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Short Note

The representation potential of raptors for globally important nature conservation areas

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ABSTRACT

Stemming from a pervasive lack of knowledge on biodiversity, important areas for conservation are typically identified using a subset of well known species, commonly termed surrogate or indicator groups. Birds have been commonly used as biodiversity surrogates due to the good level of knowledge on their taxonomy, ecology and distribution. Raptors in particular have been often proposed as an effective surrogate for other biodiversity based on their dietary diversity, being at the top of the food chain, their preference for highly productive areas, their generally threatened status and high public appeal. However, so far the surrogacy effectiveness of raptors has been largely studied locally or using a narrow selection of surrogate and surrogated taxa.

Here we use a spatial conservation planning tool to quantify the surrogacy performance of raptors, overall and by different raptor groups (hawks and eagles, falcons, vultures, owls) to represent important biodiversity areas (such as IUCN protected areas and key biodiversity areas), wilderness areas and the worlds ecoregions. We compared the above surrogacy performance with that of all other non-raptor avian species.

We show that raptors perform marginally worse than all other avian species in representing important biodiversity areas and ecoregions. However, raptors representation for wilderness areas was similar or slightly better compared to that of using all non-raptor birds. We also report a large variation in the representation performance by the four raptor groups. Falcons had a particularly high potential in representing protected areas and wilderness areas, equaling or largely surpassing the representation potential provided by all raptors and all other non-raptor birds.

Overall, the results suggest that raptors, and particularly falcons, can perform relatively well in representing some important areas for conservation, such as protected areas and wilderness areas, but are relatively poor surrogates for key biodiversity areas and ecoregions. These rather contrasting results call for caution on the use of raptors as global surrogates of wider biodiversity.

1. Introduction

Knowledge about biodiversity and its distribution, commonly referred to as the Linnean and Wallacean shortfalls, is very limited (Whittaker et al., 2005). Consequently, the identification of priority areas for biodiversity conservation often relies on a narrow selection of species acting as surrogates of wider biodiversity (the surrogacy concept; Caro, 2010). However, typically this narrow selection of surrogate species (i.e. typically well monitored species used to represent other species, the surrogated species, in attaining a conservation objective; Caro, 2010) is assumed, implicitly or explicitly, to be an effective surrogate of biodiversity (Larsen et al., 2012). This assumption often remains untested, leaving us in an uncertain and potentially misleading situation of false belief that prioritizing conservation

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towards areas important for specific surrogate taxa does have an impact on a much wider range of species.

Birds are commonly used as surrogates of biodiversity owing to the large and typically high quality relevant information on their taxonomy and distribution, their broad appeal to the public and often conspicuous nature (Larsen et al., 2012). Among birds, raptors have been particularly highlighted as a potentially effective surrogate group for wider biodiversity (Sergio et al., 2006, 2008). Raptors, as most large predators, are generally globally threatened by increasing human activities, with populations of several species, like many vultures, rapidly declining (McClure et al., 2018). Being at the top of ecological food chains, raptors may act as sentinels of environmental change, giving early warnings of potential anthropogenic impacts on biodiversity (Burfield, 2008; Donázar et al., 2016). Raptors preference for a diversity of prey across the food chain, and for highly productive areas, may facilitate their role as umbrella for other biodiversity (Sergio et al., 2008; Burgas et al., 2014). Moreover, due to their appeal and charisma, raptors are widely appreciated by the public and well studied by scientists (Buechley et al., 2019), and can act as flagship species, leveraging funds to help preserve biodiversity as a whole (Donázar et al., 2016; McGowan et al., 2020).

While local studies have attempted to quantify the surrogacy effectiveness of raptors at the local scale and/or with a narrow selection of surrogate and surrogated species, a global analysis of the surrogacy effectiveness of raptors is still lacking. Most importantly, the studies conducted so far have exclusively focused on raptor representation of other species (Sergio et al., 2006, 2008; Burgas et al., 2014), whereas none have addressed raptor representation potential of important conservation areas, that is, those areas that harbor species and ecosystems of conservation concern.

