



III International Rupicapra Symposium



Book of abstracts
16-18 June 2021 | Croatia





Rupicapra
Abstracts

III International Rupicapra Symposium

-  **Physiology & Disease**
-  **Management & Conservation**
-  **Genetics & Systematics**
-  **Behavior & Ecology**

16-18 June 2021 | Croatia

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As Chair of Organizing Committee, it is my pleasure to welcome you to III International Rupicapra Symposium. Eight years after the last symposium, which was held in Spain, we decided to organize a symposium in the picturesque Mediterranean coastal town of Makarska in southern Croatia. The organization of such events has completely changed in the last year or two due to the worldwide covid pandemic and unfortunately forced us to organize the symposium online. At this point I would like to thank everyone who helped in any way, IUCN, Croatian Hunting Association, Croatian Forestry, Nature Park Biokovo, Help Nature and Resbios.

The Makarska region does not represent a typical habitat for chamois, but above the town, Mount Biokovo rises directly from the Adriatic Sea. Mount Biokovo stretches for about 36 km with an average width of 9.5 km and its highest peak "Sveti Jure" at 1762 m a.s.l. It covers a relatively small area of only about 200 km² and represents an isolated habitat of one of the largest and most stable Balkan chamois populations. The population was established in the 1960s through one of the most successful reintroductions, when 48 chamois (36 females, 12 males) were translocated here from the Čvrsnica and Prenj mountains in neighboring Bosnia and Herzegovina. Today we assume that Mt. Biokovo is inhabited by at least 600 Balkan chamois.

Due to the isolation of the habitat and current and future negative anthropogenic impacts (construction of highways, tunnels, cable cars, urbanization and mass tourism), as well as the occurrence of large predators (wolf, lynx and brown bear) on the chamois population, it is becoming increasingly important to understand the biology of the population and the species in order to ensure sustainable management and possible protection. For this reason, we have focused on research on the Biokovo chamois over the last decade, which has resulted in four PhD theses that have been completed or are in progress. In conclusion, I would like to emphasize that I hope that this symposium will contribute to even greater popularization of the Biokovo chamois, which will ultimately lead to its protection and conservation. It is also my wish that this symposium becomes established in the future and is held regularly every two years.



Nikica Šprem

University of Zagreb Faculty of Agriculture



It's a good time to be a chamois researcher! The interest for this taxon has increased steadily over the recent decades, and it doesn't show signs of decline: in the 2010s, about 30 papers – on average – have been published yearly, starring or co-starring chamois. These years have seen researchers from many disciplines working on several aspects of chamois biology, generating precious insights into the intricacy of topics such as systematics, disease ecology, social behavior and life history, among others. Most welcome is the interest towards the least-known subspecies of *Rupicapra*, for which bio-ecological information is of utmost importance to scientists and policy-makers to ensure long-term viability of extant populations. Of course, there is still much work ahead to unravel the complexity of chamois biology – as a comparison, thus far the overall number of papers published on the European roe deer is about four times as high as for the chamois. This need of further research is especially important in the light of the ongoing climate and land-use changes which, despite the relative ecological plasticity of the species, are likely to severely impact key life history traits. This meeting therefore comes at a particularly timely moment for making the point and sharing knowledge on the ecology, behavior, physiology, genetics and management of this iconic mountain ungulate. Almost 8 years have passed since the last *Rupicapra* symposium in Bellver de Cerdanya: I hope this meeting will be just one of many to come in the future!

Luca Corlatti

Luca Corlatti

Chair of Wildlife Ecology and Management, University of Freiburg (Germany)



The recent IUCN re-evaluation of *Rupicapra* reveals that both species *Rupicapra rupicapra* and *R. pyrenaica* continue to be listed as Least Concern (LC) following the IUCN criteria. Status of some subspecies has dramatically changed, with most subspecies threatened: *R. p. ornata*, *R. r. cartusiana* and *R. r. caucasica*, Vulnerable (VU); *R. r. asiatica* Endangered (EN) and *R. r. tatrica* (EN). *R. r. carpatica* and *R. r. balcanica* have not been assessed yet, and the latest should be probably considered VU. Threats are due to human impacts which affect populations numbers, habitat, connectivity and genetic identity (Anderwald et al. 2021). Hunting is present on most subspecies, as well as poaching - one of the genus' main threats – Thus, many populations are declining. Reintroductions, introductions, protected areas, sustainable hunt and law enforcement continue to be important tools that help populations to recover and there is still a large potential to habitat recolonization and population recovery (Anderwald et al. 2021, Herrero et al. 2020).

