A global indicator of utilized wildlife populations: Regional trends and the impact of management

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Summary

Sustainable use of wildlife is a core aspiration of biodiversity conservation but is the subject of intense debate in the scientific literature, including the extent to which use is impacting species and whether management can mitigate any impact. Although positive and negative outcomes of sustainable use are known for specific taxa or local communities, a global and regional picture of trends in wildlife populations in use is lacking. We use a global dataset of more than 11,000 time series to derive indices of “utilized” and “not utilized” wildlife populations. Our results show that population trends globally are negative on average but that utilized populations tend to decline more rapidly, especially in Africa and the Americas. Crucially, where populations are managed, they are more likely to be increasing. This evidence can inform global biodiversity assessments and provide an operational indicator to track progress toward the Post-2020 Global Biodiversity Framework.

Data and code availability

The population data used in this paper are stored in the online database at www.livingplanetindex.org. The utilization and management data are not in the public database yet because they are being used in another manuscript. We provided a list of species from each category on our Figshare site (https://doi.org/10.6084/m9.figshare.17085998.v1). Part of the dataset includes confidential data that have been shared under an agreement and are not publicly available. In this case, the species details were anonymized, but the remaining metadata are available. The R package used for LPI analysis is available at https://github.com/Zoological-Society-of-London/rlpi.

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Introduction

Direct use of wild species is one of the ways in which biodiversity is fundamental to the subsistence and livelihoods of people.[1–6] Consequently, any unsustainable impact of anthropogenic activity on species, particularly those that are important for peoples’ livelihoods or wellbeing, presents a threat to those species and ecosystems as well as to human health and development.[7–9] Moreover, any prohibition of species use can have serious consequences for people, particularly risks to food security,[10] so striving for sustainable use is key. The importance of sustainable use of resources has been recognized as central to biodiversity conservation and is embedded in international bodies and conventions for nature.[11–15] However, progress toward achieving the sustainable use of resources globally remains a challenge. As part of the Convention on Biological Diversity’s Strategic Plan for Biodiversity 2011–20, Aichi target 4.2 was set to keep the impacts of use of natural resources well within safe ecological limits by 2020. Progress toward this target was assessed as “poor” in the final decadal review of the Aichi targets,[16] and an assessment of the research and management behind the use of wild meat found limited progress toward sustainability.[9]

Overexploitation is a highly prevalent threat to biodiversity,[9,17] with evidence showing that harvesting, logging, fishing, and hunting often occur at unsustainable levels.[3] Together with activities such as logging and agriculture, hunting and trapping have a higher average probability of impacting species compared with other threats, with hotspots of this threat largely concentrated in the tropics.[18] Combined pressures of land use change and hunting have reduced the distribution of terrestrial tropical mammals, with large-bodied species the most impacted.[19] The effect of hunting, especially for commercial use, has been implicated in the population decline of 97 tropical bird and 254 tropical mammal species,[20] and a global assessments of 301 terrestrial mammals threatened with extinction lists hunting as a primary threat.[21] In the marine realm, the percentage of commercial fish stocks that are within biologically sustainable levels decreased from 90% to 65.8% between 1974 and 2017,[22] although recent trends suggest that stocks that are scientifically assessed are now increasing on average, and intensively managed stocks are faring better.[23]

The role of wildlife management is also evident in some notable examples on land. The rise of community-based natural resource management over 30 years ago, which may include managing the use of species in place of more centralized wildlife management policies, has yielded examples of economic and ecological benefits in many countries.[6,24,25] Similarly, even in regions where utilized species have been heavily impacted over centuries,[26,27] examples of recoveries have been recorded often as a result of efforts to stem unsustainable use.[28,29]

To understand how species in use (hereafter called “utilized species” or “utilized populations”; see “definitions” in experimental procedures) are faring at the global scale, existing indicators have largely focused on the species level; e.g., the Red List Index for internationally traded species or those used for food and medicine and the Living Planet Index for utilized species.[30,31] These indices cannot integrate any potential heterogeneity of impacts of use because of factors influencing individual populations within the same species differently, as identified for commercial harvesting.[32] In the marine environment, indicators have measured fishing pressure and the proportion of fish stocks that are unsustainable.[22] At a smaller scale, harvest models are used to assess sustainability and the status of a utilized population, which can provide detailed information on how a population and ecosystem are impacted by use and inform local management.[33]

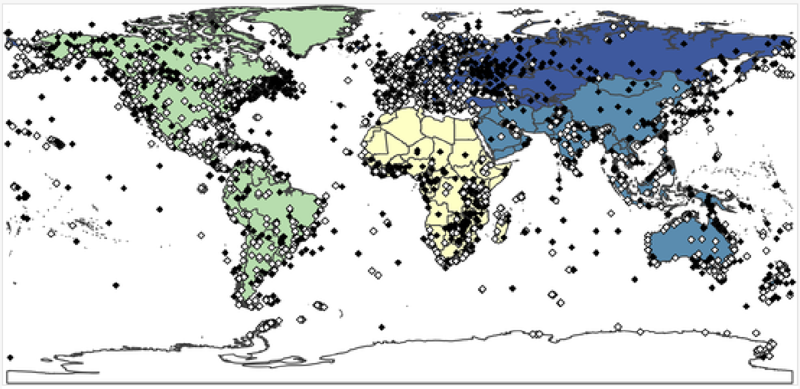
We propose that global and large regional views are needed and present a population-based approach with information on utilization at the site-level aggregated to the global scale. This approach can provide important insights that are not available at the level of species assessments through incorporating population-level information on use, threats, and management into the analysis. To follow this approach, we develop an indicator of utilized vertebrate populations following the method used to calculate the Living Planet Index (LPI),[34–36] a multi-species indicator of relative abundance based on population trends of vertebrates used to monitor progress toward international and national biodiversity targets.[37–39] We explore differences in these trends with respect to taxonomic groups and Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) regions and test the sensitivity of the indicator to data quality. The Living Planet Database, which underpins the index, collates data collected locally from around the world, which can be divided in different ways to deliver a suite of indices of species population change; the data are also suitable for within-species comparisons and identification of correlates predicting trends using mixed-effect models.[40,41] We then use this to contrast trends in utilized populations with those that are not used for the complete set of species in the dataset and only for species with data for utilized and non-utilized populations (“matched”). Finally, using mixed-effect models, we explore the role of targeted management (see “definitions” in experimental procedures) in predicting populations trends in utilized populations. Our results can help to measure progress toward policy targets and identify trends in resources that are important for people. Our results, thus, feed directly into global processes such as the IPBES thematic assessment of sustainable use of wild species[15] and development of indicators for the Post-2020 Global Biodiversity Framework.

