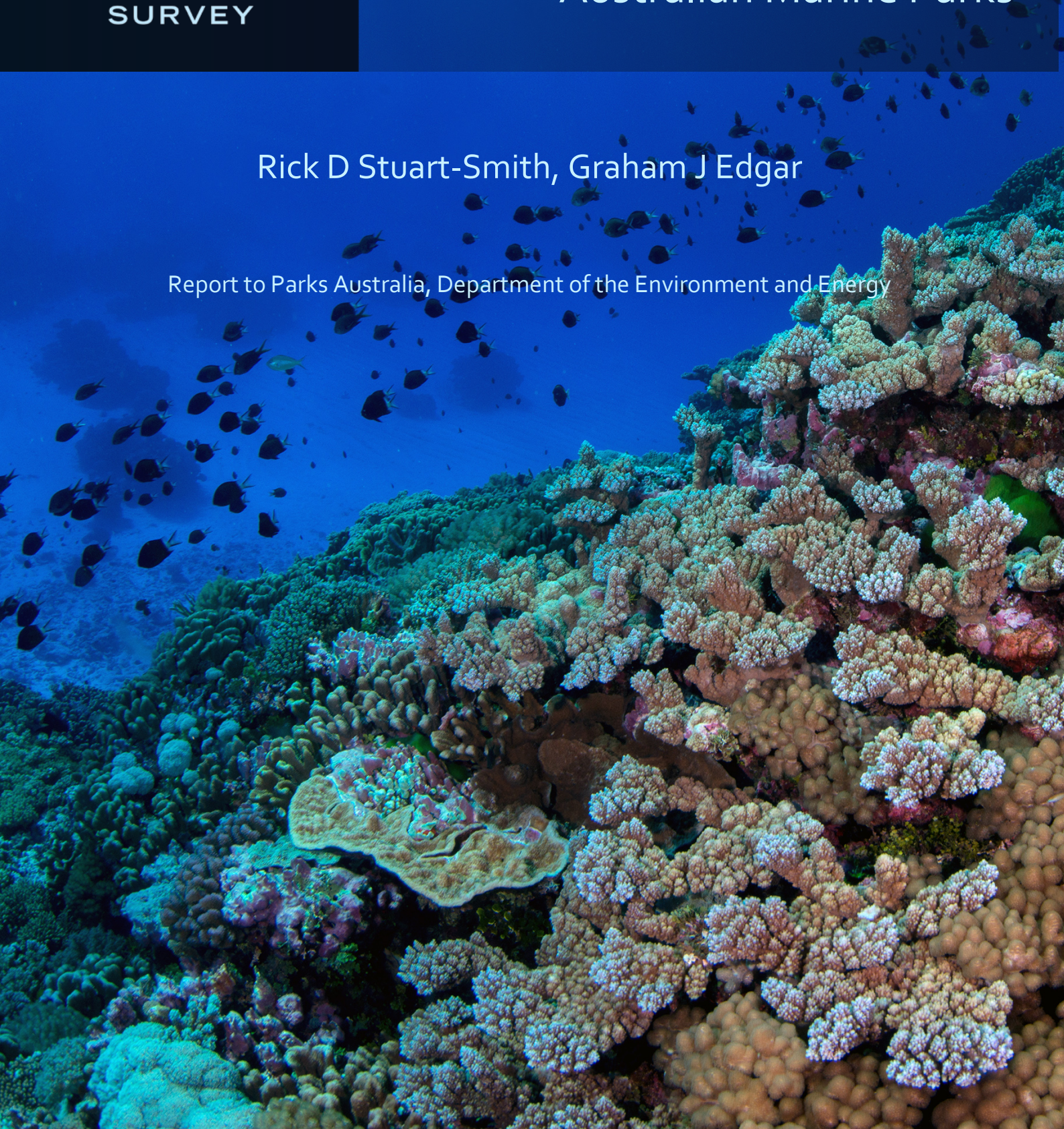# Reef Life Survey monitoring of shallow reef habitats in Australian Marine Parks

Rick D Stuart-Smith, Graham J Edgar

Photos

Rick Stuart-Smith

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Executive summary and recommendations

Parks Australia is mandated to manage Australian Marine Parks to ensure a balance is achieved between protection of the marine environment and opportunities for sustainable use. This includes evaluating options for cost-effective monitoring of the range of habitats and pressures within the marine park network. A number of recommendations are provided below to assist with this.

