Journal of Animal Environment
(E-ISSN 2717-1396, ISSN 2717-1388)
Journal homepage: https://aejournals.org/

Original Research Paper

Population Dynamics and Conservation Status Assessment of Threatened Wildlife Species in Changing Ecosystems

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Key Words

Population dynamics, Conservation status assessment, Threatened wildlife species, Biodiversity conservation, Species decline, Population viability, Extinction risk, wildlife Monitoring, ecosystem Change, conservation biology.

Abstract

Evaluating the conservation status of threatened wildlife species entails knowledge about the current species and population loss rates and the demographic methods employed to establish the viability of surviving populations. This literature review provides information on the trends in global extinction rates, the occurrence of population-level decline even among those species that have not gone extinct, and the methodologies applied in measuring the viability of populations for the purpose of explaining how population dynamics influence conservation status evaluation within changing ecosystems. Extremely conservative estimations under very cautious assumptions about the background extinction rates indicate that the current extinction rate of vertebrates is far much higher than the pre-human background rates, hence confirming the occurrence of the sixth extinction event. Apart from the extinction data of the species, there is information on defaunation, which is the reduction in population abundance of animals prior to their extinction. Standardized population indicators in thousands of vertebrate population time series demonstrate the ongoing global decline in population abundance among surviving species. On an individual species basis, research done using a meta-analysis of minimum viable population size serves as a measure against which one can compare the demographics of the existing populations. All together, these findings suggest that for proper conservation status assessment, there needs to be incorporation of information on extinction rates, trends in abundance, and population viability measures.

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Received: 25th May, 2026; Revised: 6th June, 2026; Accepted: 8th June, 2026; Available Online: 07th August, 2026
(DOI): 10.70102/AEJ.2026.18.3s.14

Introduction

The process of determining the conservation status of threatened species is a multi-dimensional approach, based on the assessment of the species' population dynamics through several dimensions: the rate of extinction of these species, the degree of decline in the numbers of those that have not gone extinct yet, and whether the population of each such species has enough individuals to survive in the long term. All three approaches give different types of information, and depending on what parameter is taken into account, one can easily underestimate or misrepresent the true conservation status of species or ecosystems. This review aims to integrate knowledge in the area of the assessment of population dynamics through all three dimensions from global estimates of extinction rates to defaunation trends and population viability analysis (Brook et al., 2011).

Global Extinction Rate Trends

The determination of whether the rates of modern extinction are abnormal compared to historical rates necessitates an examination of the current extinction rates against a reasonable estimation of the background extinction rate that would occur without any human interference. An analysis made using some very conservative assumptions, which were purposely meant to downplay the magnitude of the extinction crisis as much as possible, reveals that modern extinction rates among vertebrates are quite exceptional and rising faster than background rates, confirming that indeed, current species loss is a case of mass extinction similar in magnitude but not yet total to the other five mass extinctions observed in geological history (Ceballos et al., 2015). The above analysis uses some very conservative assumptions when determining the background extinction rate, and therefore, it can be considered a conservative underestimation of the magnitude of the present-day extinction crisis.

Defaunation: Population Decline Preceding Extinction

Though important, counts of extinctions at the level of species represent only a very small fraction of biodiversity loss since they do not consider the decrease in abundance and distribution that usually precede extinction over years and decades. This issue is being covered by the phenomenon of defaunation, which means a decrease or loss of animal populations over geographical ranges while the species persists somewhere else; this process has been described in both vertebrates and invertebrates worldwide and is considered a crucial and oftentimes neglected aspect of the biodiversity crisis working alongside with, and always preceding, the actual extinction of a species (Dirzo et al., 2014). Thus, an important implication from this perspective is that although the species can have its IUCN Red List category stable because of its persistence over the range, it can experience an ecologically significant population decline in some particular regions, making presence/absence-based conservation status assessment misleading.

Standardized Abundance Trend Indicators

It is essential to have standardized metrics which allow quantification of trends in defaunation globally and aggregation of population abundance data for many species and populations being monitored. Improvement of a globally used indicator of biodiversity involved solving an important problem of taxonomic bias which resulted from the presence of more studied taxa and regions in the monitoring datasets by means of introducing the metric which was diversity-weighted taking into account the estimate of the number of species in each biogeographical realm (McRae et al., 2017). Using the diversity-weighted correction significantly changed the result of the estimation of the global trend, since the diversity-weighted indicator showed a much sharper population trend of vertebrates from 1970 to 2012 than the non-diversity-weighted one using the same dataset (McRae et al., 2017).

Population Viability Assessment

Standardized measures should be developed to enable the quantification of the trends of defaunation worldwide and data aggregation on abundance of many species and populations under study. Improvement of a globally employed measure of biodiversity entailed solution of an important challenge of taxonomic bias that occurred due to more studied taxa and areas in the databases employed by applying the measure that is diversity-weighted accounting for the estimate of the number of species in each biogeographical realm (McRae et al., 2017). The diversity-weighted measure dramatically influenced the estimation of the global trend since it showed a more pronounced trend of vertebrate population from 1970 to 2012 compared to the measure that is not diversity-weighted but employed the same database (McRae et al., 2017).

Ecosystem-Level Consequences of Population Decline

Functional Extinction and Ecological Roles

The number of members of a population might fall so far as to render that population ecologically irrelevant before extinction occurs; a process known as functional extinction, in which the population of a species becomes too small to maintain any of the roles it formerly played in an ecosystem, whether that be dispersing seeds, acting as predator or pollinator, among others, although individual members of that species remain. The principle derives almost immediately from the defaunation paradigm, which defined range and population decline, as well as outright species extinction, as a crucial aspect of biodiversity change (Dirzo et al., 2014). Since ecological role tends to be dependent on density and interaction frequency rather than presence or absence, a species that has been assigned a category of Least Concern by the IUCN on the basis of range wide occurrence might already be functionally extinct throughout much of that range.

