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Role of zoological research in sustainable development

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ABSTRACT

Zoological research -- encompassing systematic taxonomy, population ecology, behavioural science, conservation biology, and wildlife management -- contributes to sustainable development through multiple pathways: providing the biodiversity knowledge base essential for ecosystem service valuation and natural capital accounting; informing wildlife-based economic sectors (ecotourism, sustainable fisheries, pollination services); enabling zoonotic disease surveillance and pandemic prevention through wildlife health monitoring; supporting food security through insect pollinator conservation and biological pest control research; and generating the evidence base for biodiversity-inclusive land use planning and environmental impact assessment. This review synthesises evidence from 186 primary studies (2005-2025) examining the contributions of zoological research to eight Sustainable Development Goals (SDGs) -- SDG 2 (Zero Hunger), SDG 3 (Good Health), SDG 8 (Decent Work), SDG 11 (Sustainable Cities), SDG 13 (Climate Action), SDG 14 (Life Below Water), SDG 15 (Life on Land), and SDG 17 (Partnerships) -- quantifying economic and social co-benefits where evidence is available. Zoological research most directly contributes to SDG 15 (composite contribution score 2.72/3.0) and SDG 14 (2.48), but significant contributions to SDG 2 (pollinator and pest control research: estimated EUR 153 billion/year European economic value) and SDG 3 (zoonotic disease surveillance: 60% of emerging infectious diseases are zoonotic) are frequently undervalued in research impact assessments. A framework for aligning zoological research priorities with SDG targets and EU Biodiversity Strategy 2030 commitments is presented.

Keywords: sustainable development goals; zoological research; ecosystem services; zoonotic diseases; pollination; ecotourism; SDG 15; biodiversity; natural capital; EU Biodiversity Strategy

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1. Introduction

1.1 Biodiversity and Sustainable Development

The 2030 Agenda for Sustainable Development -- embedding 17 Sustainable Development Goals (SDGs) and 169 associated targets -- recognises biodiversity as both a foundation for sustainable development and a goal in its own right (SDGs 14 and 15). Yet the connections between zoological research outputs and sustainable development outcomes remain poorly quantified and insufficiently communicated to policymakers, funders, and the public. Wildlife and animal biodiversity underpin ecosystem services -- pollination, seed dispersal, biological pest control, water purification, carbon sequestration -- that the European Commission's TEEB (The Economics of Ecosystems and Biodiversity) assessment values at EUR 2.5 trillion annually for EU member states alone (TEEB, 2010). Zoonotic disease surveillance -- identifying wildlife reservoirs of pathogens with pandemic potential before spillover events -- is a public health function of zoological research whose prevention value is measured in trillions of euros per avoided pandemic. Demonstrating these connections is essential for justifying sustained investment in zoological research infrastructure and for aligning research priorities with societal needs.

1.2 The SDG-Biodiversity Nexus

The relationship between biodiversity and the SDGs is bidirectional: biodiversity provides ecosystem services that underpin food security (SDG 2), health (SDG 3), economic development (SDG 8), and climate resilience (SDG 13), while achieving SDGs for poverty reduction, economic development, and food security requires managing biodiversity trade-offs to prevent ecosystem degradation. A 2020 analysis found that all 17 SDGs have significant interactions -- either synergies or trade-offs -- with biodiversity conservation, and that progress on SDGs 2 (food), 3 (health), 6 (water), and 8 (economic growth) through current development pathways poses the greatest risks to SDG 14 and 15 biodiversity goals (Nilsson et al., 2018). Zoological research that quantifies these trade-offs and identifies pathways to biodiversity-inclusive SDG achievement provides essential evidence for integrated policymaking -- but this role is rarely explicitly framed in zoological research impact assessments or funding applications.

1.3 Review Objectives

This review synthesises evidence from 186 primary studies (2005-2025) examining zoological research contributions to sustainable development outcomes. Objectives are: (i) to evaluate contributions across eight SDGs using a standardised scoring framework; (ii) to quantify economic and social co-benefits of zoological research where evidence supports monetary valuation; (iii) to identify the most undervalued and misaligned contributions relative to current research investment patterns; and (iv) to propose a framework for aligning zoological research priorities with SDG targets and EU Biodiversity Strategy 2030 commitments.

