D.2.1.1 Dataset of AlpsLife taxa-based indicators and aggregated indices

Authors: Michela Corsini, Valentina La Morgia, Elia Guariento, Michele Bresadola, Valerio Comple, Mathilde Maure, Chiara Paniccia.

Contributors: Matteo Anderle, Pia Anderwald, Bernard Bal, Gaia Bazzi, Simona Bonelli, Gaia Boso, Alice Brambilla, Mattia Brambilla, Cristiana Cerrato, Kilian Frühholz, Sebastian König, Julia Paterno, Elena Tello-García.

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Content

1 Introduction

The European Alps are a biodiversity hotspot of global importance (Nagy et al., 2012). Yet, this area is threatened by climate change and land-use alterations (Chemini & Rizzoli, 2003; Tasser et al., 2024). Importantly, the absence of coordinated Alpine policies across countries further challenges conservation efforts. While some areas within the European Alps are characterized by solid, long-term monitoring schemes, discrepancies exist both within and between countries. Moreover, certain locations currently lack adequate biodiversity monitoring, and this further complicates effective and comprehensive conservation strategies (Meyer et al., 2015). Among all tools available for conservation, ecological **indicators** (here defined as a species that provides a signal about the ecosystem status or about its responses to climatic or environmental changes, according to Noss (1990)) and **indices** (defined as a quantitative measure that aggregates multiple indicators to provide a representative assessment of biodiversity health (Forchhammer & Post, 2004)) are key for identifying priority areas for conservation and/or restoration measures.

Developing indices for the European Alps region

Various indices have been developed to evaluate the status and health of various ecosystems, as required by the EU's Biodiversity Strategy for 2030 and the Sustainable Development Goal 15[1]. However, we currently lack comprehensive indices for monitoring the diverse ecosystems, including mountain and alpine ones, of the European Alps region. For example, the Farmland Bird Index (FBI, Gregory et al., 2005) and the European Grassland Butterfly Index (EGBI, Schmucki et al., 2025) are employed to assess the health of agricultural and grassland ecosystems, respectively, as both Birds and Butterflies are highly sensitive to environmental changes. The Mountain Grassland Bird Index (MGIB), used in Italy, focuses on monitoring the quality and biodiversity of mountain ecosystems, particularly those associated with grassland (i.e., open) habitats.

Despite their main function, these indices are often limited to specific habitat types in the lowland, far from the alpine biogeographic region, and frequently lack data for elevated altitudes. There are some research groups that are actively developing indices for certain taxa in the alpine region, such as the ongoing work by Gamero et al. (2025, in prep.), from the PECBMS team focusing on Birds, (which also includes species located in areas outside the AlpsLife perimeter such as the Apennine Mountains). Moreover, other taxa still require more targeted efforts to create representative indices, particularly for Mammals and pollinators.

Developing a cumulative index for Mammals presents distinct challenges due to their complex ecologies, diverse behaviors, and various ecological niches. Indices must be built using rich communities, which for Mammals remain particularly challenging. For example, in the case of Chiroptera, their use as indicators or indices is complicated by technical difficulties linked with echolocation identification, as it requires expertise, targeted capture campaigns, and tendentially high costs (Russo et al., 2018). Moreover, in Europe we currently lack properly tested and readily available indices for small mammals. More specifically, we lack comprehensive and consistent datasets that accurately and effectively represent and track mammal populations dynamics across different regions and habitat types. In addition, monitoring efforts are either limited or absent in many areas. Moreover, Mammals are typically associated with habitats that vary geographically, and their populations can fluctuate significantly over time according to seasonal changes, human activities, and climate events. Capturing these patterns and dynamics is particularly difficult in the absence of extensive long-term data. As a result, developing representative indices for Mammals remains unfeasible.

Similarly, developing an index for all pollinators is challenging because of the high diversity and taxonomic differences that characterize this group of insects. Importantly, what is currently monitored does not consider pollination potential, which plays a crucial role in ecosystem integrity and functioning (Bonelli et

[1] Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

al., 2025). As most knowledge and information is present for butterflies and this group is already used to develop the European Grassland Butterfly Index (EGBI), here as a first step we aim at proposing indices that target this group within the AlpsLife perimeter. As a second step, we plan on proposing a separate index targeting the **bumblebees**, as they also play a crucial role in the reproduction of several flowering plants, and readily respond to temperature and weather conditions (Potts et al., 2010). Several bumblebee species are often linked to specific habitats, including those found in mountainous areas (Potts et al., 2010). Their presence can therefore provide insights into habitat quality and changes over time across the altitudinal gradient.

