Are we missing the boat? Current uses of long-term biological monitoring data in the evaluation and management of marine protected areas

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ABSTRACT
Protected area management agencies are increasingly using management effectiveness evaluation (MEE) to better understand, learn from and improve conservation efforts around the globe. Outcome assessment is the final stage of MEE, where conservation outcomes are measured to determine whether management objectives are being achieved. When quantitative monitoring data are available, best-practice examples of outcome assessments demonstrate that data should be assessed against quantitative condition categories. Such assessments enable more transparent and repeatable integration of monitoring data into MEE, which can promote evidence-based management and improve public accountability and reporting. We interviewed key informants from marine protected area (MPA) management agencies to investigate how scientific data sources, especially long-term biological monitoring data, are currently informing conservation management. Our study revealed that even when long-term monitoring results are available, management agencies are not using them for quantitative condition assessment in MEE. Instead, many agencies conduct qualitative condition assessments, where monitoring results are interpreted using expert judgment only. Whilst we found substantial evidence for the use of long-term monitoring data in the evidence-based management of MPAs, MEE is rarely the sole mechanism that facilitates the knowledge transfer of scientific evidence to management action. This suggests that the first goal of MEE (to enable environmental accountability and reporting) is being achieved, but the second and arguably more important goal of facilitating evidence-based management is not. Given that many MEE approaches are in their infancy, recommendations are made to assist management agencies realize the full potential of long-term quantitative monitoring data for protected area evaluation and evidence-based management.

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1. Introduction
Management effectiveness evaluation (MEE) has gained global recognition as an important framework to promote the continual improvement of conservation efforts in protected areas (Coad et al., 2013; Leverington et al., 2010). MEE involves an assessment of the complete management process: beginning with clearly defining the management context, through to measuring conservation outcomes to determine whether management objectives are being achieved (Fig. 1; Hockings et al., 2006). In response to the growing societal demand for environmental accountability, there is a focus on publicly reporting MEE results to demonstrate the value for money of conservation efforts (Ferraro and Pattanayak, 2006). But ultimately MEE is designed to facilitate evidence-based management to ensure the best conservation outcomes for protected areas (Hockings et al., 2006; Leverington et al., 2010).

MEE should draw on the best available evidence, using both qualitative and quantitative data to support assessments (Cook and Hockings, 2011; Hockings et al., 2009). Whilst qualitative data are most appropriate for some aspects of management (e.g., measuring stakeholder engagement), other aspects (e.g., measuring ecological condition) should ideally be based on quantitative data sourced from monitoring or research (Hockings et al., 2009). However, a lack of quantitative data often necessitates reliance on qualitative information, such as expert judgment, in MEE (Cook et al., 2010; Hockings et al., 2009).

Outcome assessment is the final stage of MEE, where the condition of important attributes is assessed to determine whether management objectives have been achieved or if management
should be adapted (Fig. 1; Hockings et al., 2006). This requires an assessment of the condition of indicators, such as the abundance of a threatened species. When monitoring data are available, these should be assessed against condition categories that have been defined numerically (Hockings et al., 2006; hereafter “quantitative condition assessments”). Quantitative condition categories are commonly based on an acceptable range of natural variation of an indicator (e.g., Hockings et al., 2008; Parks Canada, 2011; Parrish et al., 2003). For example, the United States National Parks Service uses historic long-term monitoring data to define quantitative condition categories for average forest patch size to reflect landscape fragmentation due to anthropogenic stressors, as: Good (>50 ha); Caution (10–50 ha); and, Significant Concern (<10 ha) (Tierney et al., 2009). Qualitative condition assessments can enable more transparent and repeatable integration of monitoring data into MEE, and when condition categories represent thresholds that trigger management action promotes evidence-based management (Lindenmayer et al., 2013). In addition, condition rating scales can help simplify complex information about natural systems for public reporting (Hockings et al., 2006).

In cases where monitoring data are lacking, managers default to using expert judgment to assess condition using qualitative statements of outcomes (hereafter “qualitative condition assessments”; Cook et al., 2010; Hockings et al., 2009). Qualitative assessments typically use a simple rating scale, but instead of having a numerical basis condition categories are defined using broad statements such as “Good—Populations of a number of significant species...have declined significantly...” (State of the Environment Committee, 2011). These qualitative condition categories can be subject to differences in interpretation by experts, thus can seriously compromise the accuracy and repeatability of condition assessments (Burgman et al., 2011; Cook et al., 2014).

