Received: 5 December 2022 | Revised: 5 October 2023 | Accepted: 31 October 2023

DOI: 10.1111/cobi.14221

Conservation Biology

CONTRIBUTED PAPER

Combining camera trap surveys and IUCN range maps to improve knowledge of species distributions

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Article Impact Statement: Combining range maps with accumulating data from ground-based biodiversity sensors provides a knowledge base for conservation mapping.

Funding information
Natural Sciences and Engineering Council of Canada and Canada Research Chairs program; China Scholarships Council, Grant/Award Number: 201708180006; McIntire Stennis project, Grant/Award Number: WVA00124; Research Council of Norway, Grant/Award Number: NFR301075

Abstract
Reliable maps of species distributions are fundamental for biodiversity research and conservation. The International Union for Conservation of Nature (IUCN) range maps are widely recognized as authoritative representations of species' geographic limits, yet they might not always align with actual occurrence data. In recent area of habitat (AOH) maps, areas that are not habitat have been removed from IUCN ranges to reduce commission errors, but their concordance with actual species occurrence also remains untested. We tested concordance between occurrences recorded in camera trap surveys and predicted occurrences from the IUCN and AOH maps for 510 medium- to large-bodied mammalian species in 80 camera trap sampling areas. Across all areas, cameras detected only 39% of species expected to occur based on IUCN ranges and AOH maps; 85% of the IUCN only mismatches occurred within 200 km of range edges. Only 4% of species occurrences were detected by cameras outside IUCN ranges. The probability of mismatches between cameras and the IUCN range was significantly higher for smaller-bodied mammals and habitat specialists in the Neotropics and Indomalaya and in areas with shorter canopy forests. Our findings suggest that range and AOH maps rarely underrepresent areas where species occur, but they may more often overrepresent ranges by including areas where a species may be absent, particularly at range edges. We suggest that combining range maps with data from ground-based biodiversity sensors, such as camera traps, provides a richer knowledge base for conservation mapping and planning.

KEYWORDS
camera trap, IUCN, mammal distribution, mammal occurrence, range map, species distributions

Combinación de censos con fototrampas y mapas de extensión de la UICN para incrementar el conocimiento sobre la distribución de las especies

Resumen: Los mapas confiables de la distribución de las especies son fundamentales para la investigación y conservación de la biodiversidad. Los mapas de distribución de la Unión Internacional para la Conservación de la Naturaleza (UICN) están reconocidos como representaciones de autoridad de los límites geográficos de las especies, aunque no siempre se alinean con los datos actuales de su presencia. En los mapas recientes de área de hábitat (ADH), las áreas que no son hábitat han sido eliminadas de la distribución de la UICN para reducir los errores de comisión, pero su concordancia con la presencia actual de las especies tampoco ha sido analizada. Analizamos la concordancia entre la presencia registrada por los censos de fototrampas y pronosticamos la presencia a partir de los mapas de la UICN y de ADH de 510 especies de mamíferos de talla mediana a grande en 80 áreas de muestreo de fototrampas. Las cámaras detectaron sólo el 39% de las especies esperadas con base en la distribución de la UICN y los mapas de ADH en todas las áreas; el 85% de las disparidades con la UICN ocurrieron dentro de los 200 km a partir del borde de la distribución. Sólo el 4% de la presencia de las especies fue detectada por las cámaras ubicadas fuera de la distribución de la UICN. La probabilidad de disparidad entre las cámaras y la UICN fue significativamente mayor para los mamíferos de talla pequeña y para los especialistas de hábitat en las regiones Neotropical e Indomalaya y en áreas con doseles forestales más bajos. Nuestros hallazgos sugieren que los mapas de distribución y ADH pocas veces subrepresentan las áreas con presencia de las especies, pero con frecuencia pueden sobrerrepresentar la distribución al incluir áreas en donde las especies pueden estar ausentes, en particular los bordes de la distribución. Sugerimos que la combinación de los mapas de distribución con los sensores de biodiversidad en tierra, como las fototrampas, proporciona una base más rica de conocimiento para el mapeo y la planeación de la conservación.