This report discusses ecological monitoring options for shallow reefs by the Reef Life Survey program, while other habitats are considered out of scope. It considers other available information and research for shallow reef habitats, but there is emphasis on the mechanisms by which Reef Life Survey can contribute to the management process for Australian Marine Parks.

Recommendations are:

1. **Apply standard Reef Life Survey methods for monitoring all shallow reef habitat in Australian Marine Parks (AMPs), where present, to enable comparisons between reserves across the Commonwealth estate**. These surveys provide baseline data and ongoing temporal trends for conspicuous and cryptic fishes, foraging sea snakes and turtles, mobile invertebrates, and habitat cover such as corals and seaweeds. Due to the detail and range of biodiversity covered, using Reef Life Survey methodology allows for maximum flexibility in the ability to analyse trends for a wide range of ecological indicators.

2. **Undertake resurveys of at least eight sites within each AMP and nearby reference sites at least every three years (or more frequent where feasible).** Some AMPs (e.g. Pimpernel Rock) do not have sufficient shallow reef to enable surveys of eight sites, while others may require more sites to be monitored. The number of sites should therefore be determined individually for each reserve, with a preliminary guide provided in Table 1.

3. **Instigate additional surveys following any major impact on biodiversity within an AMP** (e.g. cyclone, coral bleaching, invasive species outbreak, oil spill or ocean heatwave) if monitoring is not scheduled for that AMP at that time.

4. **Undertake detailed analysis and reporting of monitoring data for each AMP at least every 8 to 10 years.** This is towards the end of the major management cycle (10-yr review of management plan) and is also the timeframe by which many natural trends and substantial or unusual changes may become apparent.

1 Introduction and background

The declaration and rollout of an expanded Australian Marine Park (AMP) network covering a large proportion of the Australian EEZ comes with substantial challenges for appropriately managing this estate. There are particular challenges related to monitoring of ecological values. Indeed, very little is known of existing biodiversity values protected within the AMP networks, with little in the way of baseline information with which to evaluate the effectiveness of the management plans that are about to be implemented. Baseline ecological information is critical for determining whether the placement of zones within AMP boundaries is appropriate given the distribution of values such as threatened species or important habitats, and activities that may affect these.

Baseline information is also critical for informing expectations for AMP performance into the future. Once suitable ecological information is available, a subsequent challenge becomes measuring performance, whether this is in terms of the level of recovery of exploited populations and important ecological functions, or stability and protection of existing values in the face of widespread environmental degradation outside of AMP boundaries. Specifically, there is a need to identify whether management plans put in place with respect to activities allowed (zoning types) and zoning placement are providing best outcomes for biodiversity, or whether changes to zoning plans or additional management actions are required. Ecological monitoring is central to such assessments, ideally undertaken in a standardised way that allows direct comparisons to the baseline and between monitoring periods.

The remoteness and difficulty in accessing many of the AMPs adds to the challenges of undertaking ecological monitoring, as does variable water depth, the diversity of habitats and sheer vastness of the area under management. Monitoring all AMPs, habitats and species is impossible, and Parks Australia is thus challenged in determining where to prioritise ecological monitoring. This report focusses on shallow reef habitats, which only represent a small proportion of habitat, by area, across the AMP networks, but contain a large proportion of the biodiversity represented within AMPs. Shallow reefs are also typically the habitat within AMP and offshore regions to which the public best relate, and value.

