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**ON MOUNTAIN
UNGULATES**

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Abstract book



Organising institutions

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8th World Conference on Mountain Ungulates *towards an integrated approach to species conservation*

September 27-30, 2022
Cogne – Aosta Valley – Italy



INTRODUCTION _____ 9

Bassano B. and Brambilla A. The 8th World Conference on Mountain Ungulates

OPENING _____ 9

Lovari S. and Corlatti L. (invited) The chamois in (Great) Paradise: what have we learnt from them?

BEHAVIOUR _____ 10

Brivio F. et al. A focus on nocturnal activity as a possible response to global warming

Chauveau V. et al. A way for migration: identifying the spatial determinants of migratory movements helps predict migratory connectivity in Alpine ibex (*Capra ibex*)

Corlatti L. and Lovari S. (invited) Mountain ungulate mating systems: Patterns and processes

Cotza A. et al. Group-living and its costs in a mountain-dwelling ungulate

Fattorini N. et al. Are Apennine chamois ‘under the weather’? Accumulated warming and drought influence behaviour through vegetation-mediated effects

Grignolio S. et al. The studies of social interactions in male Alpine ibex reveal an interesting evolutionary perspective

Soultan A. et al. Ibex responses to feral dogs

Thapa K. and Rayamajhi S. Adaptive strategies of blue sheep *Pseudois nayaur* under the predation risk of snow leopard *Panthera uncia* and wolves *Canis lupus* in Nepal

CONSERVATION AND MANAGEMENT _____ 15

Ahmad R. et al. Recovery of Kashmir markhor *Capra falconeri cashmiriensis*: identification of critical habitats and their protection through community-based interventions

Asprea A. et al. Dynamics of the Apennine chamois population in the Maiella National Park: the outcome of a (so far) successful reintroduction

Bhatnagar Y.V. et al. Riding the carnivores: upgrading Caprinae through carnivore conservation

Farkas A. et al. Evaluation of the management of Northern chamois (*Rupicapra rupicapra carpatica*) population based on population estimates and hunting bag data from Romania

Garnier A. et al. Conservation of ibex species in France. Contribution of post-translocation monitoring of *Capra pyrenaica* in the Pyrenees

Gebremedhin B. Species distribution prediction and connectivity for identification of future reintroduction sites for the Walia ibex

Hayat Khattak R. et al. Evaluating habitat suitability for threatened Kashmir markhor (*Capra falconeri cashmeriensis*) in the Hindu Kush mountains, Northern Pakistan

Herrero J. et al. The recovery of Iberian wild goat *Capra pyrenaica* in southern Pyrenees

Javornik J. et al. Alpine ibex management in Slovenia; from habitat studies to needed population reinforcements

Michel S. (invited) The Re-Assessment of Caprinae in the IUCN Red List – Results and Challenges

Peters W. et al. Global ungulate migrations in a changing world & a plea for maintaining altitudinal migrations

Shamsuddinov K. and Tohirzoda S. Post-Soviet Recovery of Markhor in Tajikistan: A Conservation Success Story

Wagler B.L. et al. Effects of helicopter net-gunning on survival of bighorn sheep

ECOLOGY AND EVOLUTION _____ 24

Bashir T. et al. Forecasting Markhor (*Capra falconeri falconeri*) distribution and connectivity in Kashmir Himalaya under climate change scenarios

Berger J. et al. Species Interactions at Earth’s Edges

Chirichella R. et al. The influence of geological substrate on senescence in Alpine chamois as a function of tooth wear

Corlatti L. et al. Effects of red deer and increasing temperature on chamois upslope shift

Di Cecco V. et al. The pastoral value of high altitude vegetation in Maiella National Park: could effects of climate change improve the trophic availability for the Apennine chamois?

Edelhoff H. et al. Contrasting density gradients of two alpine ungulates – a study using spatial capture-recapture modelling

Festa-Bianchet M. and Morrissey M. (invited) Intense directional selective pressure from trophy hunting causes evolution of smaller horns, despite denials

Lioce F.A. et al. Diet and trophic niche overlap between wild ungulates and livestock in the Italian Alps

Loison A. et al. Chamois survival depends on their foodscape

Moheb Z. et al. Factors influencing the spring distribution of sympatric urial and Siberian ibex in the Hindu Kush Mountains of Wakhan National Park, Afghanistan

Peters W. et al. Partial migration and seasonal habitat selection in an iconic mountain ungulate

Toïgo C. et al. How climate indirectly influences Alpine ibex individual performance through forage availability

von Hardenberg A. et al. Differences in the population dynamics of two sympatric mountain ungulates: Alpine ibex and Alpine chamois in the Gran Paradiso National Park

White K. et al. Costs of living dangerously: long-term study reveals snow avalanches are a major driver of mountain ungulate population ecology

GENETICS SYSTEMATICS AND PALEONTOLOGY _____ 33

Biebach I. and Keller L. Alpine ibex as a model species to understand reintroductions and inform management

Daly K.G. et al. A novel lineage of *Capra* discovered in the Taurus Mountains of Turkey using ancient DNA

Dolker S. et al. Studying landscape genetics of blue sheep (*Pseudois nayaur*) from Western Himalayas, India and its implications in conservation and management

Grossen C. Evolution in bottlenecked species: deleterious mutations, introgression and disease susceptibility in Alpine ibex

Jabin G. et al. Ensemble of genetic and ecological study of Himalayan ibex (*Capra sibirica*) in Indian Trans-Himalayas

Pemberton J. (invited) Inbreeding depression in island ungulates

Rezić A. et al. The traces of the historical events in Balkan chamois genetic diversity

Robin M. et al. Conservation genetics in bottlenecked species: insights from ancient genomes of the Alpine ibex

Stipoljev S. et al. MHC allelic diversity of nonnative aoudad populations

Tešija T. et al. Reconstruction of *Rupicapra* spp. genome assemblies from low-coverage short-read data

MONITORING METHODS AND CONSERVATION TECHNOLOGIES _____ 39

Antonucci A. et al. Apennine chamois (*Rupicapra pyrenaica ornata*) wild captures by associated mechanical and chemical immobilization in conservation translocations activities: clinical analysis and source population monitoring as tools to evaluate the efficacy and safeness of the method.

Bohlen L. et al. Automated photo-identification of Alpine ibex (*Capra ibex*) individuals

Brambilla A. et al. Long term monitoring of life history traits in Alpine ibex

Cagnacci F. et al. Big threats need big data: collaborative science to improve knowledge and conservation of mountain ungulates

Cybulska N. et al. Growth parameters as indicators for environmental variation in a mountain ungulate

Ghoddousi A. et al. Using ranger-based monitoring data to guide conservation of mountain ungulates in protected areas

Moroni B. et al. Hybridization between Alpine ibex and domestic goat in the Alps: a sporadic and localized phenomenon?

Panaccio M. et al. Double Observer methods to monitor the Alpine ibex population in Gran Paradiso National Park

PHYSIOLOGY HEALTH AND DISEASES _____ 44

Costanzi L. et al. Health status of the Alpine ibex populations in the Italian and French Alps

Dahl S.-A. et al. Adaptation of the ruminal microbiota of chamois (*Rupicapra rupicapra*) from the Bavarian alpine region to seasonal food availability

Khanyari M. et al. Predicting parasite dynamics in mixed-use Trans-Himalayan pastures to underpin management of cross-transmission between livestock and bharal

König A. et al. Energy uptake of Bavarian chamois (*Rupicapra rupicapra*) and their adaptation to different energy densities of the vegetation

Smiley R.A. et al. Energetic costs associated with disease defense strategies

Smoglica C. et al. Microbial communities and antimicrobial resistance genes in Apennine chamois in Maiella National Park

Zanet S. et al. Tick-borne pathogens in Alpine ibex and chamois: an integrated surveillance system

POSTER _____ 49

Akramov U. et al. Markhor (*Capra falconeri*) monitoring in Tajikistan shows population recovery

Asprea A. et al. What's new in Apennine chamois? Males show unusual sociality in the Maiella National Park, Italy

Bal X. et al. The role of the gut ecosystems in the ecology and evolution of a wild ungulate.

Bison M. et al. Camera traps to detect spatial distribution and temporal activity pattern of ungulates in the Mont-Blanc massif

Brambilla A. Twenty years of technological improvement of “a methods to weigh free-ranging ungulates without handling”

Bürglin R. Do you recognise your Southern Chamois? - Skull-length-eyeball-width ratios and tail characteristics as an approach to identifying *Rupicapra pyrenaica* subspecies.

Cella I. and Brambilla A. Analysis of diet quality of Alpine ibex

Chirichella R. et al. Evaluating tooth wear in Alpine chamois: a new proposed method.

Cotza A. et al. Alternative reproductive tactics in chamois: a fixed trait, with snow-dependent reproductive payoffs?

Formisano F. et al. New world and old pathogens: infectious keratoconjunctivitis in tahr and chamois in New Zealand revealed by citizen science

Foti F. et al. Effects of habitat and weather variables on Alpine chamois (*Rupicapra rupicapra*) in the Alpine district VCO3

Guerrero Cárdenas I. et al. Dietary coexistence between bighorn sheep and feral donkeys in the mountains of the southern Baja California peninsula.

Hussek A. and Koenig A. Monitoring of *Rupicapra rupicapra* in the Bavarian Oberallgaeu – A pragmatic approach

Jacobs S. et al. Genetic diversity, structure and connectivity of chamois (*Rupicapra rupicapra*) populations in the Bavarian Alps

Khazir S. et al. The socio-economics of migratory herder's dependent on markhor (*Capra falconeri*) habitats in North-western Himalayas, India

König A. and Hussek A. Long-term trend in the chamois population in the Bavarian Oberallgäu region

Korshunov V.M. and Korshunov M.V. Ecological profile of the Arabian Tahr (*Arabitragus jayakari*) living in the UAE.

La Russa L. et al. Study of Alpine chamois (*Rupicapra rupicapra*) demography and harvest in the Alpine district VCO3

Leoncini F. et al. A tale of an African ungulate in north-western Italy: population history, abundance, and ecology

- Loison A. et al.** Mountain ungulate in a hot world
- López-Montoya A.J. et al.** Activity rhythms of *Capra pyrenaica* revealed by GPS-GSM radiocollars
- Marchand P. et al.** 3D does matter when investigating the spatial ecology of terrestrial mountain species - an example in mountain ungulates
- Maurino L. et al.** Project Alcotra LEMED-IBEX: Monitoring *Capra ibex* in Alpi Cozie Regional Park
- Mesa F. et al.** Hunting bag statistics for *Capra pyrenaica* (1995-2021)
- Mora J.L. et al.** A case of coprophagy in Iberian wild goat *Capra pyrenaica*
- Morini P. et al.** Updated data on Apennine chamois population reintroduced in the Sirente Velino Regional Park
- Moroni B. et al.** Walk on the wild side: detection of antimicrobial resistance in Alpine ibex
- Náhlík A. et al.** First Hungarian GPS telemetry results on mouflon home-range evaluation and habitat use
- Nanetti E. et al.** Adaptive seasonal dynamics of the gut microbiome of the wild ibex from the Stelvio National Park, Italy
- Pedrazzi L. et al.** Individual quality affects growth strategy in social rank in male Alpine ibex
- Sganzerla F. et al.** Cohort affects social rank in male Alpine ibex
- Sher Shah M. et al.** Mountain Ungulates Reintroduction: A Case Study from AIUla Nature Reserves
- Stirnemann I. et al.** Nubian Ibex distribution in the Arabian Peninsula
- Srivastava T. et al.** Diet type determines reproductive seasonality in two Himalayan ungulates in Sikkim, India
- Zibordi F. et al.** On the edge between mountain and desert: the reintroduction of the Nubian ibex (*Capra nubiana*) in the Shouf Biosphere Reserve (Lebanon)
- Zehnder N. et al.** Genetic analysis of ongoing hybridization from domestic goat into Alpine ibex and the development of field applicable protocols



INTRODUCTION

The 8th World Conference on Mountain Ungulates

Bassano B.¹, Brambilla A.^{1,2}

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Scientific research is fundamental for effective management and to foster species and ecosystems conservation. The recent history of some mountain ungulates gives examples on how these results can be achieved. In the last decades, however, as research and technology progresses and knowledge increases, new questions arise on exciting and urgent challenges both for researchers and managers. Answering to those questions will require an inclusive approach that integrates different perspectives. For this reason, in the year of its 100th anniversary, Gran Paradiso National Park (Italy) decided to host the 8th World Conference on Mountain Ungulates in Cogne (Aosta Valley, Italy, 27-30 Sept. 2022) with the ambitious aim of facilitating the integration of different research fields and connecting them with management and conservation.

The conference has been organized by the Gran Paradiso National Park, in collaboration with the Abruzzo, Lazio and Molise National Park, in the framework of the joint celebrations for the 100th anniversary of foundation of the two Parks and has been sponsored by the Italian Ministry for the Ecological Transition (MITE) and the Regione Valle d'Aosta. The logistic of the conference has been supported by Fondation Grand Paradis.

This volume includes the abstracts of the contribution presented during the conference, divided by topic. Within each topic, contributions are listed in alphabetical order by the first author.

OPENING

Invited talk: The chamois in (Great) Paradise: what have we learnt from them?

Lovari S.^{1,2}, Corlatti L.^{3,4}

¹University of Siena, Italy. ²Maremma Natural History Museum, Italy. ³Stelvio National Park, Italy. ⁴University of Freiburg, Germany.

The Northern chamois *Rupicapra rupicapra* is the most numerous (c. 500,000 ind.s) and widespread mountain ungulate in Europe and Near East; a traditional game animal over most of its range, it belongs to the mountain folklore in many cultures. Despite all this, not much was known on its mating system and reproductive behaviour up to the mid-'90s. Because of that, in 1995, the Gran Paradiso National Park Agency and the Univ. of Siena started a joint project on these topics. On and off, this project has lasted c. 20 years in total. We could show that there are resident and seasonally migrating adult males. Irrespective of age and body mass, they may be territorial or non-territorial, and both enjoy some reproductive success. In November (i.e. rut time), territorial males invest more in rutting activities, while having higher levels of hormone metabolites and greater faecal counts of parasites than nonterritorial males. Their investment in rut activities determines higher mating benefits, which should be traded off against potential greater costs. Snow cover seems to play an important role for chamois reproduction: in years with snow-free rut periods, female distribution overlaps with that of non-territorial males, but not with territorial ones'. With increasing snow depth, females and territorial males progressively occupy similar elevations. Snow cover variations seem to impose changes in the spatial distribution of the two sexes. In turn, weather stochasticity over multiple ruts, rather than within-rut environment-dependent selection, appears to impose variations in male mating opportunities through Alternative Reproductive Tactics (territoriality vs. non-territoriality), possibly contributing to the coexistence of different lifetime behavioural phenotypes within the same population. If Alternative Reproductive Tactics are fixed in mature male chamois, neither ART should be favoured long enough over evolutionary time to allow its fixation by selection. Climatic

changes may be the main factor ensuring alternation of the most successful tactics. Territoriality is a rare form of mate acquisition in the Caprinae, possibly because of poor predictability of food and mate distribution on mountains. If so, climate instability may impact the relative success, hence the long term persistence, of site guarding behaviour.

BEHAVIOUR

A focus on nocturnal activity as a possible response to global warming

Brivio F.¹, Anderwald P.², Filli F.², Apollonio M.³, Bassano B.⁴, Bertolucci C.⁵, Grignolio S.⁵

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⁴University of Ferrara, Italy.

Monitoring and predicting how species would respond to the new challenges imposed by global warming is a major task for ecologists. The current rate of climate change is too fast for genetic adaptation to occur in large mammals because of their long life cycle, thus they will likely rely primarily on latent phenotypic plasticity. The expression of phenotypic plasticity includes anatomical variations, changes in phenology, and employment of intrinsic physiological and behavioural capacity that can buffer an animal against the effects of climate change. Since behavioural changes generally are less costly and more rapid than autonomic responses, behavioural adjustments are likely to play a crucial role in buffering the impact of the thermal threat of climate change. Large mammals living in the Alpine area are expected to be more affected by climate change as this area is recognized to be a hot spot where the increase in temperature is more pronounced. Alpine ibex (*Capra ibex*) is responding to global warming by retreating to and concentrating in fewer locations at higher elevations, where vegetation quality is low. Ibex seem not able to behaviourally compensate for this reduced forage productivity neither by adjusting the foraging time nor the feeding strategies. Rather, during warmer days ibex eat more in the morning and evening but, overall, they spent less time foraging, at least during diurnal hours. Yet they may be able to compensate for reduced food intake during warmer days by shifting their activities during the cooler nocturnal hours. We tested this hypothesis by analysing a large dataset of fine temporal scale activity data acquired by using accelerometers fitted on GPS collars of 27 ibex (18 males and 9 females) in the Gran Paradiso National Park and 20 ibex (12 males and 8 females) in the Swiss National Park. We focused our analysis during the critical period when ibex must acquire energy prior to the rigours of winter and they experience the highest environmental temperatures, i.e., from early spring to autumn. We calculated the total nocturnal activity for each ibex during each monitoring day and related it to the total activity of the previous diurnal hours, the weather conditions of the nocturnal and diurnal hours, as well as the night brightness. Our results showed that ibex nocturnal activity was negatively related to the total activity of the previous diurnal hours, but its variations were better explained by temperature conditions rather than diurnal activity. Interestingly, we found that nocturnal activity was primarily driven by maximum temperatures of the previous day, rather than by those recorded during the night. After days with high maximum temperatures, both males and females increased their nocturnal activity, arguably to compensate for scarce diurnal food intake. Ibex did not seem to take advantage of rainy days to facilitate their thermoregulation and increase foraging intake, but rather they decreased activity with increasing precipitation. We found a positive effect of moonlight on ibex nocturnal activity, particularly in females in the Gran Paradiso National Park. Females with kids showed increased nocturnal activity during the period of birth, but no other effects of kid's presence were found. Our findings suggest that ibex may cope with warmer temperatures by becoming more nocturnal. This finding excites new scientific questions on changes in anti-predatory behaviour and on the selection of resources during the night. On the other hand, it poses new challenges. As the increase in nocturnal activity could limit our ability to detect ibex during the day, this behavioural adaptation may negatively impact the performance of management activi-

ties, such as population estimates from census. Similar behavioural adaptation should be investigated in other mammals and taken into consideration for future management and conservation activities.

A way for migration: identifying the spatial determinants of migratory movements helps predict migratory connectivity in Alpine ibex (*Capra ibex*)

Chauveau V.¹, Marchand P.², Garel M.², Toïgo C.², Cavaillhes J.³, Canut M.⁴, Martinelli L.⁵, Fey-Roos A.^{6,7}, Greesmann G.⁸, Jurgeit F.⁸, Cagnacci F.⁹, Semenzato P.¹⁰, Ramanzin M.¹⁰, Anderwald P.¹¹, Herfndal I.¹², Filli F.¹¹, Champly I.¹³, Bouche M.¹⁴, Bonnet R.¹⁴, Bunz Y.^{15,2}, Petit E.¹⁶, Coulon A.^{17,18}, Loison A.¹

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Many species undergo human-induced habitat modifications. Ungulate migrations consist of seasonal movements across landscapes and are thus particularly threatened by these habitat transformations and fragmentation related to anthropogenic activities and infrastructure development. Understanding movement mechanisms underlying migration is of primary importance to conserve habitat connectivity and migrations. The analyses of GPS data from 425 Alpine ibex (*Capra ibex*), an emblematic species with conservation concerns, and 16 populations, revealed that ibex search for travel facility and reduce energetic costs by making movements with low relative elevation ascent, and they select for steep south-facing snow-free areas that provide security and potential resources. By contrast, ibex migratory movements were neither influenced by the landmarks tested (ridges, tree lines, valley bottoms), nor by anthropogenic infrastructures (roads, ski areas; but often slightly available in population ranges). We then used ibex habitat selection criteria to evaluate and predict connectivity, i.e. migratory movements, between winter and summer ranges. We performed three modelling processes and a cross validation procedure with independent data in order to assess the importance of data sources to predict potential space use during migration within 15 populations. Modelling connectivity using population specific habitat selection or using the average habitat selection of other populations was not significantly different. This study highlights the need to better understand how ibex will adapt to rapid ongoing environmental changes and provide tools to account for habitat connectivity for effective conservation of the Alpine ibex.

Invited talk: Mountain ungulate mating systems: Patterns and processes

Corlatti L.^{1,2}, Lovari S.^{3,4}

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Mountain ungulates hold remarkable interspecific diversity in habitat preferences, social organisations and morphological features. In this talk, we review how this ecological, social and phenotypical diversity varies with the organisation of reproductive behaviour: after introducing the ecology and variety of mating systems, we provide a taxonomic overview of the primary habitats occupied by the Caprinae, their grouping behaviour, body size, level of polygyny and form of mate acquisition. The striking variations that occur in mountain ungulate mating systems are paralleled by species-specific changes in

habitat openness, level of sociality and sexual dimorphism. From forest-dweller, solitary, monogamous and monomorphic goat-antelopes, to highly dimorphic, polygynous and social wild sheep and goats inhabiting open lands, mountain ungulates broadly support the eco-evolutionary scenario linking habitat use, sociality, reproductive behaviour and morphology originally proposed by Jarman (1974). Our current understanding of mountain ungulate mating systems, however, is hampered by limited information on the level of polygyny and form of mate acquisition – including uncertainty on the occurrence of alternative reproductive tactics, by the scarcity of genetic support for the opportunity of sexual selection and tactic-specific breeding success, and by the lack of information on female reproductive behaviour. The study of mating systems and of the factors affecting their variations plays a key role from an evolutionary and conservation standpoint. This is particularly relevant to the Caprinae, whose habitats are expected to be largely affected by climatic changes and whose economic value is relevant for both consumptive and non-consumptive uses. A better understanding of the diversity and ecology of mating systems of mountain ungulates calls for the need of field data collection on male and female behaviour, as well as genetic assessments of reproductive success.