This report presents the outcomes of Activity 2.1 under Work Package 2 (WP2) of the AlpsLife project, focusing on the identification of key biodiversity indicators for Birds, Mammals and pollinating insects (here specifically, Butterflies) across the European Alpine region. The main objective is to review the current state of taxa-based indicators and indices within the EUSALP area and to identify a set of the most robust and policy-relevant indicators capable of detecting biodiversity trends and informing conservation efforts at the Alpine scale. The findings presented here are based on data and expert opinions gathered through transnational consultations within dedicated Working Groups, each composed of specialists in the respective taxon. These groups compiled and assessed a list of candidate indicators using a set of defined evaluation criteria (detailed in the report), including representativeness of ecological niche, policy relevance and restoration potential. In developing indicators and indices, we considered their potential contribution to Essential Biodiversity Variables (EBVs) development and their relevance within the EBVs formation workflow (details are reported in the next paragraph), as they readily provide standardized and harmonized frameworks for monitoring and tracking any biodiversity shifts across different locations and scales. Indeed, EBVs aid in developing indices and indicators by data standardization (Pereira et al., 2013), data integration (Schmeller et al., 2018), track of changes in monitoring, policy support (Tittensor et al., 2014), better protection and restoration strategies (Rondinini et al., 2011), and enhancing public awareness.

This report is intended to support policymakers, monitoring agencies, and practitioners by providing a validated and prioritized list of biodiversity indicators that can be used for consistent, large-scale assessments across the Alpine region, in alignment with EUSALP and EU biodiversity policy objectives.

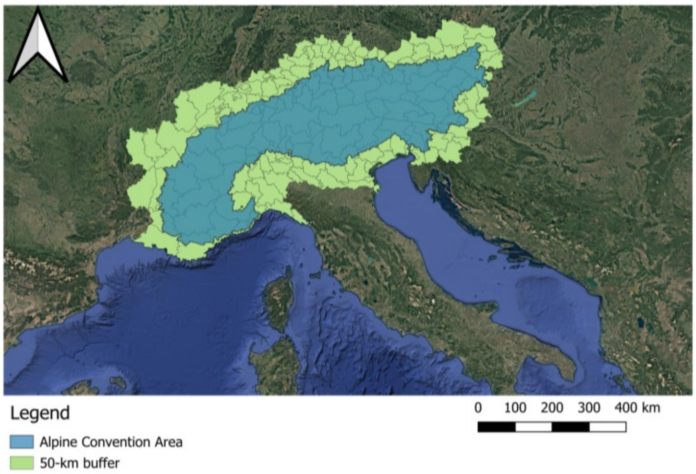

Figure 1. Study site. The map shows the spatial extent of the AlpsLife project, which encompasses the area within the Alpine Convention perimeter (source: https://www.atlas.alpconv.org/layers/geonode_data:geonode:Alpine_Convention_Perimeter_2018_v2) and includes a 50km buffer from it. Level 3 GADM administrative divisions are shown. Note that the 50km buffer follows official administrative boundaries. The map was generated in *qGIS* version 3.42.0, using the EPSG 3035 projection for geographical representation.

2 Expert-based evaluation of indicator species: assessing Birds, Mammals and Pollinators for the European Alps

To obtain an initial overview of potential indicators for the European Alps, the AlpsLife Working Package 2 (WP2) team started by organizing three Working Groups (WGs) formed by experts on Birds, Mammals and Pollinators (here, Butterflies) in the European Alps (Table 1). Namely, the WP2 focused on these three groups because Birds allow to understand habitat quality and track their responses towards changes in environmental conditions (Bibby et al., 2000); Mammals can provide insights into the broader ecological impacts derived from anthropogenic activities and climate change (Schipper et al., 2008); and pollinating insects like Butterflies are crucial for assessing ecosystem functionality and health, given their role in plant reproduction (Potts et al., 2010). These groups-related functions become particularly relevant across mountainous ecosystems, where data collection remains largely uneven (i.e., with lowlands being more monitored than sites located at higher elevations), and biodiversity monitoring schemes change according to administrative goals and protocols.

The three WGs held regular meetings from January to July 2025. After compiling an initial list of species either derived from current European legislation in force (for Birds and Butterflies) or, as in the case of Mammals, based on Essential Biodiversity Criteria (EBVs, which are often measurable and can provide actionable data at various scales, further details about EBVs are explained in the next paragraph), each expert group proceeded with species-specific scoring. Indicators scoring also occurred according to defined EBVs. We outline below the methodology used for group-specific and expert-based assessments in detail. We further provide an initial list of species selected as potential indicators within these groups. Further steps within the AlpsLife project will provide an expert-based discussion group to generate a list of potential indicators for bumblebees.

Birds Working Group	Pollinators Working Group	Mammals Working Group
Michela Corsini (PP01 – Eurac Research)	**Elia Guariento (PP01 – Eurac Research)**	**Valentina La Morgia (PP05 – ISPRA)**
Matteo Anderle (PP01 – Eurac Research)	Johannes Rüdisser (PP02 – UIBK)	Chiara Paniccia (PP01 – Eurac Research)
Gaia Bazzi (PP05 – ISPRA)	Kilian Frühholz (PP06 – BGNP)	Michela Corsini (PP01 – Eurac Research)
Gudrun Bruckner (PP08 – GNP)	Sebastian König (PP06 – BGNP)	Alexander Maringer (PP08 – GNP)
Gaia Boso (PP10 – PNGP)	Ramona Viterbi (PP10 – PNGP)	Alice Brambilla (PP10 – PNGP)
Julia Paterno (PP11 – SNP)	Cristiana Cerrato (PP10 – PNGP)	Pia Anderwald (PP11 – SNP)
Aaron Iemma (PP12 – EPNS)	Simona Bonelli (Observer, UNITO)	Luca Corlatti (PP12 – EPNS)
Mattia Brambilla (University of Milan)	Emanuele Repetto (PP01 – Eurac Research)	Luca Pedrotti (PP12 – EPNS)
Tomaž Mihelič (BirdLife Slovenia)		
Mylène Herrmann (Observer, Parc National de la Vanoise)		

