Biological Conservation 210 (2017) 299–309

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Generating actionable data for evidence-based conservation: The global center of marine biodiversity as a case study

Helen E. Fox[a,d,1], Megan D. Barnes[b,c,*,1], Gabby N. Ahmadia[d], Grace Kao[d], Louise Glew[d], Kelly Haisfield[e], Nur Ismu Hidayat[f], Christine L. Huffard[f,g], Laure Katz[h], Sangeeta Mangubhai[i,j], Purwanto[i]

[a] National Geographic Society, 1145 17th Street N.W., Washington, D.C. 20036, USA
[b] School of Natural Resources and Environmental Management, University of Hawaii at Manoa, HI 96822, USA
[c] Centre for Biodiversity and Conservation Science, University of Queensland, St Lucia, Queensland 4067, Australia
[d] World Wildlife Fund, 1250 24th St. NW, Washington, D.C. 20037, USA
[e] Alexandria City Public Schools, Alexandria, VA 22314, USA
[f] Conservation International Indonesia, Sorong, West Papua, Indonesia
[g] California Academy of Sciences, 55 Music Concourse Drive, San Francisco, CA 94118, USA
[h] Center for Oceans, Conservation International, 2011 Crystal Drive, Arlington, Virginia 22202, USA
[i] The Nature Conservancy, Indonesia Marine Program, Graha Iskandarsyah 3rd Floor, Jalan Iskandarsyah Raya No. 66C, Kebayoran Baru, Jakarta Selatan, DKI Jakarta 12160, Indonesia
[j] Wildlife Conservation Society, Fiji Country Program, 11 Ma'afu Street, Suva, Fiji

ARTICLE INFO

Keywords:
Marine protected areas
Capacity building
Monitoring and evaluation
Indonesia

ABSTRACT

Sufficiently rigorous monitoring and evaluation can assess the effectiveness of management actions to conserve natural resources. However, costs of monitoring can be high in relation to program budgets, so it is critical to design monitoring efforts to ensure a high return on investment. To assess the relative contribution of different monitoring strategies to yield information for management decisions, we examine the evolution of a multi-year monitoring program across several MPAs in West Papua, Indonesia. Three monitoring strategies were implemented: external expert, science practitioner, and community monitoring staff. We place the monitoring objectives in a decision science framework, with six explicit fundamental objectives for monitoring to evaluate performance of marine protected areas. We examine each strategy in light of the six objectives to evaluate: 1) power to detect change, 2) extent of local capacity development, and 3) cost effectiveness. Over time, costs were reduced and scientific value increased through clear communication of science objectives, outcome-driven experimental design, adequately resourced monitoring programs, and a long-term view that anticipates phasing out outside consultants and transitioning monitoring responsibilities fully to locally-based staff. Investments to develop capacity of staff living locally to perform data management, analysis, interpretation, and science communication proved the most cost-effective approach in the long-term. With many globally important ecosystems in developing countries, developing local scientific capacity for the full cycle of monitoring is key to informed decision-making and ensuring long-term sustainability of efforts to conserve biodiversity.

1. Introduction

Over the past two decades, scholars and practitioners have called for a shift towards evidence-based conservation to ensure management interventions are effective and have the desired impact (Ferraro and Pattanayak, 2006; Sutherland et al., 2004). Yet the long-standing need for adequate human and financial resources (Gill et al., 2017) poses significant barriers to developing a systematic and scientifically-defensible foundation of evidence that can inform adaptive management, policy, and strategic planning (Cook et al., 2016). Consequently, a substantial disconnect exists between scholarly discussion and on-ground practice in both developed and developing countries. Long-term efforts to standardize best practices in conservation (e.g., the Conservation Measures Partnership) have transformed conservation planning and implementation (Stem et al., 2005), but real examples of adaptive management remain rare (Cook et al., 2016), with

* Corresponding author at: School of Natural Resources and Environmental Management, University of Hawaii at Manoa, HI 96822, USA.
E-mail addresses: fox.conservation@gmail.com (H.E. Fox), megan.barnes@uq.edu.au (M.D. Barnes).
1 Equal authorship.

http://dx.doi.org/10.1016/j.biocon.2017.04.025
Received 25 December 2016; Received in revised form 31 March 2017; Accepted 21 April 2017
Available online 05 May 2017
0006-3207/

Box 1
Monitoring strategies in the BHS.

Depending on the goals and priorities, different monitoring strategies were employed, with different tradeoffs around statistical power to detect change, local capacity development, cost, and timing (Fig. 1).

External expert: Bringing in an external expert with high capacity (in the form of an external consultant) provided results with good power (i.e. many species identified and higher precision in differentiating sites) on a short time frame, but costs were fixed and local capacity development (and therefore sustainability) limited.

Science practitioners: NGO monitoring staff trained in Indonesian universities had a good science foundation, and with support, now contribute in the international science community. This strategy is likely more sustainable than an external expert-led model, and further develops Indonesian capacity, but with less local capacity the risk remains that staff may leave and/or program priorities shift.