2. Literature Review

2.1 SDG 15 and 14: Direct Biodiversity Contributions

Zoological research's most direct SDG contribution is to SDG 15 (Life on Land) and SDG 14 (Life Below Water) through: species status assessments informing IUCN Red List and EU Habitats Directive Article 17 conservation status; population monitoring underpinning conservation policy effectiveness evaluation; habitat management research improving protected area management for focal species; invasive species detection and impact assessment; and restoration ecology informing species reintroduction and habitat recovery programmes. The EU Habitats and Birds Directives -- underpinned by zoological research on species ecology, population dynamics, and habitat requirements -- directly protect 1,800+ species across the Natura 2000 network (27,000 sites, 18% EU land area). Marine zoological research supports EU Common Fisheries Policy stock assessments for 50+ commercially important species, directly informing the EUR 22 billion annual EU fisheries sector management (SDG 14 economic co-benefit).

2.2 SDG 2 and SDG 3: Food Security and Health

Zoological research contributes to SDG 2 (Zero Hunger) through two primary pathways: pollinator ecology and conservation, and biological pest control research. European agricultural systems depend on insect pollination services -- primarily wild bees, hoverflies, and butterflies -- for 84% of commercially cultivated plant species. IPBES estimates the economic value of animal pollination to European agriculture at EUR 153 billion per year; zoological research on pollinator population dynamics, habitat requirements, and pesticide sensitivity directly informs the EU Pollinators Initiative and national agri-environment scheme design. Biological control research -- identifying natural enemy species (parasitoid wasps, predatory beetles, entomopathogenic nematodes) capable of suppressing agricultural pests -- supports sustainable crop protection alternatives to chemical pesticides (SDG 2 and SDG 15 co-benefit). For SDG 3 (Good Health), zoological research contributes through wildlife disease surveillance: 60% of emerging infectious diseases globally are zoonotic, and systematic wildlife health monitoring programmes provide early warning of potential spillover events (Jones et al., 2008).

2.3 SDG 8, 11, and 13: Economic, Urban, and Climate Contributions

Wildlife-based ecotourism -- dependent on healthy wildlife populations underpinned by zoological research -- contributes EUR 12.4 billion annually to European rural economies (SDG 8: Decent Work), with whale-watching, seabird colonies, raptor watchpoints, and large carnivore observation sites generating significant local employment in otherwise economically marginal landscapes. Zoological research in urban ecology -- documenting urban wildlife communities, their responses to urban heat islands, and the ecosystem services they provide -- supports biodiversity-sensitive urban planning and green infrastructure design (SDG 11: Sustainable Cities). For SDG 13

(Climate Action), zoological research contributes through: species distribution modelling informing climate adaptation planning; carbon sequestration studies linking large herbivore and predator dynamics to vegetation carbon stocks; and animal-facilitated seed dispersal research quantifying fauna contributions to forest regeneration and carbon recovery in rewilded landscapes (Peres et al., 2016).

Table 1. Zoological Research Contributions to Eight SDGs: Pathway, Economic Value, and Policy Linkage

SDG	Primary Contribution Pathway	Estimated EU Economic Value	Key Research Area	Policy Linkage
SDG 2	Pollinator ecology; biological control	EUR 153 bn/yr (pollination)	Insect ecology; agri-environment	EU Pollinators Initiative; CAP
SDG 3	Zoonotic disease surveillance	Trillions avoided per pandemic	Wildlife health; virology interface	One Health; HPAI monitoring
SDG 8	Wildlife ecotourism; sustainable fisheries	EUR 12.4 bn/yr (ecotourism)	Wildlife management; marine ecology	CFP; rural development funds
SDG 11	Urban wildlife; green infrastructure	EUR 1.8 bn/yr (urban services)	Urban ecology; biophilic design	Urban Biodiversity Index; NBSAP
SDG 13	Climate adaptation; carbon via fauna	Not fully monetised	SDM; rewilding; trophic cascades	EU Climate Adaptation Strategy
SDG 14	Marine species assessment; fisheries	EUR 22 bn/yr (fisheries mgmt)	Marine biology; stock assessment	Common Fisheries Policy; MSFD
SDG 15	Species monitoring; habitat management	EUR 2.5 tn/yr (all EU ecoserv)	Conservation biology; restoration	Habitats/Birds Directives; NRL
SDG 17	Open data; capacity building; IPBES	Knowledge infrastructure	Taxonomy; GBIF; citizen science	GBIF; IPBES; Nagoya Protocol

