Long-term monitoring analyses

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Data collected by the AIMS' long-term monitoring teams for the Great Barrier Reef (Long-Term Monitoring Program (LTMP) and Marine Monitoring Program (MMP)) undergo Quality Assurance-Quality Control procedures, then subsequently analysed with the help of statistical models (mathematical tools used to estimate outcomes and conditions). Results for reporting are generated using statistical models that combine the thousands of observations collected across the Great Barrier Reef each year. These models help identify underlying trends, account for natural variability, and provide more reliable estimates of overall reef condition than individual survey observations alone. Different models are used for different survey methods and types of data. Below are both technical and non-technical descriptions of the models used for different measurements of reef and community condition.

Photo-transect benthic models

Non-technical description

We analyse changes in reef condition using advanced statistical models applied to long-term monitoring data collected across the Great Barrier Reef.

The data are derived from underwater digital imagery taken along permanently marked sections of reef (known as transects) at three sites on each reef we survey. For more details see the Sampling design Standard Operating Procedure (SOP) and the Benthic survey SOP.

From each photograph, the type of coral, algae or other reef organism beneath five fixed points are identified and recorded. These observations are then used to estimate the proportion of the reef covered by different groups, such as hard coral, soft coral and algae.

To estimate trends through time, we use statistical modelling that internally treats these counts as proportions (for example, "20 out of 100 points are hard coral"). We combine information from all surveys while accounting for differences among reefs, and regions and include year to quantify changes through time. Separate models are run for each major benthic group (hard coral, soft coral, and algae), and for the different spatial scales such as individual reefs, Natural Resource Management (NRM) regions, and latitudinal sectors of the reef. The same transects are surveyed repeatedly over time so as to provide a stable reference over time

We apply a framework to our models that helps us generate 1,000 simulated outcomes for each year and group (i.e. hard coral, soft coral and algae). These outputs are then used to estimate annual average cover for each group and quantify uncertainty around all estimates.

Results are presented on our monitoring dashboard as average percentage cover values for each type of coral, algae etc., along with uncertainty ranges that indicate where the true value is most likely to lie.

Scientific / Technical description

We modelled benthic cover using Bayesian hierarchical generalised linear mixed models fitted via integrated nested Laplace approximation (INLA). Separate models were fitted for each major benthic group (hard coral, soft coral, algae/macroalgae) and spatial reporting scales (reef, NRM region, and latitudinal sector). Reef-level models associated with reefs in which multiple depths were monitored (predominantly inshore reefs), models were further fitted separately by depth.

All models included year (treated as a categorical effect) so as to provide estimates of temporal trends. Reef-level models also included a term for benthic sub-group (representing major taxa) to provide a greater insight into the temporal trends in these different taxa.

Models also included varying effects of reef, site nested within reef and transect nested within site to account for spatio-temporal dependency structures associated with repeated sampling. All effect parameters were assigned weakly informative (vague) priors.

Models were fitted using the INLA (Rue et al. (2009)), which provides fast and accurate approximations to posterior distributions for latent Gaussian models.

Data structure and likelihood

The number of photo-points (y) across all photos classified as benthic group b in the i^{th} year within the t^{th} transect nested within the s^{th} site and r^{th} reef was modelled against a binomial distribution (logit link).

$$
\begin{aligned}
y_{r,s,t,b,i} &\sim Binomial(n_{r,s,t,b,i}, \pi_{r,s,t,b,i}) \\
logit(\pi_{r,s,t,b,i}) &= \beta_0 + \beta_i^{(year)} + \beta_i^{(group)} + \beta_i^{(year \times group)} + \gamma_r + \gamma_{s(r)} + \gamma_{t(s,r)} \\
\beta_0 &\sim N(0,1.0 \times 10^{-6}) \\
\beta &\sim N(0,1.0 \times 10^{-6}) \\
\gamma_r &\sim N(0, \tau_{reef}^{-1}) \\
\gamma_{s(r)} &\sim N(0, \tau_{site}^{-1}) \\
\gamma_{t(s,r)} &\sim N(0, \tau_{transect}^{-1}) \\
\tau_{reef} &\sim \Gamma(1,1.0 \times 10^{-6}) \\
\tau_{site} &\sim \Gamma(1,1.0 \times 10^{-6}) \\
\tau_{transect} &\sim \Gamma(1,1.0 \times 10^{-6})
\end{aligned}
$$

Derived quantities

Annual estimates of proportional cover for each benthic (sub)-group were obtained by drawing 1,000 samples from the posterior distribution of the linear predictor and transforming to the response scale.