As the occurrence of raptors is typically associated with areas of high species richness and intact ecosystems (Sergio et al., 2008), here we aim to quantify how well raptors can represent globally important terrestrial areas for biodiversity conservation as well as wild areas. Using a global conservation prioritization approach, we first compare the effectiveness of raptors with that of all other non-raptor bird species in representing important areas for biodiversity conservation, such as protected areas, key biodiversity areas, wilderness areas, terrestrial ecoregions. Next, within the raptor guild, we also aim to compare the representation of those areas by four distinct sub-groups of raptor species differing in their ecology, life-history and extinction risk, namely hawks and eagles, falcons, owls and vultures. This grouping follows the rationale and approach of Buechley et al. (2019).

2. Material and methods

2.1. Study region and surrogate groups

The target region for this study includes all terrestrial areas of the world.

As surrogate taxa we considered two main groups of birds, all raptors, orders Accipitriformes, Cathartiformes, Falconiformes, Strigiformes (n = 557 species) and all other non-raptor birds (n = 10353). Within raptors, we also considered four contrasting groups with distinctive ecology, life-history, and conservation status: Hawks and eagles, falcons, owls, vultures (n = 234, 64, 236, 23). The selection of raptors and their sub-groups strictly follows that used by two recent studies (McClure et al., 2018; Buechley et al., 2019). Moreover, the selection of all species as detailed above was conditional on the availability of their digitized range maps as provided by BirdLife International and NatureServe (2015) and was restricted to species whose range overlaps, at least partly, terrestrial areas. For all surrogate taxa, we only used the breeding and resident range of each species. This seasonal restriction aims to avoid noise stemming from the species being only partly present in an area, and also because most of the conservation planning studies focus on the breeding and resident range of the species (e.g. Montesino Pouzols et al., 2014; Santangeli et al., 2019a, 2019b, 2020). The range of each species was rasterized to a resolution of 50 km × 50 km. This resolution was deemed coarse enough to minimize the impact of both commission and omission errors associated to the species ranges. Changes in the resolution were however found to have only a marginal impact on the results of such types of analyses (Montesino Pouzols et al., 2014).

2.2. Surrogated groups

As surrogated groups, we focused on areas widely recognized as priority for global biodiversity conservation, wilderness areas and the diversity of the world's ecoregions. The protected areas (hereafter PA) of the global terrestrial realm are established under the International Union for Conservation of Nature (IUCN) with the aim to effectively conserve the composition, structure, function and evolutionary potential of biodiversity (Dudley, 2008). These areas are widely recognized as strongholds for biodiversity conservation (Watson et al., 2014). For the purpose of this study, we considered all PAs (i.e. all IUCN PA categories together), as well as the strictly PAs (IUCN categories I to IV) only as a separate layer. While strictly PAs are included within all PAs, the rationale for considering also the strictly protected areas is because in these sites development is not allowed and access often restricted, thereby they may represent even more important strongholds for biodiversity conservation under strong human pressures (Rehbein et al., 2020).

Similarly, within but also outside of the current PA network, Key Biodiversity Areas (KBA) are identified as essential sites to avert species extinctions, being often refugia for rare and endangered biodiversity (Newbold et al., 2015). Wilderness areas are identified as the last remaining intact ecosystems globally, which function naturally and support a disproportionate range of ecosystem services and biodiversity (Watson and Venter, 2017). Moreover, representative examples of the worlds ecosystems have been mapped through the identification of the global ecoregions which harbor exceptional biodiversity (Olson et al., 2001). In this study, we thus collected spatial data on the world's PAs (from www.protectedplanet.net), KBAs (BirdLife International, 2019), wilderness areas (Last of the Wild Data Version 2 2005) and the worlds terrestrial ecoregions (Olson et al., 2001). As for the surrogate groups, also these surrogated layers were rasterized to the same resolution of 50 km × 50 km. While some of these surrogated layers inevitably would overlap in space, such as KBAs and PAs, they are spatially separated enough, and are selected based on different criteria with different interpretations that they would allow meaningful comparisons.