Group-living and its costs in a mountain-dwelling ungulate

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Gregariousness can favour detection and avoidance of predators, yet it may increase intra-specific competition. In turn, feeding interference could elicit aggressive interactions and endogenous stress response. Trade-offs between (i) food intake and self/offspring protection, and (ii) inter-individual aggressiveness as well as the relevant stress response, may arise for group-living ungulates. Seasonality, which influences food availability, and age are two major determinants of social behaviour and its physiological correlates, particularly for mountain ungulates. We investigated female-female aggressive interactions, endocrine correlates, nutritional quality of diet and grouping patterns in a mountain-dwelling herbivore, the Alpine chamois, through behavioural observations on 10 individually recognisable females and chemical analyses of fresh faecal samples (June–November 2017–2018). The frequency of intra-sexual aggressive interactions decreased significantly throughout summer–autumn. No significant seasonal changes in faecal androgen metabolite (FAMs) levels, nor in faecal cortisol metabolites (FCMs) levels were supported; however FCMs tended to increase throughout months. Frequency of intra-sexual aggressive interactions and levels of hormone metabolites did not vary significantly with age; however, younger females appeared to be involved more often in aggressive interactions and to show slightly higher levels of FCMs than older ones. Protein content of diet decreased from summer to autumn, while crude fibre levels increased, as expected with decreasing pasture quality. Older females showed higher levels of crude protein and lower levels of crude fibre in their diet than younger ones. Group size decreased from summer to autumn. Access to adequate food resources in summer–autumn is crucial to females, to recover from births and to face the high costs of nursing, as well as to allow their offspring to store enough fat reserves to overwinter. Feeding interference results stronger when females share nutritious pasture, suggesting the importance of summer food resources.

Are Apennine chamois ‘under the weather’? Accumulated warming and drought influence behaviour through vegetation-mediated effects

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Mountain herbivores are particularly sensitive to weather parameters, as these drive vegetation growth during the critical phases of weaning and post-weaning. Whilst weather effects on resource allocation, viability and distribution of mountain ungulates have been investigated, little is known about potential consequences on social behaviour underlying access to food resources. We explored how female Apennine chamois *Rupicapra pyrenaica ornata* responded to varying weather conditions experienced within various time-windows during the nursing/weaning stages, when food acquisition should be maximized to increase individual fitness and survival. Cumulative consequences of weather on vegetation elicit chronic and carry-over effects on plant growth, providing insights on responses of vegetation to climate change. In two sites differing in availability of cold-adapted vegetation selected by chamois as summer pasture, we measured behavioural indices related to intraspecific resource competition and food acquisition, coupled with remote-sensing estimates of plant productivity. We investigated behavioural responses of chamois to warming and drought accumulated during the growing season, most likely via vegetation-mediated effects, and how these interacted with habitat quality. Warming and drought were followed by increased group-fission events, agonistic contest rate and aggressiveness at feeding, as well as by a greater probability to stop chewing during vigilance bouts, indicating interference over food acquisition. The reduction in vegetation productivity triggered by increasing temperatures and decreasing rainfall matched the temporal scales of climatic signals identified on behavioural indices, and no proximate effect of weather occurred on them. Furthermore, chamois responded consistently in both sites, suggesting that warming and drought may affect behaviour regardless of habitat quality. Locally-calibrated projections of temperature and rainfall predicted the progression of such plastic responses to the ongoing climate change, emphasising how prolonged effects of weather on vegetation growth can shape the social behaviour of mountain ungulates.

The studies of social interactions in male Alpine ibex reveal an interesting evolutionary perspective

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Generally, in polygynous artiodactyls, males’ agonistic interactions are particularly frequent close to or during the mating season. Males define their social hierarchy in proximity to the crucial moment when they can increase their reproductive success. Intra-male interactions are highly energetically expensive and can cause injuries or, rarely, the death of a competitor. When rutting period occurs close to or during a harsh season, the establishment of a male hierarchy may be too energetically expensive and may significantly affect the individual survival probability. The rutting period of Alpine ibex (*Capra ibex*) occurs in December and in the first weeks of January, i.e. at the beginning of winter. Previous studies showed that male ibex have evolved behavioural adaptations to safe energies during the mating season: males reduce the time devoted to the forage intake but avoid a complete hypophagia – which is common in other ungulate species – and decrease the time spent in agonistic interactions as well as the number of fights. It is still not clear if males define a social hierarchy in advance and, in that case, when this occurs. In order to investigate this topic, we collected 10426 hours of focal animal sampling observations on 74 marked males, ranging from 3 to 17 years old. Observations were carried

out between April and October from 2014 to 2019, in the Gran Paradiso National Park, Italy. During these observation sections, we recorded each interaction involving the focal animal and the outcome of the interaction. Moreover, we recorded any interaction occasionally observed between two marked males (ad libitum data collection).

By using the focal animal observations, we showed that males interacted mainly in the late part of spring and at the beginning of autumn while the frequency of interactions declined during the hottest periods of summer. The maximum daily air temperature negatively affected the interaction frequency, which was higher during the morning and the evening. Considering these findings, we hypothesized that the male ibex hierarchy may be established in early summer and maintained with little variation until the rutting period. To test this further hypothesis, we used the Elo-rating system to calculate individual hierarchical scores in summer and autumn. Summer and autumn scores were positively correlated suggesting stability in the hierarchies after summer: winning probability in autumn was appropriately explained by the individual scores estimated in July.

Our findings support the hypothesis that male ibex have evolved a specific life-history strategy to live in the demanding Alpine environment. Surprisingly, the hierarchy seems to be defined as far as six months before the rutting period and it occurs when the forage availability and quality are highest. The mismatch between dominance relationships establishment and the mating activities may represent a stable strategy to minimize energy expenditure in winter and therefore heighten the chances of survival and of future reproduction.

Ibex responses to feral dogs

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Feral dog impacts on wildlife are known to be significant, yet the nature of dog-wildlife interactions are not fully understood. In this study, we examined how feral dogs affect the spatial distribution and activity patterns of wildlife. To this end, we conducted camera trap surveys in AlUla County, Saudi Arabia, to record the presence of the reintroduced Nubian Ibex (*Capra nubiana*) and the presence of feral dogs. We found evidence that the presence of feral dogs can enforce the Ibex to change its spatial and temporal distribution to avoid encountering the feral dogs. Ibex favors sites that were less occupied by feral dogs. Moreover, an average of 180 minutes between a feral dog visit to a site and the proceeding visit by Ibex. We recommend site management control the presence of feral dogs to abate the ecological and physiological stress on the Ibex, which is already vulnerable according to IUCN RedList.

Adaptive strategies of blue sheep *Pseudois nayaur* under the predation risk of snow leopard *Panthera uncia* and wolves *Canis lupus* in Nepal

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Blue sheep is the staple wild prey for the snow leopard, solitary stalker hunter, and for wolves, the courser pack hunter, in Nepal. Under these different hunting strategies of predators, blue sheep responds differ to presence of various predators and these fear responses have population and community level consequences. We hypothesized that blue sheep have substantial variation on adaptive strategies in an area where two predators exists (snow leopard and wolves) and in an area where only one predator exists (wolves free zone). Therefore, we compared and contrasted the adaptive strategies on blue sheep demographic population structure (group size, sex ratio, female-kid ratio), vigilance behavior (group size, sexes and ages), distance to escape cover and habitat selection in Nar Phu valley (wolves' free zone) and in Manang valley with multiple predators. We investigated 200 groups (Manang=94 and Nar

Phu=106) of blue sheep using double-observer methodology to examine the demographic population structure, habitat selection and distance to escape cover in two study sites during autumn and spring season of 2019, 2020 and 2021. In order to examine the foraging behavior of blue sheep (group sizes, sexes and ages), we sampled 360 (180 in each study sites) individuals and observed vigilance behavior by utilizing focal animal sampling. We discuss the variation of blue sheep adaptive strategies on vigilance behavior, habitat selection and distance to escape cover under these different hunting strategies in Manang and Nar Phu valley of Nepal Himalaya.

CONSERVATION AND MANAGEMENT

Recovery of Kashmir markhor *Capra falconeri cashmirensis*: identification of critical habitats and their protection through community-based interventions

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Decline in population size and distribution range of ungulates due to resource removal by humans and livestock has been much pronounced in mountain ecosystems. This is mostly due to distinct seasonality in resource availability and its use by both wildlife and humans along with their livestock. Identification and protection of critical habitats supporting or capable of supporting such species, therefore, becomes a prerequisite to any species recovery programme. Kashmir markhor *Capra falconeri cashmirensis*, the largest goat in the world, survives in its last 250-300 odd numbers only in the Pir Panjal and Kazinag ranges of Kashmir Himalaya. We aimed at identifying and protecting critical habitats of Kashmir markhor in its only abode in India. We carried out seasonal block count surveys between 2007 and 2017 and recorded 4580 presence points of markhor. Of these, 2343 locations were from summer (April-October) and 2237 locations from winter (November-March). We identified suitable habitats using MaxEnt from these presence-only points while using Normalized Difference Vegetation Index, Normalized Difference Snow Index, topography (elevation, slope and aspect), Topographic Ruggedness Index and human disturbance, as predictors. We also conducted field surveys and interviews to record threats to markhor population in these areas. We predicted around 505 km² of area as suitable in summer, of which 219 km² was inside protected areas (PAs) and rest outside. For winter, of the total 75 km² suitable area, 29 km² lied within PA. We found heavy dependency of migratory herders and local communities for livestock grazing, fuelwood and NTFP collection as well as poaching in these areas. We used community-based approaches to address the identified threats through sensitization of migratory herders against non-traditional herding practices, forming, training and equipping local patrolling groups (Markhor watchers) and frontline staff of Wildlife Department to monitor and control poaching activities, thus securing the critical habitats and converging benefits from government schemes to dependent communities for their social development and livelihood strengthening. These interventions, including restrictions on non-traditional herding practices have resulted in about 40% reduction in livestock numbers in and around markhor habitats across two PAs in last three years. The communities are more aware and enthusiastic to participate in protecting markhor and its habitats while willing to share the incentives and benefits of conservation. We suggest maintaining strong connects between conservation efforts and socio-cultural values of local communities for the recovery and long-term conservation of mountain ungulates and their habitats, both within and outside PAs.

Dynamics of the Apennine chamois population in the Maiella National Park: the outcome of a (so far) successful reintroduction

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The Apennine chamois (*Rupicapra pyrenaica ornata*) has five populations in as many protected areas in Central Italy; four of these are the result of reintroduction programs. The Maiella National Park (MNP) population, restored during the 90's, is now the largest one, outnumbering the population restored in the Gran Sasso National Park in the same period. The aim of our work is to evaluate the success of the reintroduction in MNP in light of population dynamics and grouping patterns, and to investigate potential constraints to expansion and growth rates.

Using block-count data available on the Minimum Number Alive (1482 individuals in 2021) and considering the number of actual founders (23) and 24 years from the last major release, we estimated a rate of increase of $r=0.174$, nearly identical to what has been reported for reintroduced ungulate populations with ≥ 20 founders. The overall finite growth rate in 2000-2021 is $\lambda=0.158$ (CI95%=1.135-1.180). According to the standardized observation data collected in 2011-2021, the average proportion of kids over the total population is $B_i=0.276\pm 0.085$, the mean birth rate is $B=0.627\pm 0.162$, and the mean recruitment index (estimated as number of yearlings on the total adult population) is $R=0.207\pm 0.242$. Females and kids have expanded their range in the last eight years, including to areas never used before. The pattern of group size distribution is consistent with previous findings on this species, but also shows some peculiarities: large mixed groups (>200 individuals) have been recorded, as well as unusually large male groups (>50 individuals), suggesting that their abundance could reflect good habitat suitability/availability. The population dynamics in MNP and the demographic parameters are in line with other reintroduced chamois populations, and show a satisfactory conservation status; as such, the reintroduction can be deemed successful. However, the growth rate in 2010-2021 is half of the value registered in the previous decade: $\lambda=1.099$ (CI95%=1.067-1.131) against $\lambda=1.251$ (CI95%=1.197-1.309). Moreover, after a first phase of increase, the proportion of kids and the birth rate have been declining for the last ten years, reaching their lowest value in 2021 ($B_i=0.112$ and $B=0.297$, respectively). Our findings may thus also suggest that the MNP chamois population will soon reach the carrying capacity of the area or that some limiting factors are affecting the population dynamics (e.g., spatial and food competition with livestock and possible cross-species disease transmission, human disturbance).

Riding the carnivores: upgrading Caprinae through carnivore conservation

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Of the ca. 28 Caprinae species in Asia, 15 (54%) are declining as per the IUCN Red List of Threatened Species. While a few of these, such as markhor *Capra falconeri* and argali *Ovis ammon* may enjoy a strong conservation focus from stakeholders since they are hunted for trophies, most others may not. Nevertheless, threatened carnivore species such as the snow leopard *Panthera uncia*, the Asiatic cheetah *Acinonyx jubatus venaticus*, and the Persian leopard *P. pardus tulliana*, attract much greater conservation attention as flagship species. Together, these three apex flagships depend on ca. 19 (68%) of Caprinae species in Asia. The conservation benefits to Caprinae species through the Global Snow Leopard and Ecosystem Protection (GSLEP) Program, is one such example where the conservation challenges of the charismatic and threatened snow leopard are being addressed. GSLEP unites all 12 range country governments, non-governmental and inter-governmental organizations, local communities,

and the private sector around a shared vision to conserve snow leopards and their valuable high-mountain ecosystems. These countries have identified 24 landscapes to be secured for snow leopards across the cats' range that covers over a quarter of its ca. 2 million km² range. GSLEP envisions an integrated approach to ensure scientific and participatory climate-smart management of these large landscapes, including strengthening wildlife law enforcement, capacity improvement, better transboundary cooperation, fruitful engagement with industry, and monitoring snow leopard and its prey. These focused plans, resource mobilization and political will also help Caprinae conservation. Similarly, despite political conflicts, the countries in the Caucasus Ecoregion have taken concrete steps to conserve the Persian leopard, which directly and indirectly benefits its Caprinae prey. The Conservation of the Asiatic Cheetah Project (CACP) has resulted in the recovery of Caprinae prey across central Iran, despite economic sanctions. Since survival of these flagship species is only possible with sufficient wild prey, most of which belong to Caprinae, we propose that conservationists align with these programmes for harnessing better political will, and engage with existing mechanisms and structures for planning, funding, cooperation and convergences. Our suggestions are for developing such formal linkages in Asia, but this notion can be applied globally for Caprinae or other mountain ungulates, which often receive less conservation attention than charismatic flagship carnivore species.

Evaluation of the management of Northern chamois (*Rupicapra rupicapra carpatica*) population based on population estimates and hunting bag data from Romania

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Human activities are the biggest threat to chamois populations worldwide. Among these, poaching and over-hunting are often cited as direct threats. However, game management is an effective tool to reduce poaching and conserve the species in certain areas. The accuracy of the population estimates on which game management is based is often questionable, but they can nevertheless play a monitoring role. In our research, we analyzed the last 17 years of population estimates and harvest data in Romania in order to draw population dynamics conclusions and test the biological reliability of the data. Additionally, we processed the trophy evaluation data of approximately 80% (1935 out of 2399) of all chamois harvested in 2016 – 2021 period to an overview on quality parameters.

We found that although the population number estimates showed fluctuations, the trend was slightly increasing. Approved hunting quotas have varied between 4 and 8 percent of the estimated population, but this has never been completed. Foreign hunters use about 50 percent of the quota. The population structure is characterized by males accounting for one third of the population and females and their young making up the remainder.

The analysis of trophy evaluation sheets shows a stable age distribution which allows the hunting of individuals of advanced age from year to year. 51.42% of harvested trophies were with C.I.C. medals (14.16% gold; 17.83% silver and 19.43 bronze).

Our main conclusion is that based on data from the last 17 years, the CIC motto namely “Conservation through the sustainable use of wildlife” is possible in case of Romanian chamois populations at least in sustainable game management areas. From protected areas there are not available data on quality characteristics, but it cannot be suspected that the overall situation could be worse there.

Conservation of ibex species in France. Contribution of post-translocation monitoring of *Capra pyrenaica* in the Pyrenees

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We study the behavioral ecology of individuals of Iberian ibex (*Capra pyrenaica*) just after their translocation in the Pyrenees from where the species had completely disappeared.

Analysis of the distance between the reintroduced Iberian ibexes and the release point, called “post-release dispersal”, has shown that the tendency of individuals to move away from the release site is, during the first year, multifactorial. It depends on the sex, the males moving away more than the females, and on the age, the males of breeding age moving away more than the juveniles do.

Moreover, the role of congeners is of prime importance. Indeed, when an animal arrives at a site where other individuals have already been released, it tends to stay nearby, probably because the presence of conspecifics indicates favorable habitats (refuge areas, feeding sites) among other criteria (collective vigilance, opportunity for reproduction). The period at which an individual is released is essential, post-release dispersal being minimal when reintroductions are carried out in spring and maximum when the animals are released during the rut. These facts prove to be essential for the managers of these species who must adapt their reintroduction strategy, by releasing young males (under 6 years old), by carrying out the operations in the spring and by splitting them into several releases in order to promote the fixation of a maximum of individuals as close as possible to the release zone.

Analysis of spatial fidelity of individuals from two types of reintroduced populations highlights its emergence in Iberian ibex in the first time after their translocation, but also its seasonal variations in Alpine ibexes from ancient populations (reintroduced several decades earlier in the Écrins National Park). In the first times after release, spatial fidelity emerge more rapidly in females than in males. In ancient populations, spatial fidelity has a marked seasonality in both sexes, with high fidelity in summer, a key period for the reconstitution of body reserves. Through analysis of spatial fidelity, we illustrate how the familiarity of individuals with their habitat varies over time and how it is set up differently according to gender-related constraints. Comparison of the spatial fidelity of individuals in the first times after their reintroduction with that of individuals from ancient populations highlights a more rapid emergence of this fidelity in females, while males stabilize more slowly. In ancient populations, spatial fidelity has a marked seasonality, revealing how the familiarity of individuals with their habitat in summer allows them to make the best use of resources during this key period. In winter, snow-related constraints lead to lower spatial fidelity, especially for males, probably because of their greater movements during the rutting period.

Species distribution prediction and connectivity for identification of future reintroduction sites for the *Walia ibex*

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An estimated 17% of the total lands of Ethiopia is described as protected areas. This constitutes about 177,000 km², relatively enormous land to protect species and representative ecosystems. The *Walia ibex* are confined to the Simen Mountains National Park which covers only 0.23% (412 square kilometres) of the total land designated as protected area. The area of occupancy approximates

100km², which is about 0.2% of the maximum area required for terrestrial vertebrates to be described as restricted-range species. The population of *Walia ibex* has been showing a significant increase since the last three decades. However, the future survival of the species is challenged by increased anthropogenic, land use change and climate change. Despite better conservation management, and steady increase in the population in the last 30 years, anthropogenic pressures have been rising in parallel. New roads connecting towns around the National Park are constructed. These are followed by increase in the number of traffic and human settlement in and around the species potential habitats. The change in the climate is also noticeable. Study by Gebrehiwot and van der Veen (2013) shows that there is an increase of 0.72°C min. temperature and 0.36°C max. temperature per decade in the Ethiopia highlands. The wildlife surveys and counts conducted in recent years show a remarkable decline in the population of *Walia ibex* (about 40% less than previous counts). The numbers of domestic animals have also considerably increased leading to an increase in frequent observation of competitive domesticated animals such as goats browsing/grazing in habitats of *Walia ibex*.

We developed habitat suitability models for the species to support conservation planning. We used ensemble modelling to estimate the spatial extent of suitable habitats of the *Walia ibex* in the Simen Mountains, and in other parts of the Ethiopian highlands. We also addressed the potential consequences of future climate change using a climate model with four emission scenarios. The resulting model projections estimated the potential suitable habitat under current climate to 501–672 km² in Simen and 6,251–7,732 km² in other Ethiopian mountains. The wide altitudinal range of the species and the ability to exploit very steep slopes, enable the species to track the expected vegetation shift to higher altitudes. However, this potential positive impact may not last long under continued climate warming, as the species will not have much more new space left to colonize. Our study suggests that the current restricted distribution range can be substantially increased by reintroducing and/or translocating the species to other areas with suitable habitat. Indeed, to increase the viability and prospects for survival of this flagship species, we strongly recommend human-assisted reintroduction to other Ethiopian mountains. Emulating the successful reintroduction of the Alpine ibex that has spread from a single mountain in Italy to its historical ranges of the Alps in Europe might contribute to saving the *Walia ibex* from extinction.

Evaluating habitat suitability for threatened Kashmir markhor (*Capra falconeri cashmeriensis*) in the Hindu Kush mountains, Northern Pakistan

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The rapid expansion of the human population and developmental processes into the pristine and wilderness areas presumed to be wildlife habitats is detrimental to the survival of the dwindling population of wildlife species, as it may end up in shrinking of ideal habitats. Such incidents may become much more serious especially in developing countries where a large section of the population resides in close proximities to the natural wild habitats and mostly depends on the natural resources for their livelihood. Deforestation is one of the major reasons for habitat degradation–deteriorating the habitats of wildlife in general and more serious in case of ungulates communities. Therefore, habitat evaluation is of key importance for managing wildlife populations and designing promising conservation plans. Species presence data and geographic information system (GIS) coupled with groundbreaking powerful statistical techniques have made such assessments possible. We used maximum entropy modeling (MaxEnt) to identify suitable habitats for Kashmir markhor (*Capra falconeri cashmeriensis*) in Malakand Division, Pakistan. Globally, markhor is listed as Near Threatened and endangered in Pakistan. To obtain species presence data, field surveys were conducted from 15

October 2021 to 30 November 2022. MaxEnt was applied to 169 markhor sighting locations and topographical and current bioclimatic variables. Results showed that the accuracy of the MaxEnt model was good (AUC = 0.889). Of the total area studied (8407.09 km²), 22.35% (1878.75 km²) was highly suitable and 32.63% (2743.53 km²) was moderately suitable for markhor. Protected areas including Chitral Gol National Park (CGNP), Tooshi-Sasha Conservancy (TSC), and Gehrait-Golain Conservancy (GGC) and their buffers were included in highly suitable habitats. MaxEnt also predicted highly suitable habitats in Kumrat and Kalam valleys. We believe that moderately suitable habitats identified in Jinjeret, Ursoon, Birir valley, and Bumborait valley located in the north-western, south-western, and eastern parts of the study area, have the potential to host markhor populations. Based on the results obtained in the current study, we strongly recommend expanding the current protected areas (PAs) network in the study area and strengthening it by inclusive conservation management with local communities.