Results

Geographic, taxonomic, and threat data summary

Our final dataset comprised 11,123 population time series from 2,944 species, of which 5,811 populations from 1,348 species were coded as utilized, and 5,312 populations from 1,996 species were coded as not utilized (Table S1). For utilized populations, most data were available for fish (n = 3,233), followed by mammals (n = 2,098), birds (n = 331), reptiles (n = 142), and amphibians (n = 7). Fish and mammals had more utilized populations than not, whereas the reverse was true for birds, reptiles, and amphibians (Table S1). Compared with the expected distribution of body mass values for all species, the utilized dataset showed a skewed distribution toward larger-bodied species for birds and mammals but a distribution of body masses to all fish species (Figure S1). Geographically, our sample contained data from all IPBES regions and from 146 countries (Figure 1; Table S2). Utilized and not-utilized populations were found in all regions, but there were noticeable clusters of more utilized populations in parts of Africa, Central Asia, and Canada. The largest regional dataset was for the Americas. Results for Africa are based on the smallest dataset of the regions; data availability throughout the time series dropped after 2012, so the indices were shorter than for the other regions, finishing in 2015 and 2013 for terrestrial/freshwater and marine, respectively.

Figure 1



Locations of populations used in the analysis overlaid onto IPBES regions

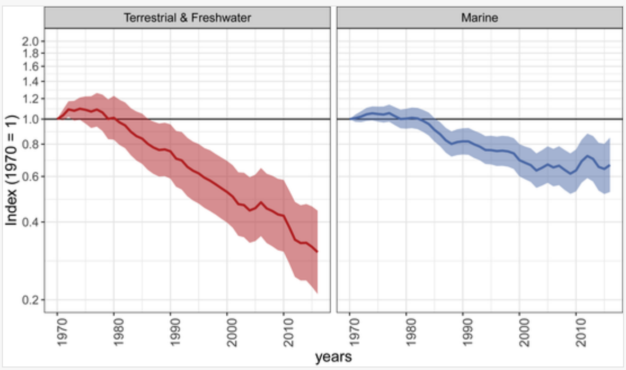
The point location is shown for the utilized (black diamonds) and non-utilized (white diamonds) populations used in the analysis (Table S2). IPBES regions shown are Americas (green), Africa (yellow), Europe and Central Asia (blue), and Asia-Pacific (light blue). IPBES regions were sourced from the IPBES Technical Support Unit on Knowledge and Data.[42]

Threat information was available for 3,195 populations—1,694 utilized and 1,501 not utilized (Table S3). There was a difference in the distribution of threats coded between utilized and not utilized populations, with a greater proportion of threats listed as overexploitation for utilized populations (Figure S2). Nearly three-quarters of the overexploitation threats coded for utilized populations were a result of hunting, fishing, and collecting (Figure S3). Of the utilized populations, 46% had information available on targeted management, and 23% were unmanaged (the remainder had no information; Table S4).

Global indices for utilized populations show decline

The index for utilized populations shows a decrease of 69% for terrestrial and freshwater populations (Figure 2; index value in 2016, 0.31; range, 0.21–0.44) and a decrease of 34% for marine populations (Figure 2; index value in 2016, 0.66; range, 0.52–0.85) between 1970 and 2016. Although the overall trend for utilized populations showed a steep decline, there was considerable heterogeneity at the level of individual populations, with 46.3% showing an overall increase, 48.9% showing an overall decrease, and 4.8% were stable in the terrestrial and freshwater index. In the marine index, 53.2% of utilized populations showed an overall decline, 42.6% an overall increase, and 4.2% were stable.

Figure 2



Index of utilized populations globally from 1970 to 2016

Shown are terrestrial and freshwater indices with 95% confidence intervals (CIs) (−69%; Number of species (nspp) = 607, Nnumber of populations (npop) = 3,123) and the marine index (−34%; nspp = 761, npop = 2,688).
See Table S5 for CIs.

We tested the robustness of the indices to time series length. This is important to check when using population trends that vary in sample duration,[43] particularly the effect of short time series that may exhibit more extreme or fluctuating trends and bias in the index.[44,45] We observed whether similar trends were seen when restricting the dataset to different thresholds for the minimum time series length in numbers of years. When a more stringent minimum threshold for time series length was applied, similar trajectories of decline were observed for indices with a minimum of 5 years, and shallower decline was reported for indices with a minimum of 10 years (Figure S4).

