# Meta-Analysis of Ecosystem Services and Biodiversity Restoration Outcomes under Different Ecological Restoration Approaches: Postprint

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## Abstract

The global decline in critical ecosystem services poses a significant threat to human society, and biodiversity underpins the provision of various products and services by ecosystems. Ecological restoration projects that rehabilitate degraded ecosystem services and biodiversity are of paramount importance for alleviating anthropogenic environmental pressures. Long-term theoretical and practical efforts have developed multiple ecological restoration approaches: (1) natural recovery based solely on ecosystem self-design, (2) human-designed interventions in environmental conditions that feedback to influence ecosystem self-design, and (3) human-designed direct intervention and reconstruction of target populations and ecosystems. These three restoration approaches can directionally influence ecosystem recovery processes to varying degrees, reflecting low, moderate, and high levels of human intervention in ecosystems. Which restoration approach and degree of intervention can achieve better restoration outcomes is a critical question in restoration ecology; however, to date, despite extensive debate, no quantitative analyses or conclusions have been reached. To address this gap, through a meta-analysis of ecological restoration literature in the ISI Web of Knowledge database, this study quantitatively compares, using mathematical statistical methods, the restoration effectiveness of three intervention approaches—low intervention (natural recovery), moderate intervention (environmental intervention), and high intervention (direct intervention) —on ecosystem services and biodiversity under different conditions. This paper investigates four aspects: (1) the classification of low, moderate, and high intervention ecological restoration approaches, (2) comparison of differences in restoration effectiveness among the three intervention approaches on ecosystem services and biodiversity, (3) the influence of contextual factors such as different climatic conditions, ecosystem types, and restoration duration, and (4) the relationship between biodiversity recovery and ecosystem services recovery. The research findings reveal the applicable conditions for different ecological

restoration approaches and their effects on the relationship between biodiversity and ecosystem recovery, providing guidance for the selection of restoration approaches in ecological restoration practice. The study also offers implications for future research, such as further exploring the mechanisms and operational patterns of low, moderate, and high intervention ecological restoration approaches for specific ecosystem services or research questions; and incorporating factors such as regional socioeconomic levels and ecosystem degradation extent into the evaluation of restoration approaches to optimize the cost-effectiveness of ecological restoration.

## Full Text

## Preamble

**Effects of Different Ecological Restoration Approaches on Ecosystem Services and Biodiversity: A Meta-Analysis**

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## Abstract

The global loss of biodiversity and critical ecosystem services poses significant threats to human society. Ecological restoration is an important approach to regaining lost ecosystem services and biodiversity. To achieve successful outcomes, various restoration approaches have been developed. While some approaches take advantage of the self-designing ability of natural restoration systems, others rely on man-made designs at various levels. Since different restoration approaches may have different effects, identifying the best approach becomes crucial for successful restoration implementation. In order to achieve this objective, we proposed herein a system to classify various restoration methods into three types of approaches, namely, high-, intermediate-, and low-intensity intervention approaches based on the intensity or the degree of human intervention. We then conducted a meta-analysis by using data obtained from ISI Web of Knowledge to study the effects of different restoration approaches on ecosystem services and biodiversity. In addition, we examined restoration effects under different climate zones, ecosystem types, restoration ages, and ecosystem service types. Finally, the relationship between biodiversity and ecosystem services was studied. We used the median response ratio as an indicator of biodiversity and ecosystem service restoration effects. Since our data were not normally distributed, Wilcoxon and Kruskal-Wallis non-parametric analyses were applied to detect statistical differences. Spearman rank analysis was used to test the correlation between biodiversity and ecosystem services. In this study, a low-intensity intervention approach indicates that restoration effects are entirely achieved by natural forces. Human contributions to ecosystem restoration occur only through behavioral changes, such as land abandonment and threat removal. The intermediate-intensity approach applies when people only alter the environment during restoration. There is no direct intervention exerted on restoration targets. Some examples of intermediate intensity approaches include fertilizer application, the establishment of green corridors to improve habitat connectivity, and the addition of large deadwood to streams in order to improve habitat heterogeneity. A high-intensity approach is defined by direct human control on restoration targets. This approach usually involves anthropogenic biological recovery of a degraded ecosystem. Tree planting and species introduction are good examples of high-intensity approaches. The meta-analysis indicated that the median increment of ecosystem services and biodiversity in restored ecosystems was 45% and 151%, respectively, when compared to that of degraded ecosystems. The median enhancement of ecosystem services and biodiversity was 31% and 25%, respectively, for the low-intensity approach, and 31% and 22%, respectively, for the intermediate-intensity approach. A positive correlation was observed between biodiversity and ecosystem services, especially in restored versus degraded ecosystems. Further detailed analysis revealed a significant variation with regard to the effects of restoration approaches dependent on restoration goals (biodiversity or ecosystem services), referring systems (degraded or reference), climatic conditions, and time elapsed since restoration. However, some prominent differences were still found in tropical and terrestrial ecosystems. In this context, the high-intensity approach generally generated the best restoration effects when compared to degraded ecosystems. However, this approach may be suboptimal if the goal of restoration is to recreate the original environmental state. Indeed, the high complexity of reference ecosystems may be more easily recreated via intermediate intensity approaches. Our study emphasizes the importance of considering socioeconomic factors during restoration planning and creating a standard evaluation system for restoration effects and sustainability based on indicators of ecosystem services.