The Reef Life Survey (RLS) program has provided a cost-effective means to greatly extend the capacity and data available for monitoring marine protected areas (MPAs) in state waters around Australia. There is also already an extensive coverage of remote and offshore reefs around Australia and the world, with >10,300 surveys of biodiversity undertaken on rocky and coral reefs in 50 countries, all using a standardised set of methods that covers fishes, mobile invertebrates and the cover of seaweeds and corals. RLS data have already provided a baseline for the majority of shallow reef systems in AMPs around the country, as recorded in individual reports. For numerous reef systems in AMPs, the RLS data are the only data to have been collected on reef biodiversity. These data have not only provided a baseline that is directly comparable across AMP networks and individual reefs within, but also across the world, allowing important context to be derived from surveys elsewhere (Edgar et al. 2015).

In addition to providing comparable baseline data across AMPs, results from RLS surveys have also provided clear management directions for improving ecological effectiveness of MPAs in general (Edgar et al. 2014) and a growing number of insights into issues of importance for management and public education (including contributing to the 2016 State of the Environment report; Stuart-Smith et al. 2017).

The primary aim of this report is to outline the details of how RLS could contribute to an ongoing monitoring regime for shallow reefs in AMPs, and the associated considerations. Such details include which AMPs could be feasibly monitored by RLS divers, and the nature and frequency of data that can be provided for these during the 10-year management cycles of Parks Australia.

2 Reef Life Survey monitoring methods

RLS methods for surveying fishes, mobile invertebrates and cryptic fishes, and corals and seaweeds are described elsewhere, with an online methods manual providing full details (http://reeflifesurvey.com/reef-life-survey/about-rls/methods/). Methods for surveying fishes and invertebrates have been developed and applied over 25 years, and the benefits and disadvantages studied and reported in a number of publications (Edgar et al. 2004a, Edgar et al. 2004b). Likewise, the training methods of RLS and data quality by RLS volunteer divers has also been assessed (Edgar and Stuart-Smith 2009a, Edgar and Stuart-Smith 2009b), with data from RLS volunteers found to be indistinguishable from professional scientists.

Corals and seaweeds are surveyed using photoquadrats – digital images of the substrate taken by RLS divers at 2.5 m intervals along each 50 m transect line. An important element of the photoquadrat method is that the images can be processed using any combination of taxonomic resolution and number of points transposed on images, depending on needs of the study. For MPA monitoring, the standard protocol applied by RLS has been to score 100 points per transect (5 points per image) for a set of pre-defined categories that distinguish functional and structural groups of sessile biota. These categories are aligned with the CATAMI classification system (Althaus et al. 2015), which allows standardisation across underwater imagery collected from deeper surveys using AUV, for example. Greater taxonomic resolution and specific analysis for sessile invasive species (e.g. *Caulerpa racemosa*) could be undertaken by re-analysis of archived images, if ever desired.

3 Monitoring schedule

Monitoring of each AMP would ideally be undertaken annually, as this would allow random or unusual events and anomalous years (i.e. spikes and dips in indicator values), in terms of fauna present, to be distinguished from long-term trends of greatest interest to management. In other words, annual surveys would provide the best chance of separating the natural variability in biodiversity values typical for each AMP (which will likely differ between AMPs) from ecological change resulting from management actions. In addition, the more frequent surveys are scheduled, the less of an impact adverse weather conditions (and subsequent failure to re-survey all sites) would have on data available for trend analysis.

Nevertheless, given high costs of monitoring an offshore estate and generally low year-to-year variability, annual monitoring is difficult to justify as the most cost-effective option. Moreover, Reef Life Survey Foundation could not commit to annual monitoring given the high number of AMPs Australia-wide, the limited number of skilled divers available for surveys each year on a volunteer basis, logistical considerations such as availability of boats, and time commitments for other RLS activities. Thus, while RLS provides much greater capacity than any other single institution in terms of divers trained in species-level underwater surveys, additional institutional assistance would be required to provide the personnel to achieve annual surveys, which would come at far greater cost. Thus, a balance is needed between the costs and personnel capacity to undertake monitoring, and the benefits gained from more frequent surveys. Consequently, a 3-yearly monitoring schedule is recommended, with additional surveys following any potentially catastrophic events such as extreme bleaching or oil spills.

