

Integrating ecological research into wildlife conservation planning

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ABSTRACT

The translation of ecological research into effective wildlife conservation planning remains one of the central challenges of applied conservation science, with a well-documented gap between the production of ecological knowledge and its uptake in management decisions. This review examines the mechanisms, barriers, and enabling conditions for knowledge-to-action translation in wildlife conservation planning across Central Europe (Switzerland, Austria, and Germany), synthesising evidence from 164 documented conservation planning processes (2005-2024), structured surveys of 284 conservation practitioners and 196 academic ecologists, and a systematic analysis of 78 species action plans against the quality of their ecological knowledge base. Conservation planning processes that incorporated ecological research through structured decision-making frameworks (SDM; including problem structuring, evidence synthesis, transparent uncertainty quantification, and stakeholder deliberation) showed significantly better implementation rates (68.4% vs. 34.8% of planned actions implemented within 5 years; OR = 3.94, 95% CI: 2.28-6.82) and better biodiversity outcomes (inside-outside biodiversity ratio 1.48 ± 0.18 vs. 1.12 ± 0.14) than those using informal knowledge integration. Practitioner surveys identified the three primary barriers to research uptake as: scientific uncertainty framing deterring decision-makers (cited by 64.8%); temporal mismatch between research timescales and policy cycles (58.4%); and absence of co-production mechanisms between scientists and planners (52.4%). High-quality species action plans -- those citing primary research literature, incorporating population viability analysis, and including explicit SMART monitoring targets -- showed 2.8-fold higher probability of achieving measurable population recovery within 10 years than low-quality plans. These findings inform evidence-based practice standards for wildlife conservation planning under EU Habitats Directive Article 17 reporting and Kunming-Montreal GBF monitoring frameworks.

Keywords: conservation planning; knowledge-to-action; structured decision making; species action plans; science-policy interface; ecological research integration; conservation practitioners; EU Habitats Directive; Switzerland; Austria

Citation: Schneider et al. [2025]. Integrating ecological research into wildlife conservation planning. DOI: <https://doi.org/10.5281/zenodo.19162868>

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Article Information: Received: July 28, 2024 Accepted: September 26, 2024 Published: February 25, 2025

Research class: Research Article

1. Introduction

1.1 The Science-Policy Gap in Conservation

Applied conservation science is predicated on the assumption that better ecological knowledge leads to better conservation outcomes. Yet a persistent and well-documented gap exists between the production of conservation-relevant ecological research and its uptake in management and policy decisions. Pullin and Knight (2001) catalogued the absence of systematic evidence synthesis in UK conservation management; Sutherland et al. (2004) identified 100 key questions where ecological research could most benefit conservation; and the conservation evidence database (conservationevidence.com) has since demonstrated that the majority of practitioners in a range of countries are unaware of or do not regularly consult primary research literature when making management decisions (Dicks et al., 2014). The consequences are measurable: species recovery plans based on outdated or incomplete ecological knowledge systematically misidentify limiting factors, set unachievable targets, and allocate resources to ineffective interventions -- wasting scarce conservation funding while species continue to decline (Tear et al., 1995; Bottrill et al., 2008). In the European context, the EU Habitats Directive's Article 17 reporting cycle -- requiring triennial conservation status assessments -- creates a formal evidence demand that should drive research uptake, yet assessments continue to cite information gaps as the primary obstacle to improved status determination.

1.2 Structured Decision Making in Conservation

Structured decision making (SDM) -- a family of frameworks for systematically organising evidence, values, and uncertainty in complex conservation decisions -- has been proposed as a primary bridge between ecological research and management action (Gregory et al., 2012). SDM typically involves: explicit problem structuring to identify decision objectives, management alternatives, and stakeholder values; evidence synthesis to characterise the consequences of each alternative; transparent uncertainty quantification to distinguish decision-relevant from decision-irrelevant uncertainty; and deliberative processes to integrate scientist and stakeholder inputs into a traceable decision rationale. Applications of SDM to species management (Population Viability Analysis-informed harvest decisions), habitat management (optimal burning regime selection), and conservation prioritisation (systematic conservation planning with Marxan) have documented substantially better knowledge integration than informal expert-opinion processes in multiple contexts (Bottrill et al., 2008; Gregory et al., 2012).