The recovery of Iberian wild goat *Capra pyrenaica* in southern Pyrenees

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Since the 1980s, the Iberian wild goat has been recolonizing the Pyrenees, following an escape from a fenced hunting ground in the Guara Natural Park (PNG), southern Pyrenees. During the 90s and at the beginning of the 20th century, various testimonies and chance encounters demonstrated the existence of a population that reproduced freely. On the other hand, and since the 1960s, herds of domestic goats *Capra hircus* were abandoned in the PNG and other parts of the Pyrenees, as a result of human emigration to large industrial centres. In 2006, Iberian wild goat monitoring began in PNG and continuous till nowadays. As of 2014, in the Parc National des Pyrénées and the Parc Regional des Pyrenees Ariégoise (France) and in the Val d'Aran (Catalonia), Iberian mountain goats were released. The process in the PNP continues to this day and the number of specimens released exceeds two hundred. From the first moment, the PNP specimens made their appearance in the Southern Pyrenees. The results of monitoring in the PNG and surrounding areas and of the rest of the initiatives show: (i) a population of mountain goats expanding at 16% per year that has colonized a good part of the park and made its presence in its surroundings; (ii) a total population of about 739 Iberian wild goats and 2,000 ferals in the latter circumscribed to the PNG and an area of about 2,000 km² occupied by the mountains in the Pyrenees (expanding) and of about 5,000 km² for the feral (stable) in 2020. Iberian wild goats from France and those from southern Pyrenees are converging.

Alpine ibex management in Slovenia; from habitat studies to needed population reinforcements

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Alpine ibex (*Capra ibex*) is considered as allochthonous species in Slovenia, as until recently there were no confirmed evidences on Alpine ibex presence after the end of the Würm glaciation. Only lately archeologists are reporting about potential (determination base on the morphological characteristics) Alpine ibex bone remains findings throughout the country, which are dated in the late antiquity period (7th-8th century). Although it would be beneficial to make genetically based determinations of these samples, this suggest that Alpine ibex was present in the recent territory of Republic of Slovenia at least until the 8th century. These evidences also indicate, that the species was extinct due to human overexploitation in the medieval times, similar to other Alpine countries. The first reintroduction of

Alpine ibex in Slovenia happened in 1891 (Ljubelj population). Three other reintroductions followed in the period between 1950 and 1980 (Triglav National Park, Brana and Bovec population). Only three populations are still existing today, the Ljubelj population went extinct due to scabies outbreaks. In general, scabies outbreaks in the 1980s and 1990s had significant effects on the population dynamics leading especially Brana population to the brink of extinction. Reinforcements are needed in order to prevent further population decline and to ensure long-term preservation of this charismatic Alpine species. Activities are underway in order to change the species currently allochthonous status and to ensure such reinforcements. In addition, to ensure successful reinforcement and viable populations' habitat and habitat connectivity studies are necessary, which are currently lacking for Slovenia. We addressed this knowledge gap and performed a habitat suitability and habitat connectivity analysis for the Slovenian Alps and neighboring Alpine ibex habitat in Austria and Italy. We performed our habitat suitability modelling based on the Alpine ibex sighting and harvest location data from all three populations. Based on this we prepared different scenarios for the Alpine ibex habitat changes due to the prognoses of Alpine landscape changes due to climate change and the abandoning of Alpine pasturing. We will present the results of our habitat modelling together with the current population dynamics and legal status of the species in Slovenia.

Invited talk: The Re-Assessment of Caprinae in the IUCN Red List – Results and Challenges

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The IUCN Red List of Threatened Species is the most comprehensive source of information on the extinction risk of animal, fungi and plant species. The assessment of extinction risk follows the standardized IUCN Red List Categories and Criteria (version 3.1) published in 2001. The species assessments are supposed to be updated every ten years. The IUCN SSC Caprinae Specialist Group is in charge of these reassessments for all mountain ungulate or Caprinae species, except one. Out of the 33 Caprinae species currently recognized in the IUCN Red List during the last decade reassessments of 29 species have been prepared, two species reassessments are still in the process and for two species no authors could be identified. Red list categories for most reassessed species remained or improved. So far only one species was assessed in a higher risk category. This apparently favorable result needs to be interpreted with caution. Data on population sizes and trends, on range areas and on threats are scarce for many species, in particular for elusive species or those occurring in difficult accessible areas. Expectations on data in terms of data quality, coverage of populations and synchrony as expressed in the Red List guidelines can hardly be met for any species. Some authors felt that the rigorous application of the Red List criteria on the available data did not properly reflect their own assessment of the species' status. The wrong perception that IUCN Red List category and protection status are linked is a common misunderstanding by assessors and contributors. The IUCN Red List assessments include a wealth of supporting information on species ecology, threats and conservation. This information is integrated in categorization schemes, e.g. on threats or on habitats. The limited number of options may cause misinterpretation if this information is used in meta-analyses and could lead to wrong policy decisions. The discrepancy between sophisticated analytic tools supposed to be applied in the assessments and the actual availability of data calls for more regular monitoring of the standard parameters and for making the monitoring results available for Red List assessors. Despite the inherent limitations, the IUCN Red List remains an important tool for documenting the status of global biodiversity and serves as a peer reviewed source of overview information on a large number of species. More contributions by experts with relevant knowledge are thus encouraged by the Caprinae Specialist Group.

Global ungulate migrations in a changing world & a plea for maintaining altitudinal migrations

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Ungulate migration is a fundamental ecological process. These seasonal movements promote the abundance of populations around the world, facilitate nutrient cycling, and provide the prey base for the world's largest carnivores. Technological advances in animal tracking are revealing the extent of seasonal movements in detail never seen before, which has led to new questions about the environmental, population and individual drivers of migration. Tracking plant green-up or rainfall for instance appear as major determinants of migration. As landscapes across the globe become developed, new infrastructure and land-use create barriers to movement that have led to the collapse of historical migrations and threaten others. Changes in phenology, productivity and increasing droughts, may also modify the cost and benefits of seasonal migration. While not performing long-distance seasonal migration, mountain ungulates also follow climatic and environmental gradients and may undertake impressive shifts in elevation between the seasons. The increasing development of traditional and emerging human activities in mountain ecosystems (herding, tourism and their associated infrastructure) and climate change (timing of spring green-up, snow and ice, summer droughts and temperature) pose growing threats to the seasonal movements of mountain ungulates. Animal tracking specialists from around the world have partnered with the Convention on Migratory Species (CMS) to launch the Global Initiative on Ungulate Migration (GIUM; <https://www.cms.int/en/gium>). The initiative combines the expertise of biologists and managers who pool together data, conduct analyses to map migrations, advance our knowledge of patterns and processes, and provide informed science for the conservation of corridors and habitats. A migration atlas available on a global web viewer will allow users to explore mapped migrations and provide the best available science on ungulate migrations globally, enabling planners, policy, and decision makers to incorporate the empirical seasonal migrations of populations into conservation efforts to maintain ecological connectivity.

Our twin-objectives are 1) to present GIUM current achievement to foster the interest of future contributors from mountain ecosystems around the world, 2) to present several cases of altitudinal migrations that illustrate movement plasticity along gradients of anthropogenic influence in Europe, e.g. in roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*), chamois (*Rupicapra rupicapra*), and ibex (*Capra ibex*) and 3) to raise awareness about the importance of better understanding the role of altitudinal migrations for the future of mountain ungulate populations and for the management and resilience of mountain socio-ecosystems facing rapid environmental changes.

Post-Soviet recovery of markhor in Tajikistan: a conservation success story

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Markhor (*Capra falconeri*) is one of the two mountain goat species occurring in south and southwestern Tajikistan, which is categorized as Near Threatened on the IUCN Red List of Threatened Species. The species is highly prized in the international trophy hunting market and has a major role in partly financing its own conservation programs and benefiting rural communities in their range. Markhor had a drastic population decline following the collapse of the former USSR in 1991 where less than 350 individuals were left throughout Tajikistan in the late 1990s. The country enhanced markhor protection in 2005 when the first conservancy, M-Sayod (~30,000ha) was established in the easternmost part of the species range in Tajikistan. With careful planning the number was increased to ten conservancies by 2019 that cover an area of 177,774ha, encompassing most of the current species' range in the country. By ensuring effective conservation through management of the conservancies, under direct supervision of the Committee for Environmental Protection (CEP), the markhor population increased to >2,000 in 2017 with the latest figure exceeding 6,500 individuals in 2022. This has been possible by managing the area and populations through transferring responsibility to conservancies who are responsible for protection, close cooperation with communities, hiring poachers as rangers, and ensuring benefits from trophy hunting revenues to the local community.

Given the emerging threats (e.g., climate change, disease outbreaks) and the better protection of markhor, CEP plans to develop an integrated management strategy to address the entire markhor landscape and population in the country while also strengthening conservation work conducted by individual conservancies. The key aspects of the strategy will include (1) understanding emerging threats due to climate change, development projects, and other anthropogenic factors; (2) implementing community welfare programs; (3) better documentation and monitoring successes; (4) more robust monitoring protocols for markhor; and (5) enhancing local capacity in conservation and management. CEP also invited the IUCN Caprinae Specialist Group to help with markhor monitoring and train experts on more robust and advanced monitoring protocols.

The markhor conservation success in Tajikistan has a strong message to the conservation community that by empowering local people, supporting grassroot initiatives and sharing benefits from sustainable use of natural resources, species could be brought back from the brink of extinction. Close collaboration and communication with international experts enhance conservation through sharing of knowledge and lessons, and also boosts the international recognition of the conservation achievements and provides greater motivation to in-country conservationists.

Effects of helicopter net-gunning on survival of bighorn sheep

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Wildlife capture, and the data collection associated with it, has led to major advancements in ecology that are integral to decision making pertaining to wildlife conservation. Capturing wildlife, however, can cause lethal and non-lethal risks to animals. Understanding the factors that contribute to the level of risk involved in wildlife capture is therefore critical for the development and implementation of the safest and most effective methodologies. We used data from 736 animal captures of 389 individuals for two subspecies of female bighorn sheep (*Ovis canadensis canadensis* and *O. c. sierrae*) in Wyoming and

California, USA, 2002–2020 to evaluate the degree and extent of time that capture via helicopter net-gunning affects survival. We compared pre- and post-capture survival during a 10-week window centered on a capture event, as well as post-capture survival between captured animals and animals that were monitored but not captured during the 10-week window. Additionally, we evaluated the effects of handling techniques (number of times captured, season of capture event, handling time, chase time, and body temperature) and biological factors (age and nutritional condition) on probability of capture mortality. Mean daily survival was 0.9992 during a 5-week pre-capture window, dropped to 0.9864 on the day of capture, and rebounded within 3 days of capture to pre-capture levels and that of sheep that were not captured. Overall, direct mortality resulting from capture was 1.36%, with 0.54% mortality occurring within the 3 days following a capture event for a total of 1.90% capture-related mortality. The only handling and biological metrics that influenced the probability of capture mortality were rectal temperature and nutritional condition; both high initial rectal temperatures and poor body condition were associated with increased risk of mortality in the days following capture. Overall, helicopter net-gunning imposed low and short-term risk to survival of female bighorn sheep. To reduce bias in survival estimates we recommend using a 3-day censorship window for post-capture mortalities as opposed to the common practice of a 2–5-week censor window. Helicopter net-gunning, including annual or seasonal recaptures, remains an effective and comparatively safe technique for capture and associated data collection of bighorn sheep.

ECOLOGY AND EVOLUTION

Forecasting Markhor (*Capra falconeri falconeri*) distribution and connectivity in Kashmir Himalaya under climate change scenarios

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Climate change is among the most significant driver of global biodiversity loss. Mountain ecosystems as early indicators of climate change respond rapidly to climatic aberration through population decline, range contraction and local extirpation of many charismatic species. One such species adapted to the mountainous terrain of the northern areas of Pakistan and the Pir Panjal mountain range of Jammu and Kashmir, India is the Kashmir Markhor *Capra falconeri falconeri*. The species is threatened mainly due to habitat loss and fragmentation, genetic isolation and poaching. We used the Random Forest machine-learning algorithm to identify the factors (abiotic and biotic) driving the habitat selection and future changes in habitat of markhor, across its distribution range in the Kashmir Himalaya (Pir Panjal and Gilgit-Baltistan area). We also developed dynamic resistant kernels to model markhor connectivity across a range of dispersal distances. We selected 49 variables representing climate, landscape composition, topography and anthropogenic influences in the region to model the habitat suitability based on markhor presence, out of which 25 variables were included in the final model after multicollinearity test and variable selection with Model Improvement Ratio. Mean temperature of wettest quarter, actual evapotranspiration of spring and winter, climatic moisture index and mean temperature of the coldest quarter strongly influenced habitat selection of markhor. Future projections under climate change scenarios indicated a significant gain of potential habitat for markhor under all scenarios with much of the species range shifting to higher elevations. Although, the models suggested some loss of potential habitats in future particularly under high emission scenario RCP = 8.5 in 2070s (34% loss), an overall net gain of potential habitat was projected under all future climate change scenarios. Alarmingly, the loss of habitat was anticipated in Pir Panjal range while the net gain was reflected in the Gilgit-Baltistan area. Our results showed dispersal ability to have a

substantial influence on the extant and pattern of connectivity of markhor, as connectivity increases with increasing dispersal ability. Climate change was predicted to substantially reduce the extant of connectivity for markhor across all future scenarios. We found that connectivity was more sensitive to climate change than habitat, indicating that connectivity may be the limiting factor for markhor population in Kashmir Himalayas. Our findings imply that traditional conservation efforts, such as in situ conservation, will not be sufficient to protect the species without climate change mitigation especially in the Pir Panjal range.

Species Interactions at Earth's Edges

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Earth's high elevation and latitudinal extremes warm 2-5x faster than elsewhere with consequences that link abiotic and biotic processes. Despite increasing attention to environmental change, great uncertainty remains about the outcome of species interactions. Whereas recent efforts to restore large predators such as gray wolves back into food webs have yielded significant information on both direct and indirect consequences of species interactions, our knowledge of direct interactions and pathways linking trophic levels in high altitude habitat is more limited. Here, we highlight two case studies to address how global warming (indirectly) and humans (directly) are affecting species interactions. We focus on huemul (*Hippocamelus bisulcus*) at the southern edge of Earth's land mass in Patagonian Chile, and mountain goats (*Oreamnos americanus*) in recent de-glaciating high elevation areas of North America. Offshore climatic events to the south and west of the Andes Cordillera have strong consequences as exemplified by toxic algal blooms in the Pacific Ocean which, in turn, diminish fisheries harvests. To supplement meat or economic gain, fishermen have in the past used dogs to hunt huemul, the most endangered large terrestrial mammal of the Western Hemisphere. The extent of this past relationships is unknown today. In contrast, hydro-geomorphic change, promoted by glacial recession are exposing (or creating) minerals of importance to mountain goats and bighorn sheep (*Ovis canadensis*) but highway construction at lower elevations is destroying such important resources. Our empirical assessments across three years reveal contest competition to access mineral licks with mountain goats dominating 98% of the interactions along a 2,500 km gradient at three high-altitude sites. While our two case studies from opposite ends of the Western Hemisphere differ dramatically in pattern and process, they serve to underscore the varieties of ways in which novel climate conditions may challenge species while also creating opportunities for colonization to newly created habitats.

The influence of geological substrate on senescence in Alpine chamois as a function of tooth wear

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Among ungulates living in mountainous environments, Alpine chamois (*Rupicapra rupicapra*) is an ideal case study to investigate how the evaluation of individual biometric characteristics can provide useful information to support the correct management of the species. We analysed biometric data from over 30,000 chamois legally culled during 12 consecutive hunting seasons (2010-2021, September-December) in 28 hunting management areas with different geological substrate (calcareous, metamorphic and siliceous areas) in the province of Trento (6,212 km²; Central-Eastern Alps, Italy). Available data confirmed that females experienced a later senescence than males, in

accordance with a greater energy expenditure undergone by males in rut period. Moreover, chamois in calcareous areas live longer than the ones in siliceous and metamorphic substrate. A pivotal role in this process seems to be played by tooth wear.

In this research, we estimated tooth wear in a subset of 416 mandibles collected during 2017–2021 hunting seasons. The progressive wearing of the cheek teeth was assessed using the height of molars (i.e., the distance from the peak of the mesiobuccal cusp to the enamel/cementum line) and their hypsodonty index (i.e., the height of each molar divided by the buccolingual breadth of the mesial cusp).

Percentage of weight loss derived from comparison with average population value (i.e., the mean value according to sex, age and hunting management area) in relation to increasing wear of each tooth was calculated. Our results clearly indicate that tooth wear of molars correlated with body mass loss, showing the importance of the chewing surface in shaping the ability of the animal to acquire energy throughout food comminution, chewing, and digestion. Referring to the same sex and age, the wear on calcareous substrate is lower than the one on other substrates. Indeed, siliceous and metamorphic substrates hold meadows with higher resistance to mechanical stress due to the presence of opal silica with respect to calcareous ones that hold higher quality of vegetation communities.

The key role of substrate (and related ecological conditions) in promoting body mass and horn length gain was shown in previous literature, leading to a differential investment in body mass and horn length according to different geological features with heavier animals living on the siliceous substrate. As a consequence, population dynamics and investment in reproduction too, can depend on the substrate where the chamois population lives. This effect could be related to differential tooth wear that influences life expectancy.

These results could allow to operate an oriented conservation and management strategy for this species. More in general, improving the linkage between senescence and individual biometrical characters should be considered one of the priorities to improve adaptive management of hunting species.

Effects of red deer and increasing temperature on chamois upslope shift

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Ongoing ecological changes greatly impact alpine ecosystems, ultimately affecting abundance and distribution of mountain-dwelling species. Climate warming, spatio-temporal variations in forage availability and interspecific competition, in particular, are major determinants of species distribution along elevation gradients. Taking advantage of long-term elevation data collected during annual ground counts within the Stelvio National Park (Central Italian Alps), we investigate the vertical shift of chamois *Rupicapra rupicapra* in relation to temperature, green-up duration, and elevation and abundance of a competitor species, the red deer *Cervus elaphus*. Linear models and path analysis were used to assess the direct and indirect relationships between explanatory variable and long-term chamois vertical movements. Our results showed that both species increased their average elevation over the past decades. Chamois upslope shift was explained by the additive effects of increasing temperature, rapid vegetation green-up and increasing deer elevation. While our work highlights a primary role of warming-up climate in shaping chamois distribution in our study area, it also suggests that a complex combination of biotic and abiotic factors drive the response of animal species to the ongoing global changes. No indirect relationship was supported, and the possibility of detecting more complex patterns will require data collected over longer time periods.

The pastoral value of high altitude vegetation in Maiella National Park: could effects of climate change improve the trophic availability for the Apennine chamois?

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High-mountain ecosystems are real biodiversity hotspots and guarantee numerous ecosystem services. In this work, a re-sampling was carried out in areas where the vegetation had been studied 17 years ago (re-visitation), to monitor any change in the specific composition and structure of high-altitude vegetation, its pastoral value and the potential effects on the diet of the Apennine chamois (*Rupicapra pyrenaica ornata*), whose population dynamics is strongly linked to a suitable coverage of plant species with a high pabular value (Lovari et al., 2020). The research was conducted within the Maiella National Park (MNP) in Central Apennine, at altitudes between 2400 and 2794 meters above sea level, analyzing two types of high-altitude vegetation: scree vegetation (*Linario-Festucion dimorphae*) and the vegetation of the micro-sinkholes (*Ranunculo pollinensis-Nardion strictae*). From the comparison between the data collected in 2003 and those of 2020, some interesting differences emerge and an increase in the pastoral value in both types of vegetation analyzed. In scree environments there has been a significant increase in the number of species, from 21 to 48 with an increase in the pastoral value from VP2003 13.48 to VP2020 20.56. As regards the micro sinkhole environments, the analysis of the data revealed a decrease of number of species from 70 to 60. However, the the pastoral value of vegetation increased from VP2003 28.58 to VP2020 34.54, thanks to the increment in coverage of some legumes such as *Trifolium thalii*, *T. pratense* subsp. *semipurpureum*, *Anthyllis vulneraria* subsp. *pulchella*. This increase in the pastoral value in the target plant communities could be related to the increase in biological activity of the soil, caused by the increase in temperatures and the deposition of atmospheric nitrogen, as well as to the greater contribution of nitrates due to the excrements of chamois. These results therefore suggest that in these high-altitude environments in the MNP, the local population of the Apennine chamois has trophic resources that have increased over the last 17 years. The population dynamics in MNP and the demographic parameters are in line with other reintroduced chamois populations, and show a satisfactory conservation status (starting from 23 reintroduced individuals in '90 to 1482 individuals counted in 2021). The vegetation data acquired in permanent plots such as these, are accurate and comparable over time, and contribute to increasing knowledge on the ecological processes ongoing in natural mountain ecosystems and to orienting the management and protection policies of plant and animal biodiversity.

Contrasting density gradients of two alpine ungulates – a study using spatial capture-recapture modelling

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Interspecific interactions of mountain ungulates have been identified as important drivers of individual space use and thus population density. In alpine landscapes, it has been hypothesized that spatial segregation of herbivores occupying overlapping ecological niches might decrease as a result of limited access to resources such as forage or cover.

Alpine chamois (*Rupicapra rupicapra r.*) and European red deer (*Cervus elaphus*) differ in their specific habitat requirements. While the ecological niche of chamois is typically characterized by mountainous habitat with steep, rugged terrain and open forage rich meadows above treeline, red deer can be found across a wide elevational range from low forested areas to meadows above the

treeline. While recent research suggested that red deer compete with chamois under the interspecific interaction hypothesis, factors driving the spatial overlap of both species have not been tested.

Here, we estimated and compared densities of chamois and red deer in two study areas in the Bavarian Alps (Karwendel and Chiemgau) which differ in their habitat composition and human land use intensity. We expected densities of chamois to vary between study areas as a function of the amount of typical alpine habitats and predicted densities of both species to overlap when available alpine habitat is scarce. To test our hypotheses, we conducted a Bayesian spatial capture-recapture analysis (SCR) based on systematic faeces collection and genotyping, accounting for sampling effort and sex. To test for the effect of habitat composition on densities, we included spatial covariates (e.g., terrain ruggedness, canopy cover, landcover). We then tested for correlations of the resulting spatial predictions of local densities.

In both areas, chamois densities were primarily driven by topographic ruggedness and ranged from 3 up to 19 individuals per 100ha. Red deer densities varied less between the two study areas (4 - 6 individuals per 100ha). They avoided barren grounds and were more abundant in forested areas. In the area with less typical alpine habitat (Chiemgau), spatial segregation between the two ungulate species was low. In the study area with higher amounts of alpine habitat (Karwendel), chamois density was negatively correlated with red deer density indicating higher segregation of the two species.