A recommended monitoring schedule is outlined in Table 1 that includes all areas of shallow reef considered feasible for RLS monitoring to be undertaken, with an indication of costs associated with different vessel options.

Table 1 Proposed monitoring schedule for AMPs using Reef Life Survey. Estimated approximate costs for option 1 are based on use of a private sailing vessel for maximum cost-effectiveness (including days required for delivery voyage to region), and for option 2 for using a commercial charter vessel. All estimated costs include field and logistics, data compilation and upload for public availability, and basic summary boxes for indicator trends, but exclude major reporting. Number of sites includes reference sites outside AMPs, and is indicative based on previous surveys and may vary depending on conditions at the time of survey.

Network	AMP	Frequency (yr)	Last Surveyed	Preferred season	Estimated cost (option 1) ($,000)	No. sites (approx.)	Estimated cost (option 2) ($,000)	No. sites (approx.) 2
Coral Sea	Coral Sea Reserve	3	Nov 16-Mar 17	Summer	90	140 (90 days)	330[1]	120 (40 days)
North-West	Ashmore, Cartier, Mermaid	3	Sept/Oct 2013	Late spring/early summer	95	100 (100 days)	210[2]	80 (30 days)
							-	
North	Oceanic Shoals, Arafura, Arnhem, Wessel, GoC, W Cape York	3	Nov-15	Late spring/early summer	85	40 (90 days)	230[3]	30 (25 days)
Temperate East	Lord Howe – Elizabeth & Middleton	3	Jan-13	Summer			78[4]	24 (12 days)
	Lord Howe – South of Balls Pyramid	2-Apr	Feb-12	Summer			3	2 (1 day added to regular biennial LHI trip)
	Norfolk Island	3	Feb-09	Summer			32	18 (10 days)
	Pimpernel Rock	3	Apr-16	Autumn			12	1
	Cod Grounds	3	Apr-16				25	10
South-West	Geographe	2	Apr-09				15	4

[1] Vessel costs estimated at $7500/d

[2] Vessel costs estimated at $6000/d

[3] Vessel costs estimated at $8000/d

[4] Vessel costs estimated at $6500/d

A consequence of a 3-year cycle as proposed is that longer time series will be needed to increase confidence that changes observed are of management significance, although contextual data from other RLS monitoring may provide additional insight into whether particular years could be considered anomalous over regional scales. Regardless, in the 10-year management cycles of Parks Australia, three data points from 3-yearly monitoring provides an important improvement over two points from 4-yearly or 5-yearly monitoring. The latter scenario would only allow comparison of two snapshots when management plans are to be reviewed, for which conclusions must be tempered by considerations of underlying

variability (Stuart-Smith et al. 2010). Thus, while two snapshots provides important information, data from three monitoring campaigns adds greater value for data interpretation than would be proportional to the difference in cost. Annual monitoring over the 10-yearly management cycle would allow natural fluctuations in biodiversity to be examined and longer-term trends to be identified that are directly related to management, or indirect effects of shifting ecological processes altered by management (Bates et al. 2014).

With any monitoring schedule less frequent than annual, it is important to mobilise additional surveys following any disasters or unusual events. Oil spills, extreme coral bleaching, cyclones, turbidity plumes, marine heatwaves and invasive species outbreaks may all impact ecological communities substantially, and affect biodiversity values protected within AMPs. Being able to identify degradation arising from such processes is important for distinguishing management-related change, as well as determining whether management intervention may be required. A key benefit of the RLS survey protocol is that it covers all major macroscopic components of ecosystems (reptiles, fishes, mobile invertebrates, corals and other sessile invertebrates, macroalgae and seagrasses), so will identify indirect as well as direct ecological consequences of impacts.

More specific timing considerations relate to individual AMPs. For example, Cod Grounds, Norfolk Island and Geographe Bay could potentially be re-surveyed the following year if poor weather interferes with scheduled monitoring. Although regular monitoring is ideal, little is lost with uneven spacing of monitoring events over a 10-year management cycle. Completing three monitoring campaigns at uneven intervals spanning 10 years is, for example, more important than evenly spacing surveys every four years.