2.3. Surrogacy analyses

In order to assess the effectiveness of raptors as surrogates of priority areas for biodiversity and ecosystem conservation, we used the spatial conservation planning software Zonation v.4 (Moilanen et al., 2014). Zonation produces balanced ranking of conservation priorities over a study landscape by iteratively removing the landscape unit of least conservation value while accounting for the remaining distributions of features (Moilanen et al., 2005). The removal rule for landscape units chosen here was the additive benefit function, as this has been recommended as the most robust function when running surrogacy analyses (Di Minin and Moilanen, 2014; Moilanen et al., 2014). Essentially, by assigning a weight > 0 to the surrogate features, and a weight of zero to the surrogated features, the algorithm identifies the key priority areas for the surrogate features and simultaneously calculates the distribution coverage remaining for each surrogated feature at each step of the iteration. In our case, across all the zonation runs (see details below), we assigned an equal weight of one to all surrogate features, and a weight of zero to all surrogated features. We set up six different zonation runs, in each the surrogate group consisted in turn in raptors only, all other non-raptor bird species, as well as four raptor sub-groups: Hawks and eagles, falcons, owls, vultures. The set of surrogated features was instead the same across the six runs and consisted on one layer for the KBAs, one for the wilderness areas, one for all PAs (including all six categories of PAs as defined by IUCN) and one for the strictly PAs (IUCN categories I to IV), and one layer for each of the 816 terrestrial ecoregions. The zonation outcome consists of maps of the priority ranking as well as performance curves that define the coverage of each of the surrogated features for each proportion of the landscape virtually protected according to the priority ranking obtained from the surrogate features. That is, how much each surrogated feature is covered when priority areas for the surrogate features are protected at a defined level, e.g. from protecting only the top 5% identified priorities for surrogates to much more. Thus, in order to expose the differences in the surrogacy potential of the six different surrogate groups, we show the performance curves of these in relation to each of the surrogated features. We also closely highlight differences in surrogacy potential when the top ranked 5, 17 and 30% of the landscape is protected based on priorities sought by considering in turn each of the six surrogate groups.

3. Results

The representation of PAs (overall as well as only the strict PAs) and KBAs was generally similar, or slightly lower (coverage loss by about 1 to 3%) when priorities are identified using raptors as compared to all other non-raptor birds (Figs. 1 and 2). Conversely, raptors in general performed similarly or slightly better (by 1% increase in coverage) than all other non-raptor birds in representing wilderness areas, but largely worse (coverage loss by up to 9%) in representing ecoregions (Figs. 1 and 2). Measurable differences in surrogacy performance between the four groups of raptors are evident, with falcons outperforming all other raptor and also non-raptor groups in representing PAs and especially wilderness areas.

4. Discussion

We show that the coverage of important biodiversity (i.e. PAs and KBAs) areas is marginally lower (loss in coverage of about 1 to 3%) when priorities are identified using all raptors as compared to using all other avian non-raptor species. Overall, this loss in representation varied according to the surrogated group, being highest, when considering strictly PAs and especially ecoregions (up to 9% representation loss when using raptors). Conversely, raptor priorities allow a similar or slightly higher coverage of wilderness areas compared to priorities identified using all other non-raptor bird species. Interestingly, the surrogacy potential effectiveness varied greatly among the different raptor groups. Falcons had a particularly high potential in representing PAs and wilderness areas, equaling or largely surpassing the representation potential provided by all raptors and all other birds.

The finding that conservation priority areas identified based on all raptors aid the coverage of important biodiversity areas at almost the same efficiency as when using all other non-raptor bird species can have practical implications. This suggests that it may be possible to use the limited number (n = 557) of raptor species, which are well known and often with dedicated monitoring and research programs (Burfield, 2008), to identify important biodiversity areas globally instead of using all other over 10 000 avian species. In a local study, Sergio et al., (2006) found that a network of protected areas was most efficient in achieving biodiversity coverage when based on raptors as compared to species at lower trophic levels. That study was based on six surrogate species, of