**Keywords:** ecological restoration; meta-analysis; ecosystem services; biodiversity

## Introduction

Human activities are intervening in the natural environment at an unprecedented rate, causing ecosystem degradation and biodiversity loss worldwide [1-2]. The healthy survival of human society is closely dependent on various products and services obtained directly or indirectly from ecosystems [1]. The reduction of ecosystem services poses a huge threat to human society [3]. The birth of restoration ecology in the 1980s marked the restoration of degraded ecosystems as a hot issue in both theory and practice [4-5]. The Society for Ecological Restoration defines ecological restoration as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed, with the primary goal of reconstructing ecosystem structure and its capacity to provide ecosystem services [6]. Scholars have proposed various indicator systems for evaluating restoration effects [7], but international work shows that biodiversity and ecosystem services are the most important ecological restoration goals and quantitative evaluation indicators [8-10]. Biodiversity, including genetic diversity, species diversity, and population diversity, is the foundation for ecosystems to provide various material products (such as food and freshwater) and services (such as atmospheric regulation and water purification) [11]. Scholars have also proposed that the restoration of biodiversity and ecosystem services is the primary goal and frontier topic of ecological restoration projects [12].

How to effectively restore biodiversity and ecosystem services in degraded systems has been widely debated. The traditional "self-design" concept in ecology holds that the restoration of degraded land should be left to nature. However, scholars have also pointed out that for severely degraded forests and desertified grasslands, relying solely on natural recovery is difficult to succeed [13]. Restoration ecology has summarized self-design and human-design theories. Self-design theory holds that degraded ecosystems will reasonably organize themselves according to environmental conditions, while human-design theory holds that degraded ecosystems can be directly restored through engineering methods and plant reconstruction. In addition to natural recovery, there are two other major restoration approaches. One involves environmental condition intervention, which affects the ecosystem' s self-design through feedback. From natural recovery to environmental intervention to direct intervention, these approaches directionally influence the ecosystem' s restoration process to varying degrees. The other involves direct intervention and reconstruction of target populations and ecosystems. These restoration approaches reflect low, medium, and high degrees of human involvement in ecosystems. Which restoration approach and degree of intervention can achieve better restoration effects is a key question in restoration ecology, but to date, there has been no quantitative analysis and conclusion [14]. To address this gap, this study uses meta-analysis of ecological restoration-related literature from the ISI Web of Knowledge database to quantitatively compare, based on mathematical statistics, the restoration effects of low-intensity, intermediate-intensity, and high-intensity intervention approaches on ecosystem services and biodiversity under different conditions.