There is an important need to implement sound demographic and sanitary population monitoring, as well as act to limit important threats that make populations decline. We hope this meeting will help to share experiences in the conservation field and promote a better knowledge on chamois.

The image shows two handwritten signatures in black ink. The signature on the left is a stylized, cursive 'JH' for Juan Herrero. The signature on the right is 'Yash Veer Bhatnagar' written in a more legible, cursive style.

Juan Herrero and Yash Veer Bhatnagar
cochairs of the Caprinae Specialist Group of IUCN



Dear participants, dear nature lovers, and especially lovers of the chamois,

It is my great honour, as director of the Public Institution of Biokovo Nature Park, to welcome you to the 3rd International Rupicapra Symposium, dedicated to just one of the many animals inhabiting Mt. Biokovo, one that is exceptionally important to us. Above all, I would like to thank the dedicated scientists at the Faculty of Agriculture, University of Zagreb, especially those who have done so much for this timid animal: Luca Corlatti, Marco Apollonio, Krešimir Kavčić and Nikica Šprem. I would like to take this opportunity to also pass on the best wishes of Dr. Tomislav Čorić, Minister of Economy and Sustainable Development, who has wished you all a pleasant and successful symposium.

Biokovo Nature Park was proclaimed in 1981. It covers an area of 193 km², and in addition to its position and the beauty of its landscapes, Biokovo is also unique because of its exceptional geomorphology, biological diversity and wealth of cultural heritage.

The highest peak, Sveti Jure or St. George, reaches an elevation of 1762 metres, making it the third highest peak in Croatia. Mt. Biokovo features all the typical phenomena of karst: sinkholes, karrens, solution pans, caves, ice pits, and pits, the deepest of which is the Njemica pit (-934 m), the fourth deepest pit in Croatia. At first glance impoverished and bare, Biokovo abounds in plant and animal species. With the sporadic old-growth forests of beech, fir and black pine, we also find numerous plant species, including many endemic species, such as the silvery dwarf harebell (*Edraianthus pumilio*), Biokovo knapweed (*Centaurea biokovensis*), pointed knapweed (*Centaurea cuspidata*) and others. The fauna of Mt. Biokovo is distinctive and diverse, with numerous endemic species and Tertiary relicts, with a wealth of subterranean fauna featuring 70 species that are endemic to Mt. Biokovo. There is much evidence that testifies to the coexistence of humans and the mountain, such as archaeological remains, churches, chapels and shepherd huts.

At Biokovo Nature Park, visitors can enjoy over 20 hiking trails, numerous educational trails and the Info Centre, and visit the Biokovo Kotišina Botanical Garden, situated on the coastal slope of Mt. Biokovo, just above the village of Kotišina.

Mt. Biokovo is just one of two habitats in the Republic of Croatia where the Balkan chamois can be found in significant numbers. Alongside Mt. Velebit and the mountainous areas of Gorski Kotar, Mt. Biokovo is the ideal habitat for chamois, since it has excellent opportunities for its seasonal vertical migrations. Mt. Biokovo is a unique and isolated area for the chamois, and has the largest population of the Balkan chamois in Croatia. The current population on Mt. Biokovo are the descendants of successfully reintroduced chamois. This reintroduction to old, original chamois habitats was carried out from 1964 to 1969, when a total of 48 individuals were brought here from the Čvrstica and Prenj locations in Bosnia and Herzegovina, as some of the most widely known European hunting grounds and habitats for chamois.

On 1 November 1964, the first 7 chamois were released here into the wild. By 23 October 1969, Mt. Biokovo had become home to the final individual in the base population of 48

individuals. The population increased until the 1980s, and accordingly, its distribution range also expanded. Today, population remains in these habitats, with home ranges of 50 to 150 ha, depending of season.

Since its reintroduction to Mt. Biokovo, the chamois population was biggest in 1990, when it was assessed that there were about 1100 individuals in the park area. The most recent data indicate that this figure is only half this today. The greatest decline was recorded during the years of the Homeland War, ending in 1995. The main reason for the declining population, alongside the wartime and post-war conditions in the Biokovo hunting grounds, was the appearance of large numbers of predators, particularly wolves, and uncontrolled hunting. The chamois population in Biokovo Nature Park has now been estimated at a minimum of 500 individuals.