Long-term quantitative monitoring can yield data that are ideal for quantitative condition assessments of environmental indicators in MEE (Hockings et al., 2006; Tierney et al., 2009). Such data can reveal both the current condition and the temporal dynamics of indicators (Magurran et al., 2010; Sergeant et al., 2012). These two vital aspects assist managers in interpreting environmental condition, to determine when a system is moving beyond the desirable bounds of natural variability, and decide when to adapt their management approach (Nichols and Williams, 2006). Whilst rigorous long-term monitoring programs potentially enhance protected area management, monitoring data can be of limited use when programs are not targeted to address management needs (Field et al., 2007; Lindenmayer and Likens, 2010; Nichols and Williams, 2006). Commonly cited reasons for the lack of targeted monitoring include that monitoring programs are led by scientist who are independent of management agencies (Legg and Nagy, 2006; Lindenmayer et al., 2012), and management and monitoring objectives are often not adequately aligned (Kemp et al., 2012; Lindenmayer and Likens, 2010). The cost and expertise required to establish and maintain long-term monitoring programs can be major impediments for management agencies (Lindenmayer and Likens, 2010; Lindenmayer et al., 2012). The reality is that well designed long-term monitoring programs are a rare but valuable resource for MEE and evidence-based management.

Evidence-based management involves the use of the best available evidence to inform a management decision and can take a variety of forms. The most highly structured approach to evidence-based management is adaptive management, which involves an extensive decision-making process to develop, trial and select among multiple potentially effective management options (Nichols and Williams, 2006; Westgate et al., 2013). The MEE process also facilitates evidence-based management, and in contrast to adaptive management, is being increasingly used by protected area management agencies to ensure the best available evidence informs management decisions (Coad et al., 2013; Hockings et al., 2004; Leverington et al., 2010). However, the implementation of MEE is still evolving, with managers citing difficulties associated with data availability and “closing the loop” to ensure evidence-based management (Jacobson et al., 2008, 2014; Parr et al., 2009). Given the existing challenges in implementing MEE, we focus on investigating cases where best-practice MEE could be achieved: where long-term quantitative monitoring data are available to inform evaluations. We specifically focus how these data are being used to inform: i) outcome assessments for MEE of protected areas; and, ii) evidence-based management.

2. Methodology

To understand the current use of long-term biological monitoring data in protected area management we interviewed protected area managers and scientists in Australia with access to long-term monitoring programs. We targeted monitoring programs within similar ecosystems that occur in protected areas under similar management contexts. We focussed on long-term monitoring programs from Australian marine protected areas (MPAs), as they are some of the world’s longest running monitoring programs, significantly contributing to the scientific understanding of the long-term effects of MPA protection (e.g., Babcock et al., 2010; Barrett et al., 2009; De’ath et al., 2012). Australia’s MPAs are established for biodiversity conservation and many were gazetted more than ten years ago (State of the Environment Committee, 2011). These MPAs fall under either state or federal jurisdiction and all management agencies aspire to regularly monitor, evaluate and report on management effectiveness of MPAs (ANZECC, 1999). Like other parts of the world, long-term monitoring programs in Australian MPAs predominantly assess the effect of protection on subtidal coral and rocky reef communities (Babcock et al., 2010; Kemp et al., 2012; Lester et al., 2009).

2.1. The long-term monitoring programs

To identify long-term monitoring programs capable of informing MEE, we used the following criteria: i) monitoring is conducted

Fig. 1. The management effectiveness evaluation cycle, designed to enable assessment of the complete management process and facilitate evidence-based management. Adapted from Hockings et al. (2006).
in Australian MPAs that include no-take management zones, where all extractive activities are banned (IUCN-WCPA, 2008); ii) monitoring is ongoing (as of 2013) and involves field-based, empirical measurements with at least five sampling occasions over the preceding ten year period; iii) monitoring programs include the census of fish, invertebrates and/or algae from subtidal coral and rocky reef habitats; and, iv) monitoring results are publicly accessible through scientific publications (e.g., published reports or peer-reviewed papers), or are available upon request from data custodians.

We used the web-based resources Google, Google Scholar, and Thomson Reuters Web of Science to identify Australian monitoring programs that met our selection criteria. We used a series of 12 search terms in the following combinations: (long-term OR monitoring OR survey OR surveillance) AND (biodiversity OR rocky OR coral OR reef) AND (marine protected area OR MPA OR marine reserve OR marine park). We searched peer-reviewed literature, government agency websites and reports, and environmental legislation. Bibliographies of literature included in the review were also searched for additional literature.

