Biological Conservation xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Biological Conservation

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

Ecological criteria to identify areas for biodiversity conservation

Irawan Asaad [a,b,*], Carolyn J. Lundquist [a,c], Mark V. Erdmann [d], Mark J. Costello [a]

[a] Institute of Marine Science, University of Auckland, Auckland, New Zealand
[b] Ministry of Environment and Forestry, Jakarta, Indonesia
[c] National Institute of Water & Atmospheric Research, Hamilton, New Zealand
[d] Conservation International-Asia Pacific Marine Programs, Auckland, New Zealand

ARTICLE INFO

Article history:
Received 19 February 2016
Received in revised form 19 September 2016
Accepted 2 October 2016
Available online xxxx

Keywords:
Ecological criteria
Biodiversity variables
Conservation area
Habitat
Species

ABSTRACT

A challenge in implementing biodiversity conservation is in reconciling criteria for identifying significant areas and representative networks for biodiversity protection. Many international environmental initiatives include biological, ecological, economic, social and governance criteria to aid selection of areas for biodiversity conservation. Here we reviewed criteria used by 15 international initiatives, and what minimum set of biodiversity variables would be needed to support them. From a range of ecological and biological criteria, we identified eight criteria commonly used to identify areas for biodiversity conservation across these initiatives. Four criteria identified areas that (1) contained unique and rare habitats; (2) included fragile and sensitive habitats; (3) were important for ecological integrity; and (4) were representative of all habitats. Another four criteria were based on species' attributes, including (5) the presence of species of conservation concern; (6) the occurrence of restricted-range species; (7) species richness; and (8) importance for life history stages. Information required to inform these criteria include: habitat cover, species occurrence, species richness, species' geographic range and population abundance. This synthesized set of ecological and biological criteria, and their biodiversity variables will simplify the process to identify additional areas of high biodiversity significance, that in turn support achieving the Convention on Biological Diversity (CBD) targets to fill gaps in the representativeness of the global coverage of protected areas.

1. Introduction

The loss of biodiversity is altering ecosystem functions and services that are essential for human well-being as well as threatening species with extinction (FAO, 2010; WWF, 2014). The primary management responses to this loss include managing human activities (Young et al., 2005) and species' populations (Stattersfield et al., 1998) and designating and implementing protected areas (Brooks et al., 2004). Protected areas are a key strategy to conserve biodiversity (Rodrigues et al., 2004), because they reduce rates of habitat loss (Butchart et al., 2012), prevent declines of threatened species (Ricketts et al., 2005), and maintain ecosystem services (Stolton et al., 2015). Several initiatives provide a framework to identify potential areas for biodiversity conservation (Brooks, 2010). The objectives of these initiatives have ranged from the protection of areas for selected taxonomic groups (Ricketts et al., 2005) to developing a network of areas designed to protect biodiversity in general (Clark et al., 2014). They have resulted in many areas having received formal protection, and/or being managed to conserve biodiversity (Langhammer et al., 2007). In addition to these initiatives, there has been a growing societal and political interest to improve the status of biodiversity by protecting areas of "importance for biodiversity that are ecologically representative through an effective, equitable and integrated management system" (CBD, 2010).

Aligned with those initiatives, the 11th Aichi Biodiversity Target of the Convention on Biological Diversity (CBD) aims to conserve at least 17% of terrestrial and 10% of marine environments globally by 2020 (CBD, 2010). Although the number and coverage of global protected areas have expanded in the past four decades (Juffe-Bignoli et al., 2014), the coverage of protected areas stands at 14.6% for terrestrial and only 2.8% for marine environments (Butchart et al., 2015). The target for terrestrial protected areas is achievable, requiring the addition of around 3.3 million km^2 to achieve the 17% target (Butchart et al., 2015). However, a further 2.2 million km^2 of marine areas within national jurisdictions and 21.5 million km^2 of areas beyond national jurisdictions need to be protected to achieve the 10% of the marine CBD target (Juffe-Bignoli et al., 2014). Moreover, the level of protection of biodiversity within protected areas can vary greatly (Costello & Ballantine, 2015). For example, only 0.7% of the oceans is within MPAs that aim to protect biodiversity at all levels, from genes to populations, food webs and ecosystems (Costello & Ballantine, 2015). It is estimated that

