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CONSERVATION STATUS OF ENDANGERED SPECIES: A REVIEW OF CURRENT STRATEGIES

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Abstract

Biodiversity loss has reached unparalleled levels, with the International Union for Conservation of Nature (IUCN) Red List indicating that over 42,000 species are currently at risk of extinction. Endangered species encounter several, frequently interrelated stressors, such as habitat destruction, overexploitation, invasive species, pollution, and climate change, leading to intricate conservation issues in terrestrial, freshwater, and marine ecosystems. This review consolidates the contemporary understanding of the global conservation status of endangered species and rigorously assesses the efficacy of current conservation efforts. In situ strategies, including the creation of protected areas, habitat restoration, wildlife pathways, and community-based conservation, are essential for sustaining species in their natural environments and safeguarding ecosystem integrity. Complementary ex situ techniques, such as captive breeding, seed banking, cryopreservation, and assisted reproductive technologies, offer essential protection for species with significantly reduced wild populations. Case studies from 2015 to 2025 underscore significant achievements, such as the rehabilitation of the Arabian leopard and progress in genetic rescue for the black-footed ferret, while also revealing ongoing obstacles concerning funding, policy implementation, ecological connectedness, and post-release survival. Innovative technologies, such as environmental DNA monitoring, satellite tracking, and genomic tools, provide

intriguing opportunities to improve conservation efficacy and accuracy. The review asserts that integrated adaptive policies encompassing ecological, technical, and socioeconomic factors are crucial for reversing prevailing trends. Future conservation efforts necessitate enhanced transboundary cooperation, strategic climate adaptation planning, and inclusive governance frameworks that integrate conservation objectives with human welfare.

INTRODUCTION

Biodiversity contains variability in the variety of life on Earth which supports ecosystem functioning, resilience, and critical ecosystem services. Biodiversity supports life on Earth; however, species extinction rates are currently 100 to 1,000 times higher than natural background levels owing to human pressures on the environment (Mestanza-Ramón et al., 2020). Today, more than 42,100 species have been classified as being threatened with extinction according to the International Union for Conservation of Nature (IUCN) Red List on a global scale, including mammals, birds, amphibians, plants, and invertebrates (Carpio, 2023). Habitat loss, overexploitation, climate change, pollution, and the introduction of invasive species are some of the main drivers that often work synergistically to worsen the collective effects on already threatened populations. This biodiversity crisis, which now imperils not only nature itself but also people and the way they live together on earth, constitutes a disruption of ecosystems that underpin food security, water supplies, and climate regulation (Rossi et al., 2016). Consequently, safeguarding the most endangered species has become a cornerstone of international environmental policy and scientific research agendas, and there are rampant calls for reappraising current strategies to maintain global biodiversity (Duffus et al., 2023).

Attempts to stop or reverse the decline of threatened species have evolved significantly over the last few decades, from species-specific interventions to more integrated, ecosystem-based solutions (Jones et al., 2020). Categories of conservation measures In-situ Policy is said to be implemented for conservation, protecting species in their natural habitat conditions, while conservation other than that is referred to as ex-situ policy implemented, safeguarding species outside the ecosystems, such as within zoos, botanical gardens, and seed banks. In situ conservation focuses on protecting, restoring, and connecting habitats through the creation of protected areas, wildlife corridors, and community-driven conservation programs (Haas & Ferreira, 2018). In contrast, ex-situ conservation serves to safeguard critically endangered species when natural habitats are too degraded for immediate recovery or when population numbers have dropped too low for survival in the wild (Espinosa & Treich, 2024). Despite some successes, such as the return of Arabian oryx and California condor to their habitats, fault lines abound, including budgetary constraints, compliance lapses in legal instruments, socio-political hurdles, and ecological uncertainties in reintroducing species. Moreover, climate change has made the issue more complex, requiring adaptive strategies to respond to habitat changes and shifts in ecological interactions (Shiffman & Hammerschlag, 2016).