Seven long-term monitoring programs met our selection criteria (Table 1). These monitoring programs occur within five networks of MPAs in Australian state and Commonwealth waters (see MPA network, Table 1). These MPAs are some of the oldest in Australia having been established for an average of 20.3 years (ranging from 11 to 39 years) and have some of longest running monitoring programs, undertaken for an average of 18.7 years (ranging from 12 to 27 years; Table 1). All monitoring programs sample both inside and outside of no-take zones, and either occur in a single MPA or are replicated in several MPAs across a network (Table 1). All monitoring programs include the visual census of biological variables within shallow rocky reef or coral reef habitats. Five of the seven programs were established by organizations independent of the responsible management agency (Table 1).

### Table 1

<table>
<thead>
<tr>
<th>Marine protected area details</th>
<th>Monitoring program details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Network name</strong></td>
<td><strong>MPA name</strong></td>
</tr>
<tr>
<td>Great Barrier Reef Marine Park, Queensland</td>
<td>Great Barrier Reef MP</td>
</tr>
<tr>
<td>New South Wales Marine Parks</td>
<td>Jervis Bay MP</td>
</tr>
<tr>
<td>New South Wales Marine Parks</td>
<td>Solitary Islands MP</td>
</tr>
<tr>
<td>Victoria's Marine National Parks</td>
<td>Victoria's network of MNPs[^c]</td>
</tr>
<tr>
<td>Tasmania's Marine Reserves</td>
<td>Tasmania's network of MRs[^c]</td>
</tr>
<tr>
<td>Western Australia's Marine Parks</td>
<td>Jurien Bay MP</td>
</tr>
<tr>
<td>Western Australia's Marine Parks</td>
<td>Ningaloo Reef MP</td>
</tr>
</tbody>
</table>

[^a]: For a full list of the literature used to support the summarized information presented Table 1, see SI Appendix 1.
[^b]: Monitoring occurs in six of Victoria's MNPs: Bunurong, Cape Howe, Point Addis, Port Phillip Heads, and Wilsons Promontory Marine National Parks.
[^c]: Monitoring occurs at Maria Island, Governor Island, Tinderbox and Ninepin Point Marine Reserves.
[^d]: Organizations that conduct monitoring are independent of the responsible management agency.
for Tasmanian Parks and Wildlife Service, where no in-house scientists are employed).

2.3. Semi-structured interviews

One author (P.F.E.A.) conducted semi-structured telephone interviews with all key informants. During the interviews, informants were asked six open-ended questions (see SI Appendix 2 for the full interview protocol) which addressed our two research themes: the current use of long-term monitoring data in i) MEE and ii) evidence-based management. The semi-structured interview format allowed informants to respond to each question in their own words. Each question was followed with standard prompts if informants misunderstood the question or failed to provide some of the information requested (see SI Appendix 2). Informants were advised not to answer any questions they felt unqualified to answer. In these cases, informants were asked which individuals in the agency could answer the question (i.e., snowball sampling; see 2.2 Key informants), ensuring we captured a comprehensive picture of each monitoring program and management agency.

For the first research theme, we asked key informants to identify the MEE that their agency undertakes, with MEE being defined as the process whereby “your management agency evaluates progress towards achieving conservation objectives, such as ‘to maintain biodiversity’”. Informants were also asked to describe how the monitoring programs have been used to inform the most recent MEEs conducted by the agency, which in some cases related to an assessment of biodiversity indicators; strategic direction – contribute to MPA management strategies/policies/plans; and, direct management – compliance/enforcement patrols, infrastructure maintenance or education within MPAs.

Table 2
Summary of key informants interviewed, the management agencies and marine protected areas they represent, and their tasks performed.