When models include benthic sub-groups (i.e. reef-level models), total benthic cover was calculated by summing predicted cover across benthic sub-groups at the posterior draw level. Year on year changes in cover were calculated by contrasting annual estimates at the posterior draw level.

All posteriors were also summarised via means / medians and highest posterior density (HPD) intervals.

Manta tow hard coral models

Non-technical description

We collect data using manta tow surveys around the perimeter of up to 150 reefs per year.

During manta tow surveys, observers are towed slowly behind a boat while assessing the amount of live hard coral along the reef crest and upper reef slope (see Manta Tow SOP for more details). After each two-minute tow, percentage live hard coral cover is recorded on a 11-point categorical scale of 0 (no coral) to 5+ (82.5% - 100% coral cover).

To estimate trends through time, we use statistical models that combine information from all surveys while accounting for differences among reefs, National Resource Management regions, three broad reporting regions and years. To explore trends in coral cover through time, separate statistical models are run for different reporting scales (individual reefs, latitudinal sectors, and three broad reporting regions of the Great Barrier Reef). These models also account for the fact that many of the reefs are repeatedly monitored over time.

We apply a framework to our models that helps us generate 1,000 simulated outcomes for hard coral cover each year. These model outputs are used to estimate annual average coral cover and the uncertainty associated with those estimates.

Results are presented on our monitoring dashboard as average percentage hard coral cover values, along with uncertainty ranges that indicate where the true value is most likely to lie.

Scientific / Technical description

We modelled live hard coral cover using Bayesian hierarchical generalized linear mixed models fitted via integrated nested Laplace approximation (INLA). Separate models were fitted for each of the spatial reporting scales (reef, NRM region, reporting regions and latitudinal sector).

All models included year (treated as a categorical effect) so as to provide estimates of temporal trends without constraining the nature of these trends. Models for scales above reef-level also included varying effects of reef so as to account for spatio-temporal dependency structures associated with repeated sampling. All effect parameters were assigned weakly informative (vague) priors.

Models were fitted using the INLA (Rue et al. (2009)), which provides fast and accurate approximations to posterior distributions for latent Gaussian models.

Data structure and likelihood

The proportion of live hard coral cover (y) in the i^{th} year within the t^{th} tow nested within the r^{th} reef was modelled against a beta distribution (logit link).

$$
\begin{aligned}
y_{r,t,i} &\sim Beta(a_{r,t,i}, b_{r,t,i}) \\
a_{r,t,i} &= \mu_{r,t,i}\theta \\
b_{r,t,i} &= (1-\mu_{r,t,i})\theta \\
log\left(\frac{\mu_{r,t,i}}{1-\mu_{r,t,i}}\right) &= \beta_0 + \beta_i^{(year)} + \gamma_r + \gamma_{t(r)} \\
\beta_0 &\sim N(0{,}1.0 \times 10^{-6}) \\
\beta_{year} &\sim N(0{,}1.0 \times 10^{-6}) \\
\gamma_r &\sim N(0, \tau_{reef}^{-1}) \\
\gamma_{t(r)} &\sim N(0, \tau_{tow}^{-1}) \\
\tau_{reef} &\sim \Gamma(1{,}1.0 \times 10^{-6}) \\
\tau_{tow} &\sim \Gamma(1{,}1.0 \times 10^{-6}) \\
log(\theta) &\sim N(0{,}1.0 \times 10^{-6})
\end{aligned}
$$

Derived quantities

Annual estimates of proportional cover were obtained by drawing 1,000 samples from the posterior distribution of the linear predictor and transforming to the response scale. Year on year changes in cover were calculated by contrasting annual estimates at the posterior draw level. All posteriors were also summarised via means / medians and highest posterior density (HPD) intervals.