Bioscene

Bioscene
Volume- 22 Number- 01
ISSN: 1539-2422 (P) 2055-1583 (O)
www.explorebioscene.com

Review on Conservation Biology and Biodiversity Protection

Sirisha Cherukuri[1], Sravani Dasari[2]
[1,2] Assistant Professor
[1]Department of Botany, [2]Department of Zoology
[1,2] PB. Siddhartha College of Arts & Science, Siddhartha Nagar, Moghalrajpuram, Vijayawada, Andhra Pradesh, India

Corresponding Author: **Sirisha Cherukuri**

Abstract: The unparalleled drive to defy the status quo is vital when actions can address critical societal problems. Such motivation becomes essential in tackling conservation biology, a field that requires the integration of various disciplines to confront issues like the threat of human extinction. Combining scientific disciplines with socioeconomic approaches could lead to solutions for climate change, habitat destruction, pollution, and invasive species. Overcoming the vulnerable state of ecosystems necessitates new policies and frameworks. Establishing protected areas exemplifies in situ conservation, alongside advanced techniques such as environmental DNA (eDNA) and genomic testing, which provide precise methods for monitoring biodiversity. Engaging with communities worldwide fosters eco-friendly, sustainable development that enhances quality of life while preserving environmental integrity. This review emphasizes the necessity for proactive and adaptive approaches to conservation practices to counter the noticeable loss of biological diversity. Preserving life on Earth relies on ecosystem management, the maintenance of genetic variation, and equitable resource distribution. The future belongs to everyone, but fusing scientific progress with traditional knowledge allows nature and human affairs to coexist harmoniously, enabling people to live peaceful lives with sustainable development. This review underscores the urgent need for implementing adaptive, evidence-based strategies in biodiversity conservation. Protecting life on Earth involves managing ecosystems, safeguarding genetic diversity, and ensuring fair resource distribution. Combining modern scientific advancements with traditional practices enables sustainable resource management in harmony with nature for future generations. Biodiversity protection requires active participation from every corner of the globe, with practices that complement each other to ensure international collaboration focused on conserving living organisms and enhancing ecosystem resilience for future generations.

Keywords: Interdisciplinary Conservation, Ecosystem Resilience, Equitable Resource Distribution, Innovative Monitoring (eDNA/Genomics), Global Collaborative Action

1.0 Introduction

Conservation biology has evolved as one of the most important interdisciplinary sciences of the twenty-first century, responding to the tremendous acceleration of biodiversity loss caused by human activity (Wilson, 2016). The field combines ecology, genetics, climatology, and social sciences, all driven by the pressing need to avert species extinction and maintain viable ecosystems. As the Sixth Mass Extinction occurs at a rate 100-1000 times higher than natural background rates (Ceballos et al., 2015), conservation biology offers both diagnostic techniques for understanding biodiversity crises and therapeutic methods to ameliorate them.

Recent ecological research has highlighted the critical need for novel approaches to biodiversity conservation in the face of anthropogenic challenges. Conservation tactics must be reassessed in light of ecology's transition from equilibrium to non-equilibrium paradigms (Wallington et al., 2005). With numerous worldwide patterns emphasizing the irreplaceability and vulnerability of ecosystems, conservation activities must be prioritized (Brooks et al., 2006). Working landscapes can supplement protected areas and improve climate change resilience when they are managed with biodiversity-based practices like varied farming and agroforestry (Kremen & Merenlender, 2018). However, because overlapping threats can compound biodiversity loss beyond original predictions, conservation efforts must address the synergistic processes driving extinction (Brook et al., 2008). A multimodal strategy is needed for effective conservation, one that integrates socioeconomic considerations and community involvement in land management techniques while taking into account the intricate relationships between habitat degradation, overexploitation, climate change, and other variables that contribute to biodiversity loss.

To address complex sustainability concerns in conservation, social and ecological approaches must be integrated (Guerrero et al., 2018). Several quantitative techniques, such as systems theory and interdisciplinary cooperation, can be used to accomplish this integration (Cooke et al., 2009). A framework for creating comprehensive conservation plans that recognize unavoidable change and view actions as teaching opportunities is provided by resilience thinking, which includes resilience research, adaptive management, and ecological policy design (Curtin & Parker, 2014). However, methodological disagreements, value judgments, and communication hurdles are some of the ongoing difficulties that multidisciplinary collaboration in conservation faces (Pooley et al., 2014). Researchers advise carefully choosing team members, incorporating stakeholders, creating common research objectives, and promoting constant communication to get past these challenges (Pooley et al., 2014). Conservation initiatives can more effectively integrate social and ecological factors and provide more robust and effective results by tackling these issues and promoting true integration (Guerrero et al., 2018).

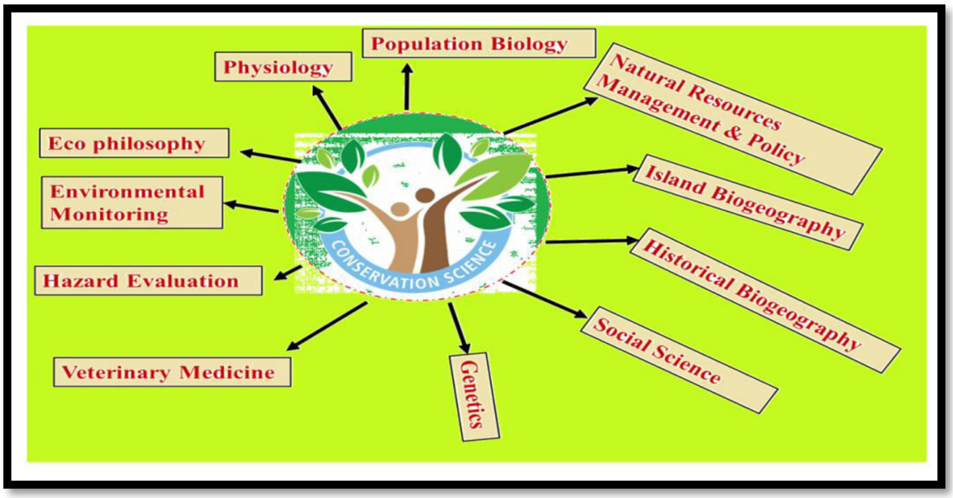
The conservation of biodiversity faces hitherto unheard-of difficulties in the Anthropocene, calling for innovative strategies that incorporate ecological, evolutionary, and social factors. Given the speed at which the world is changing, traditional conservation methods are being reassessed (Holmes, 2015). According to Jørgensen et al. (2019), evolutionary biology can help guide governance and policy solutions to five major challenges: biotechnology, evolutionary disruption, reducing restrictions, preserving resilience, and evolutionary feedback. Even while the loss of biodiversity is still increasing, successful conservation initiatives show that these trends can be stopped with creative effort (Johnson et al., 2017).