4 Indicators for tracking biodiversity change in AMPs

RLS data are rich in detail and can allow computation of the majority of commonly used measures of biodiversity and ecological condition for reef habitats, as occurred for the 2016 Commonwealth State of the Environment Reporting (Stuart-Smith et al. 2017). The indicators provided in this report (Table 2) represent an initial recommended suite of metrics for use in evaluation of biodiversity changes in the AMP network. These metrics relate to particular pressures, including some that Parks Australia may not be able to respond to through alterations of management plans or changed rules inside reserve boundaries.

It is important to note that these indicators are calculated on the basis of detailed data that are collected in a standardised fashion through time and space, and should be applied through the life of Parks Australia's management cycles. Should future research identify additional or alternative monitoring indicators, the data collected through RLS are likely to provide the flexibility to calculate such new indicators, or explore equivalent features of reef biodiversity if not. In covering the major trophic groups, RLS data provide arguably the greatest flexibility and detail among the many available methods for assessing ecological condition over such a broad scale.

Important considerations for interpreting trends in indicator values include:

- 3-yearly monitoring frequency should provide general direction of trend if a general trend is evident, but two management cycles (20 years) may be needed to detect more serious changes in ecological condition, particularly when this arises through indirect effects of management (e.g. recovery of sea urchin predators decreases urchin density and results in changes in seaweed cover, in the temperate AMPs).

- Expectations for indicator changes are relative to reference conditions, which can be evaluated on the basis of baseline data, nearby external sites with similar conditions, plus statistical modelling techniques.

- Because many AMPs are isolated and some currently experience relatively low fishing pressure, change inside IUCN II zones may be slow or undetectable. Stability inside AMPs during periods of decline outside may represent management success. Likewise, negative change that can be attributable to fishing pressure suggests management intervention is required.

Table 2 Indicators of MPA ecological performance

Relates primarily to	Indicator	Potential management response to decline
Exploitation	Total fish biomass (B)	Investigate other potential causes through targeted analyses, then:
		• Raise zoning restrictions (to IUCN II)
	Biomass of fishes 20 cm+ (B20)	• Expand area under IUCN II
	Size spectrum slope (or gamma shape) (SS)	• Investigate compliance
	Richness of fishes >20 cm (R20)	• Community education
	Shark density (Sharks)	Investigate illegal fishing activities in area
	Sea cucumber density	Investigate reported fishery activity and compliance
Ocean warming/heat waves	Community temperature index for fishes (CTI)	No immediate management response possible. Should trigger further research and effort devoted to using change as opportunity to raise public knowledge of warming impacts
	Coral cover (% live corals)	Likely as above, although reducing other pressures, and thus overall cumulative impacts, through changing zoning to IUCN II recommended.
		Installing moorings and/or channel markers also if coral loss can be attributable to anchoring/boat damage.
	Coral mortality (% recently dead corals)	As above.
	Coral bleaching (% bleached corals)	As above.
Pests/outbreaks	Crown of thorns density (CoTS)	Investigate potential removals/density reductions, water quality improvement
	Density of all coral-eating snails (DRUP)	Investigate potential removals/density reductions
		Investigate predator densities and increase zoning restrictiveness if required (to IUCN II)
Values		
Threatened and protected species	Sea snake density & richness (Snakes, SnakeR)	Instigate further research on causes, and whether potential management responses are possible by Parks Australia (or through another agency).
	Turtles	Instigate further research on causes, and whether potential management responses are possible by Parks Australia (or through another agency).
	Other threatened and protected species (e.g. groupers)	Instigate further research on causes, and whether potential management responses are possible by Parks Australia (or through another agency).
Species richness	Fishes	Investigate potential causes, including signs of association with positive changes/recovery of food web
	Mobile invertebrates	Investigate potential causes, including signs of association with positive changes/recovery of food web

*Pollution and invasive species are not covered by indicators at this time, as these are not expected to be serious risks for AMPs generally. Additional research should be instigated in the event of an oil spill/incursion.