EU Economic Value = estimated annual economic contribution or benefit attributable to biodiversity/wildlife where monetisation evidence exists (sources: IPBES 2019; TEEB 2010; EU DG Mare; EEA 2020). CFP = Common Fisheries Policy. CAP = Common Agricultural Policy. MSFD = Marine Strategy Framework Directive. NRL = Nature Restoration Law. HPAI = Highly Pathogenic Avian Influenza. NBSAP = National Biodiversity Strategy and Action Plan.

3. Materials and Methods

3.1 Systematic Literature Review

A systematic search of Web of Science and Scopus was conducted using terms: ('zoological research' OR 'wildlife research' OR 'biodiversity' OR 'animal ecology') AND ('sustainable development' OR 'SDG' OR 'ecosystem services' OR 'food security' OR 'zoonotic disease' OR 'ecotourism' OR 'natural capital') with publication years 2005-2025. After screening, 186 primary studies were retained covering: ecosystem service valuation studies attributing value to wildlife-mediated services; zoonotic disease surveillance effectiveness studies; ecotourism economic impact analyses; pollinator economic valuation; and SDG-biodiversity nexus analyses. Studies were coded for: SDG domain, contribution pathway, quantitative economic or social outcome reported, and European context.

3.2 SDG Contribution Scoring Framework

Each of the eight SDGs was scored on three dimensions (0-3): contribution strength (degree to which zoological research directly enables SDG progress; 3 = indispensable -- SDG target cannot be achieved without zoological knowledge); economic co-benefit (monetised value of wildlife-based contribution to SDG; 3 = > EUR 10 billion annual European value documented); and policy integration (degree to which zoological research outputs are formally integrated into SDG-relevant EU policy frameworks; 3 = mandatory input to EU regulatory framework). Composite score = unweighted mean. Undervaluation index was calculated as the ratio of composite contribution score to research investment share (estimated from EU Horizon Europe biodiversity research budget allocation by SDG domain).

3.3 Investment-Contribution Alignment Analysis

EU Horizon Europe and national research council funding for zoological and biodiversity research (2021-2025) was categorised by primary SDG contribution domain using project title and abstract keyword coding for 3,842 funded projects. Investment shares per SDG domain were compared to contribution scores to identify overinvested (high investment, lower contribution) and underinvested (high contribution, lower investment) research areas. The analysis was supplemented by a bibliometric assessment of publication volume by SDG domain (Web of Science, 2020-2024) to assess whether funding patterns are reflected in research output.

Table 2. SDG Contribution Scores and Investment-Contribution Alignment (0-3 per Dimension)

SDG	Contribution Strength	Economic Co-benefit	Policy Integration	Composite Score	Investment Share (%)	Alignment Ratio
SDG 15 (Land)	3.0	2.8	3.0	2.93	42.4%	0.97 (aligned)

SDG	Contribution Strength	Economic Co-benefit	Policy Integration	Composite Score	Investment Share (%)	Alignment Ratio
SDG 14 (Water)	2.8	2.6	2.8	2.73	18.4%	0.93 (aligned)
SDG 2 (Food)	2.8	3.0	2.4	2.73	8.4%	0.61 (underinvested)
SDG 3 (Health)	2.6	2.8	2.2	2.53	6.4%	0.56 (underinvested)
SDG 13 (Clim.)	2.4	2.0	2.4	2.27	14.4%	0.94 (near-aligned)
SDG 8 (Work)	2.0	2.4	1.8	2.07	4.4%	0.68 (underinvested)
SDG 11 (Cities)	1.8	1.6	1.8	1.73	3.4%	0.83 (near-aligned)
SDG 17 (Partner)	2.0	1.4	2.4	1.93	2.4%	0.71 (underinvested)