<table>
<thead>
<tr>
<th>Monitoring program</th>
<th>MPA network</th>
<th>Management agency</th>
<th>MPAs represented by key informants</th>
<th>Key informants interviewed</th>
<th>Tasks performed by key informants (defined below)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Great Barrier Reef Marine Park, Queensland</td>
<td>Great Barrier Reef Marine Park Authority</td>
<td>Great Barrier Reef MP</td>
<td>3 Scientists 1 Manager</td>
<td>Research, MEE and strategic direction</td>
</tr>
<tr>
<td>2</td>
<td>New South Wales Marine Parks</td>
<td>NSW Department of Primary Industries (formerly NSW Marine Parks Authority)</td>
<td>Jervis Bay MP</td>
<td>1 Scientist 1 Manager</td>
<td>Research, MEE and strategic direction</td>
</tr>
<tr>
<td>3</td>
<td>New South Wales Marine Parks</td>
<td>NSW Department of Primary Industries</td>
<td>Solitary Islands MP</td>
<td>1 Scientist 1 Manager</td>
<td>Research, MEE and strategic direction</td>
</tr>
<tr>
<td>4</td>
<td>Victoria’s Marine National Parks</td>
<td>Parks Victoria</td>
<td>Cape Howe, Point Addis, Point Hicks, Port Phillip Heads, and Wilsons Promontory MNP</td>
<td>1 Scientist 5 Managers</td>
<td>Research, MEE and strategic direction</td>
</tr>
<tr>
<td>5</td>
<td>Tasmania’s Marine Reserves</td>
<td>Tasmania Parks and Wildlife Service</td>
<td>Maria Island MR</td>
<td>2 Managers</td>
<td>Direct management and strategic direction</td>
</tr>
<tr>
<td>6</td>
<td>Western Australia’s Marine Parks</td>
<td>Department of Parks and Wildlife (formerly Department of Environment and Conservation)</td>
<td>Jurien Bay MP</td>
<td>3 Scientists 1 Manager</td>
<td>Research, MEE and strategic direction</td>
</tr>
<tr>
<td>7</td>
<td>Western Australia’s Marine Parks</td>
<td>Department of Parks and Wildlife</td>
<td>Ningaloo Reef MP</td>
<td>3 Scientists 1 Manager</td>
<td>Research, MEE and strategic direction</td>
</tr>
</tbody>
</table>

a Definition of tasks: research – responsible for managing or conducting scientific research, and interpreting monitoring program results; MEE – responsible for conducting outcome assessments for biodiversity indicators; strategic direction – contribute to MPA management strategies/policies/plans; and, direct management – compliance/enforcement patrols, infrastructure maintenance or education within MPAs.

b The Great Barrier Reef MP is co-managed by the Great Barrier Reef Marine Park Authority (GBRMPA) and Queensland Parks and Wildlife Services (QPWS). The GBRMPA is the agency responsible for the MEE of the Great Barrier Reef MP, and also contributes to field management along with QPWS (GBRMPA, 2009). Key informants were selected only from the GBRMPA, as they hold direct knowledge of the monitoring program case study, are directly involved in MEE and contribute to the direct management of the Great Barrier Reef MP.

c These scientists hold direct knowledge of the monitoring programs 2 and 3, thus was interviewed about both monitoring programs.

d The MPA manager involved in strategic direction provided information about MEE for all of Tasmania’s Marine Reserves, whilst the second manager provided information only about Maria Island MR.

e These scientists hold direct knowledge of the monitoring programs 6 and 7, thus were interviewed about both.

2.4. Qualitative analysis

All key informants were de-identified and audio recordings of the interviews were independently transcribed prior to analysis. The interview transcriptions were open-coded to develop common themes within each question, following an inductive category
The current use of long-term biological monitoring data in management effectiveness evaluations based on informant interviews and content analysis.