It is for that very reason that we are gathered here now, to find a formula for the protection and conservation of this valuable species. I hope that by the end of this conference, we will have results that will facilitate further management, enable us to better understand the biology of this species, and measures to increase its population.

Finally, I wish you all a very successful conference.



Slavo Jakša

Public Institution of Biokovo Natre Park



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Luca Rossi (University of Torino, Italy)

Marco Festa-Bianchet (University of Sherbrooke, Canada)

Sabine Hammer (University of Veterinary Medicine Vienna, Austria)

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14:00 - 14:10	Coffee Break
14:10 - 16:55	Session 1. PHYSIOLOGY & DISEASE
15:40 - 15:50	Coffee Break
16:55 - 17:25	Discussion – Session 1.

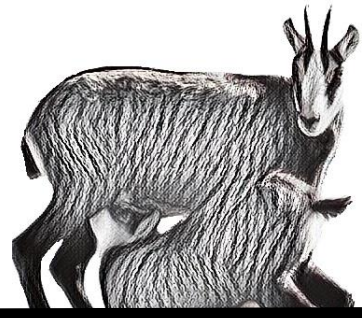
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18:20	Closing ceremony

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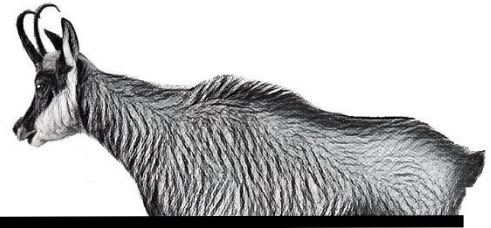
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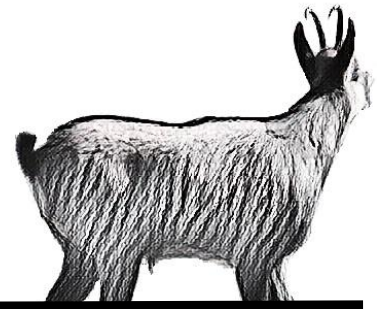
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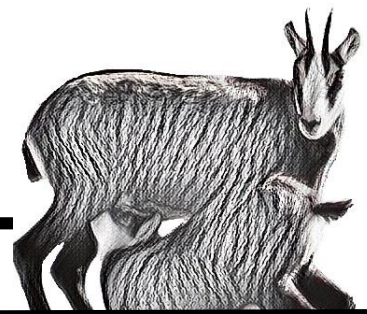
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00 | Plenary speech



Climatic changes, competition and the Dunning-Kruger Effect

Lovari, S.

U.R. Ecologia comportamentale, Etologia e Gestione della fauna, Dipartimento di Scienze della Vita, Università di Siena, Via P.A. Mattioli 4 - 53100 Siena, Italy, e-mail: sandro.lovari@gmail.com

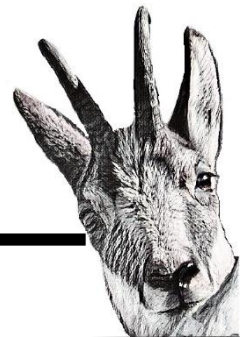
Keywords: Apennine chamois, behavioural plasticity, Dunning-Kruger Effect, global warming

In psychology, the Dunning-Kruger Effect describes a cognitive bias where someone overestimates his/her ability to work through and solve a problem. Disentangling the effects of climatic changes on the survival of mountain ungulates is a tricky multifaceted process which may elicit the D-K Effect.

We tested the effect of the D-K Effect in our study area in the Central Apennines, in the historical core area of the distribution range of the Apennine chamois *Rupicapra pyrenaica ornata*, a “Vulnerable” sub-species of the Southern chamois.