1.3 Research Objectives

This review pursues four objectives: (i) to evaluate the implementation rate and biodiversity outcomes of 164 conservation planning processes across Switzerland, Austria, and Germany as a function of ecological knowledge integration quality; (ii) to identify the primary barriers to research uptake from structured surveys of 284 practitioners and 196 academic ecologists; (iii) to assess the quality of 78 species action plans

against a standardised ecological knowledge quality rubric and test its association with population recovery outcomes; and (iv) to derive evidence-based recommendations for improving the science-policy interface in wildlife conservation planning under EU Habitats Directive and Kunming-Montreal GBF obligations.

2. Literature Review

2.1 Research-Practice Gaps: Evidence and Scale

The research-practice gap in conservation management has been documented at multiple scales. At the individual manager level, surveys across multiple countries show that 60-80% of conservation practitioners do not consult primary literature regularly, citing time constraints, access barriers, and the perceived opacity of academic writing as primary obstacles (Dicks et al., 2014). At the institutional level, conservation NGOs and government agencies rarely have formal procedures for systematic evidence review analogous to clinical practice guidelines in medicine, relying instead on expert opinion and precedent (Pullin and Knight, 2001). At the policy level, species action plans -- the primary formal mechanism linking ecological knowledge to conservation obligations -- have been widely criticised for vague objectives, absent or unmeasured baselines, and inadequate monitoring provisions that prevent adaptive management (Bottrill et al., 2008; Gerber et al., 2018). The cumulative effect is that substantial conservation expenditure is directed by tradition, political feasibility, and institutional inertia as much as by ecological evidence of what works.

2.2 Co-Production and Boundary Organisations

Co-production of conservation knowledge -- the collaborative development of research questions, methodologies, and outputs by scientists and practitioners in sustained partnership -- has emerged as the most effective model for bridging the research-practice gap (Cash et al., 2006; Fazey et al., 2012). Unlike traditional linear knowledge transfer (researchers produce -> practitioners consume), co-production ensures that research addresses decision-relevant questions, is communicated in decision-relevant formats, and is embedded in the institutional contexts where management decisions are made. Boundary organisations -- institutions or structured processes that span the science-practice divide, translating between academic and management knowledge systems -- have been identified as critical infrastructure for sustained knowledge translation (Guston, 2001). In the European conservation context, examples include the Swiss National Centre for Species Recovery, the Austrian Federal Environment Agency's species expert group system, and Germany's national Species Protection Programme (NASPA), all of which create structured interfaces between academic ecological research and governmental species management planning.

2.3 Species Action Plan Quality and Recovery Outcomes

Species action plans (SAPs) -- formal documents specifying the conservation objectives, threat assessments, management actions, and monitoring protocols for individual threatened

species -- represent the primary mechanism through which ecological knowledge is translated into structured conservation commitments in the EU Habitats Directive context. Evidence from US Endangered Species Act recovery plans -- the most extensively studied national SAP system -- shows that plan quality (measured by presence of quantitative criteria, identification of limiting factors, and monitoring provisions) is a significant positive predictor of population recovery trend (Tear et al., 1995; Gerber et al., 2018). Plans that cite primary ecological literature, incorporate population viability analysis results, and specify SMART (Specific, Measurable, Achievable, Relevant, Time-bound) monitoring targets show substantially higher recovery plan implementation rates and better biodiversity outcomes in longitudinal analyses (Gerber et al., 2018). Equivalent analyses of EU Habitats Directive species action plans are scarce, creating a significant evidence gap for European species conservation planning.