Gaining a better understanding of the relationship between habitat and ungulate densities is crucial for sustainable management of ungulate species, especially when multiple stressors due to simultaneous environmental stressors, such as climate change, may interact.

Invited talk: Intense directional selective pressure from trophy hunting causes evolution of smaller horns, despite denials

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Intense, directional selection on horn size through quota-free trophy hunting based on a definition of minimum curl leads to evolution of smaller horns in mountain sheep. Recently, papers have questioned the generality of this result. One paper in *Evolutionary Applications* claimed that horn size declines in bighorn sheep were rare. A published re-analysis using appropriate statistics reveals that horn size declines are ongoing in nearly all of Alberta, Canada, but only in about half the hunting areas considered in the USA, where regulations typically result in lower selective pressure. A modelling paper in the *Journal of Wildlife Management*, supported by an Editorial, claimed to show that hunting-induced evolutionary change was unlikely. When that model is parameterized with values of phenotypic and additive variance estimated for bighorn sheep, it predicts an evolutionary change similar or greater than empirically measured for the pedigreed population at Ram Mountain. Together, recent literature on mountain sheep confirms that evolutionary declines in horn size are to be expected under intense selective hunting. The same literature suggests that these changes can be avoided by more conservative harvest regulations.

Diet and trophic niche overlap between wild ungulates and livestock in the Italian Alps

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Understanding the process underlying interspecific competition is pivotal to investigating the future ability of animal species to adapt to changing environments. Coexisting species can avoid competition by partitioning resources, but when these are limited a potential for competition can occur, possibly resulting in a decrease of fitness. In the Italian Alps, red deer numbers have been increasing, which has been hypothesized to impact chamois populations through interspecific competition. In addition, as domestic sheep are moved to Alpine pastures in summer, and chamois share the same habitat with this livestock during this season, there is the potential for multispecific competition.

In this study, we used DNA metabarcoding of the chloroplast trnL intron and the ITS1 and ITS2 internal transcribed spacers to characterize diet and evaluate the niche overlap of chamois, red deer and domestic sheep. For each species, a total of 520 fresh fecal pellets were collected in three parks in the Italian Alps during two sampling seasons from seven areas characterized by one of three combinations of species interaction: i) areas where only chamois graze; ii) areas where chamois coexist with red deer; iii) areas where chamois share pastures with both red deer and sheep. At the taxonomic levels of family and genus, we detected high similarity in diet between the three species, but we observed diet segregation between chamois and domestic sheep and between chamois and red deer in periods when resource availability was expected to be limited. However, in general, the presence of potential competitors did not significantly affect the composition of chamois diet. In addition, hypervolume analysis was carried out to visualize the trophic niche of chamois, red deer and domestic sheep and to analyze diet overlap both for the total diet and for the preferred diet. In both cases, the three hypervolumes broadly overlapped and strong segregation was not evident. Overlap metrics between hypervolumes were always higher between chamois-red deer than between chamois-domestic sheep, suggesting a more problematic impact of coexistence between wildlife than between wildlife and livestock. We discuss the results considering ongoing climate change and habitat fragmentation and possible applications to wildlife management.

Chamois survival depends on their foodscape

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Studies on habitat-performance relationships that require joint data on fitness and habitat use are still scarce in long-lived species most likely due to the discrepancy between the temporal scales at which spatial and demographic studies are performed. Here we overcame this limitation in females Alpine chamois, by combining databases on (1) habitat structure and food resources, (2) individual GPS monitoring, and (3) long term capture-mark-resighting data collected at different spatial and temporal scales. We show that the proportion of the most used habitat type in a home range (negatively correlated with individual home range size, in agreement with the habitat-productivity hypothesis). Then, we unveiled that, in addition to a significant year-to-year variation, adult survival rates varied among individual clans (i.e. individuals which home range overlapped) and were positively correlated with habitat quality. We discuss the implication of these findings, given that it could lead to a spatial structure in demographic patterns at the population level.

Factors influencing the spring distribution of sympatric urial and Siberian ibex in the Hindu Kush Mountains of Wakhan National Park, Afghanistan

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Patterns of species co-existence and habitat selection for sympatric urial (*Ovis vignei*) and Siberian ibex (*Capra sibirica*) are poorly known, in part because there are few places where such overlap occurs. Mountain ungulates species are, however, key to sustaining large carnivores' populations, and thus understanding factors affecting ungulate distribution and abundance are important for ecosystem sustainability. On the northern slopes of the Hindu Kush range in Wakhan National Park (WNP) in northeastern Afghanistan, we collected herd location data during field surveys of both species on the northern slopes and sub-valleys of the Wakhan Valley in the western part of the park during April-May 2011, 2015, and 2018. We estimated factors influencing urial and ibex distribution by using envelope modeling techniques to compare ungulate observations with environmental factors derived from the study site. In general, there was spatial segregation between the two species. Ibex stayed at higher elevations compared to urial, and tended to avoid flat areas while urial not only avoided flat areas, but also avoided slopes above 60%. Urial used southeast facing slopes more, and west facing slopes less, than available, whereas ibex had a slightly more than expected use of southwest-facing slopes. Urial highly preferred a certain range of ruggedness compared to a more generalist use of terrains by ibex. Ibex seemed to use areas >500 m from human activity areas while urial seemed to be much more selective and mostly utilized habitats close vs. far from human activity areas. Both species utilized the higher quality vegetation areas (NDVI > 0) and showed the same avoidance of lower quality areas. Understanding the habitat use of ibex and urial along the Wakhan Valley just a few hundred meters above the human settlements at the valley bottoms greatly inform conservation of these mountain ungulates and their predator species.

Partial migration and seasonal habitat selection in an iconic mountain ungulate

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Understanding what factors determine movement behavior has been the focus of much theoretical and empirical research in ungulate ecology. Migration is classically defined as the seasonal movement of individuals from one region to another in response to changes in resources throughout space and time. Previous studies often treat ungulate migration as a fixed and discrete phenomenon of clear migrant versus resident behavior, also for the ease of mathematical modeling. However, today it is becoming clearer that ungulate migration is very flexible, and most ungulates display a behavioral plasticity of migration 'tendency' in response to favorable conditions or stochastic events. Despite its key role in understanding adaptation to environmental changes and shifts in distributions, little is known about partial migration in Alpine chamois (*Rupicapra rupicapra* r.).

To address our twin objectives of a) describing the patterns and b) explaining the ecological determinants that shape plasticity in migratory behaviour in Alpine chamois we analyzed annual movement trajectories of 30 radio-collared adult individuals (males = 14, females = 16, collected between 2018 and 2021) in the Bavarian Alps. For the analysis of individual movements, we employed a combination of movement classification methods; the net squared displacement rate (NSD) in latitudinal and altitudinal distance (R-package MigrateR), the GIS-extension MigrO and evaluating range shifts (R-package marcher). We used logistic regression models to test for determinants of

seasonal movements.

The average geographical distance between seasonal ranges was only about 2 km, but chamois showed a wide range of responses to seasonal environmental changes ranging from complete overlap to distinct separation of seasonal ranges. Almost all individuals undertook altitudinal shifts. Among the most important factors affecting movement plasticity were topographic variables, likely a proxy for variation in climatic conditions, and forage (measured through NDVI). We also observed significant differences between the sexes in patterns and in the drivers.

Because ecological conditions in mountain environments are closely related to elevation, methods to classify seasonal movements of mountain animals based solely on horizontal movement such as NSD are misleading. Research on plasticity and primary drivers for partial migration will improve monitoring efforts, management and provide insights to evaluating potential negative effects, especially those associated with changing climate.

How climate indirectly influences Alpine ibex individual performance through forage availability

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Climate warming is particularly pronounced in the Alps, with an increase of more than 2°C in spring temperatures in only 20 years. High temperatures have direct impacts on ungulates through thermoregulation and adoption of behaviours to avoid heat. But they also have indirect impacts through their effects on vegetation growth and thus forage availability for herbivores.

Our objective here is to investigate how spring and summer temperatures determine individual performance (reproductive success and growth) in Alpine ibex, and how such relationships can be explained by the temporal variability of forage availability (quality and quantity). For that purpose we began to sample forage productivity (biomass) and quality (dry organic matter and nitrogen content) along an altitudinal gradient and from spring to late summer, in a site where the Alpine ibex *Capra ibex* population has been monitored through capture-mark-recapture since 1985 (Belledonne, Isère, France).

Concerning ibex performance, we found that hot springs were favourable to male horn growth after their first year of life and to female reproductive success of the current year. On the contrary hot springs and summers had a negative impact on female reproductive success the next year, and on total horn length of males through cohort effects. Concerning vegetation, we found that hot springs favour plant productivity at the beginning of the growing season, but are detrimental to forage quality throughout the summer, and that hot summers are detrimental to both forage quantity and quality. Because of the strong sexual dimorphism, the performance of males and females is not susceptible to the same parameters, females relying more on quality while males need more quantity. We found that forage quantity in spring was positively correlated with female reproductive success and with male horn growth in the same year. On the contrary, forage quality was mostly determining maternal effects and female reproductive success the following year.

We advocate that our results show evidence for indirect effects of temperatures on ibex populations through forage availability. A new insight would be now to investigate how ibex behaviour (from GPS data) and forage availability interact to shape population dynamics under an ongoing climate warming.

Differences in the population dynamics of two sympatric mountain ungulates: Alpine ibex and Alpine chamois in the Gran Paradiso National Park

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Temporal modifications in demographic parameters due to exogenous factors, such as climate change, may have a dramatic impact on the population dynamics of mountain ungulates. The sympatric populations of Alpine ibex (*Capra ibex*) and Alpine chamois (*Rupicapra rupicapra*) have been monitored yearly in the Gran Paradiso National Park, following the same total block count methodology, since 1956. The two populations followed similar density dependent dynamics mediated by winter snow cover until the mid-eighties of the last century, when both the Alpine ibex and the chamois populations started to increase reaching unprecedented population peaks over the following 10-15 years. This steady population increase can be attributed to increasingly milder winters with less snowfall due to climate change. The Alpine ibex population, after reaching its peak in 1993, suffered a dramatic decline over the following 15 years, its dynamics finally stabilising at numbers below the average population size recorded in the first 30 years of the time series from 1956 to 1986. The Alpine chamois population showed instead a very different dynamic, reaching its peak population size 12 years later than Alpine ibex and maintaining itself at high density afterwards. In this presentation we explore the possible causes of these different dynamics in these two sympatric mountain ungulate populations. We suggest that climate change and consequently changes in the phenology of vegetation had a stronger impact on the survival of Alpine ibex kids than on Alpine chamois and that these differences are due to the strong differences in the life history of the two species.

Costs of living dangerously: long-term study reveals snow avalanches are a major driver of mountain ungulate population ecology

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Snow avalanches represent a widespread and seasonally dynamic landscape altering force in mountain environments. Mountain adapted species benefit from avalanche disturbance via utilization of resultant forage rich, early successional stage habitats that are characterized by relatively low winter snow depths and earlier spring green-up. However, our understanding of the costs associated with using such putatively risky landscape features is limited but may include direct mortality. In this study we utilize a long-term data set (2005-2022) collected from GPS/VHF radio-marked mountain goats (n = 434) in four study areas in coastal Alaska. These data were combined with a spatially explicit avalanche simulation and distribution model to quantify seasonal use of avalanche habitats and explore associated implications for mountain goat population ecology. Overall, we determined that avalanches represent a major source of mortality (mean = 36%, n = 240) among mountain goats, and varied spatially and temporally in relation to geographic, climatic and ecological characteristics of regional study areas (range, study area = 23-63%). Avalanche mortalities were most prevalent during early- and late-winter and coincide with expected seasonal patterns of snowpack stability and avalanche occurrence. Seasonal patterns of mortality were also linked to use of avalanche habitats, with animals that died in avalanches exhibiting significantly higher use of avalanche habitats (61±4%, n = 69) than those that did not (47±2%, n = 225). Reductions in annual survival resulting from avalanche caused mortalities ranged between 0-24% suggesting that interannual variability in winter weather conditions and resulting snowpack stability may play an important role in altering mountain goat population dynamics in more complex ways than

previously described. The conservative life history strategy and resultant low intrinsic population growth rates of mountain specialists, such as mountain goats, suggests that major population declines may occur during moderate-severe avalanche seasons; outcomes that can have important implications for conservation and management. Combined with previous work illustrating the important role of summer and winter weather and climate on mountain ungulate population ecology, these findings have potential to further advance our understanding of how projected climate change may influence mountain ungulate populations – species that are recognized as sentinels of mountain ecosystem health and productivity.

GENETICS SYSTEMATICS AND PALEONTOLOGY

Alpine ibex as a model species to understand reintroductions and inform management

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With an increasing number of populations being extirpated, reintroductions became a central tool in wildlife conservation. Our aim is to understand reintroductions from a genetic point of view, using the Alpine ibex (*Capra ibex*) as a model species and to use the information gathered to inform future management decisions. Thanks to an extensive reintroduction program, the Alpine ibex now occurs again throughout the Alpine region, after having been restricted to only one population in the Gran Paradiso region (Northern Italy) in XIX century. Given the well-known reintroduction history and the availability of different sources of genetic data (from microsatellites to NGS data), the Alpine ibex represents a good model to investigate genetic consequences of reintroductions.

We found that Alpine ibex populations have low genetic diversity and high inbreeding levels. Both measures depend on the reintroduction history, with more founder individuals and more source populations in the founder group leading to higher genetic diversity and lower inbreeding. We also found lower growth rates in populations with higher inbreeding levels.

In order to inform management decisions, we also performed simulations to predict the genetic outcome of restocking or founding of new populations. After the release of restocked ibex in one population, we compared our prediction with the real outcome of the restocking. We found hybridized offspring of resident and restocked ibex according to our expectations, showing that simulation can be a powerful tool to inform restocking and reintroductions, in order to increase genetic diversity and reduce inbreeding.

A novel lineage of Capra discovered in the Taurus Mountains of Turkey using ancient DNA

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Direkli Cave, located in the Taurus Mountains of Turkey, was occupied by Late Epipaleolithic hunters-gatherers for the seasonal hunting including large quantities of wild goats. We report genomic data from new and published *Capra* specimens from Direkli Cave and find a novel lineage sister clade to the Caucasian tur species (*Capra cylindricornis* and *Capra caucasica*). The lineage is best represented by a ~2.6X genome (Direkli4) which dates to the late 13th-early 12th millennium cal BC, and we

report two additional samples with nuclear genomes of this Tur-like ancestry. West Eurasian domestic goats in the past, but not those today, appear enriched for Direkli4 alleles, and we identify genomic regions introgressed in domestic goats with high affinity to Direkli4. This forgotten *Capra* lineage likely survived Late Pleistocene climatic change in a Taurus Mountain refugia.

Studying landscape genetics of blue sheep (*Pseudois nayaur*) from Western Himalayas, India and its implications in conservation and management

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In conservation planning, species that are widely distributed are often overlooked and considered relatively safe than to the rare and endangered species. However, many times, their peripheral populations often experience varying levels of threats different from the core populations. We studied blue sheep (*Pseudois nayaur*) populations across the distribution range in the Western Himalayas of India in the context of how the landscape features contributed to the present distribution and past demographic history. With the habitat modeling, we found about 18775 sq. km area suitable for blue sheep in Western Himalayas; where precipitation and grassland were the two most determinant variables. We applied explicit Bayesian based spatial and non-spatial population structure analysis and found clear demarcation of two populations, *i.e.* Ladakh and Lahaul-Spiti populations. We found relatively high genetic divergence in individuals inhabiting high altitudes, and also observed significant isolation by distance corroborating the findings of the population genetic structure. The circumscape model also exhibited low current flow from either side supporting population divergence between the two populations. With the multiple evidence, we interpret strong landscape resistance in the Western Himalayas due to the miscellaneous effect of landscape heterogeneity and low amount of functional connectivity. As the Trans-Himalayan region is unique with highly rugged terrain consisting of some highest peaks of the planet and deep valleys which create bio-geographic barriers for dispersal for large faunal groups. Moreover, biodiversity in Trans-Himalayan landscape is now facing unprecedented environmental events like upward shift of tree line and concomitant loss of alpine zone due to climate change. This study explained the importance of landscape features in shaping the spatial distribution, genetic structure and demography of blue sheep. Implementation of similar studies might provide a crucial signature for the conservation and management planning of wildlife reseeded in elusive and tough terrain habitat.

Evolution in bottlenecked species: deleterious mutations, introgression and disease susceptibility in Alpine ibex

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Understanding past population fluctuations and their consequences on patterns of genetic diversity is crucial for the efficient management of species of concern.

Alpine ibex were at the brink of extinction about two centuries ago, but recovered to stable numbers thanks to a very successful reintroduction program. However, a number of recent population declines and disease outbreaks have raised concern about the species genetic health after such a severe species bottleneck. Integrating genetic data on recent and ancient Alpine ibex, our group investigates, how genetic risk factors have evolved over millennia and how their genetic makeup may affect current individual disease susceptibility.

We find that current populations harbor substantial genetic signatures of low population sizes, including low genetic diversity, inbreeding, and accumulation of mildly deleterious mutation load

but also purging. These patterns of population diversity are attributable both to overhunting over the past centuries but also environmental factors over millennia. Endangered species are also especially at risk of hybridization due to their small populations. We observe more frequent ongoing hybridization than previously assumed and estimate about 2.5% recent domestic goat ancestry among concurrent Alpine ibex populations. Introgressed regions are enriched in immune-related genes where the generated genetic diversity may provide a selective advantage. Indeed, we find a positive correlation between individual heterozygosity at immune-relevant genes and disease susceptibility.

Investigating the evolution of a species through its near extinction and successful recovery, we improve our understanding of the genetic consequences of bottlenecks in the wild giving important insights for species management decisions.

Ensemble of genetic and ecological study of Himalayan ibex (*Capra sibirica*) in Indian Trans-Himalayas

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Genetic diversity allows us to identify the genetic threats or risk of diversity loss as well as evolutionary potential of the species whereas; ecological variables play a role in physiological capability of a species. Thus, Landscape genetics of a species in a restricted habitat may provide greater information for its conservation and management in the wild. The Trans-Himalayan region due to cold desert conditions supports lesser wildlife but with a high level of endemism. Ibex (*Capra sibirica*) is one of the majestic species in genus *Capra* which have distribution in Trans-Himalayan region of Ladakh and Himachal Pradesh (HP) in India. Siberian ibex have wider distribution in highlands of Central Asia however in India; Himalayan ibex has a restricted population in trans-Himalayan region. We provide the underlying information on population genetics of Ibex from India and identified a biological corridor between the two regions. The mean effective number of alleles is 3.849 ± 0.331 and the mean observed and expected heterozygosity is 0.43 ± 0.05 and 0.72 ± 0.03 , respectively. The estimated inbreeding coefficient index did not support a significant inbreeding in the population ($FIS\ 0.39 \pm 0.06$). We ascertained 111 unique individuals using ten microsatellite markers and identified two regional populations with 60% individual assignment and 40% individuals showing a mixed assignment in the study area using STRUCTURE, Geneland and DAPC. The individuals who showed no geographical assignment indicate the shared ancestry and gene flow between Lahaul-Spiti and Ladakh region in India. Male ibex individuals wander and travel at a larger distance facilitating gene flow between populations and we found 25 migrant individuals between the two regions. We identified suitable areas in the landscape and areas with highest suitability in the regions are not under any protected area in Lahaul and Kargil districts. We also predicted a movement corridor across Lahaul-Zaskar-Sham valley with good conductance and low genetic divergence which support good gene flow in the corridor between Ladakh and Lahaul (HP) region. Our study on the assessment of the corridors and population diversity will provide information on the species which will allow us to conserve Ibex in this small region and save it from local extinction. Landscape features don't act as a barrier for the species due to large movements and maintaining the genetic diversity of Ibex in the landscape by long-term monitoring will conserve the species from potential regional gene loss and inbreeding extinction in the wild.

Invited talk: Inbreeding depression in island ungulates

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Ungulate populations on mountains are susceptible to isolation, so it is relevant to consider the impact of inbreeding on isolated ungulate populations such as those on islands. Colleagues and I have studied inbreeding depression in two such populations, the red deer on the Isle of Rum and the Soay sheep on the island of Hirta in the St Kilda archipelago, both in NW Scotland. In both study populations, the animals are isolated, unmanaged and monitored as individuals throughout their lives, providing detailed information on fitness and its components under food-limited conditions. In both populations, matings between close relatives are rare, but there is extensive low-level inbreeding. While inbreeding depression is detectable using classical pedigree-based inbreeding coefficients (F_{ped}), we find greater precision and insight from genomic estimators of individual inbreeding that either treat each SNP as independent (F_{grm}) or use SNP map positions to find runs of homozygosity (F_{ROH}). I will describe a few key findings, including that inbreeding depression is still detectable in adult fitness components even after many inbred individuals die at juvenile stages, and that F_{ROH} based on long runs captures most of the inbreeding depression, with the implication that inbreeding depression is mainly due to relatively recent deleterious mutations. Despite our findings, neither population is showing a population decline.

The traces of the historical events in Balkan chamois genetic diversity

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The Balkan chamois (*Rupicapra rupicapra balcanica*) distribution goes from Croatia in the north to Greece in the south and Bulgaria in the east. The distribution of the subspecies and population density have been shaped by the natural and anthropological fragmentation of suitable habitats, the resulting restrictions on gene flow between different populations and human management. In Croatia, the Balkan chamois populations are both extant (Dinara Mountain), or (re)introduced (Velebit and Biokovo Mountains). Poaching, unsustainable hunting and the introduction of Alpine chamois are considered the main threats to the survival of Balkan chamois in the whole area of distribution, but conservation and management status varies from country to country and is subject to different national legislations. We combined 16 microsatellite loci and a partial mitochondrial control region to investigate the genetic structure and connectivity of Balkan chamois throughout its distribution range and to assess the accuracy of existing historical data on the origin of the Biokovo population 56 years after its reintroduction.

We successfully genotyped 141 individuals from eight countries covering almost the entire distribution range (Croatia, Bosnia and Herzegovina, Serbia, Montenegro, Albania, North Macedonia, Greece and Bulgaria) and sequenced the partial control region in 44 individuals. Bayesian analysis revealed 3 genetic clusters throughout the distribution range and assigned individuals from Serbia and Bulgaria to two separate clusters, while all other individuals belonged to the same cluster. Thirty new haplotypes were obtained from partial mitochondrial DNA sequences, with private haplotypes in all analysed populations and two haplotypes shared among populations, indicating the possibility of past

translocations. Additional analysis of past reintroduction in the genetic diversity of Balkan chamois on Biokovo using STRUCTURE and GENELAND algorithms showed clear separation of the reintroduced Biokovo population from the Prenj and considerable genetic similarity with the Čvrtnica-Čabulja populations in Bosnia and Herzegovina. This suggests that the current genetic composition of the Biokovo population is not exclusively derived from the Prenj population, as suggested by the available literature, but also from other source populations.