PALABRAS CLAVE

distribución de especies, distribución de mamíferos, fototrampas, mapa de distribución, presencia de mamíferos, UICN

摘要

可靠的物种分布图对生物多样性研究和保护至关重要。世界自然保护联盟(IUCN)的物种分布范围图被广泛认为是物种分布界限的权威表现, 但它们可能并不总是与实际出现数据一致。在最近的栖息地面积(AOH)图中, 非栖息地区域已从IUCN范围内移除, 以减少错误, 但它们与实际出现数据的一致性也未经测试。我们测试了全球80个红外相机调查区域中获取的510种中到大型兽类的出现数据与IUCN和AOH分布图之间的一致性。在所有区域中, 相机仅检测到基于IUCN范围和AOH图预期出现的39%的物种;85%的“仅IUCN类不匹配”发生在分布范围边缘的200公里内。仅有4%的物种被红外相机在IUCN分布范围外检测到。此种相机与IUCN范围之间的不匹配, 更易发于在新热带和印度马来亚以及在短冠层森林地区较小体型的哺乳动物和特化种。我们的发现表明, 分布范围和AOH地图很少低估物种出现的区域, 但它们可能高估物种的范围, 这种高估会包括物种缺失的区域, 尤其是在范围边缘。我们的研究显示, 将分布范围图与地面生物多样性传感器的数据相结合, 可为保护制图和规划提供更详实的知识基础。

结合红外相机调查和IUCN分布范围图以提升物种分布的认识

物种分布, 分布范围图, 世界自然保护联盟, 兽类分布, 红外相机, 兽类出现

INTRODUCTION

Understanding and predicting species distributions are fundamental components of biodiversity conservation and management. The assessment of species conservation status and subsequent development of conservation plans often depend on accurate range maps (Pimm et al., 2014; Zhu et al., 2021). Similarly, geographic priorities for conservation funding may be influenced by the use of range maps to delineate areas with high biodiversity or harboring threatened and endemic species

(Maxwell et al., 2020). For example, spatial patterns of the intensity of threats driving global biodiversity loss for terrestrial vertebrates have been identified based on range maps (Harfoot et al., 2021). Likewise, multiple iterations of global priority regions for mammalian conservation have been based on the known or predicted distribution of threatened species (Brum et al., 2017; Jenkins et al., 2013; Schipper et al., 2008). Inaccurate distribution maps could lead to erroneous conclusions regarding patterns of species richness and risk, thereby undermining the prioritization of conservation efforts in areas of high or threatened biodiversity (Hughes et al., 2021; Hurlbert & Jetz, 2007; Hurlbert & White, 2005) and the management of individual species (Garshelis et al., 2022; McShea et al., 2022).

Range maps were initially established to illustrate the geographic limits of species for taxonomic purposes but have been adapted for use in conservation assessment and macroecology (Marsh et al., 2022). In particular, range maps compiled by the International Union for Conservation of Nature (IUCN) are considered the gold standard for assessing species distributions and biodiversity trends (Brooks et al., 2019) and are frequently used to inform conservation efforts (Boitani et al., 2011). For example, these maps have been used to identify areas of high terrestrial diversity (Jenkins et al., 2013; Jung et al., 2021; Mason et al., 2020) and to assess the performance of the global protected area system in covering vertebrate geographic ranges (Pimm et al., 2018; Pouzols et al., 2014).