This research focuses on three aspects: (1) classification of ecological restoration approaches into low-, intermediate-, and high-intensity intervention; (2) differences in the restoration effects of these three intervention approaches on ecosystem services and biodiversity; and (3) the influence of background factors such as climate conditions, ecosystem types, and restoration time, as well as the relationship between biodiversity restoration and ecosystem service restoration. The conclusions can provide insights for selecting restoration approaches in China' s ecological restoration work and implications for future research, such as further exploring the patterns and mechanisms of low-, intermediate-, and high-intensity ecological restoration approaches for specific ecosystem services or research questions, and incorporating regional socioeconomic levels and ecosystem degradation degrees into the analysis of ecological restoration approaches to optimize restoration outcomes.

## 1. Literature Collection and Data Preparation

The literature collection and screening process followed the methodology of Benayas et al. [8] and Meli et al. [9]. We first searched the ISI Web of Knowledge database using the keywords: (ecosystem or environment*) and (restor* or re-crea* or rehabilitat* or recover*) and (biodiversity or good* or service* or function*). We then filtered by research areas including "environmental sciences ecology," "biodiversity conservation," "agriculture," "rehabilitation," "marine freshwater biology," "plant sciences," "microbiology," "forestry," "zoology," "water resources," and "fisheries." Finally, we reviewed the titles and abstracts for further screening, retaining only literature that quantified ecosystem services or biodiversity and compared restored ecosystems with degraded ecosystems.

Degraded ecosystems refer to the initial state before restoration, while reference ecosystems refer to undisturbed natural ecosystems that often serve as restoration targets. Through this process, we calculated response ratios between restored ecosystems and degraded or reference ecosystems [15] to reflect ecosystem service and biodiversity restoration effects. The response ratio is the natural logarithm of the ratio of target variables:

$$RR_{deg} = \ln\left(\frac{X_{res}}{X_{deg}}\right)$$

$$RR_{ref} = \ln\left(\frac{X_{res}}{X_{ref}}\right)$$

where $X_{res}$, $X_{deg}$, and $X_{ref}$ represent measured values of target variables in restored, degraded, and reference ecosystems, respectively. Biodiversity indicators in the literature included vascular plant richness, invertebrate abundance, soil microbial richness, and Shannon-Wiener diversity index. Ecosystem services included provisioning services (product yields such as timber), supporting services (seed dispersal, nutrient cycling), and regulating services (soil quality improvement).

We classified collected literature according to restoration methods into ecological restoration approaches and summarized the main restoration methods used in each approach. Low-intensity intervention (natural restoration) includes measures that primarily reduce or remove human activities and other stress factors, leading to unrestricted recovery dominated by natural processes. Intermediate-intensity intervention (environmental alteration) mainly influences ecosystem development through restoration of ecosystem structure and physicochemical environment. High-intensity intervention (direct intervention) involves direct control of target populations or reconstruction of ecosystems.

## 2. Data Analysis

We compared the effects of low-, intermediate-, and high-intensity intervention approaches in providing ecosystem services and biodiversity. Shapiro-Wilk tests revealed that the data were not normally distributed, so non-parametric Wilcoxon tests were used to confirm whether restored ecosystems were significantly different from degraded or reference ecosystems. Kruskal-Wallis tests were also used to examine whether there were significant differences in effects among different ecosystem services (provisioning, supporting, and regulating services). The tests were conducted in two ways: (1) for the same ecosystem service type, whether there were significant differences among low-, intermediate-, and high-intensity intervention approaches; and (2) for the same intervention approach, whether there were significant differences among different ecosystem service types.

When considering background factors, Kruskal-Wallis tests were used to examine whether there were significant differences in effects among different restoration approaches. Here we distinguished three background factors: (1) climate type (temperate vs. tropical), (2) ecosystem type (terrestrial vs. aquatic), and (3) restoration time period (<3 years, 3-10 years, >10 years, calculated from the start of ecological restoration projects). The tests were conducted in two ways: (1) for the same climate type, ecosystem type, or restoration time, whether there were significant differences among low-, intermediate-, and high-intensity intervention approaches; and (2) for the same intervention approach, whether there were significant differences among different climate types, ecosystem types, or restoration time periods.