On 2007, after noticing a strong (c. 50%) decrease of chamois and a corresponding increase of red deer, we assumed that the latter might have determined a negative impact on the former through resource competition. This view was reinforced later on by documenting the effects of deer trampling and grazing on patches of the richest plant association used by female chamois and their kids during the warm season. We selected two areas with deer and a deer-free one, all inhabited by chamois. We recorded a number of negative parameters affecting feeding and social activities of chamois in the areas with deer presence, but not in the deer-free area. We could show that kids suffered a significantly greater winter mortality in the sites with deer than in the deer-free area. Our provisional conclusion was that deer were depleting the food resources of chamois, thus outcompeting them. However, we also assessed that over the last five decades, in the Central Apennines, an increase of temperature (2 °C) has anticipated the onset of green-up in montane grasslands (c. 1700–2000 m asl) by nearly 1 month, thus mismatching the weaning of kids with the availability of best food resources in summer. A mountain ungulate may survive the new conditions either by adapting through behavioural plasticity or by shifting its range to higher elevations, if available. When neither compensatory mechanism occurs, the effect of increasing temperature could be detrimental. Climate change will determine different responses in populations of mountain ungulates in relation to their specific ecological requirements. Nevertheless, one should expect not only range shifts—where possible—but also local decreases and extinctions. Our findings suggest that increasing spring temperatures will reduce the availability of snowbed vegetation, including the best food resources for Apennine chamois, in turn leading to negative demographic consequences. The use of grassland by a competing species, such as red deer, is an important additive factor accelerating the depletion of resources for chamois.

01 | Physiology & Disease



Chairman: Emmanuel Serrano

News on chamois diseases and parasites: a review of main contributions in recent years

Rossi, L. [keynote speaker]

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Keywords: chamois diseases, infectious kerato-conjunctivitis, pestivirus, scabies,

Literature search including peer-reviewed articles and all retrievable “grey literature” that appeared since the Chamois International Congress in 2014 suggest that Northern and Southern chamois health and parasites keep on raising the interest of veterinarians and biologists, often working in interdisciplinary teams.

Main contributions dealing with outbreak diseases with potential remarkable impact on demography (the so called “Big Four”) include the following:

Pestivirus (BDV-4): the timing and localization of the spill-over event (from an ovine reservoir) which prompted the BDV-4 epidemics in the Pyrenees, and a fine description of the subsequent spread of the novel chamois-adapted viral strain; the spontaneous extinction of the disease, after a few decades from its putative introduction in a large and intensively studied herd in the French Pyrenees; the experimental demonstration of the existence of low-virulence viral strains that may induce cross-protection in chamois against high-virulence strains, showing that viral strain diversity is a significant factor in shaping the extremely diverse epidemiological scenarios in Pyrenean chamois; the description, in a Northern chamois from the Alps, of a fatal case of a novel Border Disease virus genotype (BDV-8) previously reported in domestic goats;

Scabies by *Sarcoptes scabiei*: the fine description of the macro- and microscopic pathology and its interpretation with respect to the individual outcome of the disease, including a comparison with other affected wildlife in Europe; the identification of knowledge gaps for future pathology-oriented research; the molecular epidemiological evidence that the scabies outbreak in Cantabrian chamois (*R. pyrenaica parva*) originated from spill-over at the livestock/wildlife interface;

Infectious kerato-conjunctivitis by *Mycoplasma conjunctivae*: the evidence that *M. conjunctivae* is capable of long persistence in *Rupicapra* spp. and that severe outbreaks are associated with the emergence of new strain in a given area; the identification of major behaviour and landscape features shaping the spatial spread of the disease within and among chamois populations; the identification of independent domestic and sylvatic cycles of *M. conjunctivae* occurring at the livestock/wildlife interface in alpine ecosystems; the

detection of this pathogen in the eyes but also nasal passages and ear canals of healthy Southern chamois, suggesting a complementary role of the last anatomical sites in mycoplasma persistence;

Contagious pneumonias: the identification of two putative etiological agents of acute die-offs in Northern chamois (a *Mannheimia* and a novel Respirovirus, respectively), implying possible cross-transmission from livestock.

Finally, a few contributions shed light on the risk that ongoing climate change may modify the relationships between chamois and parasite or vector-borne diseases, to the detriment of sanitary status of chamois populations.

Update of Border Disease Virus monitoring in Pyrenean chamois of Aragon, 2011-2020

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Keywords: *Rupicapra p. pyrenaica*, sanitary and demographic monitoring, disease spread.

In 2001, an outbreak of a previously unreported disease in Pyrenean chamois *Rupicapra p. pyrenaica* was associated with Pestivirus D (formerly named Border Disease Virus-BDV) infection in the Eastern Pyrenees, Spain. Epidemiological and laboratory analysis confirmed the infection by a new Pestivirus D genotype, named BDV-4 strain.