Table 1. Members forming each Working Group. For each expert, we assigned relative affiliation. Coordinators of each Working Group are indicated **in bold**.

Essential Biodiversity Variables (EBVs)

Essential Biodiversity Variables (EBVs) are a key concept in modern biodiversity monitoring, proposed by GEO BON (Group on Earth Observations Biodiversity Observation Network) as a framework to standardize and coordinate biodiversity data collection at the global scale (Pereira et al., 2013). EBVs represent biological state variables characterized by three key dimensions — space, time, and biological organization — and are designed to be globally comparable, scalable, and scientifically defined. They can be operationalized through standardized workflows and serve as a core data layer that feeds into biodiversity indicators. EBVs bridge the gap between primary biodiversity observations — often fragmented or uneven across space and time — and the indicators used to communicate biodiversity changes to policymakers, by enabling the integration of heterogeneous datasets into a harmonized framework. Kissling et al. (2018) outlined the workflow required to operationalize EBVs, using species distribution and population abundance as leading examples, and emphasized critical steps such as metadata standardization, data harmonization, gap analysis, and modelling. The EuropaBON project (for more information, see https://github.com/EuropaBON/EBV-Descriptions/wiki) identified 84 priority variables (such as Species distributions of terrestrial Birds; Phenology of the emergence of butterflies and time of arrival of migratory butterflies; Vertical structure of vegetation) that align with the EBV conceptual model and are considered key targets for EBV development in a European context (Junker et al., 2023). A central task of the forthcoming European Biodiversity Observation Coordination Centre (Liquete et al., 2024) will be to map the 84 priority variables identified by EuropaBON onto the EBV framework and to develop the workflows needed to make them operational. Since this is a complex and resource-intensive task, implementation is expected to begin with a subset of variables before gradually expanding to the full list. These efforts aim to establish a consistent and policy-relevant foundation for biodiversity monitoring in Europe, supporting both national reporting and international biodiversity targets such as the CBD's Global Biodiversity Framework and the EU Biodiversity Strategy for 2030.

2.1 Bird species scoring and selection as indicators for the European Alps according to expert-based evaluation

To effectively conduct species-specific bird scoring based on the established criteria, the Birds Working Group started by building a comprehensive list of bird species derived from existing national and European legislation, including relevant indicators and indices currently in force and applicable to alpine regions, rural and forested areas (Gregory et al., 2005). This method produced a primary list of bird species readily subjected to conservation efforts attention, which covered comprehensively the full elevational gradient for the bird species listed. Namely, the list included species within the Farmland Bird indices as referenced in the EU Nature Restoration Regulation (Regulation EU 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869, and currently enforced in Austria, France, Germany, Italy, and Slovenia), the Swiss Bird Index for Alpine Environments, the Swiss Bird Index for Woodlands (Strebel et al., 2024), the Common Farmland Bird Index (which aggregates data from 26 countries, (EEA, 2024)), the Common Forest Bird Index (also aggregated for 26 countries, PECBMS 2022), and the Mountain Grassland Bird Index (Silva & Brambilla, 2021). Ultimately, this process identified a total of 171 bird species belonging to 17 different Orders (Figure 2). The list was used for the final expert-based scoring assessment.