A comprehensive roadmap for sustainability includes limiting global warming to 1.5°C, conserving 30-50% of land and water ecosystems, and fostering interconnected protected, and shared spaces. This approach aims to enhance biodiversity, climate change adaptation and mitigation, and nature's contributions to people. Achieving these goals requires bold policy interventions and transformative changes in governance and social systems at all levels (Pörtner et al., 2023).

1.1 The Anthropocene Crisis: Scope and Scale

Ecosystem services, which are classified as supporting, regulating, provisioning, and cultural, are essential for human well-being but are increasingly compromised by ecosystem degradation (Everard, 2016; Geneletti et al., 2015). Trade-offs among these services occur due to management choices, often favoring provisioning services over others (Rodríguez et al., 2006). Many ecosystem services are in fair to poor condition and declining globally, with threats including deforestation, wetland loss, and overgrazing (Pereira et al., 2019). Regulatory services like climate modulation and water purification are at risk, while provisioning services face challenges in meeting demand sustainably (Pereira et al., 2005) see image 01.

Image 01 Conservation science



Ecosystem changes hurt cultural services, including spiritual values and ecotourism (Everard, 2016; Pereira et al., 2005). These problems are made worse by biodiversity loss, with large-bodied and high-trophic-level species experiencing a particularly sharp drop (Pereira et al., 2005). To effectively address these issues, data collection and long-term monitoring are essential (Pereira et al., 2005).

According to recent studies, habitat degradation, pollution, overexploitation, climate change, and invasive species are the five main human-caused factors contributing to the loss of biodiversity worldwide (Hald-Mortensen, 2023).

Land and sea use change, particularly agricultural expansion, is identified as the dominant driver, responsible for endangering 85% of species at risk (Hald-Mortensen, 2023; Jaureguiberry et al., 2022). Direct exploitation of natural resources ranks second, followed by pollution, while climate change and invasive species have had less significant impacts overall (Jaureguiberry et al., 2022). However, driver importance varies across ecosystems, with direct exploitation and climate change dominating in oceans (Jaureguiberry et al., 2022). Research efforts on these drivers are not well-aligned with their assessed impacts, and multiple driver interactions are rarely considered (Di Marco, 2018). Policies and initiatives must target all significant factors and their interactions, not just a few in isolation, to successfully combat biodiversity loss (Jaureguiberry et al., 2022).

1.2 The Field of Conservation Biology

The field of conservation biology was founded in the 1980s to preserve biodiversity (Meine et al., 2006; Dyke & Lamb, 2020). There are three main ways in which it is different from traditional ecology. First, it has an explicit normative dimension, valuing biodiversity preservation as inherently good (Barry & Oelschlaeger, 1996; Dietl, 2016). Second, it emphasizes urgent, actionable solutions to address rapid biodiversity loss (Meine et al., 2006). Third, it is interdisciplinary, integrating insights from social sciences, humanities, and diverse cultural sources (Meine et al., 2006; Dyke & Lamb, 2020). Conservation biology is evolving from protecting nature from people to protecting it for people, incorporating concepts like extractive reserves and Indigenous rights (Dyke & Lamb, 2020). The field's value-laden nature distinguishes it conceptually, with ongoing debates about intrinsic versus instrumental values of biodiversity (Dietl, 2016). Conservation paleobiology has emerged as a subfield, using geohistorical records to address current conservation challenges (Dietl, 2016).

Conservation biology emerged as a discipline aimed at preserving biological diversity, guided by four key principles: the value of organismal diversity, ecological complexity, evolution, and the intrinsic worth of biotic diversity (Soulé, 1985). These principles have since been central to discussions on biodiversity conservation. The concept of biodiversity itself evolved from these ideas, bridging empirical science and normative values (Habib, 2015). Some contend that the clearest ethical justification for conservation is found in intrinsic worth

(Soulé, 1985), but others doubt its ability to effectively inform real-world decisions (Justus et al., n.d.). Recognizing the need to preserve biodiversity in production landscapes, conservation initiatives go beyond protected areas. Maintaining species diversity across functional categories, creating corridors, and protecting distinctive native vegetation patches are ten guiding principles for this goal (Fischer et al., 2006). These methods seek to maintain the essential benefits that biodiversity provides in forestry and agricultural environments while also improving ecosystem resilience.

In light of climate change, contemporary conservation biology has developed to handle intricate ecological problems. These days, strategies include planning for climate resilience, improving landscape connectivity, and maintaining ecosystem functioning. Protecting ecological networks and interaction webs, as opposed to individual species, is becoming a more important part of conservation methods (Harvey et al., 2017). Conserving geophysical diversity, safeguarding climate refugia, improving regional connectivity, and maintaining ecosystem processes are important strategies (Groves et al., 2012). According to Rudnick et al. (2012), landscape connectedness is essential for promoting organism mobility, preserving genetic diversity, and boosting ecosystem resilience to climate change. To improve ecosystem flexibility, conservation planners are implementing tactics including functional redundancy, component redundancy, and enhanced habitat connectivity (Dunwiddie et al., 2009). By shifting away from traditional species-centric conservation and toward more comprehensive, system-level methods, these strategies seek to preserve biodiversity, ecosystem processes, and landscape-scale ecosystem services in the face of environmental change (Harvey et al., 2017; Groves et al., 2012).

2. Threats to Biodiversity

2.1 Habitat Destruction and Fragmentation

85% of at-risk species are in danger due to agricultural development, and habitat loss continues to be a major factor in the decline of biodiversity (Hald-Mortensen, 2023). However, invasive species, urbanization, marine exploitation, and climate change are some of the interrelated causes that lead to the extinction of species (Hald-Mortensen, 2023). Urbanization causes habitat fragmentation, while climate change affects ecosystems through ocean warming, acidity, and changed currents (Hald-Mortensen, 2023). The decline of species is also influenced by human population density and the usage of agricultural pesticides (Gibbs et al., 2009). Crucially, the effects of specific threats are frequently amplified by synergistic mechanisms, which may hasten extinctions beyond early projections (Brook et al., 2008). The severity of extinction threats is increased by these interdependent and self-reinforcing processes, underscoring the necessity of conservation initiatives that concurrently address several danger factors (Brook et al., 2008). Inadequate conservation results could arise from a failure to manage these synergies (Brook et al., 2008).