* Corresponding author at: Institute of Marine Science, University of Auckland, New Zealand.
E-mail address: i.asaad@auckland.ac.nz (I. Asaad).

http://dx.doi.org/10.1016/j.biocon.2016.10.007
0006-3207/

only 27% of coral reef ecosystems (Burke et al., 2012), 6.9% of mangrove forests (Giri et al., 2011), and about 15% of threatened vertebrates have been protected within existing protected areas networks (Venter et al., 2014). Furthermore, the past establishment of protected areas often occurred in a biased or ad hoc fashion and did not deliver optimal biodiversity conservation (Stewart et al., 2007). Thus, identifying additional areas for biodiversity conservation is a prerequisite for achieving the CBD targets to fill gaps in the representativeness of the global coverage of protected areas (Spalding et al., 2013; Juffe-Bignoli et al., 2014; Venter et al., 2014; Butchart et al., 2015).

Various initiatives have developed biological, ecological, economic, social and governance criteria to identify areas of biodiversity importance. Biological and ecological criteria are the primary consideration in meeting biodiversity conservation objectives (Roberts et al., 2003; Gilman et al., 2011). A number of variables have been applied to quantify these criteria, although they vary across the initiatives. For example, several initiatives apply a criterion of biological diversity (e.g. Man and Biosphere Reserve, Particularly Sensitive Sea Areas, Natura 2000 sites, Ecologically and Biologically Significant Marine Areas). These initiatives broadly define biological diversity as an area that contains significant diversity of biodiversity elements (e.g. ecosystems, habitats, communities, species, and genetic diversity). Various indices that have been proposed to measure this criterion include richness of biodiversity elements, evenness level, and taxonomic distinctness. Naturally, each initiative's criteria reflect its area of special interest (e.g., species, habitats) (Roberts et al., 2003; Clark et al., 2014; IUCN, 2016). Here, we consider if it is possible for conservation management to address the needs of multiple initiatives through a common set of ecological and biological criteria. In addition, the availability of common variables to support the criteria would complement existing initiatives.

Standardized ecological and biological criteria would enable the systematic identification of areas of high biodiversity value (Gilman et al., 2011), support an ecosystem-based approach (Crowder & Norse, 2008), and categorize areas that potentially deliver the greatest contribution to preserving biodiversity (Pressey et al., 1993). Previous reviews on the criteria to identify areas important for biodiversity conservation have generated an extensive list of relevant ecological and biological criteria (Day et al., 2000; Roberts et al., 2003; Gilman et al., 2011). However, some criteria are not self-explanatory and only a few identified the biodiversity variables needed to assess their criteria (Hiscock, 2014).

If particular variables are used to identify areas for biodiversity conservation, then they are likely also important for monitoring biodiversity change within and outside protected areas. Data on these key variables is critically important, due to major gaps in our understanding of biodiversity change, particularly on the global scale (Pereira et al., 2012). The Biodiversity Indicator Partnership (BIP, www.bipindicators.net) provides global indicators of the CBD Aichi Biodiversity Targets (Bubb et al., 2014), and The Living Planet Index monitors trends in species populations (WWF, 2014). More recently, Pereira et al. (2013) proposed a framework of Essential Biodiversity Variables (EBVs) as a minimum set of indicators to measure biodiversity change. This was inspired by the application of Essential Climate Variables to support the Global Framework for Climate Services (GCOS, 2010). The EBVs comprise six classes of variables, ranging from genetic composition to ecosystem function, with each class consisting of multiple variables, and are conceptually located between primary observations and indicators (Pereira et al., 2013). However, these approaches require several primary variables (Geijzendorffer et al., 2015; Kissling et al., 2015; Schmeller et al., 2015; Brummitt et al., 2016). Amongst these, Costello (2013) proposed species occurrence as a Fundamental Biodiversity Variable (FBV) because it identifies species of conservation, ecological and economic importance, and provides the simplest metric of biodiversity (i.e. species richness). As the most widely used measure of biodiversity (Butchart et al., 2010; Tittensor et al., 2014), species occurrence is already supported by standardized sampling methods and open-access biodiversity databases (Costello et al., 2016a). It has also been proposed as one of three minimum EBV for invasive species monitoring, along with species alien status and impact (Latombe et al., 2016). EBVs have also been proposed to assess biodiversity change at the national level (Turak et al., 2016a) and in the freshwater environment (Turak et al., 2016b). However, the minimum EBVs for conservation management have not yet been identified. We suggest that the same variables used to identify areas for biodiversity conservation can also be used to monitor trends in biodiversity.