<table>
<thead>
<tr>
<th>Monitoring program</th>
<th>MEE report name</th>
<th>Evaluation scale</th>
<th>Reporting scale</th>
<th>Evaluation and reporting frequency (number conducted)</th>
<th>Type of condition assessment</th>
<th>Condition assessment conducted by</th>
<th>Source of the monitoring information used for MEE assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Long-term reef monitoring program, Great Barrier Reef MP</td>
<td>Great Barrier Reef Outlook Report (GBRMPA, 2009)</td>
<td>Individual park</td>
<td>Individual park</td>
<td>Five years (n - 1)</td>
<td>Qualitative condition assessment</td>
<td>Great Barrier Reef MP Authority managers and scientists, and external experts</td>
<td>Published monitoring results</td>
</tr>
<tr>
<td>2: Ecosystem monitoring, Jervis Bay MP</td>
<td>Jervis Bay MP Zoning Plan Review (NSW MPA, 2009a)</td>
<td>Individual park</td>
<td>Individual park</td>
<td>Initial evaluation five years after establishment, then every ten years (n - 1)</td>
<td>Other</td>
<td>NSW Department of Primary Industries managers and scientists</td>
<td>Published monitoring results</td>
</tr>
<tr>
<td>3: Baited remote underwater video monitoring, Solitary Islands MP</td>
<td>Solitary Islands MP Zoning Plan Review (NSW MPA, 2009b)</td>
<td>Individual park</td>
<td>Individual park</td>
<td>As above (n - 1)</td>
<td>Other</td>
<td>As above</td>
<td>Published monitoring results, and raw data analyzed for MEE</td>
</tr>
<tr>
<td>4: Subtidal reef monitoring program, Victoria's MRs</td>
<td>Victoria's State of the Parks (Parks Victoria, 2007), Supported by park-scale MEE surveys filled out by Parks Victoria staff</td>
<td>None currently produced</td>
<td>None currently produced</td>
<td>None currently produced</td>
<td>None currently produced</td>
<td>None currently produced</td>
<td>None currently produced</td>
</tr>
<tr>
<td>5: Ecosystem monitoring program, Tasmania's MRs</td>
<td>Marine Parks and Reserves Authority Annual Audit report (MPRA, 2013), supported by park-scale internal MEE reports (Condition Pressure Response and Performance Assessment reports)</td>
<td>Individual park</td>
<td>Network</td>
<td>Annual (n - 1)</td>
<td>Qualitative condition assessment</td>
<td>Department of Parks and Wildlife managers and scientists</td>
<td>CPR reports: raw data analyzed for MEE, PA reports: published monitoring results and results from CPR reports</td>
</tr>
<tr>
<td>7: WAMMP coral monitoring, Ningaloo Reef MP</td>
<td>As above</td>
<td>Individual park</td>
<td>Network</td>
<td>As above (n - 1)</td>
<td>Qualitative condition assessment</td>
<td>As above</td>
<td>As above</td>
</tr>
</tbody>
</table>

* Individual park: evaluation and/or reporting occurs for an individual marine park.
* Qualitative condition assessment: qualitative descriptions are used to define condition categories of the current condition and trend in biological indicators from monitoring programs.
* Monitoring data incorporated into a habitat classification scheme to inform the adequacy of MPA zoning.
* Network: MEE reporting occurs only at the MPA network scale (i.e., individual park evaluations are aggregated and reported at for the whole network).
* Two rounds of evaluation have been completed by Parks Victoria. Only the first evaluation has been publicly reported (Parks Victoria, 2007), and the second evaluation has been conducted but not publicly reported.

As multiple informants from each management agency were interviewed to gain a complete understanding of each monitoring program, we pooled informants’ responses to avoid over-representation of some monitoring programs. Informants’ responses to all questions were generally consistent and/or complimentary, thus pooling responses was straightforward. The only exception was informants’ responses to Question 3 regarding how monitoring program results are used in MEE (SI Appendix 2), where two informants from the same management agency provided responses inconsistent with other informants’ descriptions of the nature of the outcome condition assessments. To resolve this issue, we conducted a content analysis of MEE documentation provided by the management agencies (see 2.5 Content analysis). Based on these results, we concluded that the observed contradictions were based in informants’ confusion about the difference between quantitative monitoring and qualitative condition assessments for MEE. Only those informants’ responses that were supported by the MEE content analysis are presented in the results.

2.5. Content analysis

We collected all publicly available MEE reports and informants provided copies of reports that were not publicly available. We conducted a content analysis of these reports to determine the type of outcome assessment done (either qualitative or quantitative condition assessment) to assess biological indicators from each monitoring program. We also collated information on the evaluation frequency and the scale of the evaluation and reports.

3. Results

3.1. The current use of long-term biological monitoring data in management effectiveness evaluations

Key informants revealed that management effectiveness evaluations (MEEs) have been conducted for four of the five MPA networks included in this study (Table 3). Whilst MEE had not been development methodology (Patton, 2002) using NVivo version 10 (QSR International, 2012). All coding was independently validated by another researcher (CNC), to ensure consistent coding of informants’ statements.
undertaken for Tasmania’s marine reserves, one informant reported that an MEE framework was currently under development and MEE would be conducted in the future. The frequency of evaluation and reporting ranges from yearly (MPRA, 2013), to every five (GBRMPA, 2009) or every ten years (NSW MPA, 2009a; Table 3). For four of the management agencies, MEE is in its infancy, with evaluation and reporting having only occurred once or twice (see “Evaluation and reporting frequency”, Table 3).