Spearman rank correlation analysis was used to analyze the relationship between biodiversity and ecosystem service restoration effects under different restoration approaches. Scatter plots were drawn for cases that simultaneously assessed both biodiversity and ecosystem services. For studies that used multiple indicators to assess biodiversity or ecosystem services, we took the average of the corresponding category response values to ensure each study had only one biodiversity and one ecosystem service response value. To ensure sufficient sample sizes, we did not distinguish ecosystem service types here. Detailed information on climate types and restoration time for the 143 literature sources is provided in the supplementary materials.

All data analysis was performed in SPSS 21.00.

## 3. Results

### 3.1 Classification of Ecological Restoration Approaches

From the literature, we extracted a total of 1,390 ecological restoration effect data points, which were categorized according to response ratio type, restoration target, area, and ecological restoration approach (Table 2).

We classified ecological restoration measures into three categories (Table 1): (1) Environmental intervention, including prohibiting human activities, adopting low-impact management models, and removing other stress factors; (2) Improving or constructing suitable habitats for restoration targets through physical means; and (3) Direct intervention on target populations, communities, or ecosystems, including vegetation reconstruction, changing population structure, transforming land use patterns, and ecosystem reconstruction.

The distinction between intermediate- and high-intensity intervention does not consider the scale or cost of ecological restoration projects, but rather the degree of human dominance over the direction of ecological restoration. Although low-intensity interventions such as stopping logging, converting to extensive agriculture, and leaving natural habitat strips at farmland boundaries share similarities with high-intensity interventions like returning farmland to forest/grassland and maintaining natural habitat strips at farmland boundaries, the fundamental difference is that the former focuses on weakening or eliminating stress impacts, with restored ecosystem structure and function completely determined by natural recovery forces. High-intensity interventions include continuous and active human management of restored ecosystems [16,17].

In intermediate-intensity interventions, in addition to physicochemical measures affecting ecosystem structure and environment, biological measures such as removing invasive species and planting flowers/grasses enable the recovery of target plant, bird, and other populations [18]. While this appears similar to population structure regulation and vegetation reconstruction in high-intensity interventions, the former affects the living environment of target organisms, whereas the latter directly acts on the target organisms themselves [19,20].

### 3.2 Overall Restoration Effects on Biodiversity and Ecosystem Services

When converting response ratios between restored and degraded ecosystems to percentage improvements, we found that biodiversity increased by 151% and ecosystem services by 45% compared to degraded systems. Compared to reference systems, low-intensity intervention showed 25% and 31% improvements in biodiversity and ecosystem services, respectively; intermediate-intensity showed 22% and 31% improvements; and high-intensity showed 39% and 45% improvements.

Non-parametric test results showed significant differences in enhancement effects among intermediate- and high-intensity intervention approaches. Compared to degraded ecosystems, high-intensity intervention achieved the best restoration effects. Compared to reference ecosystems, intermediate-intensity intervention achieved the best effects (Figure 1).

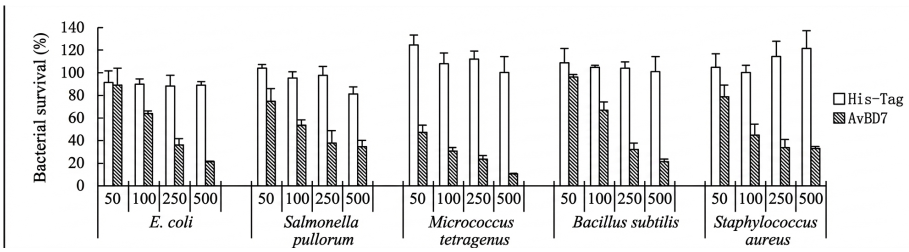


Figure 1: Figure 1

### 3.3 Effects on Different Ecosystem Service Types

Comparisons of different restoration approaches for various ecosystem service types are shown in Figure 2. Our sample data did not include cultural services, so only provisioning, supporting, and regulating services were included. The median response values in the figure indicate that different ecological restoration approaches significantly improved all three ecosystem service types, with restored levels exceeding those of undisturbed reference ecosystems (except for low-intensity intervention on provisioning services). Non-parametric test results showed that when the restoration target was regulating services, high-intensity intervention was significantly more effective than low- and intermediate-intensity approaches. When the target was supporting services, intermediate-intensity intervention was more effective than low- and high-intensity approaches. Other comparisons were not significant.