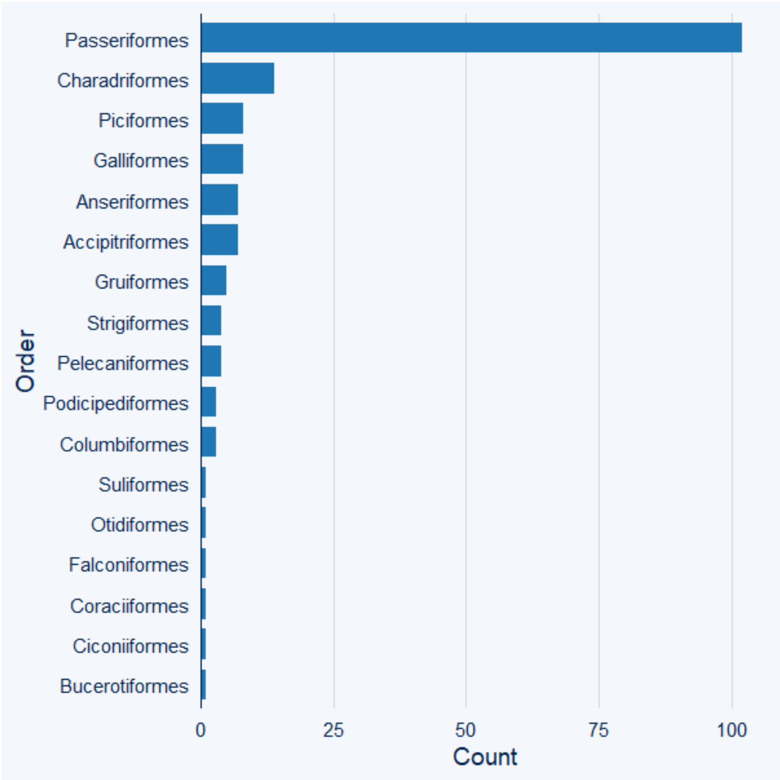

Figure 2. Number of species per bird Order (for the 171 species used in the expert-based assessment). The list was generated by combining European and national-level bird species included as indicators or indices.

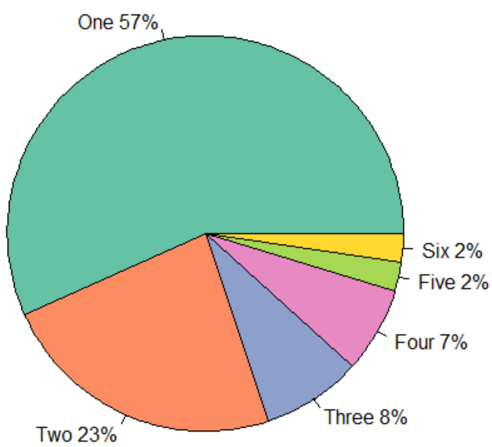

Figure 3. Frequency of mentions by each index listed above for each of the 171 bird species listed on the selected bird-indices and indicators then evaluated by experts of the Birds WG.

The expert-based bird species scoring was completed by eight members of the Birds WG and consisted in evaluating each of the 171 bird species in the list using an excel document, which was sent to the WG coordinator after its completion. The evaluation was completed by assessing the following EBVs-related criteria:

Ecological niche indicated whether the bird species in the list was identified as a *generalist* or as a *specialist*. The habitat specialization was established by analyzing Birds' diet and habitat specialization. Namely, ***habitat specialization*** was evaluated as low (1) for taxa that can thrive across various habitat types, moderate (2) for taxa that tolerate some variability across habitat types, or high (3) for taxa that use only specific habitat types or elements. In terms of ***diet specialization***, we used low (1) for species defined generalists, that can access various food items, moderate (2) for species that tolerate some variability in food items, for instance according to food available depending on seasonal changes, and high (3) for specialists, thus, species that can access a strict spectrum of food resources.

Climate response established whether a species was not sensitive (0) or very sensitive (10) to climate change. Namely, the scale took into consideration the following species-specific characteristics: migratory status, habitat specialization, dispersal ability, changes in habitat suitability, changes in food availability, and changes in extreme climatic conditions.

Migratory status was considered low (1) for year-round residents, moderate (2) for short-distance migrants (referred to movements primarily restricted to the Paleartic zone), or high (3) for long-distance migrants (i.e., species that migrate at least to the Afrotropical realm).

Dispersal ability was evaluated as low for taxa with high dispersal ability (1), moderate for taxa with average dispersal ability (2), and high for taxa with low dispersal ability (3).

Changes in habitat suitability were evaluated as low if habitat suitability is expected to increase or decrease by 0-10% (1), moderate if habitat suitability was expected to decrease by 10-50% (2), and high if habitat suitability was expected to decrease by >50% (3).

Changes in food availability were evaluated as low if food availability for a taxon would remain unchanged or increase (1), moderate if there was evidence that food availability may decrease (2), and high if there was evidence that there would be major decreases in food availability (3).

Changes in extreme weather was evaluated as low if there was no evidence (1) that a taxon would be exposed to more frequent or severe extreme weather events, moderate (2) if a taxon was expected to be exposed to some increase in extreme weather events, and high (3) if a taxon was very likely to be exposed to major increases in the number and duration of extreme weather events.

Environmental representativeness indicated the elevation (as altitudinal zone) where each species is usually found and consisted of up to three categories named according to Figure 4.

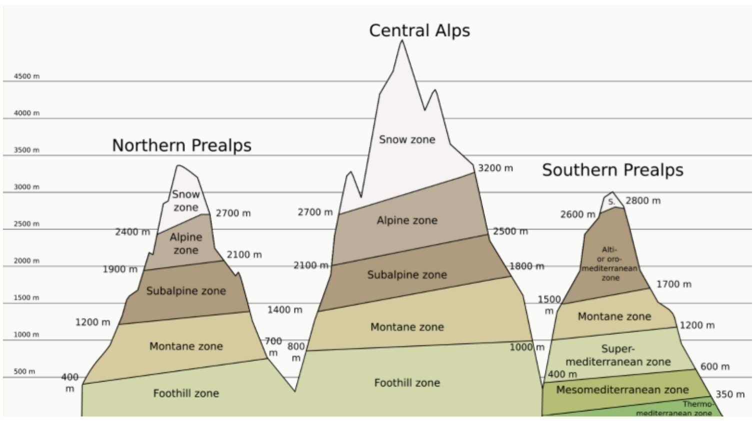

Figure 4. Categories used to select environmental representativeness. The figure was extrapolated from *Fleurs des Alpes, balade d'un botaniste des plaines aux sommets, François Couplan* (Nathan, 2005).