Regional indices show steeper decline in the tropics

The indices for utilized populations trends since 1970 grouped by IPBES regions show disparate trends, with largely tropical regions faring worse than the global indices of utilized populations (Figure 2) and compared with more temperate regions (Figure 3). Africa showed the greatest decline since 1970 in the terrestrial/freshwater and marine subsets; both indices show steeper decline than the global average for utilized species (Figure 3; terrestrial/freshwater index value in 2015, 0.07; range, 0.03–0.16; marine index value in 2013, 0.08; range, 0.04–0.17). The Asia-Pacific index shows a near-continuous decline in the marine index from 1970 to 2016 and an 83% overall decline, which is worse than the global marine index (Figure 3; index value in 2016, 0.17; range, 0.09–0.31); the terrestrial and freshwater index fluctuates from a positive to a negative trend, with high variation in the underlying species trends, and ends at a baseline value similar to 1970, above the global average (Figure 3; index value in 2016, 1.07; range, 0.31–3.76). The terrestrial/freshwater index for the Americas showed a trajectory of decline very similar to the global terrestrial and freshwater index of 67% between 1970 and 2016 (Figure 3; index value in 2016, 0.33; range, 0.19–0.58), whereas the marine index fluctuated throughout the time series and ended at a baseline value similar to 1970, with no significant overall change and a more positive trend than the global marine index (Figure 3; index value in 2016, 1.07; range, 0.78–1.45). The marine indices for Europe and Central Asia showed a slow increase for most of the time series after an initial decline, ending in an overall increase of 41% between 1970 and 2016 (Figure 3; index value in 2016, 1.41; range, 0.95–2.13). The terrestrial/freshwater index had a fluctuating trend for most of the time period but ended with a recent decline (Figure 3; index value in 2016, 0.76; range, 0.43–1.30). Both of these regional indices had trends that were better than the respective global indices.

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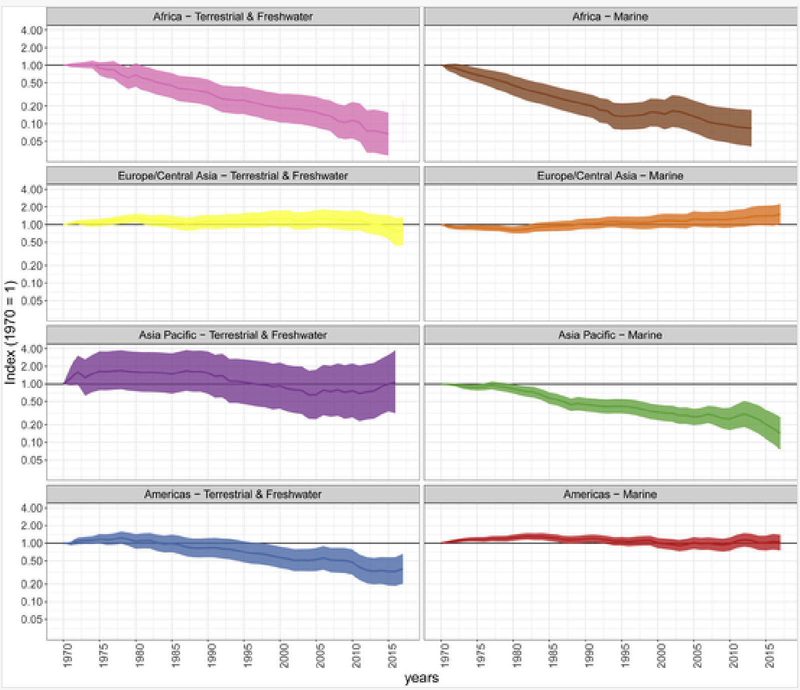
Figure 3

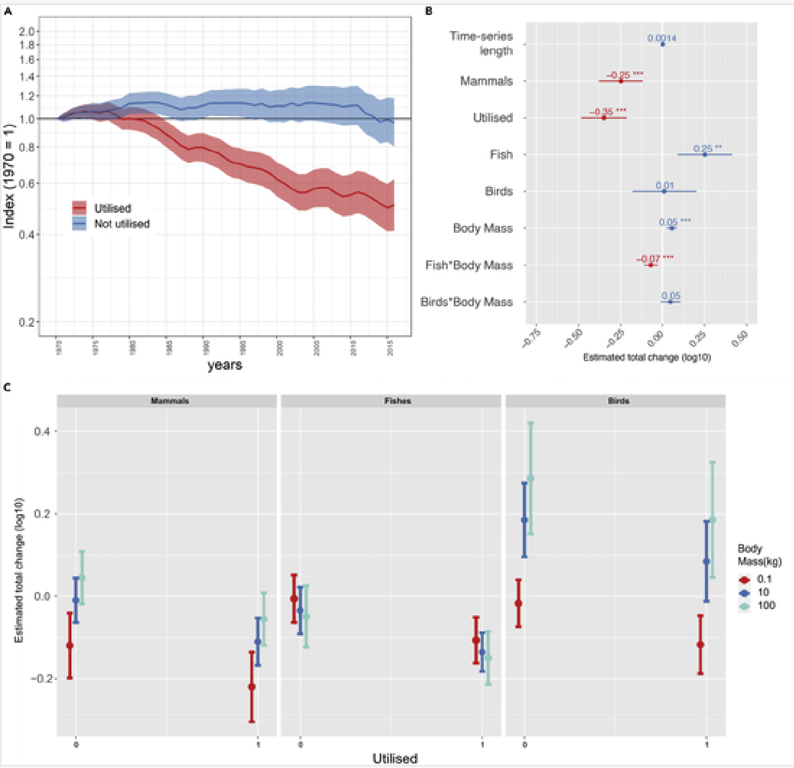


Index of utilized populations for IPBES regions from 1970 to 2016
Shown are terrestrial and freshwater indices with 95% CIs (left panels): Africa (−93%; nspp = 110, npop = 314), Europe and Central Asia (−24%; nspp = 124, npop = 1886), Asia-Pacific (+7%; nspp = 166, npop = 286), and Americas (−67%; nspp = 239, npop = 637) and marine indices (right panels): Africa (−92%; nspp = 77, npop = 132), Europe and Central Asia (+21%; nspp = 100, npop = 252), Asia-Pacific (−83%; nspp = 204, npop = 349), and Americas (+7%; nspp = 465, npop = 1,852).
See Table S5 for CIs.