Cascading Effects on Co-Occurring Species

It is not uncommon for the decline in population of one species to propagate and impact population dynamics in the case of other ecologically connected species, which raises the concern that species-by-species conservation status assessment would be prone to overlook consequences that can be discovered only by looking at the trends in the entire ecological community. Modern extinctions have been framed within the context of previous extinction events in which extinction did not simply involve a loss of particular species, but instead was caused by reconfiguration of the entire ecological community following the loss of crucial species interactions (Ceballos et al., 2015), and the defaunation literature directly states that species interactions disruptions and not only loss of populations are a significant ecological consequence of population decline (Dirzo et al., 2014).

Regional and Taxonomic Disparities in Data Availability

As indicated by the review of the population dynamics literature, there are clear limitations of unequal geographic and taxonomic distribution of evidence, which has implications for the accuracy of global conservation status assessment. Specifically, the application of the taxonomic bias correction to the standardized abundance indicator revealed that the inclusion of the unevenness in monitoring efforts in biogeographic realms and taxonomic groups changed the global population trend estimate significantly, with the bias-corrected estimate revealing much steeper decline than the uncorrected one of the same data set (McRae et al., 2017). These results suggest that regions and taxonomic groups with historically poor monitoring efforts of their populations, being mainly represented by tropical and biodiverse but under-resourced areas, will have conservation status assessments that do not reflect the actual extent of population change within them. In addition, population viability meta-analysis, which included data from 212 species, was dominated by vertebrates, implying that the benchmark viability criteria for invertebrates, plants, and fungi, which represent the vast majority of global species richness (Traill et al., 2007), are still underdeveloped. The fulfillment of these two monitoring requirements is a pre-condition for any conservation status evaluation to be able to characterize the population dynamics of these threatened taxa in their entirety, not just the biased subset which is currently covered by existing data.

Emerging Approaches to Population Monitoring

However, innovations in monitoring technologies are slowly filling in some of the data and methodology gaps that have been highlighted through the population dynamics research discussed above. The use of environmental DNA surveys, camera-trap networks, satellite habitat surveys, and citizen science observation platforms have increased the geographic and taxonomic diversity of data on population sizes available for use in conservation status assessment far beyond that possible using traditional field surveys alone, directly solving the taxonomic and regional monitoring biases that had been highlighted in the literature on standardized abundance indicators (McRae et al., 2017). Moreover, the use of these technologies is particularly useful in increasing data availability on those regions which are historically undersampled where true population decline will likely be underestimated through use of traditional monitoring, based on the taxonomic bias correction evidence (McRae et al., 2017), and in detecting the range and population reductions that are characteristic of the defaunation framework when full species extinction has yet to occur (Dirzo et al., 2014). However, incorporating these data sources into population trend indicators, which are both standardized and comparable, as well as into individual species viability assessments that meet the standards of demographic and genetic modeling described in the population viability literature (Traill et al., 2007), is a current methodological challenge.

Discussion

When combined, these complementary pieces of evidence produce a much more comprehensive view of the dynamics of populations in shifting ecosystems compared to what any of these pieces alone can offer. Extinction rate evidence provides proof of extinction itself taking place at rates that far surpass natural levels, based on deliberately conservative assumptions (Ceballos et al., 2015), while the defaunation concept proves that the level of loss indicated by extinction rate evidence significantly underestimates the reality of biodiversity loss because population and range reductions among living species represent another aspect of the loss phenomenon (Dirzo et al., 2014). The standardized abundance indicator evidence supports this assertion empirically, showing that accounting for taxonomic bias in monitoring produces an even greater decline in global vertebrate species compared to raw data, thus proving that even quantitative population trend indicators must be carefully analyzed in order not to underestimate the level of decline (McRae et al., 2017). Population viability evidence offers the demographic standard required to convert the general decline trend into specific species conservation statuses, while reminding us that viability analysis might underestimate the actual level of species threat by omitting genetics (Traill et al., 2007). All these findings point towards the need for conservation status assessment schemes that integrate extinction rate, defaunation-oriented monitoring of population trends, and genetic viability analysis, instead of focusing on one single indicator, because all indicators discussed have demonstrated themselves insufficient on their own for assessing species declines.

The implications of these results are relevant to the application of conservation status categories in resource management decision-making. Assessments of conservation status based largely on range-wide presence data, in the absence of within-range abundance dynamics that would be considered in light of defaunation-sensitive monitoring, run the risk of assessing the species' conservation status too optimistically in cases where local population declines are occurring over wide areas of its range (Dirzo et al., 2014; McRae et al., 2017). Likewise, conservation efforts that assume that meeting the requirements of the single minimum viable population is enough to consider recovery achieved and without consideration of the taxonomic-specific factors such as genetic diversity that the literature on population viability indicates are often overlooked in modeling can prematurely assess the conservation effort as successful in cases where a population's genetic vulnerability has not been addressed (Traill et al., 2007). The pattern of each indicator being insufficient in capturing the extent of decline found in the four sources of evidence suggests that conservation status assessment systems combining multiple population dynamics indicators may more accurately depict the level of intervention required than any single indicator currently widely used.

Conclusion

There is empirical support for the conclusion that the conservation status of threatened wildlife species living in ecosystems undergoing change is more at risk than is determined by the use of any one of those methods alone. Conservative extinction rate calculations confirm a current mass extinction crisis, defaunation studies show that population and range loss occurs well before and exceeds losses in terms of recorded extinctions, corrected abundance calculations show a greater decline in the world than does uncorrected abundance, and population viability analysis offers the means by which to do demographic assessment of species risk, yet still showing gaps in genetic considerations.

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