### 3.4 Effects in Different Climate Zones

Our sample data involved two climate types: temperate and tropical. Figure 3 shows restoration effects of different approaches on biodiversity and ecosystem services across climate zones. All median response values were positive, indicating that ecological restoration improved ecosystem services and biodiversity under different climate conditions, with ecosystem service restoration even exceeding reference ecosystem levels. Non-parametric test results showed that differences among restoration approaches were more pronounced in tropical regions. Compared to degraded systems, high-intensity intervention was most effective, but compared to reference systems, intermediate-intensity intervention was most effective while high-intensity was least effective. In temperate zones, only biodiversity restoration compared to reference systems showed significant differences between high- and low-intensity approaches; other comparisons were not significant.

[FIGURE:3]

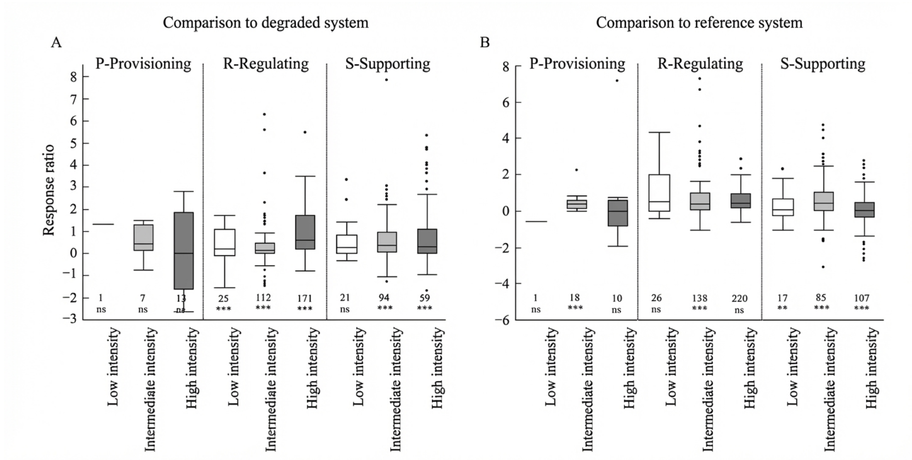


Figure 2: Figure 2

Pairwise comparisons between temperate and tropical restoration results showed no significant differences between low- and intermediate-intensity approaches across climate zones. However, high-intensity intervention effects differed significantly between climate zones: compared to degraded ecosystems, restoration effects were better in tropical than temperate zones; compared to reference ecosystems, effects were better in temperate than tropical zones.

### 3.5 Effects in Different Ecosystem Types

Our sample data involved aquatic and terrestrial ecosystems. Figure 4 shows the enhancement effects of different restoration approaches on biodiversity and ecosystem services in these ecosystem types. All median response values were positive, indicating that ecological restoration improved ecosystem services and biodiversity in both degraded aquatic and terrestrial ecosystems, with some restored levels even exceeding undisturbed reference ecosystems. Non-parametric test results showed that in aquatic ecosystems, different restoration approaches had similar effects on ecosystem service and biodiversity restoration. In terrestrial ecosystems, except for biodiversity restoration compared to reference systems, all other comparisons showed significant differences among restoration approaches.