The utilized index declines more than the non-utilized index

To explore the effect of utilization, we compared trends between utilized and non-utilized populations. For this analysis, we removed all reptile and amphibian data because these two taxa contained low numbers of species and populations in general but particularly those that are in the utilized category, resulting in a large proportional difference when comparing utilized with non-utilized populations. This is likely to make unbalanced comparisons, especially when dividing the dataset into systems (Table S1). This is not to suggest that these two taxa are not important to consider in the context of utilization; indeed, chelonians are one group particularly at risk from use.[46] Comparing the trend for mammals, birds, and fish, populations that are not utilized show a more stable trend, with index values above the 1970 baseline throughout the period, except for a recent decline, resulting in an overall decrease of 3% over the time period (Figure 4A; index value in 2016, 0.97; range, 0.80–1.18). In comparison, the index for utilized populations for the same taxa showed an overall decline of 50% (Figure 4A; index value in 2016, 0.50; range, 0.41–0.62). After 1985, there is no overlap in the confidence intervals of each index, which means they are significantly different.

Figure 4



Comparison of trends in utilized and non-utilized populations from 1970 to 2016
The dataset included 2,163 species and 9,284 populations.
(A) Index with 95% CIs of utilized and non-utilized populations for species of birds, mammals, and fish. Between 1970 and 2016, on average, utilized populations had declined by 50% (0.41–0.62), and non-utilized populations had declined by 3% (0.80–1.18).
(B) Estimated overall total change from the best linear mixed-effect model including family, binomial, and location as random effects. Coefficients show the estimated overall change (log10) in each group with 95% CIs. We found no significant interaction between taxonomic group and utilization, with utilized populations of any taxa (Utilized) significantly more likely to be in decline. Larger species tended to be less likely to be in decline, except in fish. where the opposite trend was seen.
(C) Estimated overall population change from the best linear mixed-effect model including family, binomial, and location as random effects. Coefficients show the estimated overall change (log10) for the body mass values 0.1, 10, and 100 kg with 95% CIs, highlighting the impact of the interactions on the estimated response for different body mass values.
See also Tables S5 and S6; Figures S5 and S6.

Replacement Image: Figure 4.pdf

Replacement Instruction: Updated spelling from "utilised" to "utilized"

Utilization is a predictor of population trends

We used mixed-effects models to explore the relationship between utilization, taxonomic class, body size, and time series length with overall population trends as the response variable. Utilization was consistently a useful predictor of overall population trends, with utilized populations more likely to be declining than non-utilized ones (Tables S6–S9). Removing utilization from our models produced significantly worse predictions of population trends ($\Delta AIC = -10$, $\chi^2 = 11.835$, $p < 0.01$). In general, our models did not suggest an interaction between utilization and taxonomic group, highlighting that all taxonomic groups are impacted by utilization. Using our most comprehensive dataset (mammals, birds, and fish in terrestrial, freshwater, and marine systems), body size interacting with class was in our top model, and the coefficients suggest that bird population trends are slightly positive, more so for larger birds; however, the confidence intervals span zero, so these are non-significant (Figures 4B and 4C). Fish trends were significantly positive but with larger species in decline, whereas mammal populations are in decline, but larger species show positive population changes (Figures 4B and 4C). The length of a population time series has no clear positive or negative effect on overall population trends. In the full model, which was very close in AIC value to the top model, there is a suggestion that the observed relationship with body size for fish (with smaller species generally doing better than larger species in utilized and non-utilized populations) may be reversed, but only for non-utilized fish populations (Table S6; Figure S5).

We explored two modifications to this dataset. The first removed marine populations, most of which comprise marine fish, which may represent groups of species that have been under long-term utilization pressure that is heavily managed. However, after removing marine populations, our results showed the same pattern, with utilized populations in more significant decline and larger species showing positive trends, but here the interaction between body size and taxonomic class was no longer supported (Figure S6B).

Because our classification of utilization is at the population level, this may result in our models comparing groups of different species (e.g., all utilized populations may be different species than those that are not utilized). We therefore also explored a second refinement of the data, only including bird, mammal, and fish species for which we had both utilized and non-utilized populations (4,255 populations of 339 species; Figure 5). The comparison of trends between utilized and not utilized indices shown in Figure 4A largely holds when the trends for “matched” species are compared, although there is considerable overlap in confidence intervals until the final 10 years of the time series (Figure 5A). Our models suggest that even in these matched species populations, utilized population trends are negative compared with positive trends in the non-utilized populations (Figure 5B). Body size and interactions are not in the best model here (Table S8).

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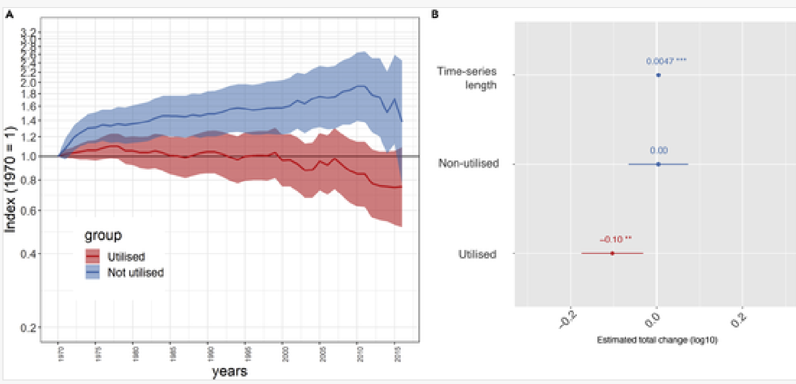
Figure 5



Index of utilized and non-utilized populations for matched species of terrestrial, freshwater, and marine birds, mammals, and fish. (i.e., species that have both utilized and non-utilized populations: 339 species and 4,255 populations)

(A) Index with 95% CIs of utilized and non-utilized populations for matched species of bird, mammals, and fish. Between 1970 and 2016, on average, utilized populations had declined by 25% (0.51–1.09), and non-utilized populations had increased by 138% (0.77–2.46). See also Table S5.