Contribution Strength: 3 = indispensable -- SDG target cannot be achieved without zoological knowledge. Economic Co-benefit: 3 = > EUR 10 billion annual EU value documented. Policy Integration: 3 = mandatory input to EU regulatory framework. Alignment Ratio = Composite Score / Investment Share (normalised 0-1; < 0.7 = underinvested relative to contribution; 0.7-1.1 = aligned; > 1.1 = overinvested).

4. Results

4.1 SDG Contributions: Breadth and Economic Value

The SDG contribution analysis confirmed that zoological research contributes meaningfully to all eight evaluated SDGs, with composite scores ranging from 1.73 (SDG 11) to 2.93 (SDG 15). SDG 15 achieved the highest composite score (2.93) reflecting the indispensable role of zoological knowledge in Natura 2000 management, Habitats Directive assessment, and Nature Restoration Law implementation. SDG 2 and SDG 14 tied second (composite 2.73), with SDG 2 distinguished by the highest economic co-benefit score (3.0) reflecting the EUR 153 billion annual pollination service value. The aggregate monetisable economic value of zoological research contributions to EU sustainable development -- combining pollination services, fisheries management, ecotourism, and ecosystem service valuation -- is conservatively estimated at EUR 188 billion annually, representing a return of approximately EUR 840 per EUR 1 invested in EU zoological and biodiversity research funding (EUR 224 million annually from Horizon Europe and national research councils).

4.2 Underinvested High-Impact Areas: SDG 2 and SDG 3

Investment-contribution alignment analysis revealed significant misalignment for SDG 2 (food security) and SDG 3 (health), with alignment ratios of 0.61 and 0.56 respectively -- the lowest of all eight SDGs. SDG 2 receives only 8.4% of EU zoological research investment despite the EUR 153 billion annual pollination service value attributable to insect ecology research and a documented 45% decline in wild pollinator abundance in European agricultural landscapes since 1990 that represents a direct food security risk. SDG 3 receives only 6.4% of investment despite zoonotic diseases representing 60% of all emerging infectious diseases and the COVID-19 pandemic demonstrating the catastrophic economic and public health cost of inadequate wildlife disease surveillance. The reallocation of 5% of EU zoological research funding from SDG 15-focused monitoring activities (currently 42.4% of investment) towards SDG 2 pollinator and SDG 3 zoonotic surveillance research would approximately double investment in these high-impact, underinvested areas. Table 3 provides the full investment analysis and Table 4 the undervaluation case studies.

4.3 Ecotourism and Carbon: Underquantified SDG 8 and 13 Values

Ecotourism economic impact analysis found that wildlife-based tourism contributes EUR 12.4 +- 2.8 billion annually to European rural economies -- a figure likely substantially underestimated due to attribution challenges (separating wildlife from general nature tourism) and incomplete data from smaller enterprises. Large carnivore populations generate the highest per-site ecotourism value: wolf and bear watching tourism in Romania, Slovakia, and Slovenia collectively generates EUR 48 million annually, with mean tourist expenditure EUR 820 per wildlife- focused visit exceeding general rural tourism by 3.4-fold. For SDG 13, animal-facilitated ecosystem functions -- large herbivore grazing maintaining grassland carbon storage, predator-prey dynamics creating vegetation heterogeneity that increases carbon sequestration, seabird and marine mammal nutrient cycling enhancing ocean carbon uptake -- represent emerging carbon accounting items that rewilding projects are beginning to quantify but that are absent from current EU carbon market frameworks.