In pairwise comparisons between aquatic and terrestrial ecosystems, significant differences in restoration effects were found in several cases: compared to degraded systems, intermediate- and high-intensity interventions improved biodiversity better in terrestrial than aquatic ecosystems, while low-intensity intervention improved ecosystem services better in aquatic than terrestrial ecosystems. Compared to reference systems, intermediate- and high-intensity interventions improved biodiversity better in aquatic than terrestrial ecosystems, while low-

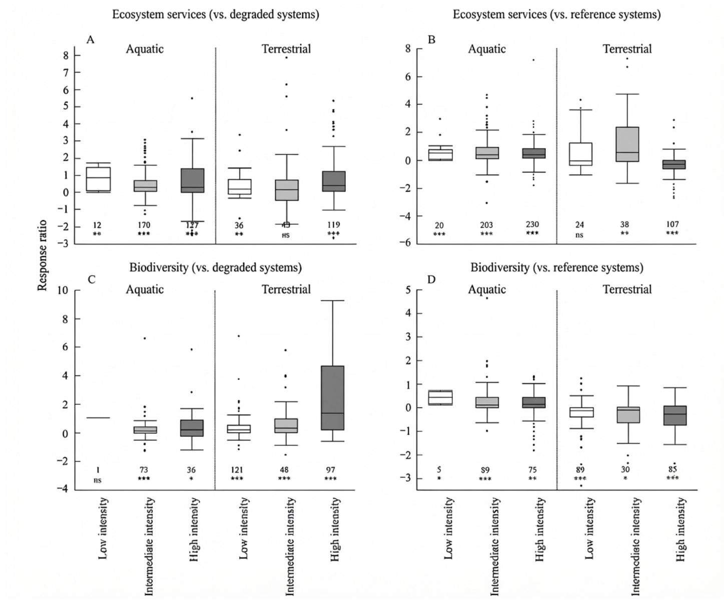

Figure 3: Figure 4

and high-intensity interventions improved ecosystem services better in aquatic than terrestrial ecosystems.

### 3.6 Effects Over Different Restoration Time Periods

Our sample data involved three restoration stages: short-term (<3 years), medium-term (3-10 years), and long-term (>10 years). Figure 5 shows the enhancement effects of different restoration approaches on biodiversity and ecosystem services across these time periods. All median response values were positive, indicating that different intervention approaches significantly improved biodiversity and ecosystem services in degraded ecosystems, with restored ecosystem service levels even exceeding undisturbed reference ecosystems.

Combined with non-parametric test results, we found that for biodiversity restoration in degraded ecosystems, there were no significant differences among approaches in the short term, but significant differences emerged in the medium and long terms, with high-intensity intervention showing the best effects. For ecosystem service restoration, significant differences existed in the short and medium terms, also with high-intensity intervention being most effective, but differences became non-significant in the long term.

Compared to reference ecosystems, intermediate-intensity intervention achieved the optimal restoration effects for both biodiversity and ecosystem services. In the short, medium, and long terms, there were no significant differences among intervention approaches.

Analysis of temporal effects within each approach showed that compared to degraded ecosystems, low-intensity intervention had the best short-term effects on both biodiversity and ecosystem services, while high-intensity intervention showed medium-term best effects for biodiversity and short-term best effects for ecosystem services that gradually declined over medium to long terms. Compared to reference systems, intermediate-intensity intervention had the best short-term effects on biodiversity that declined then rose again in the long term, while high-intensity intervention had the best medium-term effects on ecosystem services.

### 3.7 Correlation Between Ecosystem Services and Biodiversity Restoration

Figure 6 shows the correlation between biodiversity and ecosystem services under different restoration approaches. Biodiversity and ecosystem services showed stronger positive correlations when compared to degraded systems than when compared to reference systems. Under all restoration approaches, biodiversity and ecosystem services were significantly correlated when compared to degraded ecosystems ($P<0.05$), with the strongest correlation under intermediate-intensity intervention (P_{low} > P_{high} > P_{medium}). When compared to reference systems, only high-intensity intervention showed significant correlation between biodiversity and ecosystem service restoration.

