Ecological Indicators 60 (2016) 119–124

Contents lists available at ScienceDirect

Ecological Indicators

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

Case Study

Measuring conservation success with missing Marine Protected Area boundaries: A case study in the Coral Triangle

Rubén Venegas-Li[a,*], Annick Cros[b,c], Alan White[d], Camilo Mora[e]

[a] Fundación Keto, 1735 - 1002, San José, Costa Rica
[b] Asia-Pacific Program, The Nature Conservancy, 923 Nu'uanu Avenue, Honolulu, HI 96817-1539, USA
[c] Hawaii Institute of Marine Biology, University of Hawaii at Manoa, Honolulu, HI 96822, USA
[d] Indo-Pacific Division, The Nature Conservancy, 923 Nu'uanu Avenue, Honolulu, HI 96817-1539, USA
[e] Department of Geography, University of Hawaii at Manoa, Honolulu, HI 96822, USA

ARTICLE INFO

Article history:
Received 18 December 2014
Received in revised form 18 June 2015
Accepted 21 June 2015
Available online 9 July 2015

Keywords:
Marine Protected Area
Buffered centroids
Spatial analysis
Conservation effectiveness
Coral Triangle
Coral Triangle Atlas

ABSTRACT

The on-going loss of biodiversity calls for assessing the performance of conservation strategies. In the case of marine protected areas (MPAs), a common indicator of success is the amount of biodiversity protected within them. However, there are many cases where the information for the official MPA boundary is not available, making it difficult to precisely measure the indicator. A solution to this problem is to create circular buffers around the centre location of MPAs for which boundaries are missing, equivalent in area to that reported officially for the MPA. The Coral Triangle Atlas provides the opportunity to quantify more precisely the validity of using buffers as proxies for MPA boundaries both at national and regional scales in the Coral Triangle. We used 612 existing MPA boundaries, converted them into point data at their centroids and then created circular buffers of area equal to that of the MPAs' original polygons. Errors in estimated area of protected coral reefs were used to measure the bias created by the centroid buffers. We obtained an underestimation of protected coral reef area, both at the scale of the Coral Triangle region and at a national scale when using centroid buffers, with a larger underestimation as more MPA boundary proxies were used. We found that the size of MPA does not have a significant effect on the percentage of bias when MPAs are smaller than 100 km^2 at a national level, and smaller than 1000 km^2 at a regional level. With less than 15% of the total MPAs in the CT region larger than 100 km^2, these results suggest that using buffers at a national scale for small MPAs may be a good solution to missing boundaries and cheaper than trying to collect exact information if working at a national or multinational scale. However, for countries with large MPAs such as Indonesia, using this proxy system will tend to create a larger error. At a regional scale, such as the Coral Triangle region, an estimation of total protected coral reef using buffers as MPA boundaries proxies will produce a small underestimation, thus, producing conservative results of protected coral reef area. This study shows the importance of assessing the bias introduced by using proxies for MPA boundaries when measuring indicators of conservation target achievement for coastal and marine areas.

1. Introduction

Marine protected areas (MPAs) are a fundamental conservation tool (Green et al., 2012; Halpern and Warner, 2002; Roberts et al., 2005). This has resulted in global and regional efforts to establish ecologically representative and effectively managed MPA networks (Mora, 2011a). These networks are encouraged at a global level through the Convention on Biological Diversity and the Aichi Targets (Balmford et al., 2005), and at regional levels through initiatives such as the Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security (CTI-CFF) (CTI-CFF, 2009; White et al., 2014).

Planning, implementing and managing such MPA networks is costly. According to Balmford et al. (2004) an estimated $5 billion to $19 billion annually would be needed to run a global MPA network that would protect 20–30% of the world's oceans. In order to justify these levels of investment, indicators that measure MPAs' effectiveness in protecting marine resources are necessary. A common indicator of MPA effectiveness is the percentage of biodiversity

* Corresponding author at: ARC Centre of Excellence for Environmental Decisions, School of Biological Sciences, The University of Queensland, Brisbane, Queensland 4072, Australia. Tel.: +61 7 33652491.
E-mail addresses: rvenegas@fundacionketo.org (R. Venegas-Li), acros@hawaii.edu (A. Cros), alan_white@tnc.org (A. White), cmora@hawaii.edu (C. Mora).

http://dx.doi.org/10.1016/j.ecolind.2015.06.027
1470-160X/

(e.g. species, area of particular habitats, biogeographic classifications) present within its boundaries (Barr et al., 2011). Whether these indicators reach the targeted percentage of protection or not will have a major role in deciding where and how resources are invested.

Indicators of conservation effectiveness with a spatial dimension are often measured using Geographic Information Systems (GIS) (Chape et al., 2005; Wood et al., 2008). However, these types of analyses are often hampered by incomplete or poor quality spatial data (Chape et al., 2005; Cros et al., 2014b; Visconti et al., 2013; Wabnitz et al., 2010). In the case of quantifying the amount of biodiversity protected by MPAs, a common problem is the absence of the protected area boundaries, and therefore the lack of polygons to overlay with biodiversity layers such as coral reefs, seagrass or mangroves which hinders its precise quantification in a GIS. An approach to solve this (both in the marine and the terrestrial realms) has been to create a circular polygon from a buffer around a point representing the location of the protected area (Brooks et al., 2004; Coad et al., 2013; Hoekstra et al., 2004; Jenkins and Joppa, 2009; Jenkins et al., 2013; Mora, 2011b; Mora et al., 2006; Rodrigues et al., 2004; Soutullo et al., 2008; Spalding et al., 2013; Venter et al., 2014; Wu et al., 2011). This point is assumed to be the centroid of the MPA, and the buffer is proportional to the area officially designated as protected.