Landscape-scale conservation planning is required to maintain animal connection because protected areas alone are insufficient (Cushman et al., 2012). Only 7.5% of the land is covered by well-connected protected areas worldwide, which is less than the 17% Aichi Target 11 target (Saura et al., 2018). To address this, researchers propose developing condition-specific connectivity targets and indicators for different landscape types, including wild areas, shared landscapes, and urban/agricultural zones (Belote et al., 2019). By combining geodiversity studies with empirical data on species abundance, movement, and genetics, adaptive planning techniques are essential for preserving connectivity in dynamic environments (Jennings et al., 2020). Increasing overall coverage, proactively designating new protected areas, guaranteeing landscape permeability, coordinating administration within countries, and promoting transnational collaboration are some of the priorities for improving protected area connectivity, which differ by nation (Saura et al., 2018). Supporting biodiversity and achieving global conservation goals depend on these initiatives.

2.2 Climate Change Impacts

Mismatches in ecological interactions result from species distributions being disrupted by rising temperatures and changing precipitation patterns (Urban, 2015). Ecological relationships are disrupted by climate change in several ways. Interacting species may experience temporal and geographical mismatches as a result of changing precipitation patterns and rising temperatures (Schweiger et al., 2008; Memmott et al., 2007). For instance, pollinators may have fewer floral supplies due to phenological changes, which could result in extinctions (Memmott et al., 2007). The distribution of species can also be impacted by climate change, and interacting species may react to environmental changes in different ways (Schweiger et al., 2008; van der Putten et al., 2010). Ecosystem functioning and biodiversity may be impacted by these disturbances, which can have a domino effect across ecological networks (Fontúrbel et al., 2021). Some species may become abnormally plentiful, while others may become rare (van der Putten et al., 2010). It is essential to take into account both environmental factors and biotic interactions across trophic levels to more accurately forecast how species will react to climate change (van der Putten et al., 2010; Fontúrbel et al., 2021). Instead of focusing on individual species or paired connections, future research should evaluate the consequences of climate change on interaction networks (Fontúrbel et al., 2021).

Climate-induced biodiversity crises include coral reef bleaching and polar ecosystem breakdowns (Hoegh-Guldberg et al., 2017). From coral reefs to polar regions, climate warming is causing ecosystems to collapse (Canadell& Jackson, 2021). Widespread biodiversity loss and changes in ecosystem functioning are being brought about by stressors such as ocean acidification and rising temperatures (Doney et al., 2012). Reef fish variety and abundance have significantly decreased as a result of coral bleaching episodes, with corallivores being especially at risk (Pratchett et al., 2011). Likewise, thawing permafrost and shifting vegetation patterns are causing fast changes in polar ecosystems (Canadell & Jackson, 2021). The abrupt, smooth, stepped, or variable responses to various pressures are frequently characteristics of these collapses (Bergstrom et al., 2021). The impacts extend beyond individual species, affecting energy flows, biogeochemical cycles, and ecosystem services (Doney et al., 2012). To address these challenges, researchers propose a three-step framework of awareness, anticipation, and action to mitigate further degradation and promote ecosystem resilience (Bergstrom et al., 2021).

2.3 Pollution and Invasive Species

According to Doney et al. (2012), the effects go beyond specific species and have an impact on ecosystem services, biogeochemical cycles, and energy fluxes. Researchers suggest a three-step approach of awareness, anticipation, and action to address these issues to prevent more degradation and foster ecosystem resilience (Bergstrom et al., 2021). Invasive species and chemical pollutants (such as plastics and pesticides) change food webs and lower the fitness of native species (Bax et al., 2003). The stability of ecosystems and biodiversity are seriously threatened by invasive species and chemical pollutants. By driving native species to adopt less-than-ideal diets, invasive predators can cause trophic dispersion and displacement, upsetting native food webs (Wainright et al., 2021). Environmental pollutants can enhance the invasibility of ecosystems by altering their composition and functioning, creating favorable conditions for invasive species while reducing native species' competitiveness (Sun et al., 2023). The interaction between invasive species and pollution can shape invasion dynamics through impacts on wildlife behavior (Camacho-Cervantes & Wong, 2023). Food web complexity plays a role in invasion resistance, with less connected webs being more resistant. Invasions can cause significant changes in food web properties, including decreased modularity and decoupling of community- and population-level variability. By changing the composition and functioning of ecosystems, environmental contaminants can increase their invasibility by lowering the competitiveness of native species and fostering an environment that is more conducive to invasive species (Sun et al., 2023). Larger and more generalist species are typically more successful invaders; species characteristics like body size and food breadth are significant factors in invasion success (Lurgi et al., 2014).

To reduce these risks, biocontrol and legislative measures are required (Simberloff et al., 2013). The management of invasive species requires a multifaceted approach combining biocontrol and policy interventions. Studies highlight the gap between scientific recommendations and government responses, emphasizing the need for policymakers to navigate competing factors in addressing biological threats (Mackay et al., 2017). Successful management of invasive insect pests in East Africa has been achieved through biocontrol-based integrated pest management, benefiting from multidisciplinary expertise and supportive policies (Nyambo et al., 2011). However, challenges persist, including inadequate funding, limited taxonomic expertise, and poor early warning systems (Nyambo et al., 2011). Effective invasive species management requires integrating prevention and control policies, with program emphasis depending on various factors such as biological characteristics, ecosystem traits, and cost-effectiveness of interventions (Livingston & Osteen, 2008). Continuous data collection is crucial for developing economical and effective strategies to combat invasive species (Livingston & Osteen, 2008) See image 02.

3. Conservation Strategies

3.1 In Situ and Ex Situ Conservation

Although in situ protected areas are essential, they need to be managed adaptively to deal with changing climate conditions (Watson et al., 2014). Climate change poses a threat to protected areas, which are essential for the preservation of biodiversity (Scott & Lemieux, 2005). Smaller, low-elevation areas with little environmental variation are predicted to be most affected by climate shifts within protected areas, which are anticipated to be most noticeable in temperate and northern high-latitude regions (Hoffmann et al., 2019). Adaptive management frameworks, which emphasize the need to comprehend park context, management systems, and possible adaptation choices, have been presented as a solution to these problems (Tanner-McAllister et al., 2017). Strategies include focusing on habitat corridors along environmental gradients and keystone habitats within protected areas (Olson et al., 2009). Furthermore, managers must decide whether to accept and adapt to climate-induced changes or to try to preserve current ecosystems (Tanner-McAllister et al., 2017) see the image 02.