[FIGURE:6]

## 4. Discussion

### 4.1 Selection of Ecological Restoration Approaches Under Different Conditions

Our analysis indicates that when using degraded systems as reference, high-intensity intervention approaches focusing on direct population regulation and ecosystem reconstruction achieve the best restoration effects for both biodiversity and ecosystem services, particularly in tropical and terrestrial ecosystems. Tropical ecosystems have optimal hydrothermal conditions for plant growth and theoretically strong natural recovery potential [21]. Taking the restoration of logged tropical rainforest sites as an example, although bare land can generally develop into secondary forest after natural recovery, the effects still cannot match direct ecosystem structure intervention [22]. The advantage gap between high-intensity and low/intermediate-intensity interventions is more pronounced in terrestrial than aquatic ecosystems, likely related to differences in natural recovery forces. Aquatic ecosystems have higher fluidity and renewal rates than terrestrial systems [23]. Controlling pollution sources can improve river or lake water quality within days to years [24], while natural recovery of damaged terrestrial ecosystems generally takes much longer [25,26]. Casper et al. [27] showed that removing three dams on Maine' s Kennebec River increased benthic animal diversity by an average of 41% within 12-35 years, while Reay and Norton

[28] found that artificial planting restoration of forests in New Zealand only increased biodiversity by about 25%.

From a temporal perspective, high-intensity intervention also shows significant advantages for biodiversity restoration in the medium to long term and for ecosystem service restoration in the short to medium term. In degraded ecosystems where original structure and species composition have been destroyed, facilitating suitable pioneer species is often needed to improve soil and microclimate conditions and reach biodiversity thresholds, enabling other species to colonize and initiate subsequent successional processes [13]. However, if the restoration goal is to recreate undisturbed natural ecosystems, intermediate-intensity approaches often achieve the best results. The biodiversity level and species composition in the initial restoration stage have long-term influences on subsequent successional trajectories [29]. In mine site restoration, using fast-growing, stress-tolerant exotic species can quickly control soil erosion but may block succession toward stable zonal vegetation [13]. Even with reasonable pioneer species, artificially reconstructed ecosystems often differ from natural ecosystems in species composition and complexity [30].

We should also recognize that in many cases, the three approaches show no significant differences in effects. For example, in aquatic and temperate ecosystems, restoration effects are not sensitive to intervention level differences. The low differentiation in aquatic ecosystems may be due to their high fluidity and renewal rates as mentioned earlier, while in temperate ecosystems it may be because high-intensity approaches are often used in severely degraded systems where restoration effects are less significant than in tropical ecosystems. For example, in China' s Loess Plateau with severe soil erosion, high-intensity restoration only increased ecosystem service capacity by 31% [31]. In these cases where effect differences are not significant, cost and site conditions can be considered more heavily when selecting restoration approaches.

### 4.2 Correlation Between Ecosystem Services and Biodiversity Restoration Effects

Biodiversity is part of ecosystem structural attributes, but its relationship with ecosystem services is not linear [32]. Biodiversity and ecosystem service restoration can promote each other but are not completely consistent. Compared to biodiversity, ecosystem service formation and maintenance require a series of normal ecosystem structure and function operations. In some cases, because different ecosystem service types have trade-off or synergy relationships [33], restoring ecosystem structure and function is more complex than simply restoring biodiversity, thus having greater uncertainty [34]. When human high-intensity intervention is applied directly, biodiversity restoration is much easier than ecosystem service restoration. Improving ecological conditions to promote ecosystem self-repair can achieve better synergistic effects.

In areas with high biodiversity, ecosystem service capacity enhancement may show saturation effects, where higher biodiversity leads to diminishing increases in ecosystem function [32]. This saturation effect can explain why Figure 6 shows stronger correlation between biodiversity and ecosystem services when compared to degraded systems. Degraded ecosystems are the starting point for restoration, and cases comparing restored to degraded systems often focus on early restoration stages. Benayas et al. [8] also support this conclusion. Some scholars like Bullock et al. [35] have pointed out that policies emphasizing ecosystem service restoration may lead restoration projects to focus on single services, which is not conducive to biodiversity restoration. Artificial fast-growing forests in mine restoration are a typical example: stress-tolerant, fast-growing species can quickly control soil erosion but hinder successful colonization by native species, making it difficult to form ecosystems with complex food web structures and high biodiversity. However, our results show that such conflicts between biodiversity and ecosystem services are not obvious overall in existing ecological restoration work.