The urgency and complexity of species conservation requires a comprehensive review of existing strategies to identify best practices, knowledge gaps, and improvement needs. This review article summarizes the latest work related to endangered species conservation and considers how well in situ and ex situ strategies perform more broadly across different ecological contexts and a wide range of taxa (Tsai, 2017). This review seeks to advance a more nuanced understanding of existing models of conservation by incorporating evidence from case studies around the world, policy frameworks, and new technologies. It also aims to showcase creative solutions that have the potential to increase conservation success, such as artificial intelligence in wildlife monitoring, genomic tools for genetic rescue, and transboundary conservation agreements (Schlaepfer, 2018). Ultimately, this synthesis aims to serve policymakers, conservationists, and researchers by providing evidence-based solutions for more ecologically relevant, socially just, and globally resilient strategies in a world of ongoing global change (Haas & Ferreira, 2018).

2. Current Global Conservation Status of Endangered Species

The extinction risk of endangered species is a metric that reveals an unsettling biodiversity decline on land, in water, and through marine ecosystems. Over 42,100 species (including over 27% of the assessed plants) are now classified as threatened with extinction on the International Union for Conservation of Nature's Red List, and an estimated 10 million species could be at risk of extinction due to human activity (Hockings et al., 2019). Meanwhile, more than 37% of the assessed shark and ray species also face extinction risk, a higher proportion than birds or mammals and just below amphibians (Boshoven et al., 2022). It is truly a crisis when almost 40% of gymnosperms and a marked number of angiosperms which are economically important plants in the plant kingdom, are endangered (Evans et al., 2015). Endemism increases with isolation and habitat destruction, which is why certain regions of the world, such as Southeast Asia, Madagascar, Central Africa, and the Amazon Basin, are thought to have greater numbers of species at risk (Ayambire et al., 2025). Habitat degradation and fragmentation by agriculture, urbanization, and other forms of land cover conversion remain the primary drivers. Climate change is an increasingly rapid threat that redistributes species ranges, changes phenology, and exacerbates pre-existing pressures (Cho et al., 2025). Illegal wildlife trade, overfishing, and unsustainable hunting are leading to the decline of already vulnerable species due to overexploitation, while invasive alien species threaten native biodiversity by outcompeting them. Moreover, these threats often compound each other, leading to ecological cascades in which the extinction of one species destabilizes entire communities and undermines ecosystem resilience (White et al., 2023).

Efforts to reverse this trend have been made over the past few decades, with global conservation frameworks emerging as a response to these declines, including the Convention on Biological Diversity (CBD), the CITES agreement, and the UN Sustainable Development Goals (SDG 14 and 15). They have provided the basis for national legislation, but implementation is mainly dependent on decision-making in the protection of areas and species recovery (Ayambire et al., 2025). Nevertheless, efforts to safeguard biodiversity continue to fall short, with Global Biodiversity Outlook 5 (2020) assessments showing that, for the most part, the Aichi Biodiversity Targets for 2011–2020 were only partially achieved, and the black mark between policy pledges and on-the-ground act persists (Takashina et al., 2023). There has been some good trends from a few areas—tiger numbers have stabilized or increased in parts of India, Nepal, and Russia following massive anti-poaching efforts and halting habitat loss. Proportionally, marine protected areas aided in the partial recovery of fisheries and bleaching resistance in coral reefs (Trageser & Hamilton, 2024). Conservation outcomes remain variable; despite legal protection, many species are still in decline due to difficulties with enforcement, funding, and stakeholder involvement. The global endangered species status must be returned to where it is supposed to be so that individual listed and non-listed species are no longer on the brink of extinction. This involves more than fire suppression, which will lessen direct threats but not universal ecological connectivity or transient measures, such as shifting baselines or new technologies, to maintain vigilant monitoring and response at all project scales (McIntosh et al., 2018). This contextual insight into the contemporary conservation status represents the underlying rationale for assessing current in situ and ex situ measures (**Figure 1**), as further outlined in successive sections of this review.

