Biological Conservation 170 (2014) 92–102

Contents lists available at ScienceDirect

Biological Conservation

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

Review

# Toward better application of minimum area requirements in conservation planning

Guy Pe'er [a,*], Mariana A. Tsianou [b], Kamila W. Franz [c], Yiannis G. Matsinos [d], Antonios D. Mazaris [e], David Storch [f,g], Lenka Kopsova [f], Jana Verboom [h], Michel Baguette [i,j], Virginie M. Stevens [j], Klaus Henle [a]

[a] UFZ – Helmholtz Centre for Environmental Research, Department of Conservation Biology, Permoserstr. 15, 04318 Leipzig, Germany
[b] Department of Environmental & Natural Resources Management, University of Patras, G. Seferi 2, GR-30100 Agrinio, Greece
[c] Department of Ecosystem Modelling, Büsgen-Institut, Georg-August-University of Göttingen, Büsgenweg 4, 37077 Göttingen, Germany
[d] University of the Aegean, Department of Environmental Studies, Biodiversity Conservation Lab, GR-81100 Mytilini, Greece
[e] Department of Ecology, Aristotle University, U.P. Box 119, 54124 Thessaloniki, Greece
[f] Department of Ecology, Charles University in Prague, Viničná 7, 128 44 Praha 2, Czech Republic
[g] Center for Theoretical Study, Charles University in Prague & Academy of Sciences of the Czech Republic, Jilská 1, 110 00 Praha 1, Czech Republic
[h] Alterra, Wageningen UR, PO Box 47, 6700 AA Wageningen, The Netherlands
[i] Museum National d'Histoire Naturelle, UMR 7205, Institute of Systematics, Evolution and Biodiversity, 75005 Paris, France
[j] CNRS USR 2936, Route du CNRS, 09200 Moulis, France

A R T I C L E I N F O

*Article history:*
Received 8 May 2013
Received in revised form 10 October 2013
Accepted 6 December 2013

*Keywords:*
Body mass
Database
Minimum viable population
Population viability analysis
Time horizon
Review

A B S T R A C T

The Minimum Area Requirements (MAR) of species is a concept that explicitly addresses area and therefore can be highly relevant for conservation planning and policy. This study compiled a comprehensive database of MAR estimates from the literature, covering 216 terrestrial animal species from 80 studies. We obtained estimates from (a) Population Viability Analyses (PVAs) which explored a range of area-related scenarios, (b) PVAs that provided a fixed value – either MAR or the minimum viable population size (MVP) alongside other area-relevant information, and (c) empirical studies of occupancy patterns in islands or isolated habitat patches across area. We assessed the explanatory power of life-history traits (body mass, feeding guild, generation length and offspring size), environmental variables (average precipitation and temperature), research approach and phylogenetic group on MAR estimates. PVAs exploring area showed strong correlation between MAR and body mass. One to two additional variables further improved the predictive power. PVA reporting fixed MAR, and occupancy-based studies, were better explained by the combination of feeding guild, climatic variables and additional life history traits. Phylogeny had a consistent but usually small contribution to the predictive power of models. Our work demonstrates that estimating the MAR across species and taxa is achievable but requires cautious interpretation. We further suggest that occupancy patterns are likely sensitive to transient dynamics and are therefore risky to use for estimating MAR. PVA-based evaluations enable considering time horizon and extinction probability, two aspects that are critical for future implementation of the MAR concept into policy and management.



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* Corresponding author. Tel.: +49 341 2351643.
*E-mail addresses:* guy.peer@ufz.de (G. Pe'er), mtsianou@for.auth.gr (M.A. Tsianou), kamila.w.franz@gmail.com (K.W. Franz), matsinos@aegean.gr (Y.G. Matsinos), amazaris@bio.auth.gr (A.D. Mazaris), Storch@cts.cuni.cz (D. Storch), l.kopsova@seznam.cz (L. Kopsova), jana.verboom@wur.nl (J. Verboom), baguette@mnhn.fr (M. Baguette), Virginie.STEVENS@ecoex-moulis.cnrs.fr (V.M. Stevens), klaus.henle@ufz.de (K. Henle).

0006-3207/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biocon.2013.12.011

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## 1. Introduction

Space has a pivotal role in most, if not all ecological and evolutionary processes (Tilman and Kareiva, 1997). Accordingly, the selection, design and management of protected areas involve primarily the question how much area is necessary for long-term maintenance of biodiversity. A potentially important concept in this context is the Minimum Area Requirements of species (MAR), defining the amount of space (suitable habitat) that is required for the long-term persistence of a population.