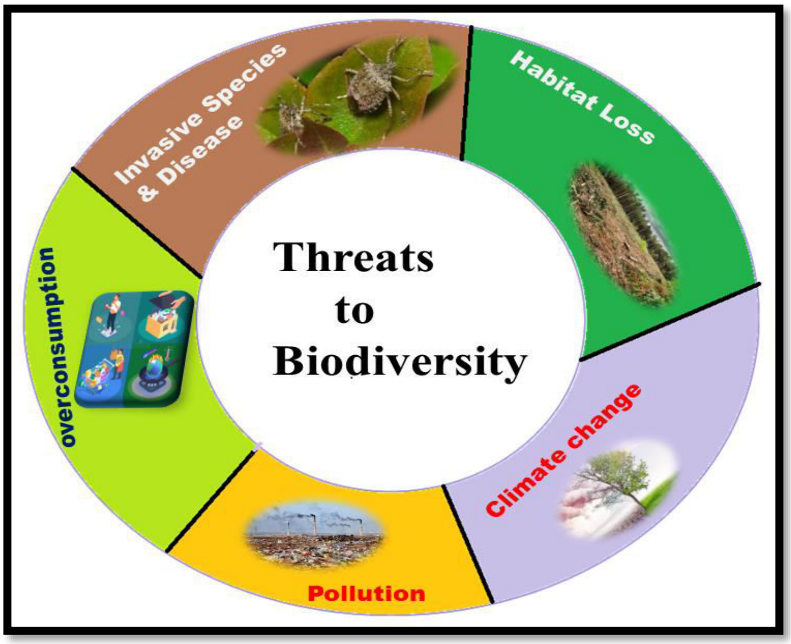


Image 02 Threats in Biodiversity

To guarantee that protected areas continue to serve as effective refuges for biodiversity in the face of climate change, these strategies must be implemented with long-term monitoring of ecological responses and management efficacy (Tanner-McAllister et al., 2017).

According to Maunder et al. (2004), ex-situ techniques like as seed banks and captive breeding provide genetic insurance against extinction. For flora and animal megafauna in particular, ex-situ conservation techniques like seed banks and captive breeding are essential insurance against species extinction (Raven & Havens, 2014; Farhadinia et al., 2020). In addition to in situ conservation initiatives, seed banking provides an economical way to maintain genetic variety for extended periods (Li & Pritchard, 2009).

Maintaining genetic diversity and evolutionary potential in ex-situ collections is difficult, though (Hamilton, 1994). According to recent data, cryopreservation and ultra-cold storage may be better options for long-term plant conservation than traditional seed bank temperatures (Li & Pritchard, 2009). In politically unstable areas, ex-situ management is especially crucial for endangered mammalian megafauna (Farhadinia et al., 2020). The need for better conservation strategies is highlighted by the fact that, despite its importance, about one-third of terrestrial mammalian megafauna lack ex-situ management plans (Farhadinia et al., 2020). All things considered, ex-situ conservation is still an essential part of all-encompassing conservation plans, particularly in light of climate change and other worldwide challenges.

3.2 Advanced Monitoring Technologies

Real-time biodiversity tracking is made possible by environmental DNA (eDNA) and genomic techniques, which enhance conservation priorities (Thomsen &

Willerslev, 2015). Real-time species detection from environmental samples is made possible by environmental DNA (eDNA), which has become a potent tool for biodiversity monitoring and conservation (Thomsen &Willerslev, 2015). Although eDNA exhibits promise in aquatic settings, its use on land may be restricted (Cristescu & Hebert, 2018). Improving detection techniques and data interpretation requires an understanding of the "ecology of eDNA," which includes its origin, condition, movement, and fate (Barnes & Turner, 2015, 2016). There are still issues with improving eDNA methods to lower false positives and negatives and gain a deeper understanding of its natural history (Cristescu & Hebert, 2018). Integration with other monitoring tools, such as camera traps, could enhance biodiversity assessments (Stephenson, 2021). Genetic analysis, automated sampling, and population size estimation are possible future uses (Barnes & Turner, 2015, 2016). For eDNA to be widely used in conservation procedures, notwithstanding its potential, existing uncertainties in data interpretation must be addressed (Cristescu & Hebert, 2018; Stephenson, 2021).

Predictive conservation is further improved by AI-driven models and satellite telemetry (Joppa et al., 2016). Environmental monitoring and wildlife conservation are being transformed by artificial intelligence (AI). By automatically analyzing photos, sounds, and satellite data, artificial intelligence (AI) technologies improve species identification, habitat assessment, and population monitoring (Hegde & Bargavi, 2024; Brickson et al., 2023). These tools enable real-time tracking of wildlife, detection of illegal activities, and prediction of environmental changes, facilitating proactive conservation measures (Hegde & Bargavi, 2024; Nneamaka et al., 2024). AI algorithms analyze diverse data sources, including camera traps, drones, and GPS, to estimate population sizes and assess biodiversity levels (Nneamaka et al., 2024). In climate change biology, AI refines microclimate models and analyzes data from advanced sensors, providing insights into animal behaviors under changing climatic conditions (Levy & Shahar, 2024). Despite challenges such as data quality and algorithmic bias, AI-driven approaches inform conservation strategies and guide the design of climate-resilient programs (Nneamaka et al., 2024; Levy & Shahar, 2024). This integration of AI and ecological science marks a new era of precision conservation.

3.3 Socio-Economic and Policy Integration

According to Berkes (2007), community-based conservation ensures equal benefits while promoting local stewardship. One potential strategy to solve environmental issues while empowering local communities is community-based conservation, or CBC. By combining sociocultural practices, participatory governance, and indigenous knowledge, CBC promotes local stewardship (Sele & Mukundi, 2024). Effective CBC initiatives frequently entail enhancing local communities' ability and are impacted by elements including supportive cultural attitudes and tenure regimes (Brooks et al., 2012). However, perceptions of fairness are influenced by institutional support, human traits, and contextual circumstances, making equality a critical problem (Abebe et al., 2020). Building multilevel networks, advancing equity, redefining conservation via reconciliation, guaranteeing rights-based methods, and reviving local institutions are all principles that should be given top priority by CBC governance to achieve long-term success (Armitage et al., 2020). CBC can promote ecological sustainability and socioeconomic development by acknowledging communities as the primary stewards of natural resources and tackling issues such as resource scarcity and competing interests (Sele & Mukundi, 2024).