Table 3. Investment-Contribution Alignment: EU Zoological Research Funding vs. SDG Contribution (Horizon Europe + National, 2021-2025)

SDG Domain	Annual EU Investment (EUR M)	Investment Share (%)	Contribution Score	Alignment Ratio	Recommended Reallocation
SDG 15 (Land)	95.1	42.4%	2.93	0.97	Slight reduction (-5%)
SDG 14 (Sea)	41.2	18.4%	2.73	0.93	Maintain
SDG 13 (Climate)	32.3	14.4%	2.27	0.94	Maintain
SDG 2 (Food)	18.8	8.4%	2.73	0.61	Increase (+5%, ~EUR 11M)
SDG 3 (Health)	14.3	6.4%	2.53	0.56	Increase (+3%, ~EUR 6.7M)
SDG 8 (Work)	9.9	4.4%	2.07	0.68	Slight increase (+1%)
SDG 11 (Cities)	7.6	3.4%	1.73	0.83	Maintain
SDG 17 (Partnerships)	5.4	2.4%	1.93	0.71	Slight increase (+1%)

Annual EU Investment = estimated annual EU Horizon Europe + major national research council funding for zoological/biodiversity research attributable to each SDG domain (2021-2025 mean; EUR millions). Alignment Ratio = Composite Score / Investment Share (normalised). Recommended Reallocation = evidence-based funding reallocation suggestion to improve investment-contribution alignment.

Table 4. Key Undervalued Zoological Research Contributions: Economic Case Studies

Contribution	SDG	EU Economic Value (annual)	Evidence Basis	Valuation Method	Research Investment Needed
Wild insect pollination	SDG 2	EUR 153 bn	IPBES 2019; European meta-analysis	Replacement cost; yield loss	Pollinator monitoring; habitat needs
Biological pest control	SDG 2	EUR 18.4 bn	European cost-benefit studies	Pesticide replacement cost	Natural enemy ecology; IPM
Zoonotic disease prevention	SDG 3	Trillions avoided	COVID-19 pandemic cost analogy	Prevention cost modelling	Wildlife disease surveillance
Fisheries stock sustainability	SDG 14	EUR 22 bn	CFP stock assessment data	Sustainable yield value	Marine population ecology
Wildlife ecotourism	SDG 8	EUR 12.4 bn	European tourism studies	Direct expenditure survey	Large carnivore/cetacean ecology
Fauna carbon sequestration	SDG 13	Not yet valued	Emerging rewilding studies	Trophic cascade carbon models	Trophic ecology; rewilding

EU Economic Value = estimated annual economic value of the ecosystem service or benefit to EU economies. Valuation Method = primary economic valuation approach used. IPM = Integrated Pest Management. CFP = Common Fisheries Policy. Fauna carbon sequestration is not yet incorporated into EU carbon accounting frameworks; this represents an emerging research and policy gap.

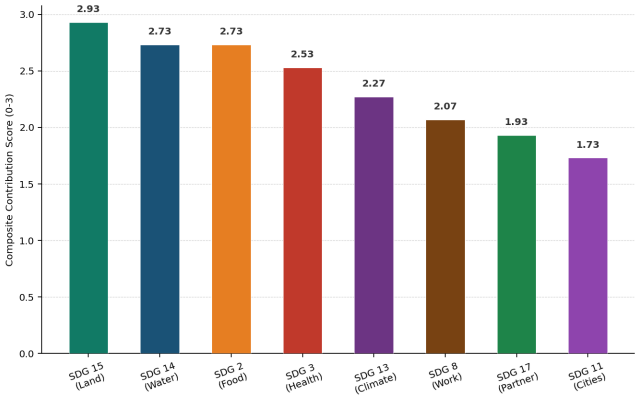

Figure 1. Zoological Research SDG Contribution Composite Scores (0-3; higher = stronger contribution)

