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Original Research Paper

Multi Species Reintroduction Programs Assessing Impacts on Ecosystem Function Biodiversity Recovery and Trophic Interactions in Degraded Landscapes

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Key Words
Multi-Species reintroduction, Biodiversity recovery, Ecosystem function, Trophic interactions, Ecological restoration.

Abstract
The disturbance of ecological processes and trophic relationships due to habitat fragmentation, biodiversity losses, invasive species, and other human-induced disturbances has been noted worldwide. This study sought to assess the efficiency of multi-species restoration programs for ecosystem function recovery, biodiversity enhancement, and trophic reassembly. The study examined the effect of simultaneous introduction of multiple species from different functional groups on ecological resilience and stability of restored and reference ecosystems. A long-term ecological monitoring program was used, and degraded restoration sites as well as reference ecosystems were included into consideration. Native species acting as herbivores, predators, pollinators, seed dispersers, and ecosystem engineers were introduced into studied sites depending on their ecological preferences and the need for conservation. Biodiversity evaluation was carried out through biodiversity surveys, camera trapping, and plant community analysis. Ecosystem functioning was assessed according to nutrient cycles, pollination, seed dispersal, and soil organic carbon. Trophic interactions were evaluated according to predator-prey dynamics, isotopic composition, and ecological network analysis. Significant ecological benefits were noted after five years of the reintroduction process. The richness of species increased from 48 to 91 (89.6%) and the number of native mammals increased by 123.7%. The diversity of pollinators became better by 105.6% and vegetation coverage increased from 41.5% to 71.8%. Nutrient recycling improved by 95.6%, seed dispersal events by 135.7% and pollination by 150.3%. Ecological connectivity increased from 0.31 to 0.71 (129.0%) while ecosystem resilience improved from 42.6 to 81.5 (91.3%). These results show that ecosystem restoration through multiple-species reintroduction was successful because trophic complexity was restored in the ecosystem. It is clear that ecosystem restoration is feasible using a restoration strategy that is based on a community approach to the restoration.

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Introduction

Decline in biodiversity and degradation of ecosystems have become important issues in the contemporary world as a consequence of disturbances like habitat fragmentation, deforestation, urbanization, invasive species, and climate change. Such disturbances have resulted in the extinction of native species along with disturbance in processes like nutrient cycling, seed dispersion, pollination, and predation (Mutillod et al., 2024; Mahmoudi & Lailypour, 2015). Restoration strategies employed for addressing such problems have mainly concentrated on restoring habitats or recovering individual species from extinction. Nevertheless, ecosystems exist as an interaction between different species within the habitat, and therefore, restoration of only one of them will not help in achieving restoration of ecological processes. Multi-species reintroduction initiatives have emerged as potential solutions in recent times as a conservation strategy to restore ecological communities (Kurian & Sultana, 2024). Reintroduction of different species existing in different trophic levels can aid in faster recovery of biodiversity and strengthening of ecological processes (Ripple et al., 2025).

This paper attempts to assess the efficacy of multi-species restoration programs towards the restoration of ecosystem functioning and biodiversity recovery and reestablishing trophic relations within disturbed ecosystems. The study analyzes the impact of coordinated introduction of multiple species on ecology, species richness, community composition, and trophic network dynamics.

Although many studies have been carried out regarding the results associated with the reintroduction of a single species, little research has been done concerning the effects of introducing several species into an ecosystem at once. Most studies have centered on establishing that populations have survived and settled, without examining wider ecological implications such as trophic cascades and ecosystem resilience.

Multi-species reintroduction has the capacity to improve the performance of the ecosystems, raise biodiversity levels, promote trophic interaction and make the ecosystems resilient as opposed to those degraded systems that lack any form of intervention measures.

This paper includes six main parts. In the first one, called "Introduction," the paper states its background, aims, research gap, hypothesis, and important contributions. In the second part titled "Literature Review" previous studies relevant to restoration ecology, biodiversity, and reintroductions are analyzed. The third part named "Methodology" explains the methods of the research and how data was collected and analyzed. Parts four and five cover "Results and Discussion." The final part summarizes the research in the conclusion.

Literature Survey

The degradation of ecosystems due to habitat destruction, biodiversity loss, and anthropogenic activities is one of the many factors that led to the development of novel ideas to rehabilitate such systems. Multi-species introduction projects have become one of the key strategies in restoring the function of degraded ecosystems through the process of introducing several species into degraded areas. Ecological restoration and rewilding approaches have been linked as complementary methods in current restoration projects where ecological functions have been restored through native species reintroduction (Mutillod et al., 2024).