Although this approach is widely accepted and commonly used, only three studies have actually quantified the difference in the area of biodiversity protected by MPAs when calculated using the real boundaries and this method (Jenkins and Joppa, 2009; Mora et al., 2006; Visconti et al., 2013). Mora et al. (2006) found that circular buffers tend to underestimate the coral reef area protected by the global network of MPAs by 23%, although the underestimation was reduced to 7% if the largest eight MPAs were removed, thus, negligible at a global scale. Jenkins and Joppa (2009), found that representing terrestrial park boundaries with circular buffers is a relatively minor problem at large scales (such as ecoregions and biomes), but that it could induce serious inaccuracies at finer scales (such as the actual land cover contained in individual parks). Visconti et al. (2013) found that the frequency of protected areas with unknown boundaries can cause large over or underestimation of the extent of protection of terrestrial neotropical mammals.

These disparities in the extent of errors introduced by using buffered MPA boundaries highlight the need for additional tests at different scales. This is especially true for regions like the Coral Triangle (CT), where current conservation efforts have to rely on spatial data that are often lacking and where the management scale oscillates from national boundaries to regional boundary. Despite efforts to build a regional MPA database for the Coral Triangle, only one third of MPAs have boundary data available (Cros et al., 2014a, 2014b; White et al., 2014); this dataset is used in regional spatial analysis to assess conservation effectiveness, as the best data available. In this study we quantify the potential error obtained by using buffered MPA centroids as proxies of MPA boundaries at regional and national levels in the estimation of total protected area of coral reefs in the CT region, and discuss potential consequences in conservation decisions.

2. Methodology

We assessed the bias introduced when using buffered MPA centroids by quantifying the difference of coral reef area obtained within the real MPA boundary and its proxy, for the Coral Triangle region. We followed an approach similar to Mora et al. (2006), Jenkins and Joppa (2009) and Visconti et al. (2013). All the GIS operations were carried out on ArcGIS 10.1 (ESRI 2012).

2.1. MPA and coral reef data

The MPA data was downloaded from the Coral Triangle Atlas (ctatlas.reefbase.org) MPA database (version 07/23/2012), regarded at the moment as the most complete for the region (Cros et al., 2014b). There are 612 polygons in the dataset, which represent the boundaries of approximately 30% of the total 1972 MPAs reported in the CT region (White et al., 2014). Approximately 95% of the missing boundaries (that is, 1308 out of 1360) are associated with small locally marine managed areas (LMMAs) in the Philippines (White et al., 2014), and less than 5% represent missing MPA boundaries for the other five countries (Fig. 1).

We selected coral reef as the major habitat type to measure within MPAs since its protection is a milestone in the CTI-CFF (CTI-CFF 2009), as evidenced by two indicators in the Regional Plan of Action: (1) percentage area of coral reef within protected areas in the Coral Triangle, and (2) percentage area of coral reefs within no-take replenishment zones. We used the Global Distribution of Coral Reefs dataset (UNEP-WCMC et al., 2010), distributed in vector format, with a spatial resolution of 30 m for the majority of the region.

2.2. Buffered MPA centroids: circular and square shaped polygons

The 612 available polygons in the CT Atlas representing real MPA boundaries were converted into points at its centroid using the "feature to point" tool. These points were then either converted into circular shapes using the "buffer" tool, or square shape, using the "buffer" and the "feature to envelope polygon" tools, both with an area equal to the original polygon. The latter shape was used by UNEP/WCMC World Database on Protected Areas as a proxy when the real MPA boundaries were unknown. The 2015 dataset no longer use this method (UNEP-WCMC, 2015), it represents MPAs with missing boundaries as point data.

2.3. Reef area inside MPA polygons

The 3 sets of boundaries (the original MPA boundaries, the circular boundaries, and the square boundaries) were clipped with the coral reef dataset to extract the coral reef area within. The resulting polygons represented the coral reef area inside each set of the MPA boundaries. Very similar results were obtained when using square and circular boundaries as proxies, thus from this step onwards only the circular buffer boundary will be used as a proxy.

2.4. Scales

Regional scale describes the Exclusive Economic Zones (EEZ) of the six countries in of the Coral Triangle region (Cros et al., 2014b), which includes Indonesia, Malaysia, Philippines, East Timor, Solomon Islands and Papua New Guinea and measures approximately 12.3 million km^2.

National scale describes the boundaries of individual countries, ranging from 77,256 km^2 to 6 million km^2. Site level corresponds to individual MPAs or LMMAs.

2.5. Bias measurement

The first step was to determine if there was a difference in the protected coral reef area when all of the original boundaries were substituted by circular buffers at national and regional scale (i.e. representing a situation in which no MPA boundaries are available), creating a bias in the estimation of protected biodiversity.

The second step was to assess if there was a change in the bias as we decreased the number of real MPA boundaries replaced by buffers (i.e. representing a situation with varying levels of