(B) Estimated overall total change from the best linear mixed-effect model including family, binomial, and location as random effects. Coefficients show the estimated overall change (log10) in each group with 95% CIs. Utilized species were more likely to be declining, but the effects of class, body mass, and any interaction were no longer important for explaining trends.
See also Table S8.

Replacement Image: Figure 5.pdf

Replacement Instruction: Updated spelling from "utilised" to "utilized"

Populations that are managed show less negative trends

For species where we also record whether the populations are under some form of management, we find that populations within our “matched” dataset show a positive trend when management actions are in place (Figure 6). This is mirrored by looking at the number of increasing and declining trends among utilized populations, where unmanaged populations show a greater proportion of declining trends than those that are managed; this applied across all three taxa (Figure S8). Our models suggest that, within our limited data, managed utilized populations may be stable, but unmanaged utilized populations tend to show steeper declining trends. However, many populations with unknown management status were removed, so this dataset is smaller than other sections of our analysis.

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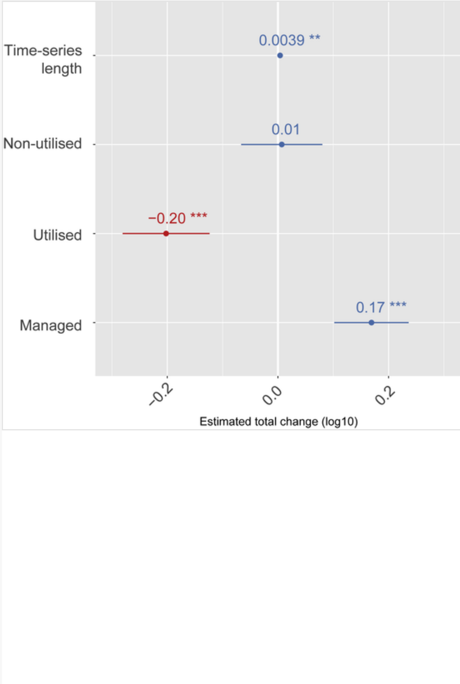
Figure 6



Role of utilization and management together for the matched dataset

For a limited number of species (316 species and 2,867 populations) for which we had information on populations that were managed and unmanaged, we estimated overall total change from the best linear mixed-effect model including family, binomial, and location as random effects. Coefficients show the estimated overall change (log10) in each group with 95% CIs. Utilized populations were more likely to be declining, and populations that were managed were more likely to be increasing.

See also Table S9 and Figure S8.

Replacement Image: Figure 6.pdf

Replacement Instruction: Updated spelling from "utilised" to "utilized"

Discussion

Global and regional trends in utilized populations

Here, we present a global indicator of trends in utilized vertebrate populations that show that, on average, monitored utilized populations declined, and more so than non-utilized ones, between 1970 and 2016. This trend was even starker among terrestrial and freshwater populations compared with marine ones. Although populations that are not utilized may be affected by threat processes such as habitat loss, it appears that the impact of utilization in addition to the presence of other threats is significant, as suggested in other studies.[19,20] However, the global average masks some interesting variation because just under half of the utilized populations had a stable or increasing trend over the time period. This implies that, for some populations, the use may be sustainable (according to population trend only) and that uncovering explanatory factors behind what drives population trends is crucial.

Our results also uncovered regional differences in trends in utilized populations with overall positive trends in the Americas, Europe, and Central Asia among marine populations; the Asia Pacific index was the only terrestrial and freshwater region with a positive trend. It is important to note that comparisons between regions should be interpreted with care because of the vastly different environmental conditions around the world at the onset of our data in 1970; assessments can skew the state or trends in biodiversity without considering shifting baselines.[47] The baseline year chosen can be important for assessing long-term trends,[48] particularly in regions where high human impact has been prevalent over centuries. In the case of North America and Western Europe, the baseline of 1970 hides a historical decline in species abundance that occurred as land use was transformed after the industrial revolution;[49] after 1970, trends may therefore show less decline as populations stabilize, but at lower numbers.

Data availability was a limitation when assessing trends for Asia Pacific and Africa; for the latter, it was mainly an issue in the later years of the time series. With the analysis conducted at a regional scale, the results may mask the relative differences between countries and even communities.[24] For example, successful examples of conservation and development have been identified in many African countries, particularly those managed by local communities.[25,50] These regional indices therefore have the advantage of providing a large-scale indicator as an overview, but the results do not necessarily represent trends at smaller scales and can hide many local examples of "best-practice." However, the data and method described here are applicable at national and regional levels[51–53] and could be tailored to assess trends in utilized species at difference scales, provided sufficient data are available.

Results in the context of sustainable use and management

Our results show a long-term decline, on average, among utilized populations globally, suggesting that use, overall, is likely unsustainable. This aligns with broad-scale findings of the threat and impacts of utilization on mammals and birds [20,21] and of trends in utilized fish.[22,54] Sustainable use as a tool is harder to analyze explicitly with this dataset because implementation of this as a tool was not recorded; for example, we did not measure whether any initial population decline plateaued when levels of use remained constant. However, utilized populations where use was incentivized for conservation are likely to also be categorized as "managed" because of regulations or guidance to manage the use; for example, populations of the saltwater crocodile (*Crocodylus porosus*) from the Northern Territory of Australia, where controlled harvesting of eggs has been an incentive for its conservation,[55] are coded as utilized and managed in our dataset. Other populations are utilized as a consequence of management through culling; e.g. red deer (*Cervus elaphus*) in Europe. These examples illustrate how the terms "utilized" and "managed" are closely linked, and more work to categorize these terms into types of use and management would aid further interpretation.