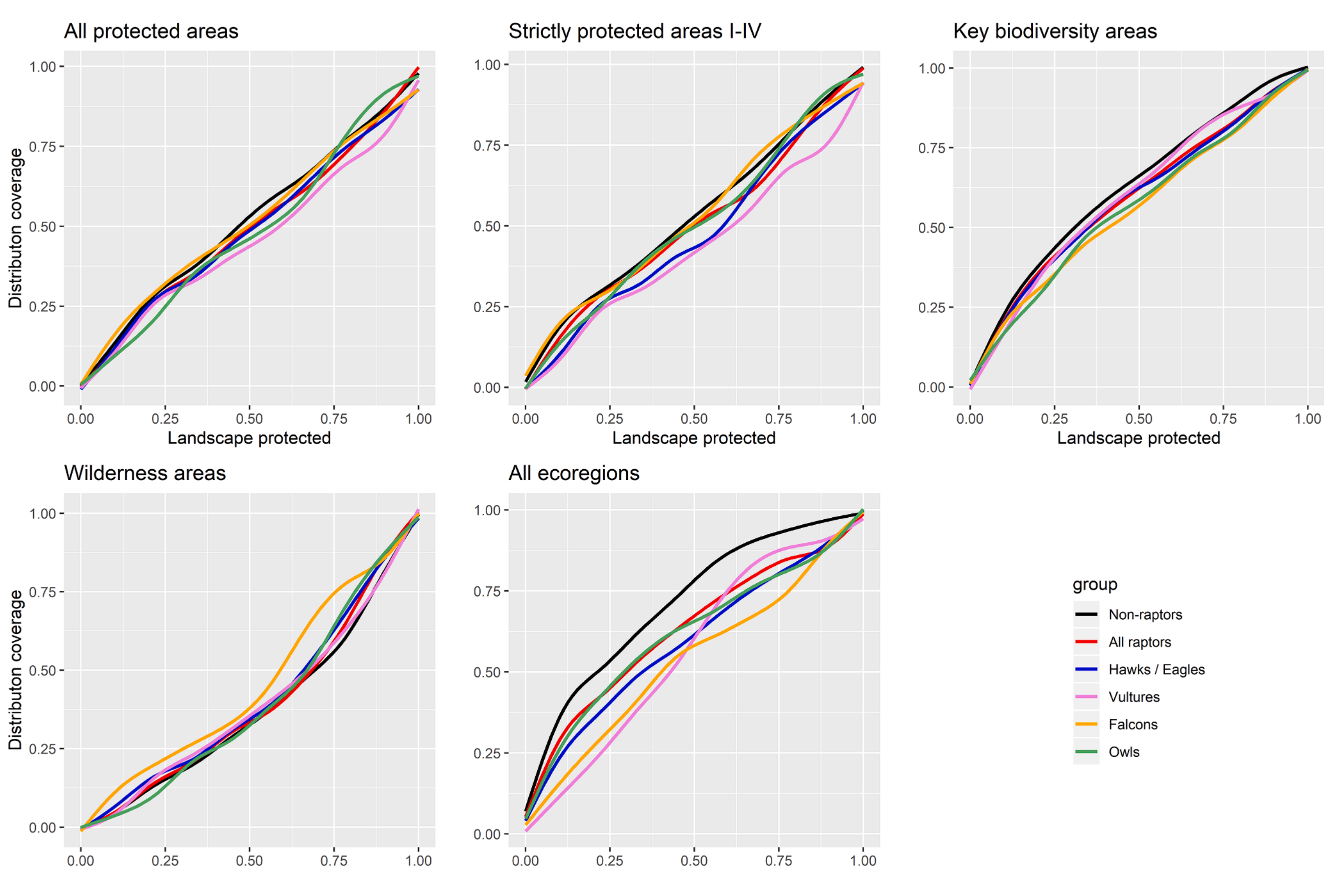

Fig. 1. Zonation performance curves representing the increase in coverage of each biodiversity area (Y-axis in each of the 5 panels) as the hypothetical proportion of landscape protected increases (X-axis). Each panel shows the performance in covering each of the five biodiversity areas (IUCN PAs, IUCN strictly protected areas categories I to IV, key biodiversity areas, wilderness areas and the worlds ecoregions) by each of the six surrogate groups considered: Non-raptor bird species, all raptors combined, hawks and eagles, vultures, falcons and owls.