These maps are designed to represent the distributional limits of each species while minimizing omission errors (i.e., false absence of a species) at the cost of commission errors (i.e., false presence of a species). To create these maps, known occurrences of the species, expert knowledge of the taxon and its range, and information about habitat and elevation limits (IUCN, 2021) are used. However, comprehensive empirical data are limited for many species; therefore, range maps may be prone to bias and error (Drescher et al., 2013; Merow et al., 2017). The IUCN range maps may overestimate species distributions by including outdated or incorrect assessments of occurrence areas (Boitani et al., 2011; Rondinini et al., 2006). Range overestimation may result from range maps simply reflecting the extent of occurrence (EOO), defined as "the area contained within the shortest continuous imaginary boundary, which can be drawn to encompass all the known, inferred, or projected sites of present occurrence of a taxon, excluding cases of vagrancy" (IUCN, 2021). The EOO is often determined using a minimum convex polygon drawn around all known occurrence points (IUCN, 2021). Consequently, the resulting maps may be too liberal in extent because they include contiguous areas with similar landscapes that are uninhabited by the target species (Hurlbert & White, 2005). Alternatively, IUCN ranges may underestimate species distributions (Boitani et al., 2011; Rondinini et al., 2006). For instance, experts may conservatively restrict putative occurrences to areas with certain habitat characteristics, presumably, habitat where the species is known to have occurred rather than is suspected to occur, or disregard occurrences far beyond confirmed occurrence locations (Herkt et al., 2017; Schipper et al., 2008).

Therefore, reducing commission errors in range maps while minimizing omission errors is a critical step in accurately assessing species' distributions. One approach to achieving this is through the use of deductive modeling as it is applied, for example, in the area of habitat (AOH) approach. The AOH is defined as the habitat in the species' range and is derived by removing areas that are not habitat based on habitat and environmental information, such as land cover and elevation (Brooks et al., 2019; Lumbierres et al., 2022). Although AOH maps have recently become available for most mammals (Lumbierres et al., 2022), their large-scale validation has yet to be conducted (Ficetola et al., 2014; Rondinini et al., 2011). Furthermore, it remains unclear whether the AOH approach reduces commission and omission errors compared with the original IUCN range maps used to generate the AOH maps.

Previous researchers have compared IUCN range maps with species occurrence data derived from point sampling and found range maps are accurate for amphibians (Ficetola et al., 2014) but to often overestimate ranges for birds (Hurlbert & Jetz, 2007; Ramesh et al., 2017) and other taxa (Hughes, 2019; Hughes et al., 2021). However, inaccurate locality data can adversely affect the accuracy of IUCN maps (e.g., Hjarding et al., 2015). There is a need for IUCN mapping to take advantage of extensive high-quality occurrence data generated by the rapidly increasing use of ground-based biodiversity sensors, such as camera traps, which have become a prominent method for surveying medium- to large-bodied mammals (Ahumada et al., 2020; Hughes et al., 2021; Rondinini et al., 2011; Steenweg et al., 2017). Most studies of mammalian range maps have focused on underestimation, which can be quantified by documenting species occurrences outside their estimated range (Ficetola et al., 2014; Ramesh et al., 2017). By contrast, determining range overestimation is more difficult because confirming the absence of species is challenging and requires a large sampling effort (Dahal et al., 2021). For example, Li et al. (2020) used camera traps to document the likely absence of carnivores in several protected areas in China by surveying all major vegetation types over 3 years (> 5000 camera trap days in each protected area). Camera traps and other species-level biodiversity sensing technologies show great promise for faster assessment of potential over- or underestimation of species distributions (Kissling et al., 2018).

Estimation errors in species ranges may be associated with species ecology (Hughes, 2019; Jetz et al., 2008) and the extent of existing research on a given species (Ficetola et al., 2014; Martin et al., 2012). For example, small-bodied species can have limited ranges, and administrative boundaries may be used to delimit their range, especially in cases where ecological data are lacking. One might thus predict that the discrepancy between range maps and occurrence data may be higher for small-bodied than large-bodied species (Hughes, 2019). Additionally, the range maps more accurately capture the distributions of generalist species, which have wide ranges and broad habitats or environmental tolerances, compared to those of specialist taxa with narrow ranges (Wilson et al., 2004). Furthermore, the probability of detecting a given species during ecological field surveys can influence the understanding of its occurrence.