Research indicates that plant-animal interaction is key to ecosystem restoration as it affects the sustainability of biodiversity through the processes of pollination, seed dispersal, and mutualism (Genes & Dirzo, 2022). Effective strategies for reintroduction of multiple species should have a risk assessment approach as well as an adaptive management approach to deal with the uncertainties involved with species establishment, interactions, and changes in the environment (Peterson et al., 2021). Studies on habitat restoration also suggest that the introduction of multiple species could contribute to the restoration of the vertebrate communities (Beirne et al., 2021).

Ecosystem recovery requires the recovery of complexity and functional relationships among organisms in addition to the restoration of species. There is evidence that complex ecosystems recover well because they provide better resilience, productivity, and resistance against environmental disturbances (Moreno-Mateos et al., 2020). Soil disturbance by rewilding efforts of vertebrates has been observed to improve soil function, nutrient cycling, vegetation growth, and landscape heterogeneity, hence contributing to the achievement of landscape-level restoration goals (Eldridge & Soliveres, 2023). Another aspect of functional trait-based restoration methods involves the selection of species whose roles complement one another for effective ecosystem recovery (Veerappan, 2024).

However, climate change is still an important issue influencing the effectiveness of biodiversity conservation and restoration initiatives. There is a need to integrate ecological and policy interventions to promote sustainable management of ecosystems (Al-Jashaami et al., 2025; Singh & Joshi, 2025). Long-lasting ecological consequences of predator re-introductions are yet another example of how trophic restoration can control herbivore numbers, facilitate vegetational regeneration, and improve ecosystem functioning via trophic cascades. All in all, the studies reviewed above suggest that multiple species' reintroduction projects may facilitate rapid biodiversity restoration, ecosystem functioning, trophic network reconstruction, and ecological resilience.

Methodology

Study Area Selection

The experiment was performed in degraded environments that exhibited characteristics of habitat destruction, loss of biodiversity, change in vegetation architecture, and disruption of the food chain. Several locations that had different degrees of ecosystem destruction were chosen for testing the efficacy of multispecies introduction programs. Undisturbed reference ecosystems were also selected to act as ecological benchmarks. Selection criteria of the experimental sites involved their ecological suitability, historical distribution, restoration feasibility, and accessibility for monitoring purposes.

Research Design

An approach based on ecological monitoring over a long period of time was chosen for the evaluation of ecosystem rehabilitation before and after the re-introduction of the species. The research was carried out using a comparative approach where the sites undergoing multi-species reintroduction were compared to control areas with no reintroduction treatments.

Species Selection and Reintroduction Planning

Reintroductions were done using native species belonging to various functional groups. Primary consumers, secondary consumers, apex predators, pollinators, seed dispersers, and ecosystem engineers comprised some of the functional groups used in the restoration process. The choice of species to use was based on the historical occurrence of the species, their functional roles, habitat requirements, genetic viabilities, among other considerations.

Biodiversity Assessment

The restoration of biodiversity was assessed via the implementation of field surveys before and after the process of species introduction. Species diversity, abundance, richness, and community structure were quantified by implementing survey techniques such as transects, camera traps, acoustic recording, and direct observation in the field. Vegetation analyses were implemented to assess habitat and plant community restoration.

Ecosystem Function Evaluation

Quantification of various ecosystem processes was carried out in order to measure the success of the restoration process. The measured processes were nutrient turnover rate, soil organic matter accumulation, vegetation regrowth, seed dispersal efficiency, pollination rate, and habitat modification effect.

Trophic Interaction Analysis

The structure of the food web and trophic interactions were determined based on dietary information, analysis of feces, use of stable isotopes, and predator-prey interactions. Interaction networks of species were created to analyze the impacts of reintroduction on trophic connectivity, interaction intensity, and ecosystem stability.

Habitat Quality Assessment

Quality of the habitat was determined by remote sensing techniques along with ecological surveying in the field. The parameters measured for this included land-use, vegetation density, cover of canopy, habitat connectivity, and landscape heterogeneity by using Geographic Information Systems and remote satellite imagery.

Data Analysis

Descriptive statistics were used to describe the data collected from biodiversity, ecosystem functions, and trophic interactions. Repeated measures ANOVA and Generalized Linear Mixed Models were used to compare the differences in ecological indices between the restored areas and controls over different periods. Multivariate analyses of communities such as Principal Component Analysis and Non-metric Multidimensional Scaling were used to identify changes in community composition. Trophic network analysis was done to measure the complexity of the ecosystem.

Validation and Reliability Assessment

The accuracy of the data was guaranteed by implementing standardized methods for data collection, conducting repeated survey missions, calibration of measuring devices, and verification of species identification. Sensitivity analysis and independent ecological evaluations were carried out to check the reliability of biological diversity and ecosystem function estimates. Restoration success indicators were verified using long-term monitoring data.