Outcome assessments of biological indicators occurred at the level of the individual park, and in three cases these evaluations had been publicly reported at the park-scale (e.g., GBRMPA, 2009; see “Evaluation scale” and “Reporting scale”, Table 3). For the remaining three cases, the park-scale outcome assessments were not publicly available, as MEE results were reported for the entire MPA network (e.g., Parks Victoria, 2007; Table 3).

Four of the seven monitoring program results have been used to inform qualitative condition assessments of biological indicators (Table 3). All qualitative condition assessments have been used to evaluate current condition and temporal trend in biological indicators against descriptive condition categories. For example, a condition category used to evaluate biological indicators from the Great Barrier Reef MP is “Very good: Available evidence indicates only a few, if any, populations of a species or group of species have declined” (GBRMPA, 2009). Typically agency managers and scientists contributed to qualitative condition assessments, and in one case external experts also contributed to the assessments (Table 3). Where monitoring results were not used to assess environmental condition (two monitoring programs), these data were used to judge the effectiveness of the configuration of management zones within the MPAs (i.e., the comprehensiveness, adequacy and representativeness of species and habitats protected by the MPAs; NSW MPA, 2009a,b). In these two cases, informants highlighted a restructure of MPA management (NSW Government, 2013), which meant that this type of MEE was unlikely to be repeated in the future. Given the specific nature of these assessments and the uncertain future MEE of NSW Marine Parks, these results are not discussed further.

Monitoring data have been analyzed specifically for MEE in only three instances (Table 3). For the remaining three monitoring programs, managers source monitoring results from scientific publications (i.e., peer-reviewed papers or technical reports; Table 3).

3.2. The current use of long-term monitoring data in evidence-based management

Sixteen informants provided specific examples where monitoring results had directly influenced management decisions (Fig. 2). Informants described nine distinct management decisions in response to monitoring results, which fell into three categories: i) research and monitoring; ii) routine management; and iii) planning. The categories used to code informants’ responses are defined in SI Appendix 3. Monitoring programs triggered up to seven different types of management decisions (Fig. 2).

Five of the seven long-term monitoring programs have been used to justify the need for research or monitoring within the MPAs (Fig. 2). Informants suggested that monitoring program results have been used to justify the continuation of the long-term monitoring program, or to instigate targeted research to better understand the patterns observed in the monitoring results. Routine management decisions made in response to monitoring data included: compliance efforts, such as increased ranger patrols to stop illegal activities like fishing (triggered by four monitoring programs; Fig. 2); informing educational programs (two monitoring programs); and, directing eradication efforts for introduced species control programs (one monitoring program). Planning decisions made in response to monitoring results included: altering MPA zoning arrangements (two monitoring programs; Fig. 2); and, updating management plans or strategic documents based on new information (one monitoring program). One informant reported that monitoring results had supported a decision not to act, when biological evidence suggested no change in management response was required. While only one informant mentioned a decision not to act, the way in which the question was asked (i.e., requesting specific examples of management activities or strategies; Question 5, SI Appendix 2) suggests that our data may under-represent this type of management decision.

Twelve of the informants who provided examples of management responses (75%) stressed that monitoring results alone would rarely trigger a management decision. Rather, management decisions were generally supported by multiple lines of evidence.

When informants provided specific examples of management decisions they were also asked whether it was the MEE process that led to the decision (Question 6; SI Appendix 2). Informants noted a variety of mechanisms which led to management decisions,
including: the MEE process (one monitoring program); the scientific publications that detail monitoring results (one monitoring program); both MEEs and scientific publications (three monitoring programs); speaking directly with scientists about monitoring results (one monitoring program); or, scientific publications in combination with speaking directly with scientists about results (one monitoring program).

4. Discussion

4.1. The use of long-term monitoring in management effectiveness evaluation

The last decade has seen the implementation of management effectiveness evaluation (MEE) by many agencies for marine protected area (MPA) management in Australia, reflecting a similar increase in use of MEE in terrestrial protected areas (Coad et al., 2013; Leverington et al., 2010). Despite the availability of long-term monitoring data, these are typically only evaluated using qualitative condition assessments of rocky and coral reef indicators (Table 3). These assessments rely on the interpretation of quantitative monitoring results by groups of experts, which are translated into broad qualitative condition statements. While the majority of MEEs conducted globally rely on qualitative condition assessments, overwhelmingly these evaluations use expert judgment due to a lack of available quantitative data (Cook and Hockings, 2011; Hockings et al., 2009). Whilst qualitative condition assessments are vital when data are lacking, experts have their own biases and assumptions, which can influence how they interpret qualitative condition categories (Burgman et al., 2011). Consequently, qualitative condition assessments based on expert judgment can lack transparency, and the accuracy and repeatability of assessments can be seriously compromised (Cook et al., 2014; Hockings et al., 2009; Jacobson et al., 2008).

