyphidodon	0.26	0.50
Chromis	0.70	1.46
Chrysiptera	0.37	0.86
Neoglyphidodon	0.28	0.57
Neopomacentrus	0.66	1.53
Plectroglyphidodon	0.23	0.48
Pomacentrus	0.20	0.40

Table K4: Average minimum detectable rate of change for percent cover of different taxa of benthic organisms based on **regional** means for sites on reefs. MDD over 6 years is the minimum detectable rate of change for the average trend, MDD (current) refers to the minimum detectable rate of change at the most recent survey. Note that these values are absolute: they apply to both positive and negative rates of change. These values are used in conjunction with Figure K1.

Taxon	MDD over 6 years	MDD (current)
Hard Corals	0.26	0.61
Acroporidae	0.41	1.02
Tabulate *Acropora* spp.	1.28	3.88
Other *Acropora* spp.	0.45	1.09
Montipora spp.	0.83	2.42
Faviidae	0.32	0.95
Pocilloporidae	0.55	1.45
Poritidae	0.54	1.61
Soft Corals	0.36	0.91
Algae	0.36	1.01

Broad scale survey data

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

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

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

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

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

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

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

Statistical computing

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