In the following years, the disease spread to the West with unusual high mortality and in 2011, it was detected in the Aragon region. Signs include irregular alopecia, darkness skin with hyperkeratosis, uncompleted summer moult and cachexia. To identify the outbreak's aetiology, between 2011 and 2020 we examined 325 dead Pyrenean chamois in order to detect pestivirus antigen. Pestivirus was detected in 101 out of 315 chamois (32%). Total population numbers were between 13,117 (2011) and 11,693 (2020). Seven (41%) out of 17 monitored mountain ranges were affected. The outbreak lasted 2-4 years per massif, with isolated cases in three of them. During 2016-2020, no outbreak was confirmed, only isolated cases in three mountain ranges during one year each and where the infection was detected previously. Comparing annual counts before and during the outbreak of the affected mountain ranges, the decrease ranged 53-63%.

The disease shows different dispersal, persistence, detectability, and mortality patterns comparing mountain ranges. Necropsies represented a negligible part of the populations and ill or dead animals were difficult to find. Sighting ill animals was not easy to diagnose and late summer moult was confusing. Only combined demographic and sanitary monitoring allows describing its dynamics. Hunting was almost banned during the outbreak with less than 1% of hunting quota.

Gastrointestinal parasites of Alpine chamois (*Rupicapra rupicapra rupicapra*): coprology vs. intestine examination

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Keywords: Chamois, gastrointestinal parasites, coprology, intestine examination

Alpine chamois (*Rupicapra rupicapra rupicapra*) is autochthonous game species in Croatia, inhabiting mountain areas of Gorski Kotar, Velebit, Dinara and Biokovo, sharing its habitat partly with Balkan chamois (*Rupicapra rupicapra balcanica*). Since the health status of chamois in Croatia was rarely investigated, the aim of this study was to analyse gastrointestinal parasitic fauna. Complete digestive system of 20 chamois from Gorski Kotar and Velebit region in Croatia were collected. Faeces was analysed using standard coprological examination (ZnSO₄ flotation technique) while content of the intestine was washed through two sieves with different mesh size and collected parasites were morphologically identified. Intestine analysis revealed presence of 9 parasite species, including *Oesophagostomum venulosum* (P=45%), *Trichuris ovis* (P=35%), *Haemonchus contortus* (P=20%), *Chabertia ovina* (P=10%), *Moniezia* sp. (P=10%), *Ostertagia* sp. (P=5%), *Cooperia* sp. (P=5%) and *Nematodirus helvetianus* (P=5%). On the outer surface of forestomachs in 25% of animals we have detected *Cysticercus tenuicollis*, a developmental stage of *Taenia hydatigena*. Coprology revealed four parasite species including *Eimeria* sp. oocysts (P=50%), *Nematodirus helvetianus* (P=33.3%), *Capillaria* sp. and *Trichuris ovis* (P=5.6%, each). Beside them coprology also revealed the presence of strongylid eggs (38.9%) and lungworm larvae (P=66.7%). Obtained results indicated intestine examination as more reliable technique, however, as certain parasites were detected only by coprological analysis, and in order to achieve more accurate prevalence data we suggest combination of both methods. Our results are comparable with studies on Alpine chamois from Italy. Detection of *Cysticercus tenuicollis* requires further studies to reveal the origin of *Taenia hydatigena* eggs in the chamois environment.

Scabies (*Sarcoptes scabiei* var. *rupicaprae*) in Bavarian Chamois (*Rupicapra rupicapra*) Population: or why haven't Chamois in Bavaria Scabies?

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Keywords: wildlife disease, population density, game management

Scabies is the disease most likely to have the greatest impact on the development of the chamois population and is spreading throughout large areas of the Alps. In severe epidemics, up to 80 % of affected population can be lost due to the outbreak of scabies. Once affected by scabies chamois population don't get rid of this pest. One exception of this rule is the chamois population in Bavaria.

There, scabies was registered for the first time in the year 1824 among the chamois population of the Berchtesgaden region, and disappeared 6 years later. For the next 119 years, the chamois populations in the Bavarian Alps seemed not to be infected by scabies. But in 1949 scabies occurred again in the Bavarian chamois populations east of the River Inn, with origin in the Berchtesgaden region. Scabies has been recorded repeatedly since then. Whereas between 1949 and the early 1990s scabies had a great impact on the development of the chamois populations in the Bavarian Alps east of the river Inn, the disease has had little significance since 1995.

As it is assumed that there is a link between high population density and the occurrence of scabies among chamois, hunting bags were compared with the recorded scabies cases among chamois populations in the Bavarian state forests east of the river Inn. Data collected from the Berchtesgaden Forest Office were further analysed according to age and sex parameters.