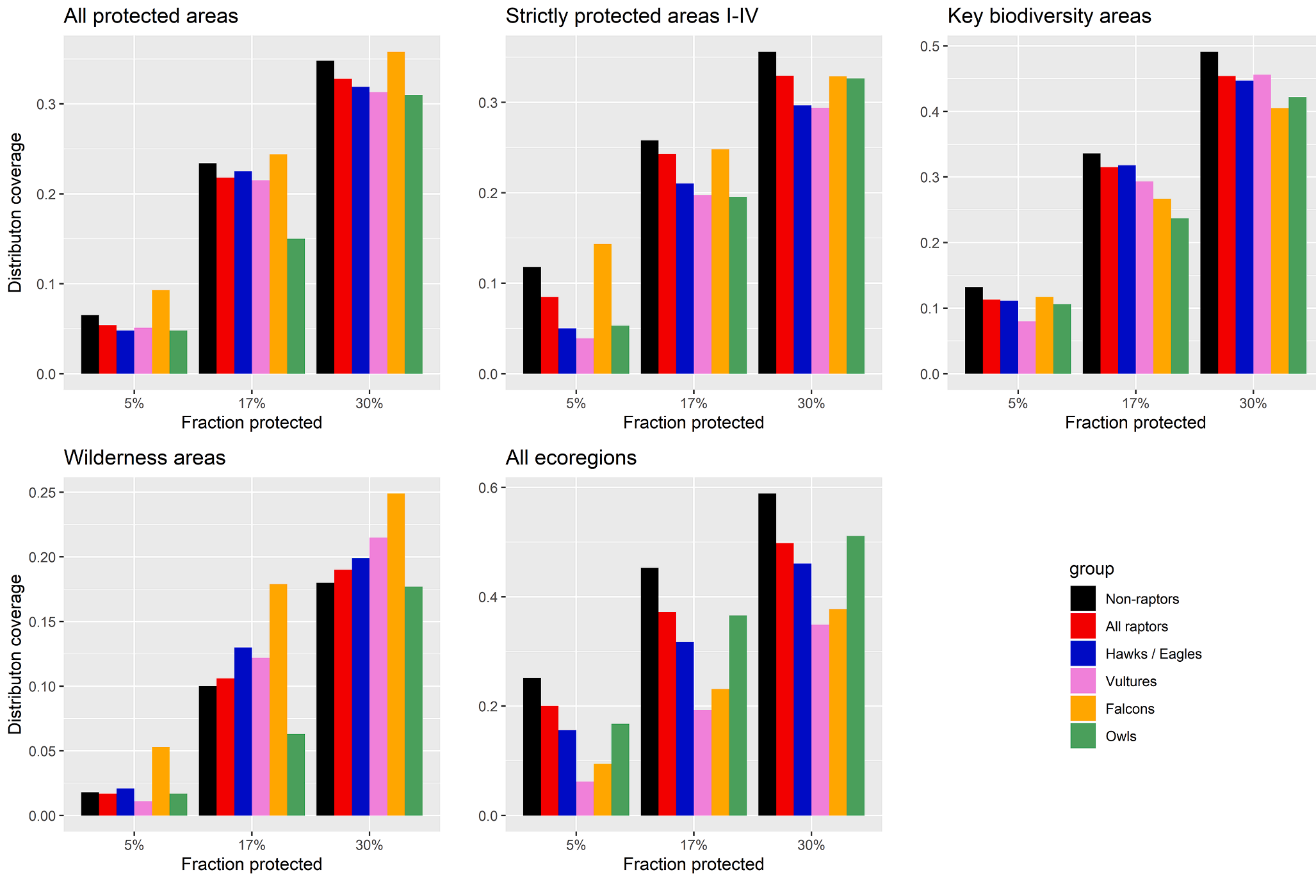

Fig. 2. Representation of the five biodiversity areas (IUCN PAs, IUCN strictly protected area categories I to IV, key biodiversity areas, wilderness areas and the world's ecoregions) by each of the six surrogate groups considered (non-raptor bird species, all raptors combined, hawks and eagles, vultures, falcons and owls) when 5, 17 and 30% of a hypothetical landscape would be protected. Please note the change in scale of the y-axis between the panels.