Major pressures and threats included a list of major pressures and threats for a given bird species, some examples included: hunting, forestry practices, land use, human activities, pollution, seasonality shifts in plants' phenology, climate change, and other (if applicable). Threats were listed according to literature research and/or by indicating if there was no clear major pressure or threat (1), or if there was a clear, major pressure or threat (2).

Potential for restoration was indicated with **a scoring system ranging from 0 (indicating no potential for restoration) to 10 (indicating a high potential for restoration)**, allowing the expert to use half-point increments. This score was determined after assigning a score for the *Major pressures and threats*, for Redlist CH and for Redlist EU).

Red List CH (Red List CH, 2025) & Red List EU (BirdLife International, 2021)

Scoring	Abbr.	Cat. IUCN Red List, English
1	LC	Least Concern
2	NT	Near Threatened
3	EN	Endangered
4	VU	Vulnerable
5	CR	Critically endagered
6	RE	Regionally extinct

Table 2. IUCN Red List categories organized from least to most threatened in Switzerland.

For each bird species, the values were summed up as shown in the example below:

Bird species	Redlist CH	Redlist EU	Scoring Major pressures and threats	Scoring Redlist CH	Scoring Redlist EU	Scoring Result	Category result
Eurasian sparrowhawk	LC	LC	2	1	1	4	3

Finally, the value obtained from the sum was used to establish the potential for restoration according to the scoring below:

Results: 2 = 1 | 3 = 2 | 4 = 3 | 5 = 4 | 6 = 5 | 7 = 6 | 8 = 7 | 9 = 8 | 10 = 9 | 11 = 10

Distribution in the Alps: 1= absent or small distribution in the Alps, 2= distribution in certain parts of the Alps. 3= the distribution area extends over the entire European Alps.

Distribution in Europe: 1= large distribution, 2= medium distribution, 3= small distribution.

Indicator recommendation: Assessed by each expert, considering local Red List EU scoring, the ecological niche, the distribution in the Alps and the distribution in Europe. When the distribution in the Alps = 1 meant that a given species was not an optimal indicator for the Alps, therefore the indicator recommendation = 0.

After scoring according to each criterion above, every expert had to assess independently species-specific scores by using a scale from 0 (not recommended as an indicator of the European Alps) to 10 (highly recommended as an indicator of the European Alps). Such scores were finally averaged between experts' evaluations across the bird WG and subsequently used to derive the 10 highest scores for bird species suggested as indicators for the European Alps (**Table 2**).

Bird species list of indicators	Classification [1]	Expert-based indicator recommendation [2]
Bird species common name (*scientific name*)		**Mean score**
White-winged snowfinch (*Montifringilla nivalis*)	1	8.50
Rock ptarmigian (*Lagopus muta*)	2	8.13
Western capercaillie (*Tetrao urogallus*)	3	7.75
Black grouse (*Lyurus tetrix*)	4	7.50
Grey partridge (*Perdix perdix*)	5	7.25
Boreal owl (*Aegolius funereus*)	5	7.25
Wallcreeper (*Tichodroma muraria*)	6	7.00
Golden eagle (*Aquila chrysaetos*)	7	6.88
Rock partridge (*Alectoris graeca*)	7	6.88
Common rock thrush (*Monticola saxatilis*)	7	6.88
Eurasian pygmy-owl (*Glaucidum passerinum*)	7	6.88
Grey-headed woodpecker (*Picus canus*)	8	6.63
Bearded vulture (*Gypaetus barbatus*)	9	6.38
Redpoll (*Acanthis flammea*)	9	6.38
Willow tit (*Poecile montanus*)	9	6.38
Red-billed cough (*Pyrrhocorax pyrrhocorax*)	9	6.38
Northern nutcracker (*Nucifraga caryocatactes*)	10	6.25

Table 3. Expert-based list of bird species selected as indicators for the European Alps. [1] The top 10 values for bird species are ranked from highest to lowest based on their scores. [2] The mean score indicates the indicator recommendation parameter assessed by each expert on a scale from 0 (i.e., not recommended as an indicator for the European Alps) to 10 (strongly recommended as an indicator for the European Alps). Scores were assigned anonymously by eight members of the Birds WG (see **Table 1**).