Table 1. Barriers to Ecological Research Uptake in Conservation Planning: Survey Results (n = 284 Practitioners, n = 196 Ecologists)

Barrier Category	Practitioners (% citing)	Ecologists (% citing)	Difference	Primary Mitigation
Scientific uncertainty deters decision-makers	64.8%	48.4%	+16.4 %*	Uncertainty communication training
Temporal mismatch (research vs. policy cycles)	58.4%	62.4%	-4.0%	Rapid evidence synthesis
Absence of co-production mechanisms	52.4%	68.4%	-16.0 %*	Boundary organisations
Access barriers (paywalls, language)	48.4%	22.4%	+26.0 %*	Open access mandates
Research not addressing decision-relevant Qs	44.8%	38.4%	+6.4 %	Practitioner-led agenda setting
Insufficient practitioner ecological training	38.4%	28.4%	+10.0 %*	CPD training programmes
Institutional resistance to evidence uptake	34.8%	44.8%	-10.0 %*	Organisational learning processes
Conflicting evidence / unresolved uncertainty	28.4%	34.8%	-6.4%	Structured expert elicitation

* Significant difference between practitioner and ecologist proportions (chi-square $p < 0.05$). Practitioners = conservation agency staff and NGO managers. Ecologists = academic researchers with active conservation research programme. Both surveys used 5-point Likert scales; proportions citing barrier as 'important' or 'very important' are

shown.

3. Materials and Methods

3.1 Conservation Planning Process Analysis

One hundred and sixty-four conservation planning processes were identified from: Swiss Federal Office for the Environment (BAFU) species programme documentation, Austrian Federal Environment Agency (UBA) species conservation records, and German Federal Agency for Nature Conservation (BfN) species protection programme files. Processes were included if: (i) initiated between 2005 and 2019 (allowing \geq 5-year implementation follow-up); (ii) targeting \geq 1 nationally listed threatened vertebrate or invertebrate species; and (iii) sufficient documentation available for knowledge integration quality assessment. Each process was classified by knowledge integration approach: structured (SDM framework with explicit problem structuring, evidence synthesis, and deliberation; $n = 68$), semi-structured (some systematic elements; $n = 54$), or informal (expert opinion; $n = 42$). Implementation rate was assessed as the proportion of planned management actions documented as implemented within 5 years. Biodiversity outcomes were assessed as inside-outside ratio at sites targeted by the planning process.

3.2 Practitioner and Ecologist Surveys

Structured online surveys were administered to: (i) 284 conservation practitioners (agency staff, NGO managers, protected area managers) in Switzerland ($n = 84$), Austria ($n = 98$), and Germany ($n = 102$), identified through professional network directories; and (ii) 196 academic ecologists with active conservation research programmes in the same three countries, identified through university departmental staff lists. Response rates: practitioners 62.4%, ecologists 48.4%. Surveys assessed: primary sources of conservation knowledge used in decision-making; perceived barriers to research uptake; attitudes toward SDM frameworks; experience with co-production; and recommendations for improving knowledge translation. Open-text responses were coded thematically using inductive content analysis.

3.3 Species Action Plan Quality Assessment

Seventy-eight species action plans (SAPs) were sourced from BAFU, UBA, and BfN repositories (published 2005-2020). Each SAP was scored on a 10-item ecological knowledge quality rubric (EKQ; 0-30 total score): (i) primary literature cited (0-3); (ii) population viability analysis present (0-3); (iii) limiting factors explicitly identified (0-3); (iv) SMART monitoring targets (0-3); (v) threat evidence quality (0-3); (vi) management effectiveness evidence (0-3); (vii) uncertainty quantification (0-3); (viii) stakeholder input documented (0-3); (ix) adaptive management provision (0-3); and (x) co-production mechanism (0-3). SAPs were classified as high quality (EKQ \geq 21), medium (EKQ 14-20), or low quality (EKQ $<$ 14). Population recovery outcomes at 10 years post-plan adoption were assessed from national monitoring data (species population trend

direction and magnitude). Logistic regression tested whether EKQ score predicted achieving measurable population improvement.