5 Power to detect trends

Traditional power analyses rely on *a priori* decisions regarding ecologically meaningful effect sizes. For the application of surveys like those undertaken by RLS, the most important question about power relates to whether there are enough sites covered to capture a representative picture of reef biodiversity status (or indicator values) at the time of monitoring – and thus allow detection of trends through time. Too few sites and differences between monitoring occasions could be related to variation between sites, or 'noise'. Using the biomass of fishes 20 cm+ as an example indicator for exploring this 'signal to noise ratio', the log response ratio in B20 was calculated between two consecutive monitoring occasions (2 years apart for Lord Howe Island and 3 years apart for Ningaloo and Rottnest Island). The standard deviation in values when this was taken as the mean across random subsets of 2 sites, 3 sites, etc, up to the actual number of sites surveyed at that location, was used as a measure of variation about the mean change in B20 through time identified from surveys (Fig 1).

A rapid reduction in 'noise' was found with the addition of sites up to around 8-10, regardless of whether a temperate (Rottnest Island), tropical (Ningaloo) or subtropical (Lord Howe Island) location, and with diminishing gains in clarity of the temporal signal through adding further sites. In other words, a change in the mean value of B20 obtained from 8-10 sites in a given location (e.g. AMP) is much closer to the 'true' change in B20 at that location, with incrementally smaller gains from the addition of further sites - up to the point where B20 values based on 40 sites provide a very clear picture of any change to the status of large fish biomass at that location between monitoring periods.

Previous analyses have found that values of CTI vary less than B20 between sites and times (Stuart-Smith et al. 2017), and fewer sites are thus likely to be needed to detect real change in this indicator. Little information is currently available to assess changes in other indicators, but B20 is likely to be one of the more variable indicators, and so this test likely provides a conservative basis for determining the number of sites needed to detect change in other indicators.

Large AMPs like the Coral Sea will require splitting into multiple regions, ensuring each has sufficient number of sites monitored during each survey period. On the other hand, recognising the potential for variability to obscure trends will be important for assessing changes in AMPs where fewer than 8 sites can be monitored (e.g. due to small size or little shallow reef habitat).
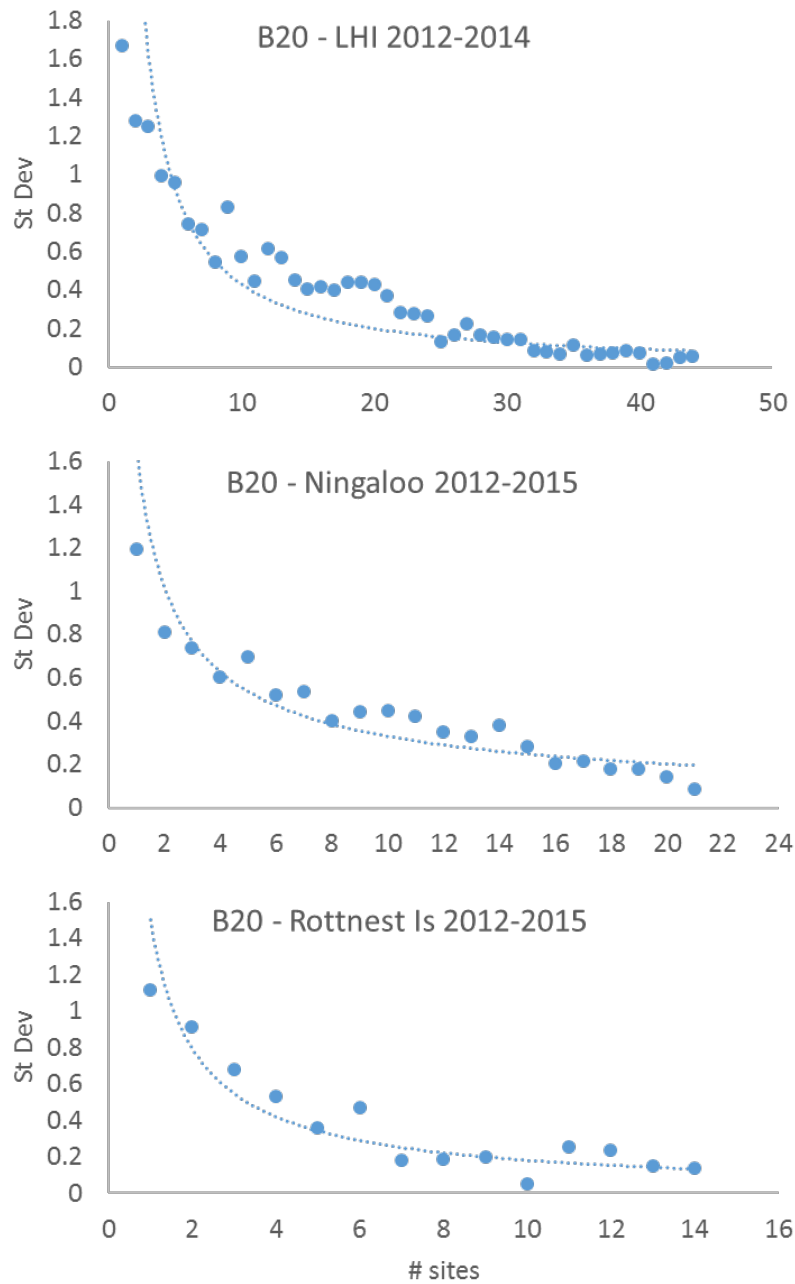
Figure 1 Standard deviation in observed change through time in the B20 indicator (measured as the difference in the natural log of B20 from time 1 to time 2) based on random subsets of sites at a given monitoring location. LHI = Lord Howe Island, NSW. Note scales differ between plots.