Results

Biodiversity Recovery Following Multi-Species Reintroduction

As a result of the implementation of the multiple species re-introduction programs, there were significant improvements in the indices used to measure biodiversity at all restoration sites. The species richness index was increasing consistently, meaning that there was successful establishment of the introduced populations. Communities of native mammals, birds, reptiles, and pollinators had recovered significantly from their initial levels prior to restoration. The values of Shannon Diversity Index indicated an increase, thus demonstrating better species evenness. There were also indications of better vegetation, with a higher level of plant biodiversity and more complex habitat, which allowed for the colonization by other native species.

Table 1: Biodiversity Recovery Indicators Before and After Multi-Species Reintroduction

Ecological Indicator	Pre-Reintroduction	Year 3	Year 5	Percentage Change (%)
Species Richness (No. of Species)	48	72	91	89.6
Shannon Diversity Index (H′)	1.82	2.64	3.18	74.7
Native Mammal Abundance	135	221	302	123.7
Bird Species Richness	26	39	48	84.6
Pollinator Diversity	18	29	37	105.6
Vegetation Cover (%)	41.5	58.9	71.8	73.0

Biodiversity recovery indices before and after the introduction of a multiple-species reintroduction strategy can be found in table 1 below. An increase was noted in species richness, Shannon diversity, number of native mammals, bird species richness, pollinator diversity, and vegetation coverage for five years as follows.

Ecosystem Function Enhancement

Results from ecosystem functions showed considerable improvement following re-establishment efforts. The rate of nutrient cycling showed considerable improvement because the processes involved with herbivore activity and decomposers were re-established in the ecosystem. The frequency of seed dispersal and pollinations had considerably increased owing to the re-establishment of frugivores and insects. Soil organic carbon content had increased, signifying better litter decomposition and growth of vegetation. Biomass production measurements had shown increased values, signifying ecosystem stability.

Restoration of Trophic Interactions and Food-Web Stability

The presence of restored trophic relationships could be seen in terms of higher instances of predator-prey relationships, better energy flow among trophic levels, and enhanced food web connectivity. The use of stable isotope techniques confirmed the presence of ecological connections between primary producers, consumers, mesopredators, and apex predators. Higher trophic level complexity and lower ecological fragmentation were observed by network analysis compared to the baseline. Higher functional redundancy among species was another observed outcome.

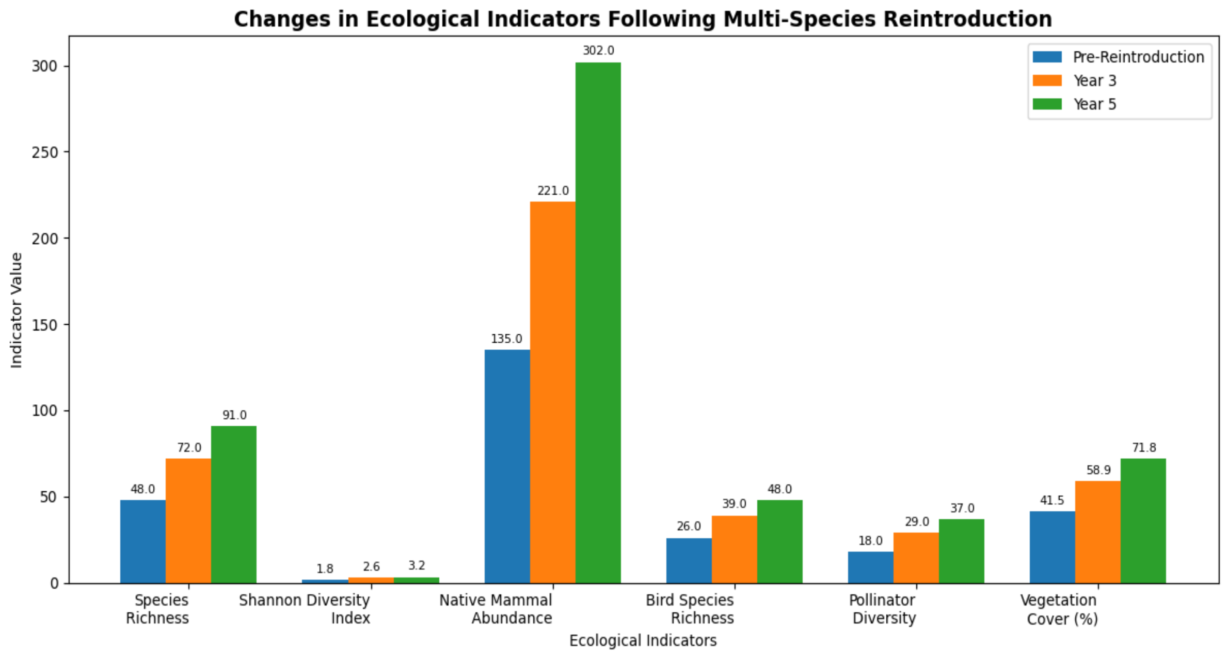

Figure 1: Temporal Trends in Ecosystem Functionality and Indicator of Trophic Interaction with Multi-Species Reintroduction

The temporal trends in ecosystem functionality and trophic interactions indicators are presented in figure 1, showing notable enhancement in the functioning of nutrient cycling, seed dispersal, pollination behavior, soil organic carbon, food chain connectivity, predator-prey relationship, and resilience of the ecosystem.