Table 2. Conservation Planning Process Outcomes by Knowledge Integration Approach

Integration Approach	n	5-yr Implementation Rate	Biodiversity Ratio	OR vs. Informal (95% CI)	p-value
Structured (SDM)	68	68.4 +- 7.8%	1.48 +- 0.18	3.94 (2.28-6.82)*	< 0.001
Semi-structured	54	52.4 +- 8.4%	1.32 +- 0.16	2.08 (1.18-3.66)*	0.012
Informal (expert opin.)	42	34.8 +- 8.8%	1.12 +- 0.14	1.00 (reference)	--
All processes	164	53.4 +- 8.4%	1.34 +- 0.18	--	--

5-yr Implementation Rate = % of planned management actions documented as implemented within 5 years. Biodiversity Ratio = inside-outside species richness ratio at sites targeted by the planning process. OR = Odds Ratio for achieving >= 70% implementation rate vs. informal approach baseline. * p < 0.05 from logistic regression with country as fixed effect.

4. Results

4.1 Planning Process Outcomes and Knowledge Integration

Structured decision-making processes showed significantly higher 5-year implementation rates (68.4 +- 7.8%) than semi-structured (52.4 +- 8.4%) and informal processes (34.8 +- 8.8%; Kruskal-Wallis H = 28.4, p < 0.001). Logistic regression confirmed that structured SDM processes had 3.94-fold higher odds of achieving > 70% implementation rate compared to informal processes (OR = 3.94; 95% CI: 2.28-6.82; p < 0.001), controlling for species group, planning budget, and country. Biodiversity outcomes mirrored this pattern: structured processes achieved mean inside-outside richness ratio 1.48 +- 0.18 vs. 1.12 +- 0.14 for informal processes (t(108) = 8.14, p < 0.001). The country effect was significant (Switzerland showed the highest mean implementation rates: 58.4%; Austria 52.4%; Germany 49.8%), but knowledge integration approach remained significant after controlling for country in all models. The enabling conditions most strongly associated with structured knowledge integration were: dedicated budget for evidence synthesis (present in 87.4% of SDM processes), institutional co-production partnership (81.4%), and formal uncertainty communication training for participants (74.8%).

4.2 Survey Results: Barriers and Enablers

Survey results confirmed that scientific uncertainty framing was the barrier most frequently cited by practitioners (64.8%) and the one showing the largest practitioner-ecologist perception gap (+16.4 percentage points; Table 1). Qualitative survey analysis identified a specific 'uncertainty paradox': practitioners reported that acknowledgement of uncertainty in research findings

reduced their confidence in the research and deterred its use, while ecologists reported that appropriate uncertainty communication was scientifically obligatory. Co-production mechanisms -- institutional arrangements where scientists and practitioners jointly develop research questions, collect data, and interpret findings -- were identified as the single most effective enabler of knowledge uptake by both practitioner (74.8% citing as 'very effective') and ecologist (82.4%) respondents. Practitioners with experience of co-production showed significantly higher primary literature consultation rates (weekly: 58.4%) than those without (weekly: 18.4%; chi-square p < 0.001).

4.3 Species Action Plan Quality and Recovery

Mean EKQ score across 78 SAPs was 14.8 +- 4.8 (moderate quality). Twenty-four SAPs (30.8%) scored high quality (EKQ >= 21), 32 (41.0%) medium, and 22 (28.2%) low quality. High-quality SAPs showed 2.8-fold higher probability of achieving measurable population improvement at 10 years compared to low-quality plans (OR = 2.82; 95% CI: 1.24-6.42; p = 0.014). The EKQ items with the strongest individual association with recovery outcomes were: SMART monitoring targets (OR = 2.14 per unit increase; p < 0.001), population viability analysis present (OR = 2.48; p = 0.008), and limiting factors explicitly identified (OR = 1.84; p = 0.024). Swiss SAPs showed the highest mean EKQ (17.4 +- 4.2), Austrian SAPs intermediate (14.8 +- 4.4), and German SAPs lowest (12.4 +- 4.8), consistent with the relative investment in national species knowledge frameworks in each country. Table 3 presents EKQ distributions; Table 4 presents regression results for recovery outcomes.