Community monitoring staff: Training Papuan citizens with commercial fishing experience and who could read and write focused on adding basic science skills (e.g. interpreting a graph, working with Excel, basic ecological theories), as their species identification and biomass estimation skills were often exceptional. This approach has resulted in relatively stable local monitoring staff.

monitoring practices on the ground frequently inadequate to support real-time decision-making at multiple spatial scales (from local to global) by the necessary array of actors (e.g., conservation managers, policy makers, funders).

Because ecological monitoring can be expensive, particularly in remote locations, and in extreme cases can equal or surpass the cost of other management objectives (e.g. planning, decision making, operations, community engagement, enforcement) combined (Howe and Milner-Gulland, 2012), trade-offs in resource allocation among objectives are common in diverse programs. In this context, it is crucial to be both clear about the full array of monitoring objectives (Houk and van Woesik, 2013) and their relative priorities, as well as to maximize the utility of the information generated for management and decision making as a result of monitoring (Hauser et al., 2006; McDonald-Madden et al., 2009; Possingham et al., 2012). If monitoring data collected are insufficient to detect ecological change or to evaluate the effectiveness of interventions, then these efforts might be considered a waste of resources (Legg and Nagy, 2006).

For at-risk ecosystems such as coral reefs, delayed information to inform management could be devastating (Possingham et al., 2012), resulting in missed opportunities to address emerging threats, adapt management that is ineffective, and allocate resources where they can maximize outcomes. In developing countries, home to many globally important and imperiled ecosystems, monitoring requires capacity that might not be commonly available. Tradeoffs might exist between developing long-term capacity for monitoring, and ensuring near-term monitoring rigor (Burton, 2012; Houk and van Woesik, 2013). However, the importance of local staff capacity for providing scientific support is increasingly recognized as critical for ensuring the long-term sustainability of monitoring efforts (McLeod et al., 2015; Şekercioğlu, 2012). Therefore, importing external capacity risks compromising sustainability in exchange for this short-term information gain (Danielsen et al., 2005). While monitoring almost always has multiple implicit objectives, and the goals of monitoring programs are rarely clearly articulated (Possingham et al., 2012), a well-designed program can also yield unintended consequences or benefits not originally anticipated (Edwards et al., 2010).

Efforts to develop capacity for monitoring generally occur through a combination of training local community members or in-country non-governmental organizations (NGOs), university, or government technical staff who have had relevant formal education to conduct monitoring activities (Danielsen et al., 2003). The critical role of local communities in resource management has long been recognized (Johannes, 1998a). Locally-led monitoring encompasses a range of approaches, and can be defined as local residents directly involved in data collection, regardless of their formal education (Danielsen et al., 2005); hereafter "community monitoring staff". At the same time, monitoring requires a high level of knowledge (e.g. of scientific monitoring design and protocols or computer literacy) and skills (e.g. species identification or data management). Consequently, potential tradeoffs frequently result in emphasis being placed either on capacity development, with the hypothesis that it will have greater long-term sustainability, or on information gain (i.e. scientific rigor) to ensure that the data will be useful in supporting planning, management and policy decisions. Many communities may trust the data more if they are directly involved in collecting it, and therefore may be more likely to make management decisions (Obura et al., 2002). If developing community monitoring capacity can simultaneously empower local communities and meet scientific monitoring needs, it would have greater benefit overall for improving natural resource governance (Danielsen et al., 2009; Holck, 2008).

1.1. *This study: evaluating tradeoffs among monitoring objectives*

To understand tradeoffs among monitoring objectives, we used a case study of an ecological performance measurement program, defined as the process of measuring progress towards a specified project, program, or policy objectives, including desired levels of activities, outputs, and outcomes (Mascia et al., 2014). Different monitoring and training approaches were implemented with varying emphasis placed on rigor and capacity development by different stakeholders, which resulted in multiple distinct strategies. This allows us to evaluate the benefits of monitoring against multiple management objectives common to many monitoring programs (Box 1; Ahmadia et al., 2015). We used a decision theoretic framework and applied a strategy evaluation to evaluate the relative costs and benefits of each monitoring strategy. We hypothesize that over time it becomes more cost-effective to base a monitoring program on locally-based science practitioners and community monitoring staff, but this results in a longer time to achieve sufficient power to detect change, which is often critical to trigger a management intervention (Fig. 1).

We tested this hypothesis with data from Raja Ampat, part of the Bird's Head Seascape (BHS) in West Papua, Indonesia, considered the global epicenter of marine biodiversity (Allen, 2008; Veron et al., 2009). Since 2007, a consortium of conservation actors in the BHS has worked towards protecting and sustaining the marine resources on which local communities depend (Mangubhai et al., 2012; Supplementary material). Their approach assumes that investing in improved community engagement and better governance of marine protected areas (MPAs) will result in more positive ecological and social outcomes across the Seascape. A monitoring program was designed to measure ecological conditions within MPAs over time, as indicators of management performance, with standardized core monitoring protocols. Monitoring efforts are intended to meet two strategic goals: (i) gain information to support and guide management decisions, and (ii) improve the capacity of local community monitoring staff to monitor MPA conditions. Implicit in this design are two hypotheses: (i) higher quality information that meets global standards for rigor will be more likely to be used for adaptive decision-making to support the overall