Incorporation of management into this analysis introduces important nuance, suggesting that more positive trends are likely when management of utilized species is pursued. Management can take many forms, and utilization itself can be a tool for conservation and human development, providing incentives for habitat and species conservation to support provision of resources for people into the future.[55,56] Establishment of communal conservancies in Namibia has been found to provide dual benefits to the local community from tourism and hunting, especially when these activities occurred in parallel.[57]

Sustainable management has arguably had more focus in the marine realm, which could offer an explanation for the more positive trends seen in the marine indices for Europe, Central Asia, and the Americas. In response to concerns about overfishing, and in light of well-documented cases of fish stock collapse, such as Newfoundland cod[58] and Northeast Atlantic herring,[59] efforts to manage fisheries at national and international levels began to develop in the 1970s and 1980s.[60] Although commercial stocks are often reported as being in decline globally,[54] there are studies that highlight positive trends in stocks, particularly those that have been intensively managed to avoid overfishing.[23] Our regional results for marine populations reflect some of this disparity because we found average population decline only in Africa and Asia-Pacific, regions where stocks in poor status were found.[23] The Americas, Europe, and Central Asia, which largely include data from the temperate Atlantic and Pacific, fared better, as broadly found in these studies.[23,54] The nature of the global fishing industry means that global management is required for many fish stocks, in particular those outside of national waters. However, for fisheries nearer to coastal communities, management at smaller scales, specifically community co-management, is advocated as a viable and realistic long-term solution for sustainable fishing.[61]

Potential use as an indicator of utilized populations

A key element of the Post-2020 Global Biodiversity Framework (Target 5: ensure that the harvesting, trade and use of wild species is sustainable, legal, and safe for human health[62]) and the Sustainable Development Goals is balancing the sustainable use of Earth's resources with halting the loss of biodiversity. The lack of appropriate indicators on how wildlife is being used has been identified as a critical gap. Our approach presents an advance of our understanding of the role of use in the trend of wildlife. We see three factors that could suggest that our approach could be used as one indicator for sustainable use. First, our index builds on data and methods that are already established in research and policy.[16,35,36,38] Second, using population trend data allows integration of site-level information on the type of utilization and management. Third, abundance trends allow incorporation of sensitivity, meaning that the index can respond quickly to changes in populations.[63] Thus, we believe that the index we present in this paper, based on locally collected data but analyzed using freely available methods that can be applied at national, regional, and global scales, can provide a valuable addition to the indicator dataset available for use in the Post-2020 Global Biodiversity Framework.

A primary shortcoming of this approach concerns the shortage of comprehensive information for all vertebrate groups and the lack of plant or invertebrate data. The dataset behind the index suffers much of the same biases as found in other datasets and indicators,[36,64] with data available for well-studied taxa such as birds and mammals and those of commercial importance, such as fish. Geographic gaps in the data also remain, particularly in South America and Southeast Asia, regions that are hotspots of wildlife trade[65] and of mammals threatened by hunting.[21] Extreme trends and random fluctuations in primary population data can bias the LPI;[44,45] these effects are often associated with temporal gaps in the dataset but can be mitigated by testing the robustness of an index to time series length, as shown in our results. It remains prudent to develop indicators in lieu of comprehensive data, providing that the gaps in data are clear and biases are addressed when feasible.[36,66]

Although population trend is one measure of sustainability, there are other factors that are not considered here and might not be appropriate to aggregate into a global indicator, such as changes in population structure or behavior.[67,68] We also note that we may not be able to attribute the use directly to the trend measured because other drivers could be contributing to any declines and that the non-consumptive component of utilization is not incorporated in this indicator at present. Finally, this index is not able to demonstrate the level of sustainable use and how far beyond this limit current levels of pressure are; i.e., how much would the current use need to be reduced to reverse the decline observed. The human dimension of sustainable use, relating to the needs and benefits of peoples' use of wildlife, is not factored into this analysis but is a fundamental aspect of how sustainably species are used.[1]

Conclusion

Alignment of conservation and human development goals is a challenge, particularly when it comes to sustainable use of resources.[1] Using a large global dataset comprised of site-level data, we added important detail to current knowledge on the status of species in use. The results presented here reveal that globally utilized populations are in decline on average, which presents a risk to the conservation of these species and to people who directly benefit from their use. We found that management of populations has a positive impact, which suggests that this decline can be mitigated with appropriate actions in place to achieve sustainability. With sustainable use, a core component of the Post-2020 Global Biodiversity Framework and the Sustainable Development Goals, indicators are required to monitor progress toward the associated targets; the index presented here can address this need.

Experimental procedures

Resource availability

Lead contact

Further information and requests for resources should be directed to and will be fulfilled by the lead contact, L.M. (louise.mcrae@ioz.ac.uk).

Materials availability

This study did not generate new unique materials.

Definitions

Three terms used in this paper often have multiple interpretations. These are defined here for clarity.

1. Sustainable use. We refer to the definition from the Convention on Biological Diversity: "the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations".[11]

2. Utilized population. This is the definition used for coding data in the Living Planet Database: a population that is intentionally regularly or systematically utilized, either individuals or eggs. This may be sustainable or unsustainable, and the population does not necessarily have to be threatened by use or overexploited. This refers to consumptive use, where individuals or parts of individuals are removed from the wild. The use may also be a secondary purpose when management, through culling, is the primary aim; e.g., culling to control populations of red deer (*C. elaphus*) in some European countries.

3. Management. This is the definition used for coding data in the Living Planet Database: a population that receives targeted management (e.g., supplementary feeding, reintroduction, sustainable use). This is usually to promote recovery in a population or can incentivize its use for conservation. It can include measures to stem "unsustainable" population growth, so these management activities are not always for the purpose of conservation.