## 5. Conclusions

Based on our research results, the main conclusions are as follows:

1. High-intensity intervention approaches focusing on direct population regulation and ecosystem reconstruction achieve the best restoration effects for biodiversity and ecosystem services in tropical and terrestrial ecosystems. However, if the restoration goal is to recreate undisturbed natural ecosystems, intermediate-intensity approaches focusing on improving ecosystem physicochemical environment and structure are most effective.
2. In aquatic and temperate ecosystem restoration, the three approaches show no significant differences in effects, and low-intensity natural recovery can generally achieve goals.
3. In existing ecological restoration work, biodiversity and ecosystem service restoration are not conflicting overall but show stronger synergistic effects.

Future research needs more and higher-quality case studies to further explore the patterns and mechanisms of low-, intermediate-, and high-intensity ecological restoration approaches for specific ecosystem services or research questions, such as tropical rainforest logging site restoration. Some scholars have hypothesized [3] that low-intensity approaches rely mainly on natural recovery and have low-cost advantages, but restoration area may shrink due to resource limitations and increasing costs as human intervention increases, though restoration effects may be faster. Future research incorporating regional socioeconomic levels and ecosystem degradation degrees into the analysis of ecological restoration approaches could help provide recommendations for optimizing restoration cost-efficiency. Evaluating ecological restoration effects based on ecosystem service capacity is also a future direction for restoration ecology [36]. Establishing a set of evaluation standards for ecological restoration effects and sustainability based on ecosystem service capacity will facilitate comparative studies among different restoration projects and enable more effective learning of restoration experiences.

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## Figures

*Source: ChinaXiv —Machine translation. Verify with original.*

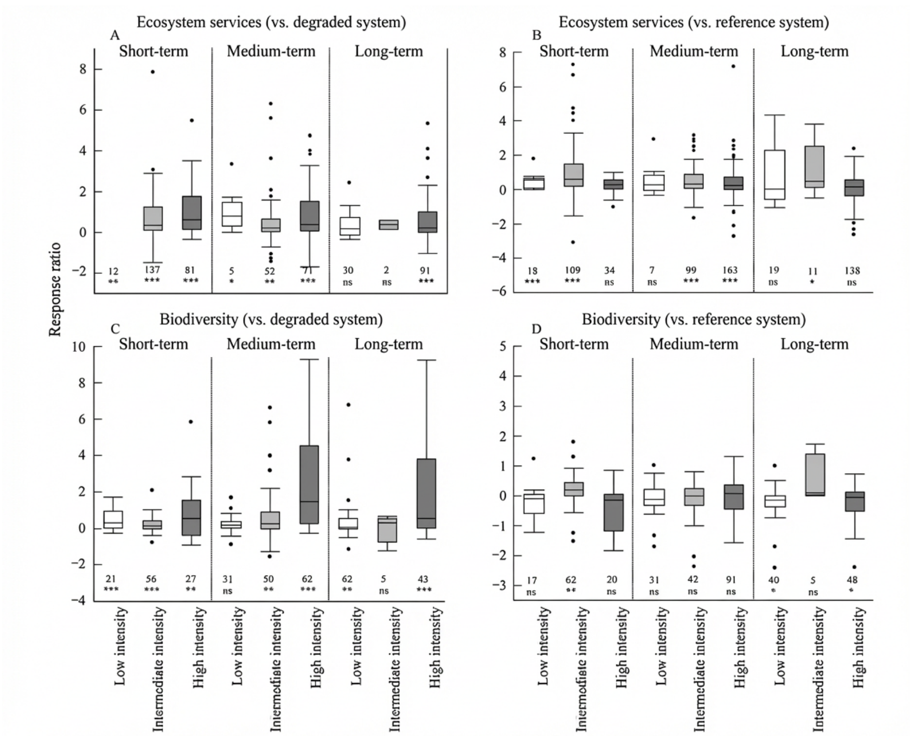


Figure 4: Figure 5