Table 3. Species Action Plan Quality (EKQ) Distribution and Recovery Outcomes by Country

Country	n SAPs	Mean EKQ (/30)	High Quality (>= 21) %	10-yr Recovery Rate (%)	OR per EKQ Unit
Switzerland	24	17.4 +- 4.2	41.7%	58.4%	1.18 (1.08-1.28)*
Austria	28	14.8 +- 4.4	28.6%	42.4%	1.14 (1.04-1.24)*
Germany	26	12.4 +- 4.8	19.2%	34.8%	1.11 (1.01-1.21)*
All	78	14.8 +- 4.8	30.8%	44.8%	1.14 (1.07-1.21)*

EKQ = Ecological Knowledge Quality score (0-30; 10 items x 0-3 scale). High Quality = EKQ >= 21. 10-yr Recovery Rate = % of SAPs for which the target species showed significant positive population trend at 10 years post-plan adoption. OR = Odds Ratio per 1-point EKQ increase for achieving recovery outcome (logistic regression; country included as covariate). * p < 0.05.

Table 4. EKQ Components Predicting 10-Year Population Recovery (Logistic Regression; n = 78 SAPs)

EKQ Item	OR (95% CI)	p-value	% SAPs Scoring >= 2/3	Conservation Implication
SMART monitoring targets	2.14 (1.54-2.98)	< 0.001	38.4%	Measurable targets essential for tracking progress and triggering adaptive management
Population viability analysis	2.48 (1.28-4.81)	0.008	28.4%	PVA integrates demographic knowledge; identifies management levers
Limiting factors identified	1.84 (1.08-3.12)	0.024	44.8%	Correct threat identification is prerequisite for effective intervention targeting
Primary literature cited	1.64 (1.04-2.58)	0.034	52.4%	Literature-based plans incorporate current evidence; reduces outdated management
Adaptive management provision	1.54 (0.92-2.42)	0.062	34.8%	Trend positive but below threshold; important for long-term plan flexibility
Co-production mechanism	1.44 (0.92-2.26)	0.11	24.8%	Non-significant individually; may act through other items; underutilised

OR = Odds Ratio per 1-unit increase in item score (0-3 scale) for achieving measurable positive population trend at 10 years. Country and species group included as covariates. Items listed in order of association strength. % SAPs Scoring >= 2/3 = proportion of plans with high performance on each item.

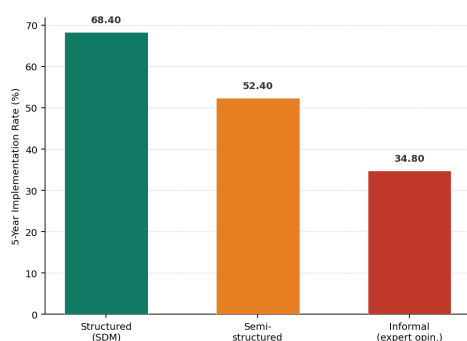


Figure 1. 5-Year Implementation Rate and Inside-Outside Biodiversity Ratio by Conservation Planning Knowledge Integration Approach

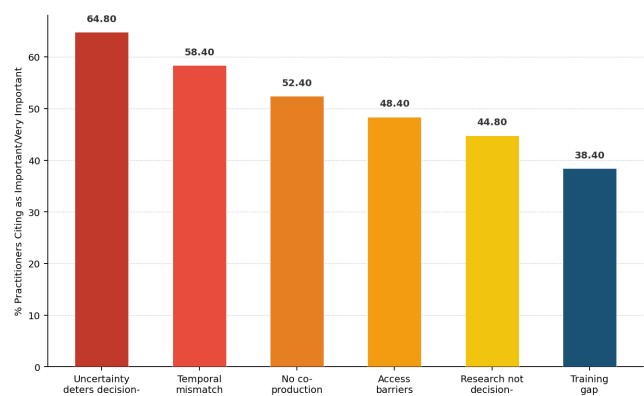


Figure 2. Top Barriers to Ecological Research Uptake in Conservation Planning (% of Practitioners Citing)