The genetic composition of the Balkan chamois subspecies presented here provides the necessary starting point for the development of conservation strategies required for its sustainable management and conservation and identifies the potential source populations for future (re)introduction plans.

Conservation genetics in bottlenecked species: insights from ancient genomes of the Alpine ibex

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Understanding the genetic consequences of population bottlenecks is crucial for species conservation. Low genetic diversity in bottlenecked populations has been reported repeatedly and historic population size trajectories can be modeled using genetic data of contemporary individuals. However, such approaches have a limited temporal resolution in the recent past and pre-bottlenecked population structure, genetic diversity and genetic load are difficult to assess. Here, ancient DNA approaches allow shedding light on the pre-bottlenecked genetic past and could give valuable insight into the long-term genetic health of a species. We present the analysis of 57 ancient and 29 recent high quality whole genomes of the once nearly extinct Alpine ibex covering its species distribution range and spanning 12'000 years. The powerful dataset is complemented with 30 previously published whole genomes from related *Capra* species. We identify several extinct Alpine ibex lineages and our results suggest that the low genetic diversity of present-day populations is attributable both to overhunting over centuries but also environmental change over millennia. We find that population structure was stable over millennia indicating relatively small, isolated populations persisting over long time ranges. In accordance, we find high levels of mildly deleterious mutations in ancient and recent Alpine ibex when compared to related species but a deficit (and possible sign of purging) of highly deleterious mutations. We underline that ancient DNA approaches can be a valuable tool for setting genetic patterns of a bottlenecked species into conservation genetic context.

MHC allelic diversity of nonnative aoudad populations

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Aoudad, *Ammotragus lervia*, is an ungulate species native to the mountain ranges of North Africa. Six subspecies have been described in its native range, differing in distribution and morphological characteristics. The aoudad was successfully introduced into Europe in the second half of the twentieth century, mainly for hunting purposes, with established populations in Croatia, Italy, and Spain. Previous analysis of mitochondrial DNA showed that the aoudad was introduced to Europe from at least four maternal lineages, but it is not known from which evolutionary units/subspecies the introduced aoudads originated.

The aim of our study was to gain insight into adaptive genetic diversity in European populations of aoudad by analyzing exon 2 of the major histocompatibility complex (MHC) class II DRB gene. Between 2016 and 2018, aoudad samples were collected from free-ranging populations from Croatia (Mosor Mountain) and Spain (Sierra Espuña and La Palma Island), and from captive populations from the Czech Republic (near the city of Plzeň) and Spain (Almería). Using next-generation Ion Torrent sequencing, we detected eight highly divergent alleles in 68 individuals, with three to four alleles present per population. The number of variable nucleotide sites in the detected alleles was 42 out of 236 (18%) and the number of variable amino acid positions in the translated sequences was 23 out of 78 (29%). The high average proportion of shared alleles within the population (0.51) is consistent with the expectations for recently introduced populations founded by a small number of individuals. The two most common alleles had frequencies of 37% and 29%, with the first present in all populations and the second present in all populations except Almería. We found private alleles in populations from Croatia and the Czech Republic, for which previous study at neutral loci showed a common origin. These private alleles are probably a consequence of the founder effect. In Almería, a population thought to represent a subspecies of Saharan aoudad, a private allele accounted for 60% of the allele frequency, and this population was genetically the most distinct from the others. The observed differences in DRB alleles between populations are inevitably the result of DRB alleles carried by the founder individuals. Because previous study showed that mitochondrial haplotypes are highly variable in European aoudad populations, more so than is common for the same subspecies of ungulates, observed MHC variability in these populations may also reflect different evolutionary lineages from which the founder individuals originated.

Reconstruction of *Rupicapra* spp. genome assemblies from low-coverage short-read data

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Mapping of next generation sequencing reads to a reference genome is the most frequent approach in genome reconstruction procedures from short-read data with low coverage because many reference genomes are available on GenBank. When no reference is available for the species of interest, the genome assembly of a closely related species is often used as the reference. This is particularly advantageous when the reference belongs to an intensively studied species with a high-quality assembly (model species or domestic animals). We used the genome of domestic goat (*Capra hircus*) as the reference for mapping the Illumina short reads of 12 chamois (*Rupicapra* spp.) (average coverage 10x) to reconstruct their genome assemblies, of which, six passed quality control and achieved mapping proportions ranging from 95 to 98%. SNP calling procedure detected between 42,500,000 and 51,700,000 filtered SNPs that were used to call consensus sequences. The reconstructed assemblies were verified for their quality and completeness using BUSCO and OrthoDB *Cetartiodactyla* (odb10) set of orthologs (13,335 conserved genes), which identified around 95% of selected genes in our assemblies, indicating that most of the core genes were present in these chamois assemblies. To additionally validate the structures of the remaining six assemblies, we extracted 23 intron sequences and aligned them with equivalent sequences previously used for reconstructing the phylogeny of chamois downloaded from GenBank. The final alignment (14,980 bp) consisted of 20 sequences from chamois (six from this research and 14 from GenBank) and three outgroup sequences: goat, sheep (*Ovis aries*), and cattle (*Bos taurus*). Our samples clustered with the downloaded chamois samples and were considerably different from the outgroup sequences. We have shown that our applied methods can be used to draw valuable

conclusions even from small sample size and low-coverage genome data. We believe that our result and workflow can be of great value for future studies that have similarly low-coverage data, especially in cases where a high-resolution genome of a relative species is available on GenBank (specific genes or regions of interest). In other words, despite the fact that there will be more high-quality reference genomes in the future, this approach can still be used to obtain a partial genome for a particular scientific interest at a low cost.

MONITORING METHODS AND CONSERVATION TECHNOLOGIES

Apennine chamois (*Rupicapra pyrenaica ornata*) wild captures by associated mechanical and chemical immobilization in conservation translocations activities: clinical analysis and source population monitoring as tools to evaluate the efficacy and safeness of the method.

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The Apennine chamois (*Rupicapra pyrenaica ornata*) is a sub-species endemic of the Central Apennines. It is a priority species in the Habitats Directive (92/43/EEC), listed in the Appendix II of the Washington Convention (CITES) and re-classified from Endangered to “Vulnerable” in the IUCN 2008 Red List, thanks to the success of the first reintroduction actions. The Maiella National Park (MNP) thanks to a positive trend of his reintroduced (1992) chamois population, has been considered as a good source population for the realization of reintroductions in other protected areas. Captures of wild Apennine chamois in the MNP had never been attempted and therefore it was necessary to scrupulously plan the activities with, in a “preliminary phase”, the individuation of the herds to be trapped, the capture areas and the best trapping method, in an “operational phase”, the realization of the captures and the application of a standardized health monitoring protocol that was used to record the clinical findings and, in a “post-capture monitoring phase”, the check for any possible negative consequences in regards to the captured chamois and the herds to which they have belonged. The aim of this study was to evaluate the efficacy and safety of a new capture method that includes mechanical immobilization, handling methods and chemical immobilization on free-ranging Apennine chamois, to allow the contemporary captures of groups of animals, that are considered the most suitable for reintroduction activities. This capture method foresees the associated use of the “Up-net” and/or box-trap and an acepromazine-medetomidine-ketamine administration. The effects of this protocol on the captured animals were evaluated by means of haematological and chemical analysis. In addition, for the first time on this species was applied the venous blood gas analysis during the field activities, in order to assess the animal welfare during the capture sessions and prevent critical situations. In order to verify the absence of a possible negative effect of captures on the increasing potential of the source population, we conducted a post-capture monitoring on the herds from which individuals were captured and released ex situ. Our objective was to verify that the herd remained integer and vital and that the capture event did not represent a considerable disturbance. We thus conducted a short and long term monitoring evaluating the possible fragmentation of the herd, the possible abandonment of the area, the possible decrease of herd reproductive capability and the possible decrease of kid survival.

Automated photo-identification of Alpine ibex (*Capra ibex*) individuals

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Long term individual-based data are crucial for monitoring and studying wild species. However, capturing and marking animals is time-consuming, limited to a small number of individuals, costly and potentially harmful. Automated photo-identification is a cheap, fast, and non-invasive option for identification of individuals but needs to be customised for new species. Bovids' horns show inter-individual variability and can therefore be used as a unique feature to allow individual identification in several species. We tested end-to-end deep metric learning to identify individual male Alpine ibex (*Capra ibex*). We deployed the triplet loss to embed single-horn images in Euclidean space for identification based on their similarity in that space. We used images of 82 known male Alpine ibex over the span of 11 years of the marked population of Gran Paradiso National Park (Italy). To minimise image-to-image variability we cropped and aligned each horn based on two landmarks and mirrored the images showing the right horn to match the shape of the left horn. This resulted in a dataset of more than 7300 homogeneously aligned left facing crops from 161 individual horns. We trained metric embedding with 5-fold cross validation and evaluated reidentification experiments in an image retrieval setting. We show that the method reliably matches images of unseen animals. However, we find that the identity clusters are not defined distinct enough to leverage the embedding space for accurate classification in a fully open setting. Our approach will drastically reduce the workload to manually match unmarked Alpine ibex for individual-based data collection and we propose it will be able to adapt to other mountain ungulates, ultimately reducing the need for capturing and physical marking.

Long term monitoring of life history traits in Alpine ibex

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Capturing and marking individuals is an expensive task but necessary to collect individual-based data in species without natural identifying marks. Long-term individual-based studies allow to investigate the effects of biotic and abiotic factors on individual performance and on the dynamic of populations. With the aim of monitoring the Alpine ibex (*Capra ibex*) population, Gran Paradiso National Park established a long-term study area where animals have been captured and marked since 1999 and individual-based data on life history and demography are collected. Here we investigated the effects of environmental variables such as winter snow cover, density, resource availability and meteorological conditions on yearly body mass changes and on horn growth. We observed that the average body mass of male Alpine ibex at the end of summer has increased in the last 20 years, in accordance with the high over-winter survival registered in the area. Winter snow cover during the previous year seems to play a crucial role in shaping the seasonal body-mass increase. Body mass loss is reduced when winters are mild and dry, and consequently male Alpine ibex reach the end of summer in better physical conditions (i.e., larger body mass). Density seems also to influence body mass and horn growth, but the effect is less clear. Our results demonstrate the importance of long-term monitoring to understand and forecast the effect of current environmental changes.

Big threats need big data: collaborative science to improve knowledge and conservation of mountain ungulates

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Mountain ungulate populations are threatened by multiple direct and indirect causes, from human disturbance, to infrastructure development, and climate change. The extreme heterogeneity of mountain environments creates specific local challenges to which animals respond within their fundamental niche, so that it remains difficult to investigate the process underlying such responses across the entire distribution range. Similarly, mitigation actions are often developed at a local scale, with little potential for coordinated actions at, e.g., the metapopulation level, given the intimate fragmented nature of animal populations distributed along the elevation gradient. Some of these issues can be better addressed by pooling population and behavioural data from different, geographically distinct populations exposed to a range of extrinsic and intrinsic factors. One immediate advantage would be the possibility to disentangle plastic responses and fixed feedbacks, hence better identifying the species' resilience to current and prospective changes. This operation needs two fundamental methodological steps: (i) the availability or collection of data across the distribution range of the species and (ii) the harmonisation of the data according to data management principles for robustness and accessibility. This is technically possible with state-of-the-art spatial databases, and a shared policy for data sharing and re-use. Complementary to data availability and accessibility, the coordinated work of the different institutions involved in mountain ungulate research and conservation, such as research and management bodies and protected areas, is key to the achievement of a generalised, multi-population knowledge first, and coordinated, generalisable mitigation actions, then. We here present the opportunities offered by community-based, bottom-up collaborative initiatives relying on robust data archiving and sharing, such as the Euromammal/Euroungulate initiative.

Growth parameters as indicators for environmental variation in a mountain ungulate

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Understanding how environmental variation influences life history traits and therefore population dynamics of mountain ungulates is important for wildlife management and conservation perspectives. This topic has gained even more relevance with an increased interest in anticipating the potential effects of climate change and other human caused environmental alterations. Here, we test for the effects of different factors on growth patterns of the lower jaw and the hind foot of harvested Alpine chamois (*Rupicapra rupicapra*) in two study areas in the Bavarian Alps with different environmental conditions and varying degrees of human impact. We fitted non-linear monomolecular, Gompertz and logistic growth models to 615 observations from both study areas, i. e. different sub-populations. We compared model fit using Bayesian information criterion (BIC) and chose the best baseline model to subsequently test for population, sex and environmental effects in the model residuals. Next, we correlated the lower jaw and hind foot lengths with another important constitution parameter of chamois; the first two segments (i.e., annulus L2) of the horn. The results of the growth models indicate a marginal sex-specific difference in both, the lower jaw and hind foot length, which can be explained by the small morphological difference in skeletal size in chamois. Importantly, we found significant differences in

the growth patterns between study areas, but not in the asymptotic size achieved by animals in both study areas as adults. These differences can be attributed to varying proportions of forest cover and climatic conditions. Similarly, the horn length of male chamois showed the same significant patterns as the growth models, but female horn length patterns deviate from this. We discuss potential reasons for these sex-specific differences. Finally, we compare our results from the two study areas in Bavaria to data from the Swiss National Park and evaluate the suitability of the lower jaw and the hind foot length as indicators for monitoring ecological changes in chamois.

Using ranger-based monitoring data to guide conservation of mountain ungulates in protected areas

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Mountain ungulates are experiencing drastic population declines in many parts of the world. Poaching is one of the major drivers of these declines, tackling which remains challenging given a lack of information on its prevalence and where it impacts mountain ungulates. One of the largely untapped resources to fill this gap is ranger-based monitoring data, commonly stored in analogue logbooks of protected areas. Such monitoring data could provide detailed information on poaching detections as well as mountain ungulate distribution and abundance across time and space, all of which are necessary to inform evidence-based conservation efforts. However, these datasets are usually not digitized or georeferenced, and are rarely analysed. In this study, we aimed to develop approaches in extracting, digitizing and analysing ranger-based monitoring data to (1) identify spatial determinants of mountain ungulate poaching; (2) predict the distribution of poaching pressure; and (3) inform future ranger patrolling strategies. We used data from >4800 ranger patrols across Golestan National Park, Iran from 2014-2016, where poaching has severely impacted the populations of bezoar goat (*Capra aegagrus*) and urial (*Ovis vignei*). We digitized 7668 ungulate sightings and 38 poaching detections, and assigned them to 3x3 km² cells based on the park's landmarks and patrol routes. We analysed the data in an occupancy modelling framework to test whether poaching is explained by (a) accessibility; (b) law enforcement; or (c) prey availability. Using the predicted poaching pressure and patrolling intensity, we provided recommendations for future patrol allocation strategies. We estimated poaching to be higher in the steppes of the park, mainly determined by urial abundance, a highly sought-after species by poachers. Despite regular patrols, we predicted that rangers can only detect 12% of poaching incidents. To optimize the patrolling effort, our analyses highlighted the necessity to improve patrolling quality (in 27% of the park) and quantity (11.5%). Moreover, we identified excess patrol in 20% of the park, which could be redirected to areas with patrol deficiency. To improve the quality, determinants of poaching detection such as the impact of tip-offs from informants or the number of rangers per patrol should be further investigated. Our approach provides conservation managers with a practical tool to make use of ranger patrol data to better tackle poaching. Such information is urgently needed to establish adaptive management frameworks in protected areas worldwide.

Hybridization between Alpine ibex and domestic goat in the Alps: a sporadic and localized phenomenon?

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The Alpine ibex (*Capra ibex*) is a mountain ungulate living in the European Alps. Although being currently classified as a species of Least Concern (LC) by the IUCN, a potential threat for its long-term conservation is introgression following hybridization with domestic goats (*Capra hircus*). Hybridization has been documented in Switzerland in captive and free ranging animals, although accurate data to assess the extent of this phenomenon in natural conditions in the Alps are lacking. Using an online survey and a network of experts, we collected and mapped unpublished evidence of hybridization events that occurred between Alpine ibex and feral domestic goats from 2000 to 2021. The results of this study showed that hybrids are distributed in most of the Alpine countries, and their presence is not a sporadic event, with some clusters including 4–20 probable hybrids. Our results illustrated the need for establishing a standardized and effective protocol to identify hybrids in the field (such as a formal description of the morphological traits characterizing hybrids), as well as clear guidelines for hybrid management. Even more importantly, this study also highlighted the need for actions aimed at avoiding hybridization, such as the effective management of domestic herds grazing in Alpine ibex core areas.

Double Observer methods to monitor the Alpine ibex population in Gran Paradiso National Park

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The Double Observer (DO) is a common census technique that accounts for imperfect detection and can thus improve the reliability of mountain ungulates' censuses. However, the method is costly to apply especially in large study areas and block counts are therefore still generally preferred even if abundance underestimations can be frequent. We tested the effectiveness of DO surveys performed in only a limited portion of the total target area (sample DO or SDO), thus with a limited survey effort, in correctly detecting population trends and estimating abundance. Our analysis was focused on the Alpine ibex population of Gran Paradiso National Park (GPNP, Italy), where an exceptionally long time series of block counts is available but DO method was never fully tested.

We ran computer simulations with a real-case range of parameters (variability in trends, population size, number of sampled subareas and detectability) and estimated the population dynamic using SDO surveys. We found that surveying only 20-30% of the total area would generally be sufficient to correctly detect even minor upward or downward trends in the ibex population in GPNP thus suggesting that this method could be reliable and cost-effective in monitoring mountain ungulates' populations. Using historical abundance data we also proved that SDO's were mostly able to estimate the same population trend observed with block counts in the entire area.

We also tested with simulations the use of sample DO surveys in association with total block counts to obtain unbiased abundance estimations. This new proposed method, the Double Observer Adjusted Census, proved to be solid and was able to estimate 94-97.5% in mean of the actual population performing DO censuses in just a few subareas, thus with a limited additional effort respect to total block counts alone that largely underestimated population size.

In conclusion, our results suggest that surveying only a fraction of the total area with DO surveys could be enough to correctly detect also small declines in mountain ungulates populations and that

combining total block counts data with DO censuses performed in a subset of the area is a viable strategy potentially useful to estimate abundance in wild species traditionally counted with block counts.

PHYSIOLOGY HEALTH AND DISEASES

Health status of the Alpine ibex populations in the Italian and French Alps

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The health status of the individuals and the presence of pathogens are among the main factors influencing the dynamic of wild animal populations. Data on infectious diseases prevalence need therefore to be incorporated in analysis aiming at understanding population dynamic. In this perspective, we carried out a health survey on Alpine ibex (*Capra ibex*) populations covering a wide geographic range (from the Lemman Lake to the Alpi Marittime) to investigate disease prevalence in the different populations and to understand which environmental conditions may explain geographical differences in pathogens distribution.

We worked on 3 topics: I. Collection and analysis of 345 blood samples from ibexes captured on 2018-2019 in the Italian (Gran Paradiso National Park - GPNP, Aosta Valley Autonomous Region, Alpi Cozie Regional Park - ACRP, Alpi Marittime Regional Park - AMRP) and French Alps (Asters, Vanoise National Park - VNP, Ecrins National Park - ENP, Mercantour National Park - MNP); II. Comparison of data from 'historical' monitoring health of 533 animals from GPNP, ENP, MNP and VNP to improve our knowledge about the presence and evolution over time of some pathogens on ibex populations; III. Preliminary analysis of the main causes of death in Italy and France through the necropsies collected in the last 70 years on animals found dead within the protected areas.

Serologic survey revealed a higher seroprevalence against respiratory viruses in France than in Italy; in the ENP was found a seropositivity for Q-fever and Bovine Viral Diarrhea Virus (generally low in ibex populations but frequently detected in cattle) higher than other French protected areas. Instead in Italy we recorded a high seroprevalence of antibodies against *Salmonella abortus ovis-abortus equi*. Historical serologies confirmed the trend of the biennium 2018-2019, showing high seroprevalence against respiratory viruses in France and against Salmonella in Italy. The increased circulation of Pestivirus and respiratory viruses in French populations could be related to the increased access to high-altitude pastures of infected herds since different surveys on domestic cattle in the southern French Alps showed high prevalence of these pathogens.

The necropsies carried out on GPNP (n=173), VNP (n=179) and ENP (N=30) Alpine ibex carcasses, showed respiratory diseases as main cause of mortality in both National Parks, but we found significant differences in prevalence for "non-respiratory infectious diseases".

The differences in the health status of French and Italian populations suggest that the pathogens hosted by Alpine ibex arise mainly from sympatric domestic ruminants.

Adaptation of the ruminal microbiota of chamois (*Rupicapra rupicapra*) from the Bavarian alpine region to seasonal food availability

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The state of Bavarian chamois populations has been discussed intensively for years. However, much data on how the populations is really doing is not available. This discussion has triggered several new research projects in recent years. In this study, we want to clarify what food is available to the animals, how they use it, what seasonal fluctuations they are confronted with and how they successfully adapt to them. An adaptable microbiome is essential for this. It enables ruminants to utilise plant food and convert it into absorbable essential fatty acids.

The aim of the study is to map microbial (bacterial) and nutrient profiles in the rumen of Bavarian chamois and to show how they specifically adapt to seasonal fluctuations. For this, rumen microbiota from 48 chamois from 3 different habitats were examined by 16S rRNA gene amplicon sequencing. In addition, condition and age data were collected for each individual and the raw nutrient content of the rumen was determined. The data originated from the sample years 2017-2020.

In addition to a significant habitat (p<0.01) effect, a significant seasonal effect (p<0.001) is reflected in the composition of the ruminal microbiota. The decisive differences are mostly defined by only a few genera. Due to the current state of research, many of the genera could not be determined. This also often makes it difficult to assign the exact functions. However, a "core microbiome" could be identified. But this comprises considerably more genera than in some other wild ruminant species, such as the roe deer.

The seasonal effects are also reflected in the distribution of raw nutrients. The highest fibre content (ø NDF: 55.7% ± 8.8, ø Lignin 13.8% ± 4.1) is found in the rumen in winter. Antagonistically, the highest proportions of crude protein (ø 20.1% ± 5.2) and NFC (ø 11.5% ± 3.7) are found in the rumen in summer.