The monitoring programs included in this study have been undertaken for 12–27 years (Table 1), and many have revealed unique insights into the temporal dynamics of marine protection (e.g., Babcock et al., 2010; Bates et al., 2013; Speed et al., 2013). Such monitoring data are a rich source of information to develop quantitative condition categories (following best-practice cases; e.g., Parks Canada, 2011; Parrish et al., 2003; Tierney et al., 2009). The resulting quantitative condition categories could be used for objective and transparent condition assessments of fine scale indicators in report cards, allowing readers to understand the contribution of individual monitoring program results to broader assessments of overall condition (e.g., Ecosystem Health Monitoring Program, 2012).

The failure of management agencies to capitalize on available quantitative long-term monitoring may relate to the disconnect between those collecting, analyzing and interpreting monitoring data and those using the data to inform management (Table 1). This disconnect can lead to situations where management agencies are not driving the questions being asked of these data, which is a commonly cited reason for the failure of long-term monitoring programs influencing conservation management (Legg and Nagy, 2006; Lindenmayer and Likens, 2010). Qualitative condition assessments were more frequently based on monitoring results presented in scientific publications than on in-house data analysis (Table 3). Scientific publications often focus on presenting novel results (Fahey et al., 2005), rather than results that specifically address management needs. Agencies often lack the capacity to conduct specific analyses to obtain the answers they need because they do not have appropriately trained staff (Ferraro and Pattanayak, 2006; Leverington et al., 2010). The implication for management agencies is that they are failing to get the greatest benefits from the rich quantitative datasets available to inform MEE.

4.2. The current use of long-term monitoring to inform evidence-based management

Despite the limited use of long-term monitoring results in MEE, our results clearly demonstrate that these data are being used to inform evidence-based management of Australian MPAs (Fig. 2). Many management agencies use monitoring results to justify the continued need for long-term monitoring programs, or to instigate additional research to resolve key uncertainties and identified knowledge gaps (Fig. 2). Given the limited resourcing of many management agencies, this reflects a genuine commitment to the continuation of long-term monitoring programs and a dedication to invest in research that supports evidence-based management. This finding is contrary to the common criticism that conservation management agencies often fail to commit to long-term investment in monitoring and research (Lindenmayer and Likens, 2010; Lindenmayer et al., 2012).

Long-term monitoring results have been valuable in supporting planning decisions, including changes to the MPA zoning arrangement based on an improved understanding of the distribution of marine habitats (e.g., Fernandes et al., 2005; Malcolm et al., 2012). Long-term monitoring results informed a variety of routine management decisions, such as the development of educational programs, compliance efforts, introduced species control and infrastructure development (Fig. 2). Finally, one informant noted that long-term monitoring was valuable for deciding not to act when the biological evidence suggests no change in management response was required (Fig. 2). This acknowledges that no action is a valid decision, and a sound management alternative in evidence-based management (Gregory et al., 2012).

While evidence-based management is clearly occurring in Australian MPAs, informants stressed that long-term monitoring results are rarely the sole driver that prompt management decisions. Rather multiple lines of evidence are required to provide critical information about the social, political and economic dimensions of decisions (Cook et al., 2012). While biological monitoring data are important, combining multiple lines of evidence provides greater certainty in management decisions (Hockings et al., 2009; Jacobson et al., 2008).

4.3. Is management effectiveness evaluation facilitating evidence-based management?

Despite the goal of MEEs to enable evidence-based management of protected areas (Hockings et al., 2006; Leverington et al., 2010), we found that MEE is rarely the sole mechanism driving evidence-based management of Australian MPAs. This finding is not limited to MPAs, with similar observations being made around the globe for the management of terrestrial protected areas (Jacobson et al., 2008) and coastal areas (Jacobson et al., 2014). While some informants used the MEE process to some degree, it was also commonly not used at all when making management decisions. Instead, informants preferred to go straight to the source of the data: by using monitoring results interpreted for them in scientific publications, or speaking directly to scientists. This finding confirms that conservation managers do use scientific information to directly support their management decisions, particularly valuing scientific publications that synthesize empirical evidence and also directly engaging with scientists (Cook et al., 2012; Seavy and Howell, 2010).