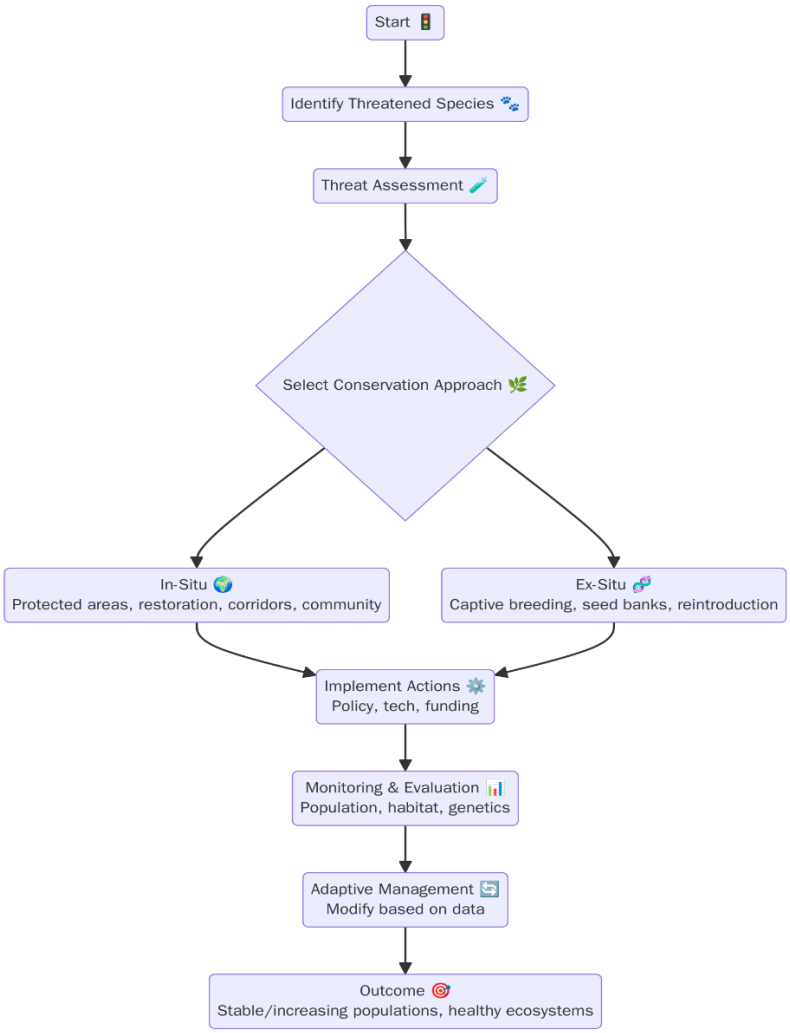

Figure 1: Flowchart depicting the conservation strategy process from species identification to adaptive management and ecological outcomes.

3. In-Situ Conservation Strategies

One approach to conserve biodiversity is in-situ conservation, which involves keeping species inside their natural habitats, where ecological interactions are preserved, and evolutionary processes can take place along with genetic diversity, as illustrated in **Figure 2**. This includes the creation and maintenance of protected areas, such as national parks, wildlife reserves and sanctuaries, nature reserves, marine parks, and biosphere reserves which now cover approximately 17% of terrestrial and 8% of marine areas worldwide (Trifanova et al., 2023). When properly enforced, protected areas can save species and limit the loss of vital ecosystem services, from carbon storage to water filtration to pollination. In particular, the Serengeti National Park in Tanzania has been essential for conserving migratory ungulates and related predator populations, and similar benefits have been observed at the Great Barrier Reef Marine Park, where resilience to climate-driven bleaching events in coral ecosystems has occurred (Dalton et al., 2023). Habitat restoration projects, such as reforestation, wetland rehabilitation, and removal of invasive species, that restore degraded ecosystems and enhance habitat connectivity between areas work to allow for the movement and delivery of genes to managed ranges. Wildlife corridors, such as the Terai Arc Landscape in Nepal and India, are a ready-made example of linked fragmented habitats, enabling species movement to disperse beyond individual

patches of habitat and reduce incestuous mating (Bezaury-Creel, 2024). In more desirable locations, such as Namibia, conservancies offer a powerful community-based conservation initiative necessary in places where local livelihoods are dependent on the health of biodiversity and wildlife by incorporating sustainable resource use and socio-economic benefits for traditional communities (Bezeng et al., 2025).