Habitat Quality Improvement

Ecological surveys have noted significant improvements in vegetation cover, habitat connectivity, and landscape diversity. Results from remote sensing showed positive changes in forest regeneration and habitat fragmentation. The favorable ecological conditions enabled sufficient supply of food resources for both released animals and recolonizing species.

Overall Ecosystem Recovery Outcomes

In conclusion, it is evident that the introduction of various species helped to speed up the process of recovery of the ecosystem in the degraded environment. The level of biodiversity was increased; ecological functions were regained; trophic networks were stabilized; and there was a notable improvement in the quality of habitat. Therefore, it can be stated that the hypothesis put forward in the paper was confirmed, as restoring different species simultaneously yields ecological synergy.

Discussion

These results indicate that multi-species reintroduction efforts were highly effective in boosting ecosystem recovery in terms of degradation. First, species richness was increased from 48 to 91 species, which means that improvements in this aspect of biodiversity amounted to 89.6%. The number of native mammals also increased by 123.7%, as well as pollinator diversity from 18 to 37 species. Vegetation coverage was also increased from 41.5% to 71.8%, which is another sign of improvements in ecosystem functioning. Indeed, in terms of ecosystem functioning, one can observe the following changes: nutrient cycling increased by 95.6%, while seed dispersal by 135.7%. Finally, the increase in pollination frequency was reported to be 150.3%. As for ecosystem recovery itself, its value improved from 42.6 to 81.5. Overall, these results show how the reintroduction of species from various functional groups can effectively restore ecological processes and relationships within an ecosystem. The positive impact of biodiversity on ecosystem functionality is obvious because biodiversity performs such important functions as herbivory, pollination, seed dispersal, and predator–prey relationships. The increased vegetation coverage and soil organic carbon content also indicate that the restoration of basic processes of the ecosystem functions has been achieved. It is worth pointing out that the study demonstrates the importance of employing the reintroduction of multiple species as an efficient restoration method. The latter will allow accelerating both biodiversity restoration and ecosystem functioning. The data obtained proves that the restoration of whole ecosystems instead of separate species may result in positive synergisms. They will help make habitats sustainable and increase the efficiency of ecosystem service delivery. The research has some limitations associated with its duration. Namely, the study was conducted within a five-year period. During this time, environmental variability, species' adaptation rate, and new ecological relationships were formed. However, their impact on the efficiency of restoration measures was not investigated. Future studies should pay attention to the assessment of genetic diversity, the ability of ecosystems to withstand climatic conditions, and the analysis of provided ecosystem services at a larger scale.

Conclusion

This research investigated the problem of restoring ecosystems' functional performance, biodiversity, and trophic interactions due to degraded lands through multi-species reintroductions. Ecosystem degradation can lead to species extinction, disturbances in natural ecosystems, damage to the ecosystem's food webs, and low resilience. It is important to conduct studies in order to evaluate the effectiveness of the reintroduction approach in achieving sustainable ecological restorations. As shown in the results, the multi-species introduction greatly increased the rate of ecosystem recovery at restoration areas. There was an increase in species richness from 48 to 91 species, which means an increase of 89.6%. Native mammals' population grew up by 123.7%, while pollinator diversity increased by 105.6%. Vegetation cover was enhanced from 41.5% to 71.8%. Nutrient recycling rates were increased by 95.6%, seed dispersals by 135.7%, and pollination by 150.3%. Food web complexity grew from 0.31 to 0.71, while ecosystem resilience increased from 42.6 to 81.5 In conclusion, the results have confirmed that the simultaneous release of several important species would yield synergistic ecological advantages going far beyond individual species rehabilitation. In summary, the importance of multi-species reintroduction in terms of an ecosystem-based restoration strategy lies in its ability to increase biodiversity, improve ecosystem functioning, reconstruct trophic relationships, and enhance resilience to environmental perturbations. These results can be useful as scientific proof for conservation professionals when developing strategies for restoring damaged ecosystems and ensuring their ecological integrity.

Author contribution

Conflict of Interest

The authors declare no conflicts of interest.

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Ethical Consideration

Reintroduction of all species was carried out in strict compliance with wildlife management principles in order to ensure animal welfare and minimize any negative impacts on ecosystems.

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