2.2 Mammals' species scoring and selection as indicators for the European Alps according to expert-based evaluation

Unlike Birds, where harmonized long-term monitoring datasets and standardized indices exist (e.g. Farmland Bird Index, Swiss Bird Index), Mammals lack comparable data coverage across the Alps. Monitoring schemes are uneven, methods are diverse (camera traps, genetic monitoring, direct counts), and for many taxa (e.g. small mammals, bats) information is limited or technically difficult to obtain. Because of these gaps, it was not feasible to build an exhaustive initial list and apply a systematic ranking of all species across categories.
To organize a list of mammal species before proceeding with the expert-based scoring, the Mammals WG thus worked differently from the approach used by the Birds WG, as experts had to jointly share experiences and knowledge on specific key criteria based on the concept of Essential Biodiversity Variables for different mammal species (EBVs, Pereira et al., 2013; Navarro et al., 2017).
The selection of mammal species for the indicator framework commonly shared by the Mammals WG was guided by the objective of representing the ecological, spatial, and functional diversity of Alpine ecosystems, and it was namely based on the following core principles (more details per species are reported in the Appendix, excel file titled "*AlpsLife-Mammals-principles.xlsx*"):

Ecological niche: The selected species should span a wide range of ecological niches – including alpine specialists, forest dwellers, and generalists – to ensure coverage of key ecosystem functions and trophic roles. This diversity allows for the detection of changes across different habitat types and ecological processes, reflecting responses from both habitat-restricted and wide-ranging species.

Environmental representativeness: The list of species selected must reflect geographic and habitat diversity in terms of altitudinal gradient, (i.e., it must include lowland, subalpine, and alpine zones, see Figure 4) to capture biogeographic variation and climate sensitivity across the Alpine region. This stratification supports assessments of spatial patterns of biodiversity change (e.g., upward shifts in distribution) and enhances environmental representativeness.

Major pressures and threats: The list should encompass species with varying sensitivities to disturbance, including direct human pressures (e.g., hunting, land use change), ecological threats (e.g., interspecific competition, hybridization), climate-related impacts (e.g., snow cover dynamics, phenology shifts), and Alien species interactions (e.g., grey squirrels´ *Sciurus carolinensis* invasion). This ensures the species set is diagnostic of multiple stressors.

Policy relevance and data availability: Selected species should contribute directly to the Kunming-Montreal Global Biodiversity Framework (GBF), e.g., they should be related to Target 4 (species extinction and genetic diversity), Target 5 (sustainable use and harvest), and Target 6 IAS (Invasive Alien Species). For each species, the alignment with EBVs was specified, and links to ongoing projects, protection levels, and IUCN status were provided to ensure policy alignment and implementation feasibility.

Potential for restoration: The list also considered the potential for conservation action and habitat restoration, including species that can serve as flagship or umbrella taxa, or those likely to benefit from or indicate the success of restoration interventions.

This collective selection step replaced the exhaustive ranking process used for Birds, ensuring that the chosen set of Mammals remains both ecologically representative and feasible to monitor despite heterogeneous data availability. The chosen set of mammal species was subsequently evaluated by a total of 9 experts of the WG independently and anonymously, which provided a score (indicator recommendation) on a scale from 0 (not recommended) to 10 (highly recommended). For Mammals scored with a value > or = 8, each expert specified what peculiar characteristics of that species made them provide a high score (more details are reported in the Appendix material, see excel file titled "Mammals_IndicatorRecommendation.xlsx").

Proposed Mammal species	Group	Indicator parameters related to EBVs		
Mammal species common name (*scientific name*)		Change/Trends	EBV class	EBV name
Chamois (*Rupicapra rupicapra*)	Ungulates	Trends	Species populations	- Species distributions - Species abundances
Alpine ibex (*Capra ibex*)	Ungulates	Changes	Genetic composition	- Genetic differentiation - Effective population size - Inbreeding
		Trends	Species populations	- Species distributions - Species abundances
		Changes	Species traits	- Phenology
Alpine marmot (*Marmota marmota*)	Rodents	Trends	Species populations	- Species abundances
		Changes	Species traits	- Phenology
European snow vole (*Chionomys nivalis*)	Rodents	Trends	Species populations	- Occupancy
		Trends	Species traits	- Phenology
Common dormouse (*Muscardinus avellanarius*)	Rodents	Trends	Species populations	- Species distributions
		Trends	Species traits	- Phenology
Eurasian red squirrel (*Sciurus vulgaris*)	Rodents	Trends	Species populations	- Species abundances
		Changes	Species traits	- Health status (parasite prevalence)
Mountain hare (*Lepus timidus*)	Lagomorphs	Changes	Genetic composition	- Genetic differentiation - Hybridization
		Trends	Species populations	- Species distributions
		Changes	Species traits	- Phenology
Northern bat (*Eptesicus nilssonii*)	Bats	Trends	Species populations	- Species distributions
Lesser horseshoe bat (*Rhinolophus hipposideros*)	Bats	Trends	Species populations	- Species abundances
Golden jackal (*Canis aureus*)	Large carnivores	Trends	Species populations	- Species abundances
Grey wolf (*Canis lupus*)	Large carnivores	Changes	Genetic composition	- Effective population size - Inbreeding

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		Trends	Species populations	- Species distributions - Species abundances
		Changes	Species traits	- Phenology
Brown bear (*Ursus arctos*)	Large carnivores	Changes	Genetic composition	- Genetic differentiation - Effective population size - Inbreeding
		Trends	Species populations	- Species distributions - Species abundances
		Changes	Species traits	- Phenology

Table 4. Expert-based list of Mammals' species proposed by the WG with relative EBVs.