which one is a hawk (*Accipiter gentilis*) and the others are owls. Another similar study found the same hawk species to perform well in indicating areas of high biodiversity, also outperforming an owl species (*Strix Uralensis*; Burgas et al., 2014). Our results, while bearing in mind the differences in the approach, seem to partly align to those from earlier studies, particularly with regards to the surrogacy performance of hawks and eagles, and falcons. We show that falcons in particular outperform all other raptors and non raptor birds in representing PAs overall, and also the strictly PAs when the top 5% priorities are considered. Global falcon richness and conservation priority areas are strongly biased towards highly productive regions in the tropics (Buechley et al., 2019). These areas, being often under severe pressures from anthropogenic activities, also include a large number of PAs, which may explain their increased coverage when priorities are set based on falcons as compared to other groups.

Falcons in particular, but also other groups of diurnal raptors, including hawks and eagles, and vultures, were found to outperform all other non-raptor birds and owls in representing wilderness areas. This result may likely stem from the long-history of persecution, particularly on diurnal raptors (Thiollay, 2006; Amar et al., 2012; Pohja-Mykra et al., 2012), that may have shaped their preference towards the most pristine, remote and wild places left on Earth. At the same time, intact ecosystems may also offer wider nesting and foraging resources, with an overall larger carrying capacity of these environments compared to more degraded ones (Watson et al., 2018), thereby supporting larger populations of diurnal raptors compared to other groups.

Raptors in general performed worse than all other non-raptor species in representing the world's ecoregions. This finding may stem from the fact that ecoregions are homogeneously scattered across the globe, therefore a larger set of surrogate species with different life-histories, ecology and biogeography, such as the non-raptor category in this study, makes it more likely to represent wide regions globally as compared to a narrow selection of surrogate species (Larsen et al., 2012), such as raptors. This assertion is also supported by our finding showing that owls perform best among all raptor groups in representing ecoregions. Owls richness is among the most widely distributed globally of all the four raptor groups (Buechley et al., 2019), which may allow this group to cover most of the ecoregions.

This is the first attempt to quantify the surrogacy potential of raptors at a global scale. Similar analyses have been conducted at the global level using the world's carnivores (Di Minin et al., 2016). The results from such global analyses should thus be interpreted with caution, as they can highlight broad patterns that need to be confirmed locally or regionally using higher-resolution data. For example, here we used a rather coarse resolution of 50 km $\times$ 50 km. While this resolution may reduce omission errors (when the species is mistakenly thought to be absent) in the distribution data, it may still suffer from commission errors (when the species is mistakenly thought to be present). Beyond the local studies which are already available (Sergio et al., 2006, 2008; Burgas et al., 2014; Di Minin and Moilanen, 2014), it will be thus important to perform surrogacy analyses of the type presented here at the national or regional level and by considering a broader taxonomic diversity, including non-avian species. This can be possible by harnessing the unprecedented information on species ecology, life-history and biogeography that is now made available thanks to citizen science programs and open data platforms such as e-bird and Global Biodiversity Information Facility (Fink et al., 2020; GBIF.org, 2020).

5. Conclusions

Under a pervasive shortage of knowledge on species ecology and distribution, and a lack of resources for monitoring and conservation, good surrogates for biodiversity can help to prioritise areas for conservation and preventing species extinction. Raptors, and particularly falcons, perform relatively well in representing PAs and especially wilderness areas, but are relatively poor surrogates for KBAs and ecoregions. As such, we caution on the use of raptors as global surrogates of wider biodiversity, as their representation performance clearly varies based on the group of raptors and the type of conservation area considered.

CRediT authorship contribution statement

A. Santangeli: Conceptualization, Methodology, Investigation, Visualization, Writing - original draft, Writing - review & editing. **M. Girardello:** Conceptualization, Methodology, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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