Collection and coding of dataset

Vertebrate population time series data were extracted from the Living Planet Database (LPD),[69] a global repository of annual abundance estimates collated primarily from the scientific literature and online databases.[35,36] The annual abundance measures were collected using a consistent monitoring method in a given and consistent location. The time series vary from 2 to 46 years in terms of length of time frame and in the number of raw annual data points. Units of abundance were population size estimates, densities, or proxies of abundance, such as nests or breeding pairs (see McRae et al.[36] for more details). Alongside the abundance data for each population, several ancillary data fields were extracted to use for summaries, disaggregation, and modeling of the data (Table S10).

The use of species can be consumptive (hunting, fishing, harvesting) or non-consumptive (tourism, cultural experiences, catch-and-release fishing) and for commercial, subsistence, or recreational purposes.[70] The definition of "utilized" in the Living Planet Database (LPD) refers only to consumptive use and does not include non-consumptive use (Table S10). The definition of "management" in the LPD refers to a targeted form of management for a population that may or may not be utilized. We acknowledge that utilization can be deployed as a form of management, and these terms may not be seen as distinct; however, this does not impact the analysis we conduct here because the two categories still allow us to differentiate between populations that are utilized and under management and those that are utilized and unmanaged. If a population is utilized as a form of management, then it will be tagged as "utilized" and "managed" because both terms apply. Not all populations that are "managed" are also "utilized." For example, some populations are managed for some other purpose; e.g., provision of nest boxes for a species whose nesting habitat has been degraded.

We also incorporated species body size into the analysis because it can be an important factor in predicting species trends,[71] especially when related to use.[19] We used body mass data collated from sources listed in Table S12, according to the method detailed in Noviello et al.[72] Body mass values were log10 transformed and used as a continuous predictor variable in the mixed models.

Index calculation

Using the R package rlpi (https://github.com/Zoological-Society-of-London/rlpi) and following the Generalized Additive Modeling framework in Collen et al.,[35] we calculated global and regional indices of abundance for populations that were utilized and populations that were not. For the global and regional indices of utilized populations, we divided the dataset into terrestrial, freshwater, and marine populations. This was to show a marine- and land-based comparison because many freshwater species, with the exception of fish, are not freshwater obligates, and combining them with terrestrial species was more appropriate. We explored the influence of marine populations on the trends later in the analysis. IPBES regions were chosen to divide the datasets to allow the information to be used in the IPBES sustainable use assessment and future thematic assessments. Because marine areas beyond national jurisdiction and Antarctica lie outside IPBES regions, 248 populations from the dataset from these areas were not included in the regional analysis. The indices were calculated for different subsets of the data (Table S11). The subset of species in the dataset with data for both utilized and non-utilized populations are referred to as "matched" species (Figure S7).

The finer-scale subregional analysis was conducted for three subregions: Southern Africa, Central and Western Europe, and North America. Wildlife management in these subregions has arguably been more widespread, so a comparison with the wider regional trends is of interest.

The baseline year set for the index was 1970, and it was run until 2016 because data availability decreases beyond this year as a result of the publication time lag. Each population trend carried equal weight within each species, and each species trend carried equal weight within each index. We did not incorporate any diversity weighting by taxa and regional species richness, as done for the global LPI,[36] because the species richness for utilized species only is not known, and we assume that the numbers may not necessarily be proportional to overall species richness across regions and terrestrial, freshwater, and marine habitats This means that indices produced here are not directly comparable with the global LPI because of the difference in weightings used. The confidence intervals were calculated using bootstrap resampling of 10,000 iterations to indicate variability in the underlying species trends.[35]

Mixed models

We considered how total population abundance change (T_lambda, cumulative year-on-year population change at the end of the time series) varied in response to utilization (Utilized) and body mass (Body Mass) for different taxonomic groups (Class: Mammalia, Aves, Fish). Time-series length, the number of years between the first and last population measure, was included to understand whether longer population trends tended to reflect more positive or negative overall change. Taxonomic and site effects were accounted for by including a random intercept for family, binomial (genus and species) and population location. T_lambda values were taken from the rlpi package, which generates a matrix of annual rates of change for each population. The annual rates were summed to give a logged value of total change in abundance for each population. The most complex/maximal model we considered therefore included Utilization, Class, and Body Mass all interacting. We compared this with a null model and with simpler models using Akaike information criterion (AIC). See Tables S6–S9 for a full model selection table comparing AIC values for each model. Here we reported models with the lowest AIC. Other models may have similar (e.g. <2 AIC) scores, in which case we report the simplest model (which, in our results, were also the top models). To manipulate data, construct models, compare their performance, and visualize their coefficients, we used the following packages: plyr,[73] dplyr,[74] lme4,[75] performance,[76] and sjPlot.[77] We also explored how including marine populations affected our results (Table S7). Finally, for a subset of these populations, we also have information on whether they are subject to some form of management. We therefore assess a second series of models including Management as an additional explanatory factor (Table S9).

[Instruction: Please note that UNEP-WCMC is based in the United Kingdom so please link appropriately.]**Acknowledgments**

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Author contributions

Conceptualization, all authors; data curation, L.M. and R.F.; formal analysis, L.M. and R.F.; funding acquisition, N.D.B; writing – original draft, L.M.; writing – review & editing, all authors.

Declaration of interests

The authors declare no competing interests.

Supplemental information

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The corrections made in this section will be reviewed and approved by a journal production editor. The newly added/removed references and its citations will be reordered and rearranged by the production team.