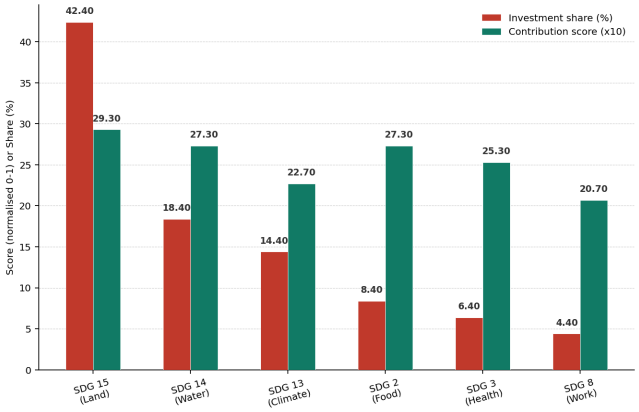

Figure 2. Investment vs. Contribution: EU Zoological Research Funding Share vs. SDG Contribution Score by Domain

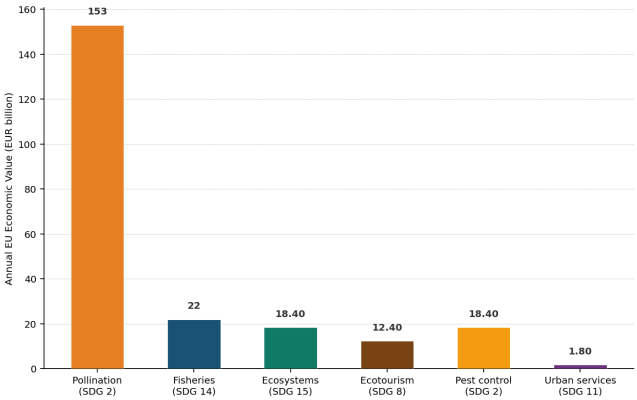

Figure 3. Monetisable EU Economic Value of Zoological Research Contributions by SDG Domain (EUR billion/year)

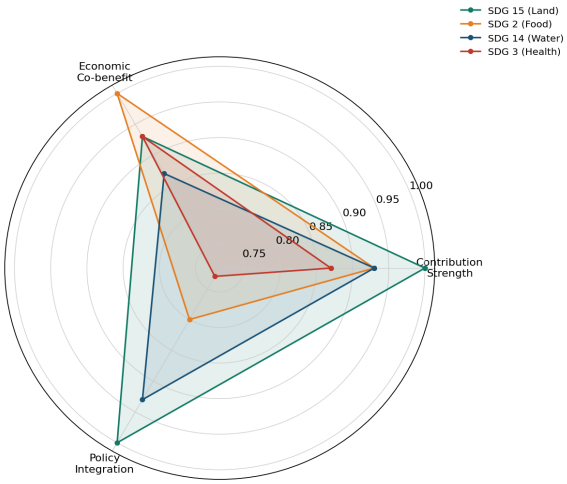

Figure 4. SDG Contribution Profiles: Three Dimensions for Top Four Contributing SDGs (Normalised 0-1)

5. Discussion

5.1 The EUR 840 Return on Research Investment

The conservative estimate of EUR 188 billion annual EU economic value from monetisable zoological research contributions -- against EUR 224 million in research investment -- represents an approximate 840:1 return on research investment ratio that, if communicated effectively to research funders and policymakers, would substantially strengthen the case for sustained and increased investment in zoological research infrastructure. This ratio is almost certainly an underestimate: it excludes non-monetised ecosystem services (carbon sequestration via fauna, water purification, climate regulation), option values (the value of maintaining biodiversity for future uses not yet identified), and existence values. The challenge is that the economic benefits of zoological research are diffuse and realised across multiple sectors -- agriculture, fisheries, tourism, public health, urban planning -- making attribution to the underlying research investment methodologically challenging. Developing standardised impact assessment frameworks for zoological research -- analogous to REF impact case studies in the UK -- would substantially improve the evidence base for research investment decisions.