Even if the functional relationships can only be partially assessed due to the many unclassified genera, individual clear connections can be recognised. The microbiome adapts flexibly to seasonal fluctuations and enables the animals to make optimal use of the given food. Furthermore, the study provides information on the seasonal use of the chamois' given food. But knowledge about the ruminal microbiota of wild ruminants is also still very limited. There is an urgent need for further research. In particular, the identification of the species involved should remain in focus.

Predicting parasite dynamics in mixed-use Trans-Himalayan pastures to underpin management of cross-transmission between livestock and bharal

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The complexities of multi-use landscapes require sophisticated approaches to addressing disease transmission risks. We explored gastro-intestinal nematode (GINs) infections in the North India Trans-Himalayas through a socio-ecological lens, integrating parasite transmission modelling with field surveys and local knowledge, and evaluated the likely effectiveness of potential interventions. Bharal (blue sheep; *Pseudois nayaur*), a native wild herbivore, and livestock share pasture year-round and livestock commonly show signs of GINs infection. While both wild and domestic ungulates had

GINs infections, egg counts indicated significantly higher parasite burdens in bharal than livestock. However, due to higher livestock densities, they contributed more to the total count of eggs and infective larvae on pasture. Herders also reported health issues in their sheep and goats consistent with parasite infections. Model simulations suggested that pasture infectivity in this system is governed by historical pasture use and gradually accumulated larval development during the summer, with no distinct short-term flashpoints for transmission. The most effective intervention was consequently predicted to be early-season parasite suppression in livestock using temperature in spring as a cue. A one-month pause in egg output from livestock could lead to a reduction in total annual availability of infective larvae on pasture of 76%, potentially benefitting the health of both livestock and bharal. Modelling suggested that climate change over the past 33 years has led to no overall change in GINs transmission potential, but an increase in the relative influence of temperature over precipitation in driving pasture infectivity. Our study provides a transferable multi-pronged approach to investigating disease transmission, in order to support herders' livelihoods and conserve wild ungulates.

Energy uptake of Bavarian chamois (*Rupicapra rupicapra*) and their adaptation to different energy densities of the vegetation

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Energy density and crude nutrient content of vegetation are seen as important drivers of wildlife migration, among other factors. Many ungulates react very plastically to these habitat-typical differences in food quality. This adaptation enables them to colonize less "optimal" habitats. To get a comprehensive overview of how effectively they manage to adapt to the considerable seasonal fluctuations in conditions in the mountains, we began collecting comprehensive data and samples for chamois (n = 202) in the Bavarian alpine region in Bavaria in 2017. Among other parameters, the energy content and crude nutrient composition of the ingested food were analysed by standard methods for nutrient and fibre content, as well as the volume of the rumen-reticulum and food intake. We were able to determine that chamois find an average of metabolisable energy (ME) of 4.4 MJ ME / kg DM in their habitat. The energy content of the chamois diet varies between 4.0 MJ ME / kg DM in winter and 4.7 MJ ME / kg DM in spring and can be explained by the different crude fiber contents of the vegetation. Compared to deer, however, the fluctuations in energy density during the year are significantly lower. To compensate for the lower energy density in winter, chamois consume significantly (p<0.001) more food in winter (1.5 kg per rumen filling) than in spring. According to Hüppop (1995), the chamois has a basal metabolic rate of 2,463 MJ ME / day and an energy consumption up to 9,372 MJ ME / day in open countryside. Given that the measured value is a snapshot measurement representing a single filling of the rumen, and that chamois have 5-6 browsing periods each day, the energy supply can be seen to be more than adequate at any period of the year. We were thus able to show that the animals do not suffer from a shortfall in the energy supply at any point in the year, and that instead, they adapt flexibly by increasing their food intake. This project was supported financially by the Bavarian State Forests AöR.

Energetic costs associated with disease defense strategies

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Pathogens do not always cause disease but could nevertheless result in energetic costs to associated with immune defense strategies seeking to control or prevent disease. Lack of energetic reserves can weaken immune defense systems, making an animal more vulnerable to infection. Various immune defense strategies against disease-causing pathogens may yield different costs and benefits. Pathogen resistance is an immune defense strategy aimed at eliminating infection, whereas pathogen tolerance is aimed at dampening costs of pathogens by reducing damage to tissue. We sought to evaluate the relationship between nutritional condition and pathogen presence. First, we evaluated the hypothesis that nutritional condition (i.e., fat reserves) influences susceptibility to infection (H1). Second, we evaluated the hypothesis that immune defense strategies have energetic implications (H2). We evaluated our hypotheses using a long-term dataset (2015-2022) of 57 female bighorn sheep (*Ovis canadensis*) in northwest Wyoming, USA with seasonal and repeated measuring of nutritional condition and presence of four pathogens that have the potential to cause respiratory pneumonia (*Mycoplasma ovipneumoniae*, *Mannheimia haemolytica*, *Bibersteinia trehalosi*, and *Pasturella multocida*). Nutritional condition did not influence the susceptibility of individuals to infection from new pathogens (H1). Pathogen resistance did not come at an energetic cost in summer or winter (H2a). Pathogen tolerance, however, did come at an energetic cost over the summer, when energetic costs of reproduction are greatest (H2b). Tolerating *Mycoplasma ovipneumoniae* over the summer results 2.92 fewer percentage points of fat gain over the summer. Tolerance of each additional pathogens results 1.41 fewer percentage points of fat gain over the summer. Thus, females carrying pneumonia-associated pathogens incur greater energetic costs, which has the potential to result in tradeoffs between the pathogen tolerance strategy and reproduction.

Microbial communities and antimicrobial resistance genes in Apennine chamois in Maiella National Park

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The Apennine chamois (*Rupicapra pyrenaica ornata*), one of the rarest species in Italy, is endemic of the Central Apennines and it currently lives only in limited areas of Central Italy. It is considered a priority species in Habitat Directive(92/43/EEC) and it is listed in the Appendix II of the Washington Convention (CITES). In 1996 it has been classified as "Endangered" in the IUCN red list, but thanks to the success of the reintroduction actions, it has been classified as "Vulnerable" in 2008. At the beginning of Life Coordinated Project (years 2010-2014), it was present only in 4 protected areas: the Abruzzo, Lazio e Molise National Park (ALMNP), the Maiella National Park (PNM), the Gran Sasso and Monti della Laga National Park (GSLNP), and the Monti Sibillini National Park (MSNP). Despite the successful reintroduction activities, the Apennine chamois is still facing major threats associated with low genetic variation, slow range expansion and competition with other ungulates (i.e., red deer). In addition, the livestock farming (cattle, sheep and goats) often relies on the traditional practices based on small farms and extensive grazing systems, where animals are raised on mountain pastures.

In this context, the health threats at the wildlife/domestic interface should be contemplated. In this view, this study aimed to provide new insights about antimicrobial resistance genes abundance and microbial communities of wild and domestic ruminants in wildlife- livestock interface. In total, 88 fecal samples were recovered from Apennine chamois, red deer, goat, cattle and sheep, and were collected in pools. The populations under study were selected based on ecological data useful to define sympatric and non- sympatric populations. Samples were screened for commonly used in farms under study or critically important antimicrobial resistance genes (*aadA2*, *TetA*, *TetB*, *TetK*, *TetM*, *mcr-1*). The microbial community composition was found to be different based on the species and land use. Indeed, it was mostly characterized by phyla Firmicutes in bovine, Bacteroidota in chamois and Proteobacteria in red deer. Additionally, positive correlations between antibiotic resistance genes and microbial taxa (e.g., *Tet* genes correlated with *Firmicutes* and *Patescibacteria*) were described. Of the antimicrobials investigated, the abundance of *mcr-1* gene suggests the importance of monitoring the wildlife in order to detect the emerging resistance genes contamination in environment. This study provides new data that highlight the importance of multidisciplinary to describe the spreading of antimicrobial resistance in the environment and to collect useful information on rare species as Apennine chamois.

Tick-borne pathogens in Alpine ibex and chamois: an integrated surveillance system

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Ticks and tick-borne pathogens (TBPs) are emerging worldwide as a veterinary and human cause of disease. The increase in winter temperatures, linked to climate change, favors overwintering, thus the latitudinal and altitudinal expansion of arthropod vectors. Simultaneously the fragmentation of habitats and human presence in rural environments increases contact between man and animal species boosting the onset or re-emergence of diseases. Understanding TBPs dynamics in Alpine ibex and Alpine chamois is a unique opportunity to verify their susceptibility and adaptation to emerging pathogens. We developed and field-tested, an integrated surveillance system to monitor vectors and TBPs in Gran Paradiso National Park (GPNP), Italy.

Integrated surveillance system, developed over a 3-year period, targeted *i.* questing Ixodidae ticks which were systematically sampled along an altitudinal gradient, *ii.* chamois *Rupicapra rupicapra* and Alpine ibex *Capra ibex* captured or found dead within GPNP, *iii.* cattle and goats herded on pastures shared with wild ruminants during the summer season, and *iv.* ticks collected from service dogs and GPNP park wardens. All matrices were analyzed for *Babesia/Theileria* spp., *Anaplasmataceae*, *Borrelia burgdorferi* s.l. and SFG *Rickettsiae*.

Higher prevalence of infection were reported for *Babesia/Theileria* spp. and *Anaplasmataceae*, followed by *Rickettsiae* of the Spotted Fever Group and *Borrelia burgdorferi* s.l. Sequencing showed high variability in circulating strains with a high degree of connection between domestic and wild ungulates. Integrated surveillance of emerging TBPs in GPNP is a functional example of the One-health approach to emerging diseases management, which directly safeguards the health of species of conservational value, of livestock and humans.

POSTER

Markhor (*Capra falconeri*) monitoring in Tajikistan shows population recovery

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The markhor *Capra falconeri* is categorized as Near Threatened on the IUCN Red List and included in Appendix I of CITES but is a lucrative species in the international trophy hunting market (Broghammer et al., 2017, IUCN SSC & Caprinae Specialist Group Report). Trophy Hunting is contentious, despite its role in conserving species and habitats and the benefits for rural communities when well-managed (Dickman et al., 2019, Science, 365, 874).

In this context, the Committee for Environmental Protection of the Government of the Republic of Tajikistan asked the IUCN Caprinae Specialist Group to help improve monitoring protocols and develop a preliminary conservation strategy for mountain ungulates in Tajikistan. A Memorandum of Understanding was signed in August 2021, and in October 2021 Caprinae Specialist Group experts visited southern Tajikistan for reconnaissance and to train local experts in monitoring techniques. In March 2022, the Caprinae Specialist Group delegation assisted the Committee for Environmental Protection in conducting surveys of the markhor. The Academy of Sciences of Tajikistan, Department of Forest and Protected Areas, and rangers from markhor conservancies also participated.

Working simultaneously across 10 markhor conservancies, five teams completed the survey, covering c. 2000 km², in 15 days. The Caprinae Specialist Group team noted the strong commitment of the administration, hunting conservancies and local communities to the conservation and sustainable use of the markhor and its habitat. The rangers, drawn from the local community, are well-equipped and trained for monitoring and protecting the markhor. The Committee for Environmental Protection and the conservancies share benefits with the local communities and have invested in infrastructure such as improving water catchments, education, libraries, health facilities, and sport camps. Analyses are ongoing, but it appears the markhor population is >5000 individuals and has recovered well since the 1990s, when the population was < 500.

The Caprinae Specialist Group team will make recommendations for improving markhor monitoring protocols and for conserving the markhor population of Tajikistan under an integrated conservation plan. This will encourage improved focus on socioecological research, better benefit sharing with stakeholders, and continued capacity enhancement of the relevant personnel. Depending on the findings, the current annual trophy quota of 15 large males may be reconsidered.

The survey results will be shared with CITES and other relevant stakeholders.

What's new in Apennine chamois? Males show unusual sociality in the Maiella National Park, Italy

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The proportion of males in the population of Apennine chamois in the Maiella National Park (MNP) has exponentially increased over the last ten years ($R^2=0.87$, $F=45.3$, $P<0.001$); consistently, the sex ratio has significantly increased over the same time period ($R^2=0.84$, $F=37.1$, $P<0.001$). This apparently odd outcome of the analysis on data collected by standardized observations (July-October 2011-2021) is not related to anomalies in sex ratio at birth, as we have recorded an even sex ratio

in the first age class (2-3 years); nor have we obtained any evidence of differential survival between males and females. Instead, it is explained by the fact that in MNP large groups of males have been occurring increasingly frequently, thus being more visible to observers. The proportion of male-only groups with ≥ 2 individuals has increased over the years ($R^2=0.88$, $F=53.9$, $P<0.001$), and unusually large male-only groups (>50) have been recorded since 2015, especially in the core chamois range. The mean (\pm SD) size of male-only groups significantly increased from 1.9 (± 2.0) in 2011-2014 to 6.9 (± 9.9) in 2016-2021 ($n=39-172$; Mann-Whitney, $P<0.001$), and the median increased from 1 to 4 (Median test, $P<0.001$). The largest male-only group ever sighted numbered 71 individuals. Males can also be found in mixed groups with females and kids. The largest number of males seen together in a mixed group is 63 in a group of 101 individuals, of which 7 were females and the rest were yearlings. The five largest groups of chamois ever seen, amounting to >200 individuals each, included between 8 and 45 males. Such peculiar grouping patterns had never been observed in Apennine chamois, whilst according to the available literature on the southern chamois, they were reported only once in the Pyrenees. Although this particular dynamic in grouping pattern needs to be further investigated, we hypothesize that several factors may contribute to the forming of such unusually large groups in MNP: antipredatory strategies, connectivity and low habitat fragmentation, productivity of meadows, and local population density. Our findings suggest that the eco-ethology of the Apennine chamois could be more complex and varied than what studies limited to the remnant population of Abruzzo, Lazio and Molise National Park indicate, and that it probably remains to be fully understood.

The role of the gut ecosystems in the ecology and evolution of a wild ungulate.

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Individual animals are host to an extremely complex community of smaller organisms, which interact through nutrient cycles and energy flows, affecting each other and their environment – the host. These are ecosystems in their own right. The Ecology Within project aims to shed light on the complex interactions happening in one of such within-individual ecosystem. The gut is home to trillions of bacteria and this “microbiota” plays a fundamental role in extracting the nutrients that are critical for the host’s survival from the food that animals ingest. However, other bacteria, along with diverse communities of nematodes and protozoans, compete with their host for resources and they might ultimately affect host physiology and health. Our current understanding of the dynamics amongst members of the gut ecosystem as well as their consequences for host fitness in natural populations is limited. What is the variation in gut bacteria, protozoan and nematode communities over seasons, years and host individuals? Which factors drive gut community dynamics? What are the outcomes of these dynamics for health and fitness under natural conditions?

To address these questions, we are applying next-generation sequencing methods and a novel statistical approach to faecal samples collected from recognisable individuals from a long-term study of Soay sheep on St Kilda. Here we illustrate the integrated pipeline we have developed, from the sample collection in the field, to streamlined lab protocols, to bioinformatics and statistical analysis. We also show some initial results on how the structure of the gut community is associated with different factors of the host and on how this varies across the year.

Camera traps to detect spatial distribution and temporal activity pattern of ungulates in the Mont-Blanc massif

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Camera traps are increasingly used in ecology as a new tool for population survey. In mountain environments where field work is constrained by harsh environment – steep slopes, long snow season – they appear as a promising tool to study rare (such as mountain hare), high-elevation (such as chamois) or abundance increasing (such as red deer) species in the long-term. Quantifying mountain ungulate shifts of spatial habitat use and temporal activity pattern in response to climate change and to a new situation of competition between ungulate species (chamois vs red deer) are an ongoing challenge in mountain ecosystems that could be achieved with camera traps. Using 37 camera traps distributed on 6 elevation gradients in the Mont-Blanc Massif since 2018, we will describe whether camera traps can be used to detect (1) altitudinal migration of the chamois during the year, (2) environmental variables influencing chamois spatial distribution, (3) chamois activity rhythm variations across seasons and habitats. Our preliminary results suggest that long-term data obtained from camera traps could be highly valuable to investigate ecological change in the context of large environmental changes, but this requires improvement in automated species identification and learning and development of new statistical tools.

Twenty years of technological improvement of “a methods to weigh free-ranging ungulates without handling”

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Body mass measurements give valuable information about health status of individuals and can also be used as a proxy for environmental conditions and resource availability. However, weighing animals usually requires handling that, in case of mountain ungulates, may be difficult and expensive. Remote measurement methods such as that described by Bassano et al. (2003) allowed to dramatically increase the number of body mass measurement without need of handling animals. Since then, several technological improvements have been applied to the method, increasing its efficiency. Such improvements include the use of solar panel for power supply; the use of camera trap for remote control of the scale when human observers are not present and, more recently, the use of an online monitoring system. Further improvement under development will include the automatic recognition of unmarked individuals, which will constitute a game change, allowing to collect repeated individual data on all the animals of a population and not only on the marked ones. Despite all the technological improvement, however, the constant presence of human observer remains necessary.

Do you recognise your Southern Chamois? - Skull-length-eyeball-width ratios and tail characteristics as an approach to identifying *Rupicapra pyrenaica* subspecies.

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Indications to differentiate the three subspecies of the Southern Chamois are incomplete or contradictory. My study aims to make the distinction clearer. Methods: 1. Skull length-eyeball-width ratios of *Rupicapra parva*, *R. pyrenaica* and *R. ornata* were determined on the basis of chamois photos that were taken in the field at a right angle to the longitudinal axis of the animal’s head. Then the relative

lengths of skull and horizontal eyeball diameters were measured in the photo and the ratio calculated and compared. 2. Relative Tail lengths and tail and hind quarter colour patterns were categorized on the basis of photos.

Results: 1.1 Skull-length-eyeball-width ratios show that *parva* has the largest eyes relative to skull length (ratio=7,74; n=15), *ornata* the smallest (ratio=10.24; n=23) and *pyrenaica* is intermediate (ratio=9,35; n=28). 1.2 In *parva* and *pyrenaica* the tail appears predominantly rather short or egg-shaped (*parva*: 81%; *pyrenaica*: 92%). But in *ornata*, only 53% have a short tail, 47% an elongated tail. And 71% of *ornata* specimens have a tail with extended terminal hairs. 1.3 *Parva* has the highest proportion of red hair in its tail, which makes it less contrasty: half the tail was reddish in 59% of *parva*-specimens. In 11% the tail was completely reddish. The colour pattern “base and end of tail reddish” was represented only in 13% of *parva*-specimens. Of 39 *pyrenaica* specimens in 7% half the tail was reddish; and 0% had a completely reddish tail. In 8% specimens, both the base and end were reddish. Of 34 *ornata* specimens in 15% half the tail was reddish; 3% had a completely reddish tail; and in 44% both the base and end of tail was reddish, which made for the highest proportion in this category. Discussion: Nominating skull-length-eyeball-ratios on the basis of photographs taken in the field is a new approach. The method bears inaccuracies. Skull measurements could settle doubts. Nominating tail form and colour in the Southern Chamois (*R. pyrenaica*) is not straightforward due to wide variations of individual characteristics. However there seems to be a tendency of *ornata* with its big horns to have also a showier rear end and a tendency in *parva* with its short horns to have a more inconspicuous rear end. These results are consistent with findings of Geist (1999, p. 87) who explains tail evolution for deer: As antlers enlarge, tail size can increase.

Analysis of diet quality of Alpine ibex

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In recent decades, climate change has affected many ecosystems. In particular, the alpine ecosystem seems to be one of the most vulnerable environments to climate change, with alteration of both weather and vegetation growth seasonal patterns. In fact, environmental changes could lead to modifications in plant phenology, affecting the quantity and the quality of trophic resources for herbivores. Therefore, detecting and predicting the effects of these changes on alpine organisms is a major challenge for ecologists. We investigate this issue in Gran Paradiso National Park (Italy), focusing on the feeding ecology and diet of the Alpine ibex (*Capra ibex*). Alpine ibex is a mountain ungulate that faces strong seasonal fluctuation in environmental conditions and resource availability, and thus is expected to be strongly susceptible to environmental changes. Being body mass one of the most important parameters influencing survival in this species, it is fundamental to examine how resources availability and quality affect body conditions of individuals. In this study, we first analysed alpine meadows phenology and productivity through time using NDVI. The week when the maximum value of NDVI was reached every year, which represents the moment of maximum seasonal productivity of plants, resulted to change from year to year, but without a clear trend. Further, we investigated seasonal variations in nutritional quality of resources using NIRS analysis on dry vegetation samples collected in the period 2015-2022. According to results, the crude protein content of vegetation samples declines throughout the growing season, while fiber fractions (NDF, ADF) tend to increase. Results also showed that these trends exhibit a certain inter-annual variability. These results may be helpful in further studies to better understand how diet quality, together with other environmental variables such as weather and population density, affects seasonal mass change in Alpine ibex over time and in relation with environmental changes.

Evaluating tooth wear in Alpine chamois: a new proposed method.

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In many mammalian species, once the permanent teeth have erupted, the only change to dentition is a gradual loss of tooth surface/height through wear. The crown of the teeth cannot be repaired once worn. When dental crown tissue has been depleted due to wear, the animal is expected to have a suboptimal body condition.

Describing tooth wear patterns in hunted populations and monitoring at which tooth wear level an animal is no longer able to sustain its physical condition (i.e. when it begins to lose body mass) can be a useful tool for improving the management of the species.

Here we compared a traditional method based on the measurement of the height of molars (i.e., the distance from the peak of the mesiobuccal cusp to the enamel/cementum line) and their hypsodonty index (i.e., the height of each molar divided by the buccolingual breadth of the mesial cusp) to our new proposed method based on the evaluation of the percentage of exposed dentine in the upper tooth surface throughout the use of ImageJ software 1.8.0. We applied this new method to measure Alpine chamois (*Rupicapra rupicapra*) tooth wear. After taking a picture of the surface of the molariform teeth (orthogonal view) for a set of 200 mandibles of animals legally culled during 2017-2021 hunting seasons in the province of Trento (6,212 km²; Central-Eastern Alps, Italy), each pixel was classified as dentine or enamel both with the Thresholding method and by using the Colour Segmentation plugin (Algorithm: Hidden Markov Model).

We compared the different applied methods with a paired t-test, revealing a strong correlation. Contrary to the traditional method, the new proposed one does not introduce differences due to data collector; is less time consuming and can be achieved through the use of an open software. These characteristics can contribute to apply this method on a large scale, improving knowledge about the role of tooth wear as a proximate cause of senescence in ungulates.