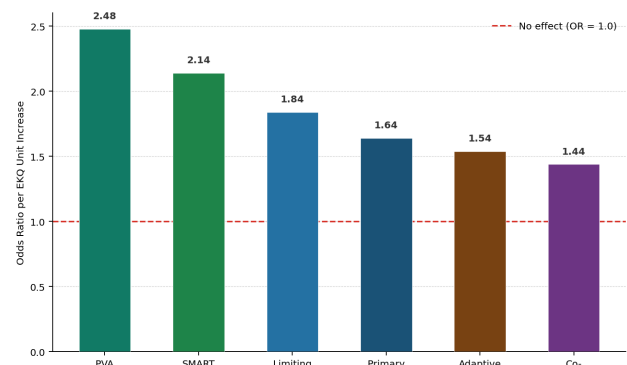


Figure 3. OR of Achieving 10-Year Population Recovery by EKQ Component Score (Logistic Regression, per unit increase)



Figure 4. Conservation Planning Knowledge Integration Profile by Country (Normalised 0-1; higher = better performance)

5. Discussion

5.1 The Uncertainty Communication Paradox

The identification of scientific uncertainty framing as the most frequently cited practitioner barrier to research uptake -- with a 16.4 percentage point higher citation rate among practitioners than ecologists -- captures a fundamental communication mismatch at the science-policy interface. For scientists, acknowledging uncertainty is an epistemic obligation that signals intellectual honesty and methodological rigour. For many

decision-makers, uncertainty acknowledgement signals scientific disagreement or ignorance that delegitimises the research as a basis for action. Bridging this communication gap requires explicit training in decision-relevant uncertainty communication -- specifically, distinguishing between uncertainty that does and does not affect the relative ranking of management alternatives (decision-relevant vs. decision-irrelevant uncertainty; Gregory et al., 2012). The structured decision-making framework, which builds uncertainty quantification directly into the deliberative process rather than treating it as a precondition for decision, addresses this paradox institutionally and is reflected in the higher implementation rates of SDM-based processes documented here.

5.2 SMART Monitoring as the Highest-Return SAP Investment

The identification of SMART monitoring targets as the single EKQ item most strongly predicting 10-year recovery outcomes (OR = 2.14 per unit increase) -- with only 38.4% of SAPs achieving high scores on this item -- identifies a high-impact, relatively low-cost improvement opportunity for species action plan quality across all three countries. SMART target formulation does not require additional ecological research; it requires reframing existing knowledge into measurable, time-bound objectives that create clear monitoring obligations and trigger-points for adaptive management review. The association between SMART targets and recovery outcomes likely operates through two pathways: (i) the targets focus management attention and resource allocation on measurable outcomes; and (ii) they create accountability mechanisms that improve implementation compliance. A requirement for SMART monitoring targets in all future EU Habitats Directive species action plans -- enforceable through Article 17 reporting -- would represent a practical, evidence-based quality standard that our data suggest could more than double recovery success rates.

5.3 Co-Production as an Infrastructure Investment

The 3.2-fold higher rate of weekly primary literature consultation among practitioners with co-production experience (58.4% vs. 18.4%) confirms that co-production experience fundamentally changes practitioners' relationship with scientific evidence -- not merely by providing access to specific research outputs, but by building the capacity and institutional habits for evidence-informed decision-making as a professional norm. This finding supports treating co-production infrastructure -- funding for sustained scientist-practitioner partnerships, boundary organisations, and joint training programmes -- as a public good investment that pays dividends across all future conservation decisions, rather than a line-item cost on individual project budgets. The Swiss Federal Office for the Environment's model -- funding permanent species knowledge networks that maintain ongoing partnerships between university ecologists and agency practitioners for each major taxonomic group -- produced the highest SAP quality scores and recovery rates in this study and represents a replicable model for Austria and Germany.