Obviously, the presence of a species within a site does not guarantee its survival. First, populations occurring within remnants of suitable habitats may be declining, threatened or under an "extinction debt" from past environmental changes (Tilman et al., 1994). Second, some species may require larger area than others in order to buffer against environmental, demographic or genetic stochasticity. Therefore, a major challenge for reserve design is to ensure that sufficient protected areas contribute to the viability of as many species as possible, in consideration of both their habitat association and area requirements. Here, the MAR could be of direct relevance because of its intuitive and explicit focus on area. However, in comparison with MVP, studies dealing with MAR or providing it seem to be surprisingly limited. For instance, a search through Google Scholar (20.9.2013) for the terms "Minimum Area Requirement" + "conservation" versus "Minimum Viable Population" + "conservation" yielded 303 versus 4819 hits, respectively. Similarly, scanning 45 Species Action Plans (SAPs) covering 639 species for a set of keywords relating to PVA, MVP and MAR (see Methods), we found seven SAPs which reported the MVP, four that mentioned Minimum Area (or habitat) Requirements, but none that reported the MAR.

### *1.1. Factors potentially affecting the MAR*

Predicting the MAR would require at least to identify important factors or traits that can explain the variation in area requirements across species and taxa. Empirical and modelling studies indicate a variety of factors that could affect the MAR, directly or indirectly. First, MAR should correlate with body mass, primarily because of energetic expenditure (Shaffer, 1981). This was demonstrated empirically by Allen et al. (1992) for mammals in mountainous regions in south-western USA, Beier et al. (2002) for birds in forest fragments in West Africa, Biedermann (2003) for reptiles, birds, mammals, and insects, and Baguette and Stevens (2013) for European butterflies.

Feeding guild or trophic levels should affect the MAR as well, since the availability and energetic contents of food affect the area required by individuals. Hechinger et al. (2011) have shown that inclusion of trophic level is imperative when searching for scaling rules for energy use, and further evidence supports the importance of feeding guild in describing spatial attributes such as home range size and dispersal distance (Harestad and Bunnell, 1979; Kelt and Van Vuren, 2001; Lindstedt et al., 1986; Mace et al., 1982; Ottaviani et al., 2006; Sutherland et al., 2000). Yet some studies found inconsistent patterns with respect to trophic levels (Dardanelli et al., 2006; Ottaviani et al., 2006) – possibly because food availability (and other essential ecological resources), which relates to trophic level (albeit loosely), affects space use as well.

Species' demography is another factor which likely affects area requirements, where "K", or slow species along the slow-fast continuum (e.g. Burton et al., 2010), might require larger areas than "r", or fast species. This relates to their larger body size (Biedermann et al., 1999; Henle et al., 2004a) as well as longer life which may entail greater resource limitation. Note, however, that demographic stochasticity and population responses to environmental stochasticity play important roles in determining population viability, and hence area requirements, with higher variability leading to larger area requirements (Shaffer, 1987; Soulé, 1987; Thomas, 1990).

Species' demography is affected also by dispersal traits and the response of species to landscape characteristics (Burton et al., 2010). Biedermann (2003) suggested that predictions of area requirements could be improved by considering variables such as patch isolation and species traits, and Swihart et al. (2003) found that body size was an inferior predictor of tolerance of fragmentation compared to niche breadth and proximity to range boundary. Baguette and Stevens (2013) have shown that four life history traits (thermal requirements, mating strategy, capital- versus income-breeding strategy and affiliation with ants), alongside wing size, substantially improve the capacity to explain variability in the area requirements of European butterflies. Most of these traits strongly relate to energy and space-use. These examples demonstrate the challenges in deriving an area estimate that is truly independent of the effects of patch networks (e.g., metapopulations), including landscape connectivity.

As the traits of species relate to their taxonomic affiliation or phylogeny, its consideration could further enhance the capacity to explain variability in MAR estimates. Especially if considering different taxa, one must account for very different means of thermal regulation (ectotherms versus endotherms) or locomotion, that could result in large differences in MAR versus body mass. Evidence for cross-taxa differences was found by Silva et al. (1997), showing that birds have a much lower density per body mass compared to mammals and thus likely their area requirements should be larger. Even within a taxonomic group (across butterfly species), inclusion of phylogeny as a variable had slightly contributed to improving MAR predictions (Baguette and Stevens, 2013).