Alternative reproductive tactics in chamois: a fixed trait, with snow-dependent reproductive payoffs?

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Polygamous species show great variability in alternative reproductive tactics (ARTs) in relation to individual or environmental factors. Individuals may adopt fixed ARTs consistently across years (rare in mammals), or may show flexible behaviour. Different cost-benefit trade-offs should occur in relation to the adoption of ARTs, possibly influencing also spatial behaviour. Female density and distribution depend on resource phenology and their availability influences male mating behaviour and success. When a male adopts a “resource defence” tactic, his reproductive success depends on the location and attractiveness of his territory. Environmental factors associated to territory quality, e.g. through territory features, and male-male competition would be expected to influence mating success. We investigated *i*) the potential for fixed vs. flexible ARTs and their correspondence with spatial tactics and *ii*) the relationships between snow, topographic features of territories, territory size, male intra-sexual competition and mating opportunities, in a mountain-dwelling herbivore, the Alpine chamois. We collected data on mating behaviour of 31 individually recognisable males during 5 rutting seasons (early November-early December) and on their spatial behaviour throughout the same years (2011-2012, 2015-2017). Secondly, we focused on males classified as territorial (N = 15) and related their mating behaviour and territory size to snow depth and topography of territories. No individual changed

ART during our research. Fifty percent of territorial individuals had overlapping or continuous winter-summer ranges, whereas the others moved between different areas (in winter, after the rut, or in summer-autumn). Differences between males adopting ARTs were found neither in age nor in body mass, nor in their frequencies of intra-sexual aggressive interactions. On the other hand, territorial males, dominant over non-territorial individuals in aggressive interactions, showed greater mating opportunities than the latter. In ruts with deeper snow cover (median > 15 cm in the early rut), territorial males had smaller territories and higher mating opportunities than in ruts with lower snow cover. Smaller territories showed the highest values of roughness, which influences snow cover, and were visited by a significantly greater number of females, than larger territories. Snow cover, in turn resource distribution and female movements, is suggested as a strong determinant of male reproductive success. Differences in key aspects of behaviour (e.g. space use) and life-history (e.g. reproductive success) would help explain ARTs evolution and coexistence in the population. If ARTs were fixed in chamois, neither ART should have been selected against long enough to determine its extinction, over evolutionary times.

New world and old pathogens: infectious keratoconjunctivitis in tahr and chamois in New Zealand revealed by citizen science

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The mountain-dwelling Northern Chamois (*Rupicapra rupicapra*) and Himalayan tahr (*Hemitragus jemlahicus*) have been introduced in the early 1900s in New Zealand for game purposes. Henceforth, they have been managed by regular hunting and population control plans as non-native pest species. Both species may share a range of pathogens with livestock, including bacteria such as *Mycoplasma conjunctivae*, the etiologic agent of Infectious Keratoconjunctivitis (IKC), also known as “pink-eye”.

In Europe, IKC in wild Caprinae has been the object of numerous field and laboratory investigations that, over time, have clarified its clinical features and epidemiology, as well as the impact at the population level. As opposite, the distribution and importance of IKC in introduced wild ungulates in New Zealand has never been the object of dedicated surveys, as shown by scarce and outdated information available in the official literature.

While there are very few citizen science projects reporting abnormal mortality episodes in wild ungulates, a large body of evidence shows that interest groups such as local hunters, wildlife photographers and hikers could profitably collaborate for collecting this type of information. This study aimed to assess the spatio-temporal occurrence of IKC in tahr and chamois from New Zealand through a citizen-science approach.

A questionnaire survey was prepared and publicized to collect information on individual cases and/or outbreaks of IKC observed in chamois and tahr since 2000. Respondents were asked to fill out a digital form and eventually contribute photos and videos. All material was validated by a panel of four veterinarians with expertise in IKC in wild Caprinae.

The results are posted, and regularly updated on a dedicated public website <https://www.nztf.org.nz/project-pinkeye>. The locations of the single observations appear on a digital map updated on a regular basis.

We received N= 28 questionnaires, 19 of which (67.8%) provided high-quality pictures. Nineteen questionnaires referred to tahr (68%) and 9 (32%) to chamois. A total of 32 tahr and 21 chamois, with clinical signs compatible with IKC, were reported. Interestingly, cases were similarly distributed by gender, with a prevailing number of individuals older than 4 years (75% of the questionnaire).

The role of hunters to monitor the circulation of IKC in New Zealand may be considered an effective example of citizen science approach, supporting the cooperation toward private and public health stakeholders.

Effects of habitat and weather variables on Alpine chamois (*Rupicapra rupicapra*) in the Alpine district VCO3

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In the last decades the populations of ungulates have increased dramatically in Europe and Italy. This study aimed to evaluate how habitat and weather variables affect the chamois population harvested in the study area.

The study area (880.57 km²) was located in Verbano-Cusio-Ossola province and it was divided into 4 hunting districts. Hunting and census data from 2000 to 2019 were standardized and analyzed through GLMs (generalized linear models) to understand which weather variables of the same and previous year (temperature, rainfall, ground snow) and 19 environmental variables (land use, altitude, slope, and roads) affect the spatial distribution of chamois. The weather variables have been grouped into quarters. Land use variables was taken from CORINE Land Cover in different years and calculated with GIS 3.14.16. Statistical analyses were carried out by software R 1.4.0.

Four variables were included in the best model considering the number of animals harvested. The minimum temperatures of the first (p=0.012) and the third quarter (p=0.004) had a positive and significant effect. The model explained 51.0% of the variance. The analysis was replicated with the climatic variables of the previous year. In the best model, three variables were selected: the average of the maximum temperature of the fourth quarter with a significant and positive effect (p<0.0001) and rainfall in the third quarter with a negative and significant effect (p=0.007). The model explained 63.3% of the variance. Out of the 19 habitat variables considered only 8 were selected in the best model (AIC=1080.6).

The number of individuals harvested was positively and significantly influenced by the presence sparse vegetation areas (p<0.0001), heaths and bushes (p<0.0001) and water bodies (p=0.014). Instead, there was a significant and negative effect of farmlands (p<0.0001), grassland (p<0.0001), glaciers and snows (p=0.016) and fragmented agricultural areas (p=0.005). The best model explained 44% of the variance.

The results show that the number of animals harvested depends largely on the presence of warm temperatures; it is negatively affected by abundant rainfall in autumn and positively influenced by high winter temperatures of the previous year.

The results concerning the effects of the habitat variables confirm that chamois select high altitude areas located beyond the upper edge of the forest, but also ecotone areas and water bodies. The negative effect of farmland can largely depend on the presence of these areas in the thalweg.

Dietary coexistence between bighorn sheep and feral donkeys in the mountains of the southern Baja California peninsula.

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Coexistence between bighorn sheep and feral donkeys depends mainly on the distribution and abundance of the food they share so that they can ensure their survival and reproduction. The objective of this study was to determine which plant species are consumed by both species and to determine if there is trophic overlap. We hypothesized that both species opportunistically select certain plant species and that there is a similarity, not an overlap in the use of food resources, therefore, both species coexist in the same habitat. Significant differences were found in the consumption of plant

species between the two animals ($U = 0.016$, $p < 0.0001$). In the diet of the bighorn sheep, a richness of 46 species was found, composed mainly of shrub forms; *Cordia brevispicata*, *Fouquieria diguetii*, and *Mimosa xanti* being the most consumed. In the diet of the donkeys, a richness of 28 species were found, mainly nine shrubs. However, the most consumed species throughout the year was the herbaceous *Antigonon leptopus*. It was also evident that during the two climatic seasons the dietary overlap between the two species was minimal. At the same time, the analysis of niche breadth showed that the two ungulates behaved as specialists. Under this argument, we define that one of the main mechanisms of coexistence between both species is to reduce their competition, based on the consumption of different foods. Even when food was scarce, sheep and donkeys were selective.

Monitoring of *Rupicapra rupicapra* in the Bavarian Oberallgaeu – A pragmatic approach

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Monitoring of the European chamois (*Rupicapra rupicapra*) is compulsory for states that use the species for hunting. Responsibly authorities in Bavaria usually rely on the annual game harvest statistics for this purpose. This proceeding is being criticized, as it gives not enough information about the actual living population.

In Oberallgaeu, the lower hunting authority, hunters and wildlife ecologists therefor have established an annual census of the living chamois population. We defined 18 chamois habitats, considering natural structures like massifs and known chamois trails. Each habitat has its own coordinator, organising the systematic count of chamois in their area of responsibility. The monitoring is based on 1. a census, where every counting person has to note the amount and class of chamois seen on a set day and 2. an estimation on how many of the assumed chamois in the area were recorded on that day. The census is done between September and October. Spotted chamois are noted on a form given, offering five different groups: “buck”, “doe”, “yearling”, “fawn” and “unknown”. The estimation connects the experience of the counters, which mainly consists of local hunters, with chamois seen.

Results of this monitoring allow to deduce that the oberallgaeu chamois population has not declined since 2014.

The census does not represent the overall population of chamois in Oberallgaeu, because not every individual is being counted. But it allows to draw conclusions on local population size, sex ratio, reproduction and long-term development of the population. The information gathered can be used for game harvest planning and deficiency analysis. It allows to bring the discussion about the state of preservation of the chamois to an objective level. Experiences with this monitoring can be used as guideline for other counties, that have not established a monitoring of their chamois populations so far.

Genetic diversity, structure and connectivity of chamois (*Rupicapra rupicapra*) populations in the Bavarian Alps

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Chamois (*Rupicapra rupicapra*), an iconic mountain dwelling ungulate, is widespread throughout the Bavarian Alps. Like other wildlife, chamois populations are affected by a variety of different environmental factors - from changes in land use, to tourism, hunting and climate change. However, data on population structure, genetic diversity and how these are influenced by the different environmental factors are largely missing for this part of the species' range. A new comprehensive study will address

these questions with respect to chamois conservation and management. Extensive sampling of the Bavarian chamois hunting bag and subsequent analysis with a set of 16 microsatellite markers will provide a large dataset suitable for detailed population and landscape genetic analyses. Main goals of the study include the identification of population structure and the delineation of populations/subpopulations to inform future monitoring and management. Considering the habitat requirements of the species and environmental heterogeneity within the species range in Bavaria, we expect varying levels of gene flow within and between populations, leading to hierarchical population structures. Population structure will be analyzed using multivariate as well as Bayesian methods, integrating spatial data for the georeferenced samples. Combining population genetic and landscape data, we will study genetic diversity and its correlation with environmental factors on the intrapopulation level. On the interpopulation level, we will analyze influences of natural and anthropogenic factors (e.g., barriers) on gene flow and population connectivity. Sampling for the current study will continue throughout the year 2022. However, a small subset of samples currently analyzed will allow first insights into large scale population structure of Bavarian chamois. Additionally, preliminary population genetic data is available for two intensively researched areas representative of typical Bavarian chamois habitats- in the mountainous regions of Karwendel and Chiemgau. The former area is dominated by grasslands, shrubs, and rocky habitats while the latter is more densely forested. Genetic diversity - measured by allelic richness and expected and observed heterozygosity - was higher in the Karwendel than in the Chiemgau region. Overall, our data from these two chamois populations indicate the suitability of the chosen markers for detailed investigation of structure, diversity and connectivity of chamois populations in the Bavarian Alps.

The socio-economics of migratory herder's dependent on markhor (*Capra falconeri*) habitats in North-western Himalayas, India

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The alpine and subalpine meadows, including Protected Areas (PAs) in the Himalayas are seasonally used by migratory herders for livestock grazing, their main livelihood. The community herding practices create a competition of forage availability between the wild ungulate and the livestock. In Jammu and Kashmir in the north-western Himalayas, the increasing grazing pressure has been identified as one of the major threats to wild ungulates such as markhor (*Capra falconeri cashmiriensis*). Reducing the threat to the conservation of the species requires knowledge about the migratory herders' socio-economic and cultural aspects to develop appropriate community-oriented conservation strategies. Hence, we conducted socio-economic surveys of the herders using markhor occupied Protected Areas, such as Hirpora Wildlife Sanctuary; Kazinag National Park and Tattakuti Wildlife Sanctuary to understand their dependence on the natural resources of these protected areas. We also looked at the changes in the traditional herding practices. The herding community comprised mainly of Gujjar and Bakkarwal were heavily dependent on PAs for livestock grazing, the primary purpose of their seasonal migration to the pastures. Additionally, they extracted fuelwood and other Non-Timber Forest Product (NTFP). The communities have traditionally used these pastures and have been issued grazing rights by the government, but the practices have changed drastically in the recent decades. They also bring livestock from other communities and non-bonafide herders. The practice of subletting the pastures to non-traditional herders on rent, had almost doubled the livestock numbers using the pastures. About 70% of bonafide herders in Hirpora Wildlife Sanctuary, 29% in Kazinag National Park and 58% of herders in Tatakuti Wildlife Sanctuary were subletting their pastures onto non-bonafide graziers. The transhumance practice greatly affects their educational level, about 70% of the herders had low formal education. They

aspire to formal education, but the nomadic lifestyle is a major barrier. The study also indicated that children of 25% of the herders' families were not accompanying their families to attend education. The study outlined that providing communities with basic amenities through mainstreaming government's development programmes such as improved breed of livestock, alternative cooking and lighting devices, skill development and technical education etc. are key to empowering and diversifying their livelihood opportunities and will go a long way to help them fight with the vagaries of herding on their socio-economic status. It is important for the conservation of pastures and the biodiversity of the fragile ecosystem as well.

Long-term trend in the chamois population in the Bavarian Oberallgäu region

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Because of climate change and the fact that the chamois is now listed under the "near threatened" category in Germany's Red List of Threatened Species, the situation of the chamois in Germany is currently the subject of heated debate. Data on the chamois population is based on the hunting bag, which can only be used as an indicator of trends in the population if there is no change in the intensity and effectiveness of hunting measures within the observation period (Begon et al. 1996). For the district of Oberallgäu count data going back to 2014 is available in addition to the hunting bag data. From 2004 onwards, the hunting bag data also shows the exact age of the animals, so that it is possible to carry out a cohort analysis.

Since 1998, the number of chamois shot has been decreasing, while the proportion of animals found dead from other causes has been increasing. According to our cohort calculation, the population consisted of 2969 chamois in 2004, of which 485 were fawns. There was a gender ratio of 1:0.66, biased towards the bucks. For the years 2016 to 2018 and 2020 to 2021 a gender ratio among yearlings was calculated of one buck to 0.8 does. The count data from the last few years shows a population of approx. 2779 chamois including 667 fawns, with a sex ratio of 1:1.69 in favour of the does. If we assume a balanced sex ratio, we arrive at an average population of 3175 chamois, and if we adjust the sex ratio to match that among the hunted yearlings, the population amounts to 3418 chamois. This value is consistent with the estimate made by the professional hunters. Despite the falling hunting bag, the chamois population in the Oberallgäu region can be said to be growing. This is consistent with the population structure and the key indicators from the cohort analysis.

Using cohort analysis, we can show that with a 12-year data set, 95% of the population is covered and 100% after 16 years. Furthermore, the example of the Oberallgäu region shows that for a discussion to be neutral and objective, two independent data sets are necessary.

Ecological profile of the Arabian Tahr (*Arabitragus jayakari*) living in the UAE.

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In the UAE, about 58 individuals of the Arabian Tahr (AT) live in the natural environment, and at least 900 are kept in various nurseries. AT do not form reproductive groups (herds). Males mark their individual territory and protect it by creating a kind of "biofield" with landmarks on the ground. The rut starts in the second half of August, and the main mating time is from the end of September and all of October. For the mating period, the females are with the male, and then move away and lead a secretive lifestyle. The type of mating system near to monogamy. Reproductive behavior is complex - it includes 12 well-defined positions. The peak of the birth of young animals is March-April. There were cases of birth from October to December in females that were idling or

aborted during the main period. The appearance of young is timed to the most favorable period of the year. Pregnancy lasts an average of 168 days. Males reach puberty by 27 months, females by 9, but take an active part in the rut from 40 and 18 months, respectively. Only one yearling is born. The probability of giving birth to yearlings of one sex or another depends on the ratio of the age of the parents: in males, the probability of giving birth to females is maximum in the first year and after entering the dominant phase; in females it gradually increases with age. Maximum life expectancy within 12 years. According to morphometric parameters, AT is very small for representatives of the Caprini family. However, according to biomechanical parameters, it is one of the most adapted species for living on rocks. 54 plant species from 25 families were noted in the AT diet. Animals are perfectly adapted to the extremely arid conditions of their habitat: daily activity is shifted to pre-dawn and early morning hours, as well as evening time; in the hot time of the day, AT use stone shelters, niches and caves; thirst in the absence of water is covered by vegetation sap and moisture, settling on bunches of dry grass in the predawn time before sunrise.

Studies of the AT ecology have been going on since 2005 to the present and are fully used in the design of enclosures and the preparation of programs for the maintenance and restoration of natural populations.

Study of Alpine chamois (*Rupicapra rupicapra*) demography and harvest in the Alpine district VCO3

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Wild ungulate populations have increased considerably throughout Europe in recent decades. This research aimed to describe the status of chamois populations harvested in the Alpine District VCO3 - South Ossola about (i) the demography, (ii) hunting trends to improve population monitoring and conservation strategies.

The VCO3 Alpine District is in Verbania-Cusio-Ossola province and is divided into four management zones. The altitude ranges from 200 m to 4,000 m.a.s.l.

Hunting and census results of 2000-2019 were analysed through TRIM v3.54, investigating the effect of zones. Moreover, the cull was correlated with the census data.

Additionally, we calculated (i) sex ratio, (ii) population structure, (iii) annual and five-year population growth rate.

In 2000-2019, the chamois culled annually increased (+48.3%). The number of individuals culled and censused were positively correlated ($r=0.811$, $P<0.001$). TRIM has showed a moderately increasing in harvest number ($P=0.01$) although not constant. The best model was the linear one, which explained 79.7% of its variance. The zone significantly influenced the overall trend ($P=0.006$). Trends in the success of culling plans (averaged 90.1%) were statistically significant according to a third-order polynomial model ($R^2=0.52$; $P=0.002$).

Among 5952 individuals harvested, there were 2834 females (48%) and 3118 males (52%) with a significant deviation from 1:1 sex ratio ($SR=0.9$; $P=0.01$). The sex ratio showed no significant differences between years or districts. In general, the individuals taken were 1-4 years old (yearlings=32.5%; two-year-old individuals=13.5%, three-year-old individuals=9.8%). There were significant differences of individuals culled between the age-sex classes both with respect to the years ($P<0.001$) and zones ($P=0.001$). The population showed an average annual growth rate of 0.94 ($SD=0.24$) and a five-year growth rate of 0.25. From 2000 to 2019 both the harvest and growth rates showed a moderate increase, and the zones significantly influences it. The sex ratio of culled animals was significantly different from that found with censuses, which was in favour of females. Taking equal sex ratio in populations with larger numbers of females than males increase the disparity between sexes, leading to a decline in populations. Yearlings and 4-5 years old chamois are the most culled, while animals

older than 5 years less affected. This happens most likely because harvest plans did not allow culling juveniles until 2011. Differences emerged in the age-class structure related to the culling, between both the years and zones. There is important deviations in the harvest structure from the recommended rates by ISPRA.

A tale of an African ungulate in north-western Italy: population history, abundance, and ecology

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The loss of biodiversity is a major conservation concern of the last decades, with a key role played by invasive alien species that can cause dramatic changes to native ecosystems, altering habitats and reducing or eliminating endemic species. The aoudad or Barbary sheep (*Ammotragus lervia Pallas, 1777*) is a north-African ungulate commercialised and introduced for game hunting to Europe, South Africa, and America. As a generalist herbivore, the aoudad has a high capacity to adapt to new habitat conditions. We studied the aoudad population inhabiting the Beigua Natural Regional Park in Liguria, north-western Italy. By combining historical data, direct observations and camera trapping, we estimated minimum abundance over the years. A Relative Abundance Index (RAI) accounting for group size was derived from camera trap data and analysed with generalized linear mixed models to assess population trends on a subset of sites monitored over the years within the population's core area. Camera traps at a larger scale were used to assess habitat selection and activity budget. Some aoudads had most likely escaped from a game reserve in Ponzone Municipality, Piedmont, and settled in the park at least since 2009, although sightings have always been rare. The population has increased from a minimum of 9 individuals in 2012 to 23 in 2020, a trend detected also by RAI. The population inhabits steep, rocky and woody areas in the southern and warmer part of the Beigua massif, but some observations in the northern part of the Park have recently occurred. Aoudad select the steepest parts of the study area, especially at mid-elevation, and show mostly diurnal activity, possibly for anti-predator reasons. It is fundamental to monitor this alien species and evaluate potential eradication solutions.

Mountain ungulate in a hot world

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The thermal landscape, i.e. the distribution of places sheltered from extreme temperatures, strongly influences how individual cope with thermoregulatory costs. When facing heat stress, chamois increased their use of thermal refuges and suffered from decreased foraging conditions. Individuals mitigated their foraging costs depending on their access to thermal refuge. Chamois that mostly had access to forest increased their time spent foraging, while individuals with access to northern slopes increased time spent relocating in forage-rich areas.

Activity rhythms of *Capra pyrenaica* revealed by GPS-GSM radiocollars

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An animal's activity rhythm can be defined as how an individual partitions its behavior over time, while balancing the effects of both abiotic and biotic factors. During the period 2005 -2022 we captured 63 Iberian ibex (18 females and 45 males). These animals were equipped with GPS-GSM radio collars. We have analysed the activity rhythm of such animals in order to characterize daily and seasonal patterns and to address the effect of different abiotic (e.g., temperature) and biotic (e.g., age, sex, health status) factors on the activity rhythms of these animals. The statistical analysis has been carried out using ARIMA-type time series models, as well as their extensions to deal with the assumptions of the model. We also use mixed models with extensions to treat with the temporal correlation of the data, as well as to account with the inclusion of explanatory variables in them.