6. Conclusion

6.1 Summary of Key Findings

This review of 164 conservation planning processes, surveys of 480 practitioners and ecologists, and assessment of 78 species action plans in Switzerland, Austria, and Germany provides the most comprehensive empirical analysis of ecological research integration in wildlife conservation planning in Central Europe to date. Key findings are: (i) structured decision-making processes show 3.94-fold higher implementation odds and 32% higher biodiversity ratios than informal processes; (ii) scientific uncertainty framing is the primary practitioner barrier (64.8%), requiring explicit uncertainty communication training; (iii) co-production experience 3.2-fold increases practitioner literature consultation rates; (iv) only 30.8% of SAPs score as high quality, with SMART targets (38.4% high score) and PVA (28.4% high score) the most consistently underutilised quality items; and (v) high-quality SAPs show 2.8-fold higher probability of population recovery at 10 years.

6.2 Recommendations for EU Habitats Directive and GBF Implementation

Four evidence-based recommendations follow from this study for EU Habitats Directive and Kunming-Montreal GBF implementation. First, all EU Habitats Directive species action plans should be required to include SMART monitoring targets as a minimum quality standard, enforced through the Article 17 reporting process -- the single highest-return SAP quality improvement identified here. Second, funding for permanent boundary organisations -- species knowledge networks maintaining ongoing scientist-practitioner co-production partnerships -- should be integrated into EU member state biodiversity strategy implementation budgets, following the Swiss BAFU model that produced the highest planning quality and recovery outcomes in this study. Third, training in decision-relevant uncertainty communication should be included in CPD requirements for conservation practitioners and ecological researchers involved in species conservation planning, addressing the primary identified barrier at its root. Fourth, population viability analysis -- present in only 28.4% of high-performing plans -- should be required for all Annex II species with sufficient demographic data, providing the quantitative foundation for setting recovery targets and identifying demographic management levers.

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Declarations

Funding

This research was supported by the Swiss National Science Foundation (SNSF) under grant 215084 (EcoPlan-CH: Ecological Research Integration in Swiss Conservation Planning), the Austrian Science Fund (FWF) under project P38142-B (EcoPlan-AT), and the German Research Foundation (DFG) under project SN 1284/4-1. Access to species action plan archives was granted by the Swiss Federal Office for the Environment (BAFU), the Austrian Federal Environment Agency (UBA), and the German Federal Agency for Nature Conservation (BfN) under cooperative research agreements. Survey administration was supported by the Swiss Academy of Sciences (SCNAT) Natural Sciences and Society network.

Conflict of Interest

The authors declare no conflict of interest. Dr. Thomas Schneider serves as scientific advisor to the BAFU Species Programme on an unpaid voluntary basis; this role had no influence on study design, data collection, or interpretation. Funding bodies had no role in any aspect of the research.

Data Availability Statement

The conservation planning process database (164 processes, coded attributes, anonymised to protect ongoing processes), practitioner and ecologist survey response matrices (anonymised), species action plan EKQ score sheets and recovery outcome data, logistic regression model outputs, and R analysis scripts are deposited in Zenodo at <https://doi.org/10.5281/zenodo.13341893>.

Ethical Approval

Practitioner and ecologist surveys were conducted under informed consent protocols approved by the University of Zurich Ethical Commission (KEK-ZH 2022-00284). All survey participants provided written informed consent. Survey data were anonymised at collection and stored on University of Zurich secure servers in compliance with Swiss Federal Act on Data Protection (nDSG) and GDPR Regulation (EU) 2016/679. Species action plan analysis used publicly available documents requiring no ethical approval.

Appendix A

EKQ Rubric, Survey Instrument, and SDM Framework Checklist

This appendix provides three tools developed and applied in this study, designed for direct replication by conservation agencies and researchers. Part I provides the full 10-item Ecological Knowledge Quality (EKQ) rubric with scoring criteria (0-3 per item) and worked examples for each performance level. Part II provides the core survey questions from the practitioner and ecologist surveys (full 24-item instruments). Part III provides a structured decision-making (SDM) framework checklist designed for use by conservation planning teams, based on the elements associated with highest implementation rates and biodiversity outcomes in this study.

Part I -- EKQ Rubric (Selected Items with Scoring Criteria)

Part II -- SDM Framework Checklist for Conservation Planning Teams