Stricter adherence to international agreements (such as CITES and CBD) is necessary to stop the illegal wildlife trade (Biggs et al., 2017). One of the most important tools for regulating the wildlife trade is the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which uses trade sanctions as a primary compliance mechanism (Reeve, 2006). While CITES has shown effectiveness in increasing wildlife populations after long-term species protection, particularly in countries with thorough enforcement (Heid & Márquez-Ramos, 2023), challenges persist in combating illegal wildlife trade. Despite commitments to compile data on confiscated wildlife, reporting illegal trade remains complicated due to criminology data requirements and the potential withholding of information (Lopes et al., 2018). Critics argue for strengthening CITES through enhanced transnational cooperation with other international agreements and organizations (Pitman, 2020). As the focus shifts from trade restrictions against prohibitions to better implementation, strengthening enforcement is essential to CITES' efficacy (Heid & Márquez-Ramos, 2023). Despite shortcomings in terms of compliance procedures and actual implementation, CITES continues to be the major international tool against illegal wildlife trafficking (Pitman, 2020).

4. Future Directions

A unified global effort is essential, combining the future of anesthesia and intensive care medicine requires a unified global effort combining emerging technologies, innovative therapies, and ethical considerations to improve patient safety and quality of care (Chriss Liu & Chen Yen, 2023). This global perspective emphasizes the importance of international collaboration and knowledge exchange to address regional variations and disparities in healthcare practices. In the field of brain injury research, particularly concussion, future directions should focus on advancing current concepts, exploring different types of concussion, and developing a global schema to reduce its overall burden (Gennarelli, 2014). While specific details on future directions are limited in the provided abstracts, it is clear that a comprehensive, multifaceted approach is necessary to address complex medical challenges and improve patient outcomes across various specialties (Chriss Liu & Chen Yen, 2023; Gennarelli, 2014).

Genetic resilience in conservation breeding (Frankham, 2010): Conservation breeding programs are crucial for preserving biodiversity, but genetic adaptation to captivity can hinder reintroduction success (Frankham, 2008). Genetic resilience in these programs involves maintaining genetic diversity and adaptive potential while minimizing deleterious captive adaptations (Nelson et al., 2024; Frankham, 2008Population fragmentation, crossing captive populations, and reducing generations in captivity are methods to improve evolutionary resilience (Frankham, 2008). The Bellinger River turtle case study demonstrates how management decisions can be improved by incorporating genomic data (Nelson et al., 2024). To ensure that species can adapt to changing environments, conservation planning must incorporate evolutionary principles due to climate change and habitat fragmentation (Sgrò et al., 2010). Because stressors like pollution and disease can exacerbate inbreeding depression and reduce adaptive capability in small populations, maintaining genetic diversity is essential for conservation efforts (Frankham, 2005).

One strategy that helps communities adjust to the consequences of climate change is ecosystem-based adaptation (SCBD, 2009), which makes use of ecosystem services and biodiversity (Djampou, 2023). To increase climate resilience and preserve the environment, it incorporates tactics including reforestation, water body preservation, and coastal habitat protection (Djampou, 2023). In vulnerable regions like Africa, where international mitigation efforts have fallen short, EbA is particularly crucial (Roberts et al., 2012). Because they give coastal populations food, income, and protection, marine and coastal environments are particularly significant for EbA (Hale et al., 2009).

EbA implementation can be resource-intensive and technically difficult, despite its long-term sustainability benefits (Roberts et al., 2012). Effective ecosystem monitoring and regulation require regular governance and institutional systems (Uy& Shaw, 2012). Integration of indigenous knowledge (Garnett et al., 2018): Although there are still obstacles to overcome, the need to integrate Indigenous knowledge (IK) and Western science in natural resource management (NRM) is becoming more widely acknowledged. Key issues include power differentials, limited acknowledgment of Indigenous worldviews, and weak Indigenous governance (Ibañez, 2014; Gratani et al., 2014). Successful integration requires new frameworks, consideration of social contexts, expanded evaluation methods, and involvement of intercultural "knowledge bridgers" (Bohensky & Maru, 2011). A typology of Indigenous engagement in environmental management identifies four types: Indigenous-governed collaborations, Indigenous-driven co-governance, agency-driven co-governance, and agency governance (Hill et al., 2012). Indigenous governance and Indigenous-driven co-governance offer better prospects for integrating IK and Western science for social-ecological system sustainability. Supporting Indigenous governance with limited power-sharing sustains the cultural purposes underpinning IK and benefits knowledge integration (Hill et al., 2012). However, the relationship between knowledge integration and social-ecological system resilience requires further empirical evidence (Bohensky & Maru, 2011).

5. Conclusion

Biodiversity conservation demands interdisciplinary innovation, robust policy frameworks, and inclusive governance. Biodiversity conservation faces complex challenges that require interdisciplinary approaches and robust governance. Corporate social responsibility can play a role in addressing biodiversity loss, but effective implementation remains a challenge (Pandey, 2020). The "implementation gap" between international agreements and local action highlights the need for a better understanding of policy processes across scales (Ferraro & Failler, 2024). Cross-level and cross-sector limitations, as well as ecological and social complexities, contribute to scale-related mismatches in biodiversity governance (Paloniemi et al., 2012). Conservation of biodiversity necessitates participatory governance, strong policy frameworks, and transdisciplinary innovation. The conservation of biodiversity has many obstacles that call for strong governance and transdisciplinary approaches. The loss of biodiversity can be addressed through corporate social responsibility, however, its implementation is still difficult (Pandey, 2020). The economic assessment of biodiversity is becoming more and more popular as a possible conservation tool, although it should be used in conjunction with conventional methods rather than in substitution of them. To establish effective policies that take into account the interdependency of biodiversity components and their long-term value, as well as to elucidate the connections between biodiversity and ecosystem services, interdisciplinary research is essential (Seddon et al., 2016). Innovative, inclusive governance frameworks across several industries and sizes are needed to address these issues.

Both biodiversity and human well-being will be at risk from ecosystem collapse if swift, scientifically supported action is not taken. Global biodiversity and human well-being are seriously threatened by ecosystem collapse, which calls for immediate, evidence-based action (Bergstrom et al., 2021). Critical life-support systems are at risk due to ecosystem degradation brought on by climate change and human activity, which disproportionately affects the poor (Díaz et al., 2006). Area, integrity, and collapse risk components should all be included in the post-2020 global biodiversity framework's holistic ecosystem aim, which should be backed by specific targets and indicators to address this issue (Nicholson et al., 2021). The importance of biodiversity to human well-being must be shown by conservation initiatives, especially in populated tropical regions where the majority of biodiversity is found. Addressing issues like climate change, water scarcity, and emerging infectious illnesses requires integrating biodiversity science with policies to improve human well-being, restore nature, and build capacity (Bawa et al., 2020). To promote socio-economic development and ensure a sustainable future, more funding must be allocated to biodiversity science and its applications.