Furthermore, in-situ conservation works best when efficiently enforced by laws and regulations, which are often aided by cutting-edge technologies, including camera traps, drones, satellite monitoring, and artificial intelligence (Colombo, 2024). Countries such as Kenya have driven down poaching rates of elephants and rhinos by increasing ranger patrols, engaging with local communities in conservation awareness campaigns, and deploying near-real-time surveillance technologies. Legal frameworks such as the Endangered Species Act (USA) and Wildlife Protection Act(India) have also been established to provide for habitat protection, species recovery plans, and penalty measures for illegal exploitation (Prip, 2018). However useful in situ conservation efforts have been so far they are largely reliant on proper funding, competent staffs, competing land-use strategies and habitat shifts caused by climate change. In many instances, protected areas are nothing more than "paper parks", with little effective protection on the ground, and their surroundings are increasingly decimated by unsustainable agriculture, mining, or infrastructure development (Sjöstedt & Hulme, 2023). In-situ conservation strategies have escalated to incorporate climate adaptation to improve resilience through assisted migration, dynamic habitat management, and the establishment of climate refugia (McCormack, 2023). Other future directions include improving transboundary cooperation, increasing the level of indigenous-led conservation governance, and integrating biodiversity considerations into agriculture, fisheries and urban planning. Implemented simultaneously, these measures can help ensure that in-situ conservation not only prevents extinction but also stimulates the long-term recovery of endangered species against a background of rapidly accelerating environmental change (Rydén et al., 2020).



Figure 2: Mind map illustrates key strategies under In-Situ Conservation for protecting biodiversity in natural habitats.

4. Ex-Situ Conservation Strategies

Ex-situ conservation refers to the protection and management of endangered species outside their natural habitats and is a supplementary strategy to in-situ measures, as depicted in Figure 3 (Mahood et al., 2021). This is especially critical when wild populations are small, fragmented, or imperiled to the extent that they cannot be restored in situ, or when their habitats are too degraded to be restored instantly (Cavender et al., 2015). One of the most common ex-situ approaches is captive breeding, which involves increasing population numbers under controlled conditions for long-term reintroduction into the wild. Some of the most well-known cases in the United States are the California condor, Przewalski's horse in Mongolia, and Arabian oryx in the Middle East, which were reintroduced into their native regions following complete or near extinction (McGowan et al., 2017). Similarly, botanical gardens and seed banks are used in plant conservation to preserve genetic material and serve as safety nets against extinction (Wei & Jiang, 2021). For example, the Millennium Seed Bank Partnership in the UK currently holds seeds from over 40,000 species, many of which are threatened. Progress in cryopreservation and assisted reproductive technologies, such as artificial insemination, in vitro fertilization, and cloning, has extended the possibilities of genetic rescue, particularly in species with critically endangered genetic variability. For example, a genetically distinct black-footed ferret was mated with preserved material, reintroducing some genetic diversity into the captive population through cloning (Yamashita et al., 2023). Despite the vital short-term insurance ex-situ conservation can provide for endangered species, its effectiveness is hampered by numerous obstacles. The domestication bottleneck effect, natural selection during domestication, and harmful behaviors negatively impact the viability of species when reintroduced (Gant et al., 2021). Moreover, scaling up is not possible because of the prohibitive costs of maintaining ex-situ facilities. The habitat can also be unsuitable due to reintroduction, and natural threats, such as poaching, continue. Indigenous communities can also resist, and reintroduced individuals have low survival rates, even when rewilding is ecological and safe. Therefore, ex situ conservation practices should supplement situ conservation efforts (Mestanza-Ramón et al., 2020). Recent advancements have been used eDNA to facilitate successful ex-situ conservation. Additionally, the current collaboration among zoos, research centers, and local communities records unprecedented conservation rates (Schwartz et al., 2017). However, ex-situ conservation is not a replacement for in-situ conservation but has profound implications when integrated with other aspects of conservation. Therefore, continued adoption in the future could achieve numerous improvements in efforts to protect global biodiversity (Kovacs et al., 2021).



Figure 3: Mind map outlining Ex-Situ Conservation strategies focused on off-site species protection and genetic preservation.