6 Reporting schedule and content

Full detailed analysis and reporting may not be necessary for every AMP following each monitoring campaign. Multiple levels of reporting are available, and a mixture of these is likely preferable and most cost-effective. These levels include (from most informal to most detailed):

1. Immediate informal contact (e.g. email or phone) with AMP manager on any current or unfolding disasters,
2. Face to face update to Parks Australia staff through presentation of images and key observations from the monitoring period,
3. Calculation of indicator values and presentation of these in an AMP report card/managers dashboard. This would include one or two paragraphs of text to highlight/explain key findings,
4. Detailed statistical analysis and report.

Further discussion with Parks Australia staff assist in determining the best combination and periodicity for these options, but at least (1), (2) and (3) would be necessary following every monitoring campaign. Detailed reporting (4) is recommended following unusual events such as extreme heating or the emergence of particularly important findings, and at least once in every 10-yearly management cycle, at a time identified by Parks Australia as best feeds into the management plan review process. More frequent reporting may also be desirable. Costs associated with RLS providing (1), (2) and (3) are included in estimates in Table 1, but costs for (4) would be additional.

7 Recommendations

In order to optimise outcomes of management intervention across the Commonwealth Marine Reserve estate, we recommend:

- Standard RLS monitoring methods to be applied in all AMPs where shallow reef habitat is present. These surveys should cover fishes, reptiles, mobile invertebrates, seaweed and corals, to enable comparisons between reserves across the Commonwealth estate and with baseline data, while also maximising flexibility in the range of potential indicators calculated and reported.

- A set of at least eight sites to be resurveyed within each AMP plus nearby reference sites every three years (or more frequent where feasible). Some AMPs (e.g. Pimpernel Rock) will not have sufficient shallow reef to enable surveys of eight sites, while others may require more sites to be monitored. The number of sites should therefore be determined individually for each reserve, with a preliminary guide provided (Table 1).

- Additional surveys to be instigated following any major impact on biodiversity within an AMP (e.g. cyclone, coral bleaching, invasive species outbreak, oil spill or ocean heatwave) if monitoring is not scheduled for that AMP at that time.

- Detailed analysis and reporting of monitoring data for each AMP to be undertaken at least towards the end of every major management cycle (10-yr review of management plan) and after surveys when substantial change is apparent.

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