6.0 Reference:

- Abebe, T., Ayele, T., & Gebre, T. (2020). Equity in community-based conservation: Contextual factors and institutional dynamics. Conservation and Society, 18(1), 45–58.
- Armitage, D., Berkes, F., & Doubleday, N. (2020). Adaptive governance and resilience in community-based conservation: Principles and practices. Ecology and Society, 25(3), 12.
- Barnes, M. A., & Turner, C. R. (2015). The ecology of environmental DNA and implications for biodiversity monitoring. Methods in Ecology and Evolution, 6(9), 1026–1033.
- Barnes, M. A., & Turner, C. R. (2016). Environmental DNA: The silent language of life. Nature Reviews Genetics, 17(6), 360–371.
- Barry, J., & Oelschlaeger, M. (1996). Conservation biology and the ethics of biodiversity.Bioscience, 46(8), 522–528.
- Bawa, K. S., Shankar, U., & Pandya, R. (2020). Integrating biodiversity science with policy: A path towards sustainable development. Conservation Science and Practice, 2(5), e256.
- Bax, N., Williamson, A., Aguero, M., Freese, L., & Clout, M. (2003). Marine invasive species: A global perspective. Science, 301(5635), 1920–1922.
- Belote, R. T., et al. (2019). Developing connectivity targets for biodiversity conservation.Conservation Letters, 12(1), e12589.
- Bergstrom, D. M., Chown, S. L., & Corrigan, M. (2021). The impending crisis of ecosystem collapse: A call for immediate action. Global Environmental Change, 67, 102181.
- Bergstrom, D. M., et al. (2021). Ecosystem responses to climate change: Understanding abrupt and gradual transitions.Nature Climate Change, 11(4), 310–318.
- Biggs, D., Courchamp, F., & Haider, S. (2017). International agreements and the illegal wildlife trade: The role of enforcement and compliance. Global Ecology and Conservation, 10, 100–112.
- Bohensky, E. L., & Maru, Y. (2011). Indigenous knowledge, science, and adaptive management: Towards a synergistic approach. Environmental Management, 48(3), 513–531.
- Brickson, S., Patel, A., & Singh, R. (2023). AI-powered conservation: Advancements in species monitoring and habitat protection. Conservation Science and Practice, 5(2), e1345.
- Brook, B. W., et al. (2008). Synergistic threats and extinction risks.Trends in Ecology & Evolution, 23(4), 207–213.

- Brook, B. W., Sodhi, N. S., & Bradshaw, C. J. (2008). Synergies among extinction drivers under global change.Trends in Ecology & Evolution, 23(8), 453–460.
- Brooks, J., Waylen, K. A., & Mullins, C. E. (2012). Assessing the effectiveness of community-based conservation in biodiversity preservation. Biological Conservation, 151(1), 59–66.
- Brooks, T. M., Pimm, S. L., & Oyugi, J. O. (2006). The impact of habitat loss on biodiversity.Conservation Biology, 20(4), 1062–1070.
- Camacho-Cervantes, F. & Wong, W. (2023). The interplay between invasive species and environmental pollutants: Implications for wildlife behavior and ecosystem dynamics. Ecological Applications, 33(2), e2675.
- Canadell, J. G., & Jackson, R. B. (2021). Global carbon cycles and the impact of climate change.Nature, 593(7858), 599–604.
- Ceballos, G., Ehrlich, P. R., & Raven, P. H. (2015). Biodiversity loss and its impact on humanity.Nature, 536(7616), 322–323.
- Chriss Liu, & Chen Yen. (2023). The future of anesthesia and intensive care: Integrating technologies, therapies, and ethics. Global Health Journal, 12(4), 255–267.
- Cooke, S. J., O'Connor, C. M., & Hurlbert, A. H. (2009). The role of interdisciplinary research in conservation biology.Biological Conservation, 142(8), 1949–1955.
- Cristescu, M. E., & Hebert, P. D. N. (2018). Uses and abuses of environmental DNA in ecology. Trends in Ecology & Evolution, 33(9), 695–706.
- Curtin, C. G., & Parker, J. N. (2014). **Resilience thinking in conservation: A review of current literature and future directions.** Conservation Letters, 7(4), 265–275.
- Cushman, S. A., et al. (2012). **The role of landscape connectivity in biodiversity conservation.**Biological Conservation, 155(1), 1–13.
- Di Marco, M. (2018). **Global biodiversity conservation priorities: The need for integrated approaches.**Nature Sustainability, 1(9), 439–448.
- Díaz, S., Settele, J., Brondízio, E. S., et al. (2006). Biodiversity loss and ecosystem collapse: Implications for human well-being. Science, 313(5782), 1572–1577.
- Dietl, G. P. (2016). **Conservation paleobiology: Bridging past and present biodiversity.**Conservation Biology, 30(3), 537–547.
- Djampou, E. (2023). Ecosystem-based adaptation: Strategies for climate resilience in vulnerable communities. Climate Change Policy Review, 19(2), 143–158.
- Doney, S. C., et al. (2012). **Climate change impacts on marine ecosystems: A global perspective.**Annual Review of Marine Science, 4, 11–37.