Mammals' species list of indicators	**Classification[1]**	**Expert-based indicator recommendation [2]**
Mammal species common name (*scientific name*)		**Mean score**
Mountain hare (*Lepus timidus*)	1	8.75
Alpine marmot (*Marmota marmota*)	2	8.67
European snow vole (*Chionomys nivalis*)	3	8.13
Northern chamois (*Rupicapra rupicapra*)	4	8.11
Alpine ibex (*Capra ibex*)	5	7.89
Northern bat (*Eptesicus nilssonii*)	6	6.83
Lesser horseshoe bat (*Rhinolophus hipposideros*)	7	6.33
Common dormouse (*Muscardinus avellanarius*)	8	5.78
Eurasian red squirrel (*Sciurus vulgaris*)	9	5.44
Golden jackal (*Canis aureus*)	10	5.13
Grey wolf (*Canis lupus*)	11	4.25
Brown bear (*Ursus arctos*)	11	4.25

Table 5. Expert-based list of Mammals' species selected as indicators for the European Alps.(1) The mammal species classification ranked from highest to lowest.(2) The mean score indicates the indicator recommendation parameter assessed by 9 experts of the WG on a scale from 0 (i.e., not recommended as an indicator for the European Alps) to 10 (strongly recommended as an indicator for the European Alps). Scores were assigned anonymously and independently by 8 experts belonging to the Mammals' WG (see **Table 1**).

2.3 Pollinators' species scoring and preliminary selection as indicators for the European Alps according to expert-based evaluation

To simplify potential comparisons between output obtained from each WG, we used an analogous methodology to the one outlined for Birds in section 1.1. Namely, we compiled a list of 261 butterfly species recognized as indicators and/or indices by current European and national legislation. Namely, the following were used: the European Red List of Butterflies (Van Swaay et al., 2025), the Common Grassland Butterfly Index (Van Swaay et al., 2025) and Habitats Directive Species (II & IV)**.**

Namely, EBVs-related criteria included were scored as follows:

- **Ecological niche:** Several key factors were considered to establish whether a species was described as a specialist or as a generalist. These included **habitat preferences** (specific environments where a given species persists, including forests, grasslands, wetlands or agricultural lands); **food preferences** (determining food resources of larval stages) and **behavioral traits** (i.e., considering mating habits, territoriality and migration patterns).
- **Climate response:** it indicated on a scale from 0 to 10 how much a given butterfly species was sensitive to climate change (0: not sensitive, 10: very sensitive). Therefore, considering how each species responds to shifts in temperature, humidity and light, and how much these shifts may influence their distribution and abundances. The evaluation was completed independently if the reaction is net positive or negative for the species considered.
- **Environmental representativeness:** It was assessed according to the elevation ranges shown in Figure 4, indicating where a species is frequently found. Therefore, categories could include up to 3 of the following: alpine zone, subalpine zone, montane zone, foothill zone, super mediterranean zone, and mesomediterranean zone.
- **Major pressures and threats:** It indicated which are the main threats for a species among the following: forestry management practices, land use, intensification of grassland use, pollution, climate change, seasonal shifts in plant phenology, or, if needed, by adding other specific pressures and threats. In addition, each expert could add more specific threats, if not listed among the categories above.
- **Potential for restoration:** It was assessed with a score from 0 (no potential) to 10 (maximum potential), with half the scores allowed. This parameter highlighted the capacity of a degraded or altered Butterfly species to recover upon **habitat suitability** (thus, given suitable environmental conditions and resources that support a given species and at any life-cycle, from larvae to adult), **current population status** (i.e., the existing population status and genetic health of the species), **threat assessment** (understanding potential ongoing threats that may lead to degradation), and **restoration techniques** (i.e., which restoration strategies may be effective during restoration and species recovery, such evaluation was computed upon species-specific distribution and abundance).
- **Indicator recommendation:** A parameter that indicates from each expert perspective (evaluated anonymously and independently from the other pollinators WG members) how much would they recommend that species as an indicator of habitat quality (i.e., species likely to be affected by certain agricultural practices, etc.) for the European Alps on a scale from 0 (not recommended) to 10 (highly recommended). With half scores allowed.

After independent and blind scoring by five experts, the mean score was calculated per species, and it was based on the number of assessments conducted (Table 6). This step was necessary because the members of the pollinators WG operate in different regions of the Alps, and not all butterfly species are present in every area. Consequently, each expert compiled the list only for the species they have direct experience with.