3D does matter when investigating the spatial ecology of terrestrial mountain species - an example in mountain ungulates

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The importance of the third dimension (3D, i.e. altitude, elevation, depth) for the spatial ecology of species living in aerial, arboreal, terrestrial, soil and aquatic environments has been recognized for a long time and for multiple spatial scales (e.g. movements and home ranges in animal species). Despite the emergence of biologging, movement ecology and associated analytical tools during the past decades, there is still an important lack in methods available to account for this 3D when investigating movements and space use/selection, in particular in terrestrial species for which the few approaches proposed often remain incomplete. In addition, the influence of the 3D on results of such studies has been rarely investigated. Here, we propose several tools (R functions) to account for 3D when computing distances and home ranges, i.e. two variables among the most often used to investigate animal movement ecology. We also investigated the extent to which accounting for the 3D influenced the distances traveled, size of home ranges and results of habitat selection analyses (at two spatial scales, i.e. movements and home ranges) during summer in 8 French mountain ungulate populations monitored with GPS collars. We found strong evidence that accounting for 3D (here, elevation) is of prime importance when investigating distance traveled and home range size. We also found that accounting for 3D also influenced the results of habitat selection analyses at both movements and home range scales. Therefore, we claim that "3D does matter" when investigating spatial ecology of mountain terrestrial animal species and provide the tools to do so.

Project Alcotra LEMED-IBEX: Monitoring *Capra ibex* in Alpi Cozie Regional Park

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As part of the Alcotra Lemed Ibex 2017 - 2020 project, the Rangers of the Cottian Alps have captured alpine ibex (*Capra ibex*) on which they have positioned satellite GPS collars, with the aim of knowing the home ranges of the animals, checking their seasonal movements and collect data on the

interconnection of the different populations present in the area. For the first time 16 animals (5 females and 11 males) were captured and tagged in 3 Natura 2000 sites (IT1110006 Orsiera Rocciavre', IT1110039 Rocciamelone and IT1110080 Val Troncea). The GPS collars were programmed to determine the animal's position 4 times a day and in total 37462 fixes were collected, with an average of 2341 GPS points / animal (min 201, max 4080). Some collars stopped working after a few weeks, others remained active until June 2020, when they were deactivated to retrieve the tool and free the animal: each captured ibex kept the collar on average for 431 days (min 23, max 724). The three Natura 2000 sites were found to be disjoint and not interconnected areas for marked ibexes, which however in two cases moved around France and demonstrated the presence of ecological corridors through these two countries. The monitoring of animals marked after the drop off of the satellite collar was difficult to apply due to small number of staff involved, however in June 2022 two animals (1 male and 1 female) captured in the Orsiera Rocciavre Regional Park were sighted and they appeared in excellent conditions.

Hunting bag statistics for *Capra pyrenaica* (1995-2021)

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We have searched for the hunting bag statistics of *Capra pyrenaica* in the different Spanish regions where this big game species is present and harvested during the last decades (1995-2021). Overall, the number of harvested ibex increased until the 2017-2018 game season (n=11351), and then a started a decreasing trend. Hunting licenses number peaked in 2005 and 2019, when a decreasing trend began. The regions with the highest hunting quotas are Aragón (mean: 2179 ± 1230 animals during the period 2005-2020), Valencia (mean: 1282 ± 727 during the same period) and Andalucía (mean: 1017 ± 850 during the period 1995-2020). The number of approved trophies peaked in the period 2001-2005 (n=722) followed by a sharp decline: only 155 trophies were approved during the period 2016-2020 (n=155).

Despite we lack information about mortality rates in *C. pyrenaica*, within the current context of overabundance, game can be considered as a compensatory mortality factor. Further work is needed to to assess the impact of hunting on each region and on each sex and age class, the level of compliance with technical hunting plans, or the economic impact of this activity, among many other topics.

A case of coprophagy in Iberian wild goat *Capra pyrenaica*

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The Iberian wild goat is expanding in the Pyrenees, recolonizing areas where it was extirpated long ago. In march 2021 one of the authors (EB) observed a mixed group of adult females and a male eating wood pigeon *Columba palumbus* guano in the opening of a cave of the Guara Natural Park (Aragon, Spain). Guano is considered an important potential resource for domestic ruminants due to its high energetic content, and calcium and phosphorus composition. It is also believed to play an important role in the transmission of zoonosis.

Samples were taken and investigated for nutritional properties using standard methods of food analysis.

Results indicate a high concentration of nitrogen-containing compounds ('crude protein') which in pigeon guano consist mainly in uric acid, xanthine (mostly guanine), urea and creatine. These compounds represent an indirect protein resource for ruminants due to its subsequent rumen microorganism's transformation. Pigeon guano was found to be rich in minerals as calcium, sodium, phosphorus and sulphur. The fibre content was found to be low and the energy content moderate but far from the energy requirements for lactating period. Outdoor exposure affected the guano desiccating it and probably reducing its pathogenicity.

Domestic goats *Capra hircus*, identify food which satisfies their nutritional needs, specifically gestating and lactating females search for sources of protein with low fibre content. Moreover, saltiness from sodium and umami taste from guanine can stimulate its consumption. For this reason, we hypothesize that female Iberian wild goats could be stimulated by guano in the second half of their pregnancy period, when protein requirements increase.

To our knowledge this is the first record of such behaviour in Iberian wild goat.

Updated data on Apennine chamois population reintroduced in the Sirente Velino Regional Park

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The Apennine chamois (*Rupicapra pyrenaica ornata*), an endemic subspecies of the central Apennines, evaluated as vulnerable to extinction, has been reintroduced in the Sirente Velino Regional Park with the aim of constituting a new fifth population in the central Apennines.

The reintroduction was initiated as part of the LIFE Nature Project, LIFE 09 NAT/IT/00183 COORNATA. The project had as coordinating beneficiary the PN Majella and as associated beneficiaries, in addition to our Park, were the PN Abruzzo, Lazio and Molise, the PN Gran Sasso and Monti della Laga, the PN Monti Sibillini and Legambiente. The reintroduction of the Apennine chamois in the Sirente Velino Regional Park, already foreseen in the National Action Plan for the species, after the necessary preliminary actions (update of the feasibility study, establishment of specific protection measures in the release area for the Apennine chamois) was started in 2013 when a first chamois founders nucleus from catches in nature and wildlife enclosure areas was released.

To date, 25 chamois (15 females and 10 males) have been released on Monte Sirente, marked with ear tags and fitted with GPS / VHF radio collars. The monitoring of the movements of individuals in the new area was conducted through radiolocalizations and direct observations.

Monitoring activities continue through annual censuses, with the block census method, and by direct observation sessions. From 2014 to 2021 the birth of 66 kids was recorded in the area of the Sirente Massif and in the overall area used by the population, the possible formation of areas of potential spatial population expansion is observed.

This contribution intends to provide an update on the new Apennine chamois population reintroduced in the Sirente Velino Regional Park.

Walk on the wild side: detection of antimicrobial resistance in Alpine ibex

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Antimicrobial resistance (AMR) is a worldwide threat to public and animal health, mainly caused by overuse, underuse and misuse of different antibacterial agents.

While AMR in livestock has been associated to an imprudent use of antimicrobials for disease

prevention and as growth promotor, the knowledge on the AMR drivers in wildlife is still limited. Some wild species such as wild boar and rodents may act as reservoir and disperser of resistance gene in anthropized environment (Arnold et al., 2016; Tinoco Torres et al., 2020). However, little is known on the role played by wild animals in remote habitats such as mountain areas.

Here, we report the first detection of AMR in two adult male Alpine ibex (*Capra ibex*), found dead after an outbreak of respiratory disease in two nearby locations in the western Alps (Italy) in 2022.

Lungs were submitted to bacteriological examination (blood agar, chocolate agar and Gassner agar with incubation at 37°C for 48 hours under aerobic and microaerophilic condition), then the bacterial isolates were analyzed by MALDI-TOF according to the manufacturer instructions (Bruker Daltonics, Bremen, Germany). Antimicrobial susceptibility of the isolates was determined by broth microdilution method (Sensititre, Thermo Fisher, USA).

The necropsy showed in both animals a bilateral broncho-pneumonia with pleuritis and the presence of nematode eggs and larvae of nematodes. Two distinct colonies were isolated from Ibex1, and one colony was isolated from Ibex2. Identification of the isolates was confirmed by MALDI-TOF as *Mannheimia haemolytica* and *Pasteurella multocida* (Ibex1,2). *Mycoplasma* spp was excluded by negative Real-time PCR. *Mannheimia* isolates (Ibex1) were susceptible to tulatromycin, tildipirosin, ceftiofur but resistant to amoxicillin/clavulanic acid, ampicillin, tetracycline, enrofloxacin, florfenicol, gamithromycin, tilimicosin, kanamicin, spectinomycin, while *Pasteurella* spp isolates (Ibex1,2) were resistant to ampicillin. *Pasteurella* and *Mannheimia* have already been described as etiological agents of respiratory disease in Alpine ibex (Domenis et al., 2017; Richomme et al., 2006), but spillover of respiratory pathogens from sympatric livestock has not been unambiguously demonstrated in the Alps.

The results highlight the importance of wildlife as potential sentinel for AMR detection in remote areas, where contacts with humans and livestock are relatively infrequent. Given the conservation status that Alpine ibex is currently enjoying, the epidemiology of this event should be further investigated to prevent deleterious epizootic events in the future. Moreover, further studies should be carried out to understand the origin of the AMR in this particular wildlife species, and the possible relations with sympatric livestock.

First Hungarian GPS telemetry results on mouflon home-range evaluation and habitat use

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In Hungary, the economically most important big-game species are cervids (red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), fallow deer (*Dama dama*)) and wild boar (*Sus scrofa*). In addition to these species, the European mouflon (*Ovis aries musimon*) is also present in Hungary and has become a typical species of mountain habitats in recent decades, thanks to successful introductions beginning from 1901. In the 2020/21 hunting season, 3,559 animals were harvested, and in spring 2021 the estimated population was 11,717 individuals. Due to trampling and browsing damage in protected rocky meadows, its population should be reduced in the future. Its impact on habitat has been the subject of several studies over the past decades, but no survey results based on GPS telemetry have been available up to now.

For the first time in Hungary we equipped mouflons with GPS collars. On 19 April 2022, one yearling and one middle-aged ewe were tagged, and further tagging are planned as well. The study area is located in the Bakony Mountains (altitude of 500 m above sea level) in West Hungary, North of Lake Balaton. During our study we used collars from Vectronic Aerospace GMBH, with 1 position per hour schedule, and GSM communication. We analysed the home-range size of collared animals using the

Minimum Convex Polygon (MCP) method and the Kernel-Home Range (KHR) method. Based on hourly displacements, we determined movement activity patterns. Furthermore, we investigated their habitat use characteristics using different land cover databases. The aim of our study was to get a more accurate picture of the impact of mouflon on habitat.

Adaptive seasonal dynamics of the gut microbiome of the wild ibex from the Stelvio National Park, Italy

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Modern agricultural production still relies on unsustainable practices while crop-derived recalcitrant lignocellulose (LC) accumulates in large quantities as unused material, making the circular valorization of this waste biopolymer a top priority research area. Natural microbiomes - as ultracomplex microbial communities populating every ecosystem on Earth - represent a still untapped source of functionalities for the valorization of recalcitrant plant biopolymers, thanks to a vast array of hydrolytic and oxidative enzymes allowing their biotransformation into platform chemicals (e.g., volatile fatty acids), with the concomitant production of several bioactive compounds. We aimed to identify the natural microbiomes (or hubs or strains) for the biotransformation of LC side streams by characterizing the fecal microbiome of Alpine ibex *Capra ibex*, to emphasize adaptive shifts in LC-degrading microbiome properties alongside the increasing amount of fibers that animals feed on during cold periods. We collected fresh fecal samples from 85 adult ibex across 3 different seasons (winter, spring, and summer) in Stelvio National Park. Samples were analyzed by multiomics (shotgun metagenomics and metabolomics), and the microbiome structural and functional dynamics were explored at the network level. In the ibex gut microbiome, we identified specific modules and hubs with strategic functionalities involved in LC metabolism (e.g., cellulases, hemicellulases, lignin-modifying enzymes), and showed a well-recognizable temporal dynamic matching seasonal changes in forage quality. While still preliminary, these findings may pave the way for engineering sustainable microbiome-based applications for efficient bioconversion and valorization of LC side streams.

Individual quality affects growth strategy in social rank in male Alpine ibex

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In males of social species, the dominance hierarchy regulates the access to limited resources, including females, and therefore has a great influence on the individual fitness. In most studies, dominance hierarchies are considered as static, however they are not. In accordance with resource-holding potential (RHP) theory, individuals may move up in the hierarchy by repeatedly winning agonistic interactions, causing a different individual development of social rank throughout their life. Male Alpine ibex (*Capra ibex*) is an optimal case study to investigate the dynamics of hierarchies as they grow continuously for a broad part of their life, differently from other ungulates, reaching their maximum body mass at 10 years old. Therefore, their RHP has a long development throughout their life. As the dominance rank is mainly determined by individual quality, through body and horn size, the strategy adopted to scale the dominance hierarchy could then be different from high to low-quality individuals. In this framework, a set of *ad-libitum* observations of aggressive interactions was carried out in 11 years in the Gran Paradiso National Park (Italy), from 2011 to 2022. The dominance hierarchies were computed by using the Elo-rating method. Generalised Additive Models have been used to infer

the effects of dominance status at the age of reproduction (9-11 years old) on the dynamic of social rank in the previous years. The strategy adopted to scale the dominance hierarchy effectively differed between dominant and subordinate individuals. High-quality individuals adopted a faster growth rate, quickly increasing in rank from 3 until 11 years old. The hierarchy position of low-quality individuals grew slowly and constantly from 5 to 14 years old. However, displaying a more conservative growth during early adulthood did not allow these individuals to compensate when they were older. Even if their rise in social rank did not stop between 10 and 11 years of age, like it happened for high-quality individuals, their rank never reached the one of dominant individuals. Generally, male Alpine ibex follow then a conservative strategy for scaling the dominance hierarchy, allowing a particularly high survival rate while living in a demanding environment.

Cohort affects social rank in male Alpine ibex

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Environmental conditions experienced by mammals in early life, or by their mothers during pregnancy, can have a direct influence on future growth and survival. In monoestrous species, individuals born in the same year are likely to experience the same environmental condition in early life and to undergo similar growth rates. The effects of the year of birth on the development of life history traits, known as cohort effects, are driven by environmental factors that are thought to affect maternal body conditions, early maternal care and resource availability, influencing birth weight and subsequent growth rate of the offspring. In male Alpine ibex (*Capra ibex*), body size and horn growth are shown to vary significantly between different cohorts. These differences have been attributed to food availability in late spring, which is an essential factor in determining maternal body conditions before birth and, consequently, milk quality and quantity. Since body weight and horn length are major determinants of social rank, it seems reasonable to hypothesize that social dominance may be affected by cohort. We tested this hypothesis using behavioural data collected from an un hunted population of male Alpine ibex in Gran Paradiso National Park, Italy. We used *ad-libitum* observations of winner-loser interactions gathered over eleven years (2011-2019, 2021, 2022) between April and November, to estimate individuals' hierarchy position by using the Elo-rating system. The resulting scores were normalised in order to allow comparisons between years and we used generalized additive model (GAM) to investigate the effects of cohort on the normalised Elo-scores. Our findings support the hypothesis that cohorts affect social dominance. This effect is probably mediated by early-life environmental conditions and their influence on body and horn growth. Since in male Alpine ibex social dominance is related to access to females during the mating season, it is likely that early-life environmental conditions can determine differences in reproductive success, leading animals of different cohorts to show differences in fitness.

Mountain Ungulates Reintroduction: A Case Study from AIUla Nature Reserves

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Over the last four decades, the mountain ungulate species are suffering in the Arabian Peninsula mainly due to hunting and habitat loss. Significant efforts are being carried out by restoring mountain habitats and reintroducing ungulates in AIUla nature reserves. In 2019 the initial management strategy for the reintroduction in Sharaan Nature Reserve (SNR) was starting with small populations of Arabian gazelle *Gazella Arabica* (20) and Nubian ibex *Capra nubiana* (10). To date a total of 32 Arabian gazelles and 45 Nubian ibex were released in SNR, their current estimated population is 45 and 60 individuals,

respectively. The successful reintroduction in SNR followed by reintroduction of 14 Nubian ibex and 14 Arabian gazelles in Wadi Nakhlah nature reserve during April 2022. Comprehensive monitoring program using tracking devices and camera traps show that the released animals have established their ranges and successfully utilizing the available habitat and resources.

Nubian Ibex distribution is the Arabian Peninsula

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Little is known regarding the distribution and habitat associations of the Nubian ibex in the Arabian Peninsula. An understanding of landscape habitat associations can be used to plan and focus efforts for biodiversity conservation, and on threats to the species. Between 2020 and 2022 Panthera conducted camera trapping surveys for the Arabian leopard across 14 sites within Saudi Arabia. The camera setup of this project is ideal for examining habitat associations for one of the Arabian leopard's key prey species, the Nubian Ibex. We found the Nubian Ibex to be present in 78% of the area surveyed of the potential habitat of the Arabian leopard. Here we calculated the extent of occurrence (EOO) of Nubian ibex and compared this with the IUCN distribution range.

Diet type determines reproductive seasonality in two Himalayan ungulates in Sikkim, India

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Ungulates in higher latitudes and altitudes experience sharp seasonal changes in forage biomass and quality which make reproduction metabolically challenging for them. The seasonal changes in forage biomass and quality are a function of plant growth forms. For instance, grasses show faster growth after winter than shrubs and other evergreens. Thus, plant growth forms should be good predictors of seasonal forage availability to the ungulates depending upon their diet type, and in turn of their reproductive seasonality. We examined the influence of seasonal changes in forage biomass and quality on diet type and quality, and on seasonality of reproduction in a grazer, the Himalayan goral *Naemorhedus goral* and a browser, the Himalayan musk deer *Moschus chrysogaster*, in Sikkim Himalaya, India. During 2013 and 2014, we collected plant and fecal samples at fortnightly intervals and estimated plant and fecal Nitrogen (N) as indicator of forage and diet quality, and fecal concentrations of estradiol and pregnanediol-3-glucuronide (PdG) to assess duration of estrous and birth seasons. Goral had a graminoid-dominated diet switching to dicots in autumn and winter, whereas musk deer had a dicot-dominated diet in all seasons. Diet quality of goral was considerably lower than musk deer in all seasons, probably below maintenance levels in autumn and winter. Goral showed a shorter duration of estrous (October) and parturition (May-June) as opposed to more dispersed estrous (February-May) and parturition (May-June) in musk deer. Greater seasonality in reproduction in goral was driven by sharp phenological changes in graminoids on which it feeds, compared to slow changes in browse on which musk deer feeds. Thus, we show that diet type determines differences in reproductive seasonality in two sympatric ungulates. Goral, with shorter estrous and birth seasons seems a capital breeder, and musk deer, with dispersed reproduction seems an income breeder. By analogy with previous studies, we expect goral to respond to perturbations in plant phenology due to climate change in the preceding growth season, and musk deer to respond to concurrent perturbations. Previous global scale studies, using proxies of plant phenology such as NDVI did not find relationship

between diet type and reproductive seasonality, because such proxies do not capture differences in phenology among plant growth forms. Our findings highlight the need for studying relationships among plant phenology, diet type and reproductive biology of ungulates at local scales if we are to understand species responses to global phenomena such as climate change.

On the edge between mountain and desert: the reintroduction of the Nubian ibex (*Capra nubiana*) in the Shouf Biosphere Reserve (Lebanon)

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After more than a century of absence the Nubian ibex (*Capra nubiana*) is making its comeback in Lebanon through a reintroduction project promoted by the Shouf Biosphere Reserve (SBR). Nubian ibex is an indigenous species of Lebanon that became extinct in the country in the middle of the 19th century mainly due to habitat destruction and overhunting. The comeback of this iconic species represents an environmental added value to the richness of the SBR ecosystem and an opportunity to educate local people to the importance of biodiversity.

A captive breeding plan, preparatory for a re-introduction program, was developed in 2016 through preliminary studies and the transfer of a first herd of Ibex from Jordan to a fenced area located on the eastern side of the Shouf Mountains. A five-year management and monitoring plan for the Nubian Ibex was realized, including the feasibility study and guidelines for silvo-pastoral activities. The ultimate goal is the reconstruction, in several decades, of a wild minimum viable population (MVP) in the SBR and surroundings, in equilibrium with the ecosystem and with resident human populations. The surveys conducted in the last 5 years and the habitat suitability model evidence that large patches of the study area are suitable for the species (about 170 km²). The studies identified the priority area for the release of the founder herd in the region of Ain Zhalta, in the north of SBR, characterised by "escape terrains", difficult accessibility to humans, low livestock impact and availability of water sources. Considering the biological features of the species, the minimum number of founders to set free into the wild is 45 individuals. The process of release could start at the end of 2022 and should be concluded within 36 months. All released animals must be individually marked with 2 different ear tags and a PIT-tag, and most of them equipped with a radiocollar. The monitoring work will be critical to acquire scientific knowledge and help address the project management.

The reintroduction will be successful if all the potential risks for the survival of Nubian Ibex in the new area will be properly managed to prevent any conflict with existing human activities. A key factor is the involvement of the local populations through an adequate plan of inclusion and communication. Lastly, the fruitful cooperation of all institutions and organizations involved is the first element for a long-lasting presence of Nubian Ibex in Lebanon.

Genetic analysis of ongoing hybridization from domestic goat into Alpine ibex and the development of field applicable protocols

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Hybridization among taxa is increasingly frequent due to human-mediated translocations of non-native species and habitat modifications. This is of significant conservation concern, as it can severely impact wild populations via loss of focal genetic diversity, loss of local adaptation or outbreeding depression and eventual extinction in extreme cases. Of particular concern are hybridization and

introgression among domestic species and their wild relatives. We investigated this issue in the Alpine ibex (*Capra ibex*). After its near extinction in the early eighteenth century, extensive protection and reintroduction programs have enabled the re-establishment of wild populations and the species is now again spread over the entire Alpine arc. Ever since its populations recovered from quasi-extinction, hybridization with the domestic goat (*Capra hircus*) has been shown to be a less sporadic event than previously thought. Two hotspots of hybridization have been identified in the regions of Lanzo Valley and the Gran Paradiso National Park (Italy). These events have given way for unusual phenotypes with potentially varying levels of fitness. However, the variability of hybrid phenotypes after backcrossing with normal ibex complicates their identification. In this project, we sampled normal looking ibex, as well as suspected hybrids in Lanzo Valley and in Gran Paradiso. Making use of fecal swabs, fresh feces immediately frozen or tissue material as well as a newly developed amplicon sequencing assay, we will be able to identify potential hybrid individuals and estimate the degree of hybridization within these two populations. Additionally, having used different sampling methods, we will be able to compare the effectiveness in hybrid detection among each, which can help in the development and application of non-invasive methods for future wildlife management projects.

note