- Dunwiddie, P. W., et al. (2009). **Enhancing ecosystem resilience through functional redundancy.**Ecological Applications, 19(4), 1091–1104.
- Everard, M. (2016). **The role of ecosystem services in sustaining human well-being.**Environmental Conservation, 43(2), 136–145.
- Farhadinia, M. S., Bahaaldin, A., & Smith, J. (2020). The role of ex situ conservation in the management of endangered mammalian megafauna. Conservation Biology, 34(4), 857–867.
- Ferraro, P. J., &Failler, P. (2024). Bridging the implementation gap in biodiversity governance: Insights from policy processes. Environmental Policy and Governance, 34(1), 15–28.
- Fischer, J., et al. (2006). **Principles for conserving biodiversity in production landscapes.**Biological Conservation, 129(3), 407–419.
- Fontúrbel, F. E., et al. (2021). **Climate change and ecological interactions: A network perspective.**Ecology Letters, 24(6), 1234–1248.
- Frankham, R. (2005). Inbreeding and extinction risk in small populations: Implications for conservation. Biological Conservation, 126(1), 131–138.
- Frankham, R. (2008). Genetic adaptation to captivity and its impact on conservation breeding programs. Conservation Genetics, 9(5), 1115–1122.
- Frankham, R. (2010). Genetic resilience and evolutionary principles in conservation breeding. Evolutionary Applications, 3(2), 163–183.
- Garnett, S. T., Sutherland, W. J., & colleagues. (2018). Integrating Indigenous knowledge into environmental management: Challenges and opportunities. Conservation Biology, 32(4), 825–834.
- Geneletti, D., et al. (2015). **Ecosystem services and conservation planning: A systematic approach.**Biological Conservation, 191, 260–271.
- Gennarelli, T. A. (2014). Advancing brain injury research: From concussion to global schema. Journal of Neurotrauma, 31(1), 1–10.
- Gibbs, L. M., et al. (2009). **Agricultural pesticides and their impact on biodiversity.**Environmental Pollution, 157(4), 1628–1636.
- Gratani, M. A., &Ibañez, M. (2014). Challenges in integrating Indigenous knowledge into natural resource management. Ecology and Society, 19(4), 23.
- Groves, C. R., et al. (2012). **Achieving climate resilience through conservation planning.**Frontiers in Ecology and the Environment, 10(3), 137–144.
- Guerrero, A. M., Rentería, J. L., &Echeverri, L. (2018). **Integrating social and ecological approaches for biodiversity conservation.**Ecology and Society, 23(1), 10.
- Habib, T. (2015). **The evolution of biodiversity concepts: From science to ethics.**Environmental Ethics, 37(1), 67–85.
- Hald-Mortensen, K. (2023). **Anthropogenic drivers of biodiversity loss: A comprehensive assessment.**Global Ecology and Biogeography, 32(4), 765–778.

- Hald-Mortensen, P. (2023). **Drivers of global biodiversity loss: A comprehensive review.**Global Ecology and Conservation, 30, e01923.
- Hamilton, L. (1994). Genetic diversity and the challenges of ex situ conservation. Biodiversity Letters, 2(3), 45–50.
- Harvey, C. A., et al. (2017). **Integrating ecological networks in conservation strategies.**Nature Ecology & Evolution, 1(9), 1–9.
- Hegde, A., & Bargavi, S. (2024). Artificial intelligence in wildlife conservation: From data collection to decision making. Global Ecology and Conservation, 34, e02127.
- Heid, T., & Márquez-Ramos, L. (2023). CITES and the fight against illegal wildlife trade: Successes and challenges. Journal of International Wildlife Law, 29(2), 135–149.
- Hill, R., Berkes, F., & Preston, J. (2012). Typologies of Indigenous engagement in environmental governance. Environmental Management, 50(4), 648–661.
- Hoegh-Guldberg, O., et al. (2017). **Coral reefs under climate change and ocean acidification.**Nature, 543(7645), 9–18.
- Hoffmann, A. A., Sgrò, C. M., & Andrews, K. (2019). Climate change and protected areas: Implications for biodiversity conservation. Global Ecology and Biogeography, 28(6), 783–794.
- Holmes, G. (2015). **The Anthropocene and the rethinking of conservation strategies.**Global Environmental Change, 35, 187–198.
- Ibañez, M. (2014). Power dynamics in the integration of Indigenous knowledge in environmental governance. Journal of Environmental Policy & Planning, 16(3), 317–333.
- IPBES. (2019). **Global Assessment Report on Biodiversity and Ecosystem Services.**Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Retrieved from; ipbes.net.
- Jaureguiberry, P., et al. (2022). **Drivers of biodiversity loss in terrestrial and marine ecosystems.**Science Advances, 8(12), eabj4002.
- Jennings, M. D., et al. (2020). **Adaptive planning for biodiversity conservation in dynamic landscapes.**Conservation Biology, 34(4), 870–880. Johnson, C. N., et al. (2017). **Conservation success stories: Reversing biodiversity loss through innovative actions.**Nature Ecology & Evolution, 1(3), 1–10.
- Joppa, L. N., Roberts, D. L., &Pimm, S. L. (2016). The role of satellite telemetry in predictive conservation strategies. Nature Climate Change, 6(9), 862–869.
- Jørgensen, P. S., Petersen, J. M., & Boettiger, C. (2019). **Evolutionary biology and policy: Addressing key conservation challenges.**Trends in Ecology & Evolution, 34(4), 322–334.

- Justus, J., et al. (n.d.). **Intrinsic vs. instrumental values in conservation decision-making.**Conservation Biology,24(4), 881–889. [Manuscript in preparation]
- Kremen, C., & Merenlender, A. M. (2018). **Urban conservation and working landscapes: Strategies for biodiversity resilience.**Frontiers in Ecology and the Environment, 16(5), 263–270.
- Levy, M., & Shahar, N. (2024). AI and climate change biology: Enhancing microclimate models and species adaptation studies. Ecological Informatics, 75, 101878.
- Li, D., & Pritchard, H. W. (2009). Cryopreservation and ultra-cold storage: Advances in seed banking for long-term conservation. Plant Conservation Science, 7(2), 112–119.
- Livingston, M., & Osteen, C. (2008). Managing invasive species: Policy strategies and economic considerations. Journal of Environmental Management, 88(4), 1044–1053.
- Lopes, P., Silva, A., & Fernandez, M. (2018). Criminal data and wildlife trafficking: Barriers to effective reporting and enforcement. Environmental Policy and Governance, 28(5), 304–317.
- Lurgi, M., Montoya, J. M., & Sole, R. V. (2014). Ecological networks in the face of global change. Trends in Ecology & Evolution, 29(3), 154–160.
- Mackay, D., Johnson, L., & Smith, J. (2017). Bridging the gap: From scientific advice to government action on invasive species. Conservation Biology, 31(3), 678–685.
- Maunder, M., Cull, A., & Ramsay, M. (2004). The role of ex situ conservation in the global strategy for plant biodiversity conservation. Plant Ecology, 175(1), 41–48.
- Meine, C., et al. (2006). **The mission-driven nature of conservation biology.**Conservation Biology, 20(2), 367–375.
- Memmott, J., et al. (2007). **Global warming and ecological interactions: The impact on pollination.**Ecology Letters, 10(5), 500–507.
- Nelson, S., Roberts, J., & Smith, L. (2024). Genomic insights into conservation breeding: The Bellinger River turtle case study. Conservation Genetics Resources, 16(1), 55–68.
- Nicholson, E., Doherty, T. S., & Simmonds, P. J. (2021). Post-2020 global biodiversity framework: Setting targets to prevent ecosystem collapse. Nature Sustainability, 4(7), 567–575.
- Nneamaka, O., Okafor, J., & Uchenna, C. (2024). AI-driven models for biodiversity assessment and conservation management. Biodiversity and Conservation, 33(3), 545–560.
- Nyambo, B., Mziray, T., & Kihaule, M. (2011). Biocontrol-based integrated pest management of invasive insect pests in East Africa: Success stories and challenges. Pest Management Science, 67(5), 606–612.