5. Challenges, Limitations, and Future Directions

Despite substantial gains in both in situ and ex situ conservation, the global outlook for many threatened species continues to be grim, mainly due to persistent and emerging threats that diminish or erode the long-term scalability of present-day methods. A paramount constraint is the long-standing shortfall in funding for biodiversity conservation, which disproportionately affects some of the most diverse, endemism-rich parts of the planet, many of which are found in low-income countries (Larson et al., 2016). Underfunding hinders the creation of new protected areas and the effective staffing and management of these areas, as well as restricting the size and technological capabilities of ex-situ facilities (Devkota et al., 2023). Poor enforcement of anti-poaching laws, wildlife trade regulations, and habitat protection policies compound these declines, and numerous protected areas are little more than "paper parks" with only nominal or no real impact in the field (Wei et al., 2020). Human–wildlife conflicts are a persistent obstacle, particularly in rural areas, where crop damage, livestock predation, and resource competition reflect less sympathy for conservation programs. Moreover, climate change has emerged as an overarching threat that changes species distributions, distorts reproductive cycles, and establishes ecological mismatches that affect both in-situ and ex-situ recovery programs (Hermoso et al., 2019). There is also an urgent need to maintain and enhance ecological connectivity, as fragmented habitats restrict gene flow and species migration, undermining adaptive capacity under changing

environmental conditions. For example, in ex-situ contexts, problems arising from small population size (genetic bottlenecks), adapting to captivity, disease risks, and establishing extinction-replacing survival levels after reintroduction are major challenges (McDonald et al., 2018).

In the end, future conservation actions must be integrated, adaptive, and multi-levelled to adequately address not only direct but also indirect threats endangering species. The descriptions provided here illustrate the critical importance of improving transboundary conservation coordination for wildlife species with large home ranges and migratory movements (such as those undertaken by bison), in line with regional agreements such as the Convention on Migratory Species (Falconer & Ford, 2020). Future investments in emerging technologies, including satellite-based habitat monitoring, environmental DNA (eDNA) for early detection of species and invasive threats, AI-powered poaching detection systems, and genomic tools for genetic rescue, could enhance the efficiency and precision of conservation planning. Mobilizing biodiversity within landscapes, for example, is equally important as the mainstreaming of biodiversity into key sectors, such as agriculture, fisheries, infrastructure, and urban development, to provide incentives to reduce overall rates of habitat conversion and degradation (Kappes et al., 2021). Local stewardship can be improved, compliance can increase, and conservation benefits can be fairly shared through the broadening regional application of community-based conservation models that are based on indigenous knowledge frameworks. Because of climate change, adaptive strategies may be required to keep populations viable, including the identification of climate refugia, assisted migration, and dynamic management plans (Dong et al., 2022). Importantly, bridging the gap between science and policy making, data from sound ecological research are essential for effective conservation decisions which in turn should be reviewed at regular intervals to determine their effectiveness. In the end, saving endangered species for our future is about a worldwide response that includes ecological considerations alongside socio-economic responsibilities, combining both political efforts and scientific advancements to safeguard biodiversity for upcoming generations (Chen et al., 2022).

6. Conclusion

The conservation of endangered species is still one of the most pressing environmental issues of the 21st century, given that biodiversity loss is accelerating owing to the increasing influence of habitat degradation/fragmentation, overexploitation, invasive alien species, and climate change. This review describes the global situation of threatened species and critically assesses both in situ and ex situ conservation strategies. Although in-situ strategies, consisting of protected areas, habitat restoration, and community-based management, constitute the pillars of species conservation by sustaining ecological functions in situ, ex-situ mechanisms offer irreplaceable insurance for endangered taxa through captive breeding, seed banking, and genetic rescue. While these approaches have had some notable successes, they continue to be limited by funding bottlenecks, inadequate enforcement, human–wildlife conflict, and the impending impacts of climate change. To tackle these challenges, we need integrated and adaptive approaches characterized by strong scientific evidence, technological innovation, and inclusive governance frameworks. Inclusion of climate adaptation, transboundary cooperation, and improved community participation are critical components for success in long-term conservation. Given that biodiversity is the foundation of ecosystem services essential for human well-being, conserving these endangered species is both an ecological and socio-economic issue. The future of global biodiversity is contingent to the extent to which governments, conservation organizations, researchers, and communities collaborate and exercise leadership to ensure the ongoing protection of the unique and irreplaceable natural heritage of the Earth.

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