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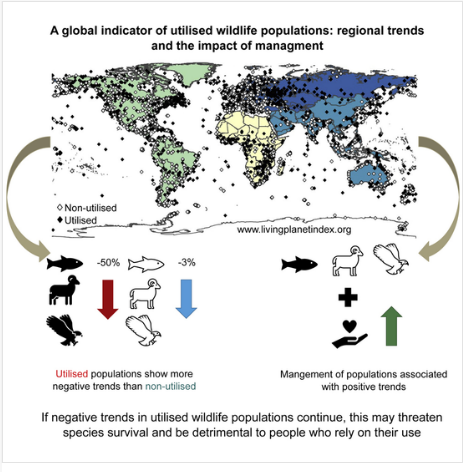
Graphical abstract

Images are optimised for fast web viewing. Click on the image to view the original version.



Highlights

- Utilized vertebrate populations declined by 50% on average from 1970 to 2016
- Body size is an important predictor of trends in utilized populations
- Importantly, populations that are managed are more likely to be increasing
- Reversal of decline in utilized populations is crucial for biodiversity and people

Science for Society

The ~~U~~use of wildlife supports many people for their food, medicine, and livelihoods. Ensuring that this use is sustainable is central to conservation to ensure the persistence of species alongside continued utilization by people. Using more than 11,000 wildlife population trends, we conducted a global analysis of local-scale data to better understand how populations respond to utilization. We found that utilized populations declined on average by 50% between 1970 and 2016 and showed steeper negative trends than populations that were not utilized (−3%). If these trends continue, then this may threaten species survival and be detrimental to people who rely on their use.

We also highlight how these trends might be reversed. Encouragingly, populations under targeted management, whether utilized or not, fared better than those that are not managed. This evidence can be used to track progress toward international and national targets on the sustainable use of species.

eToc Blurb

Sustainable use of natural resources is central to biodiversity conservation. Using more than 11,000 vertebrate population time series, we developed a global indicator of utilized populations and propose its use in the Post-2020 Global Biodiversity Framework. We found that trends in utilized bird, mammal, and fish populations were more negative than non-utilized ones and that body size was an important predictor of trends. Crucially, we found that populations where management was in place were more likely to show positive trends. Q2

Keywords: sustainable use; biodiversity indicators; ~~c~~Convention on ~~b~~Biological ~~d~~Diversity; vertebrates; population trends; overexploitation; livelihoods; wildlife management

Supplemental information

[Instruction: Please replace Document S1 with the file attached to reflect some small aesthetic changes to a couple of figures and some spelling updates.] Multimedia Component 1

Document S1. Figures S1–S8 and Tables S1–S12

Multimedia Component 2

Document S2. Article plus supplemental information

Queries and Answers

Q1

Query: In the author list, please check that all names are spelled correctly and that surnames (highlighted) have been identified appropriately. First and middle names are abbreviated in the table of contents and by abstracting and indexing services, whereas surnames are not (e.g., “X.Y. Zhang”). Please review this section carefully, and either confirm that it is approved for publication or indicate any necessary changes.

Answer: Approved for publication

Q2

Query: We are able to include up to ten keywords with your manuscript to improve searchability online. Please review the “Keywords” list on the e-Extra Content tab and indicate whether any additions, removals, or changes to keywords are needed. If your paper includes a second list (e.g., Research topic, Clinical and translational, Material advancement progression, etc.), please note we do not allow changes to this section.

Answer: Convention on Biological Diversity should be capitalised if possible

Q3

Query: If applicable, please confirm that, for any figures that contain error bars, scale bars, and/or p values, these elements have been defined in the corresponding figure legends (not simply in the main text). If any have not been defined, please indicate how and where to add definitions.

Answer: Yes, this is confirmed

Q4

Query: If any figures require simple text changes, please mark them in the proofs. If more substantial changes are needed, please replace the figure by clicking the relevant icon at the top right of the figure and explain what changes have been made.

Answer: Figures have been checked

Q5

Query: In order to hyperlink unique identifiers (e.g., accession numbers) to their corresponding external databases online, they must be formatted as “Database: XXX” or “Database: XXX, YYY, ZZZ,” e.g., “GenBank: NM_000492” or “PDB: 1TUP, 1KWR, 345X” or “Mendeley Data: https://doi.org/10.17632/3x9t5pjyzz.1.”If applicable, please confirm that any database identifiers are formatted properly throughout the text.(See https://fairsharing.org/FAIRsharing.a0f9nt for more information and a list of supported databases.)

Answer: Confirmed

Q6

Query: Did you deposit any new data or original code in an online database in conjunction with the research reported in this paper? If so, please note the following two requirements:(a) Please describe all new deposited data and original code within your data and code availability statement and include the accession number or DOI.(b) Please confirm that such accession numbers, DOIs, or datasets will be accessible to readers upon publication of your manuscript.

Answer: Confirmed

Q7

Query: Please note that the inclusion and diversity section, if present, should not be altered or edited. Any changes to this section will require the approval of the handling editor.

Answer: Confirmed

Q8

Query: If your paper uses acronyms that are not standard in your field, please add definitions for each at their first mention in the text. Here are some abbreviations that may need defining: IPBES, AIC, nspp, npop.

Answer: These abbreviations have now been defined

Q9

Query: Have we correctly interpreted the following funding source(s) and country names you cited in your article: Global Challenges Research Fund, United Kingdom; WCMC, United States; Research England, United Kingdom?

Answer: UNEP-WCMC is based in the United Kingdom

Q10

Query: We were unable to verify references 6, 24, 28, 42, 69, 70, 74, and 77. Could you please confirm that they are correct or provide any missing information, including a URL if applicable?

Answer: I have added publisher and URLs for these references

Q11

Query: The references [77, 42–76] in the list and the citations have been changed to [42–77] in order to maintain sequential order. Please check.

Answer: Yes, this is correct

Q12

Query: Please provide the page range for Ref. 56 if available.

Answer: Page range updated