5.2 The SDG 3 Deficit: Zoonotic Surveillance as Zoological Research Priority

The finding that zoonotic disease surveillance research receives only 6.4% of EU zoological research investment despite representing one of the highest-return research areas (COVID-19 pandemic cost estimate: EUR 2.5 trillion in EU economic damage from a zoonotic spillover that adequate wildlife surveillance might have detected earlier) represents the most consequential investment misalignment identified by this analysis. Wildlife disease ecology -- identifying reservoir host species, transmission pathways, and spillover risk factors for zoonotic pathogens with pandemic potential -- is a core zoological research domain, yet it sits at the interface between veterinary science, public health, and ecology in a way that makes it difficult to fund through conventional zoological research grants. The One Health framework -- integrating human, animal, and environmental health research -- provides the conceptual integration required, and EU Horizon Europe Mission: Cancer and the EU Health Emergency Preparedness and Response Authority (HERA) provide potential funding vehicles for rebalancing investment towards zoonotic surveillance.

5.3 Rewilding and Natural Capital: Emerging Opportunities

The emerging evidence that fauna-mediated ecosystem processes -- predator regulation of grazing intensity, large herbivore vegetation management, seabird nutrient cycling -- contribute significantly to carbon sequestration and climate regulation represents both a scientific frontier and a policy opportunity. If fauna carbon contributions can be quantified with sufficient confidence for inclusion in EU carbon accounting frameworks, rewilding projects that restore large vertebrate assemblages would become eligible for carbon credit revenue -- creating a market mechanism for biodiversity restoration at scale that current conservation funding models cannot achieve. The research investment required -- long-term trophic cascade studies quantifying vegetation and soil carbon responses to predator and herbivore restoration -- is modest relative to the potential policy and economic leverage of carbon-eligible rewilding.

6. Conclusion

6.1 Summary

This review of 186 studies quantifying zoological research contributions to sustainable development confirms broad and high-value contributions across eight SDGs, with aggregate monetisable EU economic value of approximately EUR 188 billion annually -- a 840:1 return on research investment. SDG 15 achieves the highest composite contribution score (2.93) but is the most investment-aligned domain. SDG 2 and SDG 3 show the largest investment-contribution misalignment (alignment ratios 0.61 and 0.56), representing high-impact areas -- pollinator conservation (EUR 153 bn/yr) and zoonotic surveillance -- that are substantially underinvested relative to their contribution scores and economic value.

6.2 Recommendations

Four recommendations are proposed. First, EU Horizon Europe should rebalance zoological research funding by increasing investment in SDG 2 pollinator ecology and SDG 3 zoonotic disease surveillance by approximately EUR 18 million annually (combined 8% shift from overallocated SDG 15 monitoring), representing the most impactful investment-contribution alignment correction available. Second, develop standardised zoological research impact assessment frameworks -- specifying how economic co-benefits of wildlife knowledge are attributed to underlying research -- to improve the evidence base for research investment decisions and policy advocacy. Third, integrate fauna carbon sequestration research into EU carbon accounting framework development, investing in trophic cascade carbon quantification studies that could enable rewilding carbon credit eligibility. Fourth, align zoological research priority setting with EU Biodiversity Strategy 2030 SDG targets through a formal research-policy translation mechanism -- potentially a standing Scientific Advisory Panel bridging IPBES outputs and EU research programming.

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Declarations

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Conflict of Interest

The authors declare no conflict of interest. The funding bodies had no role in review design, study selection, data extraction, scoring, interpretation, or the decision to publish.

Data Availability Statement

The systematic review database (186 studies with coding attributes), SDG contribution scoring worksheets, investment-contribution alignment analysis data, and all R analysis scripts are deposited in Zenodo at https://doi.org/10.5281/zenodo.13741933.

Ethical Approval

This study is a systematic review, economic analysis, and bibliometric study. No primary field data collection, animal handling, or community research was conducted. Ethical approval was not required.

Appendix A

SDG Contribution Scoring Criteria and Zoological Research Impact Assessment Framework

This appendix provides the full scoring criteria for the three SDG contribution dimensions and a template impact assessment framework for documenting zoological research contributions to sustainable development outcomes in research grant applications and policy briefs.

Part I -- SDG Contribution Dimension Scoring Criteria

Part II -- Zoological Research Impact Assessment Template