This paper reviews the conceptual framework of the international initiatives established to identify areas for biodiversity conservation. First, we reviewed ecological and biological criteria used across these initiatives, and determined key criteria that were included in most initiatives to allow objective assessment of biodiversity value. Then, we synthesized biodiversity variables required to inform these criteria. These ecological criteria provide guidance to direct assessment of areas significant for biodiversity conservation. The summarized biodiversity variables will help focus resources on what information and data should be prioritised for collection to inform conservation management across multiple biodiversity conservation initiatives. We recognized that other factors are involved in designating areas for legal protection which we do not consider here, such as the social, economic and governance context.

2. Initiatives to identify conservation areas

We reviewed 15 initiatives that identified areas important for biodiversity conservation. These initiatives have different underlying objectives, spatial scales (either local, regional or global), and environmental focus (either terrestrial, wetlands or marine). Of these, ten were established by international conventions and five by non-governmental conservation organizations (NGOs) (Table 1). The former focused on identifying and developing networks of areas important for biodiversity conservation, e.g., Man and Biosphere Reserves (MAB) (UNESCO MAB, 1996), Wetlands of International Importance (Ramsar Secretariat, 2008), Natura 2000 sites (European Commission, 2002), and Ecologically and Biologically Significant Marine Areas (EBSA) (Convention on Biological Diversity (CBD), 2008). The initiatives launched by NGOs focused on identifying areas for particular species or taxonomic groups, namely, Important Bird and Biodiversity Areas (IBA) (BirdLife International, 2004), Important Plant Areas (IPA) (Plantlife International, 2004), and Alliance of Zero Extinction Sites (AZE) (Ricketts et al., 2005).

The first initiative was introduced by UNESCO in 1971 with its Man and Biosphere Reserve programme. It promoted a balanced relationship between conservation and sustainable development (UNESCO MAB, 1996). Several of the other initiatives were focused not only on conserving species but also maintaining biodiversity in general. Two initiatives that specifically aimed to safeguard threatened, rare, endemic and other species of conservation concern are the IBA and AZE. The former focused on the long-term viability of bird populations (BirdLife International, 2004; O'Dea et al., 2006) while AZEs identified areas critical for the survival of the world's most threatened species (Ricketts et al., 2005). Currently, there are over 12,000 areas in more than 200 countries that have been identified as IBAs (BirdLife International, 2013), and more than 588 areas that have been included as AZEs (Alliance for Zero Extinction, 2010). The objectives of the other 13 initiatives were focused on conserving habitat and aimed to maintain ecosystem elements, processes, and services (Table 1). For example, IPA identified areas of global significance for plants and threatened plant habitats (Plantlife International, 2004) and EBSA identified marine areas using biodiversity surrogates such as topographic and oceanographic habitat features (Kenchington et al., 2011; Clark et al., 2014; Yamakita et al., 2015). Currently, IPAs have been identified in over 66 countries (Plantlife International, 2014), and a total of 204 EBSAs have been described (Bax et al. 2016).

Please cite this article as: Asaad, I., et al., Ecological criteria to identify areas for biodiversity conservation, Biological Conservation (2016), http://dx.doi.org/10.1016/j.biocon.2016.10.007