Butterfly species list of indicators of habitat quality	Classification[2]	Expert-based indicator recommendation [3]
Butterfly species common name (*scientific name*)		**Mean score**
Dewy ringlet (*Erebia pandrose*)	1	8.75
Apollo (*Parnassius apollo*)	2	8.60
Common brassy ringlet (*Erebia cassioides*)	3	8.33
Purple-edged copper (*Lycaena hippothoe*)	4	8.25
Alpine heath (*Coenonympha gardetta*)	5	7.80
Clouded apollo (*Parnassius mnemosyne*)	5	7.80
Lesser mountain ringlet (*Erebia melampus*)	6	7.75
Swiss brassy ringlet (*Erebia tyndarus*)	6	7.75
Glandon blue (*Agriades glandon*)	7	7.67
Damon blue (*Polyommatus damon*)	7	7.67
Knapweed fritillary (*Melitaea phoebe*)	8	7.60
Tufted skipper (*Carcharodus floccifera*)	9	7.50
Mountain ringlet (*Erebia epiphron*)	9	7.50
Large blue (*Phengaris arion*)	10	7.40
Dusky grizzled skipper (*Pyrgus cacaliae*)	11	7.38
Piedmont ringlet (*Erebia meolans*)	12	7.33
Silky ringlet (*Erebia gorge*)	13	7.25
Sooty ringlet (*Erebia pluto*)	13	7.25
Chalkill blue (*Lysandra coridon*)	13	7.25
Marsh fritillary (*Euphydryas aurinia*)	14	7.20

Table 6. Expert-based list of butterfly species selected as indicators for the European Alps. The top 20 highest values for butterfly species are ranked from highest to lowest. (3) The mean score was calculated based on the indicator recommendation parameter assessed by the WG, and evaluated using a scale from 0 (i.e., not recommended as an indicator for the European Alps) to 10 (highly recommended as an indicator for the European Alps). Scores were assigned anonymously and independently by 5 experts belonging to the Pollinators' WG (Table 1).

3 Conclusion

Our report provides three preliminary lists of potential indicators for Birds, Mammals and Pollinating insects (here Butterflies) within the AlpsLife perimeter. Moreover, for Birds and Butterflies, the species were selected starting from readily available and extended lists reported in indices derived from European legislation currently in force. For each taxonomic group, the EBVs utilized during the expert-based assessment further helped in evaluating the most suitable indicators for effectively characterizing and preserving the ecological integrity of mountainous biodiversity, ranging from individual species to entire ecosystems.

Using expert-based lists of indicators in the AlpsLife area can significantly enhance biodiversity monitoring and conservation strategies within the whole alpine region. Such comprehensive lists of indicators tailored for mountainous environments provide a solid framework for developing targeted monitoring schemes, identifying species for monitoring enables the selection of appropriate methods and techniques that align with the needs of taxonomic groups (or species).

Expert-based selected indicators can support the development of indices that validate existing data collected in each area or can provide guidelines to either adjust or start a cohesive monitoring scheme across the European Alps. By assessing whether monitored species are representative of various elevational gradients, and habitats typical of the alpine region, researchers, land managers and local stakeholders can ensure their findings are robust, representative and applicable.

Additionally, besides the methodology here presented can serve as a starting point for application in mountainous contexts beyond the AlpsLife area, we highlight that the animal species lists here presented are preliminary and were developed following an initial expert-based assessment, which prioritized certain EBVs criteria. Additional consolidated assessments into indicators and cumulated indices by each taxon will be developed upon literature revision on species within the AlpsLife perimeter. For instance, many common butterfly species are shifting their ranges to higher elevations, seeking cooler habitats (Rödder et al., 2021). Such a shift can make these species valuable biological indicators of environmental changes and ecosystem health and therefore must also be considered while generating an informative index of pollinators for the alpine region. Furthermore, by distributing targeted questionnaires investigating which monitoring schemes are currently in force and where within the AlpsLife perimeter (Activity 2.2), the WP2 will provide cues on biodiversity data available, on which areas require a major effort in biodiversity monitoring, and what are the species and communities currently being monitored including the relative methodology. Then, cumulative indices will be derived from existing data collected within the project's area. Expert-based selected indicators jointly with historical (i.e., literature reviews and data) and contemporary biodiversity datasets tracking population trends across the European Alps will facilitate the development of benchmark indices. Such indices are crucial for tracking drivers of biodiversity changes over time and space and ultimately support the preservation of any mountainous ecosystem.

List of abbreviations

BGNP	Berchtesgaden National Park
EBVs	Essential Biodiversity Variables
EGBI	European Grassland Bird Index
EPNS	Stelvio National Park
FBI	Farmland Bird Index
GNP	Gesäuse National Park
IAS	Invasive Alien Species
ISPRA	Istituto Superiore per la Protezione e la Ricerca Ambientale
MGIB	Mountain Grassland Bird Index
NRL	Nature Restoration Law
PECBMS	Pan-European Common Bird Monitoring Scheme
PNGP	Gran Paradiso National Park
PP	Partnership ID within the AlpsLife project
SNP	Swiss National Park
UIBK	University of Innsbruck
UNIMI	University of Milan
UNITO	University of Torino
WG	Working Group
WP	Working Package

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