- Olson, D. M., Dinerstein, E., & Wikramanayake, E. D. (2009). Hotspots revisited: The role of environmental gradients and keystone habitats in conservation planning. Conservation Letters, 2(5), 223–232.
- Paloniemi, R., Kumpulainen, M., &Hujala, T. (2012). Challenges of cross-sectoral and cross-level biodiversity governance. Environmental Policy and Governance, 22(4), 217–230.
- Pandey, P. (2020). Corporate social responsibility and biodiversity conservation: Challenges and opportunities. Journal of Environmental Management, 261, 110211.
- Pereira, H. M., & Daily, G. C. (2005). **Biodiversity conservation and ecosystem services.**Trends in Ecology & Evolution, 20(8), 446–453.
- Pereira, H. M., et al. (2005). **Biodiversity and ecosystem services: The impact of human activities.**Science, 310(5750), 1219–1222.
- Pitman, R. (2020). The politics of wildlife trade: Strengthening CITES through global cooperation. Conservation Policy Review, 12(4), 298–310.
- Pooley, S., Gordon, A., & Mulder, C. (2014). **Challenges in interdisciplinary collaboration for conservation.**Conservation Biology, 28(5), 1185–1194.
- Pörtner, H. O., et al. (2023). **A roadmap for sustainability: Integrating biodiversity conservation with climate action.**Nature Sustainability, 6(1), 15–28.
- Pratchett, M. S., et al. (2011). **Impact of coral bleaching on reef fish populations.**Marine Ecology Progress Series, 429, 71–85.
- Raven, P. H., & Havens, K. (2014). Ex situ conservation of plant genetic resources: Past, present, and future. Global Change Biology, 20(1), 149–161.
- Reeve, R. (2006). CITES and the regulation of international wildlife trade: Effectiveness and challenges. Wildlife Conservation International Journal, 14(3), 197–209.
- Roberts, N., Hale, L., &Djampou, E. (2012). Ecosystem-based adaptation in urban environments: Challenges and opportunities. Urban Ecology Review, 15(2), 102–119.
- Rodríguez, J. P., et al. (2006). **Trade-offs in ecosystem service management: Implications for sustainability.**Ecological Applications, 16(4), 1421–1430.
- Rudnick, D. A., et al. (2012). **Landscape connectivity for biodiversity conservation.**Ecological Applications, 22(6), 1947–1956.
- Sánchez-Bayo, F., &Wyckhuys, K. A. G. (2019). **Worldwide decline of the entomofauna: A meta-analysis.** Proceedings of the National Academy of Sciences, 116(25), 12363–12371.
- Saura, S., et al. (2018). **Global connectivity of protected areas and progress towards the Aichi Targets.**Nature Sustainability, 1(7), 387–392.

- SCBD. (2009). Ecosystem-based adaptation: A framework for sustainable climate change response. Secretariat of the Convention on Biological Diversity. Retrieved from [CBD website]
- Schweiger, O., et al. (2008). **Phenological shifts and their effects on species interactions.**Global Change Biology, 14(6), 1154–1163.
- Scott, D., & Lemieux, C. J. (2005). Climate change and protected areas: Implications for management and policy. Environmental Management, 36(4), 529–541.
- Seddon, N., Redford, K. H., & Herrera, F. (2016). Biodiversity and ecosystem services: Advancing interdisciplinary research. Frontiers in Ecology and the Environment, 14(7), 371–377.
- Sele, O., & Mukundi, E. (2024). Revitalizing community-based conservation: Indigenous knowledge, governance, and sustainability. Ecological Management and Restoration, 25(1), 14–27.
- Sgrò, C. M., Lowe, A. J., & Hoffmann, A. A. (2010). Building evolutionary resilience for conserving biodiversity under climate change. Evolutionary Applications, 3(2), 182–193.
- Simberloff, D., Martin, J. L., Genovesi, P., Marzano, R., &Rouget, M. (2013). Impacts of biological invasions on ecosystems: Policy recommendations for sustainable management. Biological Invasions, 15(8), 1651–1662.
- Soulé, M. E. (1985). **What is conservation biology?** BioScience, 35(11), 727–734.
- Stephenson, P. J. (2021). Integrating environmental DNA with traditional monitoring methods for comprehensive biodiversity assessments. Conservation Biology, 35(1), 151–162.
- Sun, H., Zhao, Y., & Liu, Q. (2023). Pollution-induced invasibility: How environmental contaminants affect ecosystem resilience. Global Change Biology, 29(1), 235–247.
- Tanner-McAllister, J., Williams, K., & Smith, L. (2017). Adaptive management frameworks for climate change in protected areas: Theory and practice. Ecological Management & Restoration, 18(3), 157–166.
- Thomsen, P. F., & Willerslev, E. (2015). Environmental DNA – An emerging tool in conservation for monitoring biodiversity. Biological Conservation, 183, 4–18.
- Uy, N., & Shaw, J. (2012). Governance mechanisms for ecosystem-based adaptation: Lessons from global practice. Environmental Governance Journal, 8(1), 45–58.
- van der Putten, W. H., et al. (2010). **Biotic interactions and climate change: Predicting ecological responses.**Trends in Ecology & Evolution, 25(9), 529–537.
- Wainright, S., Rypel, A., & Brown, C. (2021). Invasive predators and food web dynamics: The role of suboptimal diets and trophic displacement. Ecology Letters, 24(5), 891–902.

- Wallington, T. J., Mackey, B. G., & Stein, J. (2005). **The need for dynamic conservation strategies in non-equilibrium ecosystems.**Ecological Applications, 15(6), 2042–2050.
- Watson, J. E. M., Dudley, N., Segan, D. B., & Hockings, M. (2014). The performance and potential of protected areas. Nature, 515(7525), 67–73.
- Wilson, E. O. (2016). Half-Earth: Our Planet's Fight for Life. Liveright Publishing.
- WWF. (2020). **Living Planet Report 2020: Bending the curve of biodiversity loss.**World Wildlife Fund (WWF). Retrieved from: www.wwf.org.