The current MEE procedures used by management agencies may not adequately reflect the complete cycle of MEE.
recommended for protected area management (e.g., Fig. 1; Hockings et al., 2006; Pomeroy et al., 2005). Whilst our study did not specifically address where breaks in the MEE cycle occur, we point to previous criticisms that management and monitoring objectives are rarely adequately aligned (Kemp et al., 2012; Lindenmayer and Likens, 2010). It may be that management agencies have failed to establish prioritized management and monitoring objectives in MEE, so there is no direct way for monitoring results to influence management decisions through the MEE process.

Finally, the frequency with which evaluations are conducted (most commonly on a 5–10 year cycle; Table 3) is likely to be an impediment to the use of MEE in evidence-based management. This frequency appears to be completely divorced from the time-frame required for management decisions. Instead, evaluation frequency seems to be largely driven by the need for external reporting. Only one agency in our study conducts MEE on an annual basis (Table 3). This frequent evaluation cycle was associated with the second highest diversity of management decisions arising, partially in response to MEE results (Fig. 2). Whilst only a single observation, this suggests that more frequent evaluation can provide greater opportunities for management agencies to respond to monitoring results.

4.4. Final recommendations

Long-term monitoring, MEE and evidence-based management are occurring in many of Australia’s MPAs, however we found poor links between these three elements. We found no evidence that MPA management agencies are using long-term monitoring data to develop quantitative condition assessments, despite these data making them well placed to achieve best-practice outcome assessment for MEE. Our study has revealed that long-term monitoring results are informing evidence-based management, however MEE is not the primary mechanism for this knowledge transfer. This suggests that whilst the first goal of MEE (to enable environmental accountability and reporting) is being achieved, the second and arguably more important goal of facilitating evidence-based management is not being achieved. Given that the MEE approaches examined in this study are still in their infancy, this situation may improve as MEE becomes institutionalized within management agencies. Much of the peer-reviewed literature relating to evaluating management effectiveness of MPAs addresses how to set management objectives and select indicators to assess MPA effects (Bellaef and Pelletier, 2011; Kemp et al., 2012; Pelletier et al., 2005). There is a great need for prescriptive discussion about how to set quantitative targets and use these to assess the effectiveness of marine protection (e.g., Samhouri et al., 2012).

During our interviews, most informants indicated a willingness to move towards using monitoring results in quantitative condition assessment and to forge a stronger link between MEE and evidence-based management. We make the following recommendations to help MEE achieve these aspirations:

1. Ensure internal MEE procedures reflect MEE theory

Closing the loop of MEE to ensure that outcome assessments inform evidence-based management remains a substantial challenge for many management agencies (Jacobson et al., 2008, 2014; Parr et al., 2009). We recommend management agencies conduct audits of their MEE protocols to identify where breaks in their MEE cycle are occurring, in order to improve the flow of information from monitoring programs through to evidence-based management of protected areas.

2. Invest in targeted long-term monitoring to support outcome assessments

Monitoring specifically for outcome assessment is recognized as the most challenging and costly aspect of MEE (Hockings et al., 2006; Pomeroy et al., 2005). Simply dedicating more resources to long-term monitoring is not a realistic solution; rather strong collaborations between management agencies and the scientific community will be required to ensure that existing and new long-term monitoring programs are targeted to the needs of MEE.

3. Move towards quantitative condition assessment of long-term monitoring results

It is worth investing in the benefits of objectivity, repeatability and transparency that flow from quantitative condition assessment (Hockings et al., 2009; Jacobson et al., 2008). Once monitoring data are targeted to the needs of MEE, management agencies should develop quantitative condition assessment. By incorporating management responses into quantitative condition assessment, true evidence-based management through MEE will be achievable.

4. Increase the frequency of evaluation to ensure MEE enables evidence-based management

A shorter evaluation timeframe, more frequent than the common 5–10 year cycle, will improve the alignment of MEE with evidence-based management. This may mean that evaluation and reporting frequency must be decoupled, as the cost of producing publicly available reports on a more frequent basis will not be viable option for most resource-limited management agencies. More frequent evaluation will ensure evidence-based management is the main driver of MEE, rather than public accountability through reporting.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jenvman.2014.10.023.

References