There is a highly significant, inverse, non-parametric correlation between recorded incidences of scabies and hunting bags. The results of the analysis show that bucks were slightly more likely to be registered than does ($p=0.018$). Yearlings and juveniles played only a secondary role in terms of scabies prevalence. Both the historical background of scabies in Bavaria and the presented data support the above-mentioned hypothesis that the incidence of scabies in chamois is related to high chamois population densities and related low condition of the single animals. The spread of scabies and its importance to chamois populations can therefore be slowed down or prevented by increasing game bags over a large area.

First report of zoonotic *Anaplasma phagocytophilum* in Alpine chamois in Julian Prealps, Italy

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Keywords: chamois ticks, *Rupicapra rupicapra*, zoonotic parasites

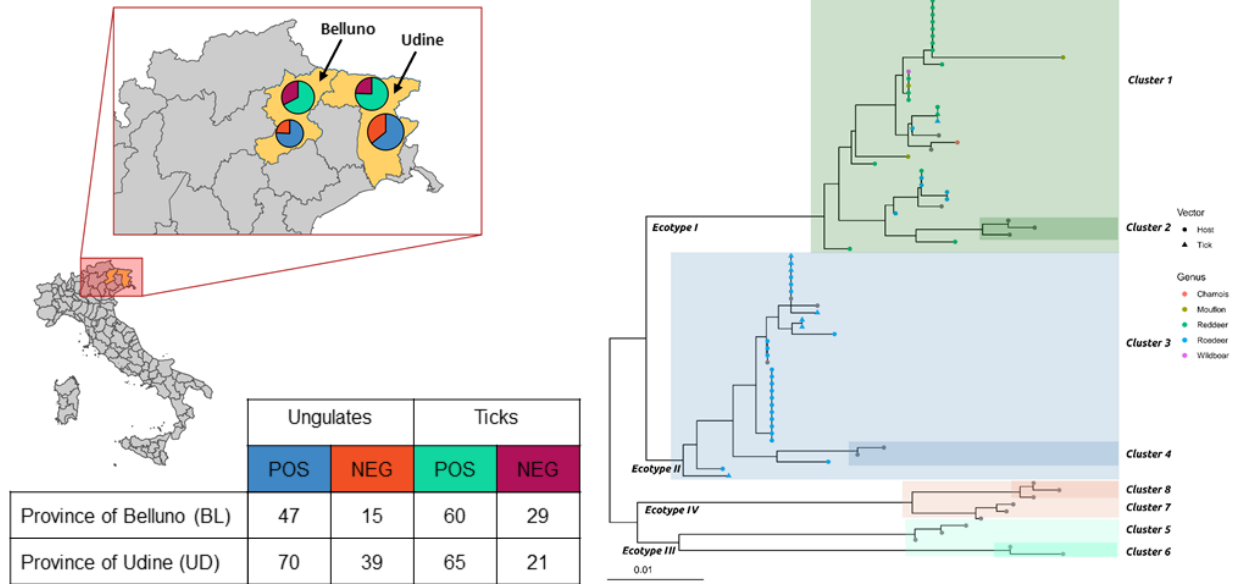
Tick-borne diseases have been reported worldwide and represent a serious risk both for animal and human health. Ticks may transmit different bacterial species of the order Rickettsiales, such as *Anaplasma phagocytophilum*, which is the causal agent of anaplasmosis in ruminants, domestic animals and humans. In Europe, *A. phagocytophilum* has been reported at high prevalence both in *Ixodes ricinus* ticks and in reservoir species as wild ungulates. In contrast, the ecoepidemiology of *A. phagocytophilum* variants is not well-understood. Four ecotypes are currently circulating in Europe and, among them, only ecotype I has shown zoonotic potential.

We addressed this gap by investigating *A. phagocytophilum* prevalence and the circulation of different strains in wild ungulates and associated ticks. This research was carried out in alpine and hilly areas of North-Eastern Italy. We collected blood samples and related ectoparasites from wild ungulates at culling. All samples were tested by real-time PCR targeting the *msp2* gene. Then, *groEL* gene was amplified and sequenced by PCR to perform phylogenetic analysis.

A total of 171 wild ungulate and 175 pooled tick samples were analysed revealing *A. phagocytophilum* prevalence of 68,4% and 71,4%, respectively. A relevant difference in prevalence emerged between wild boar (n=41; 4,9%) and other ungulates as chamois (n=9; 77,8%), mouflon (n=8; 75%), red deer (n=39; 87,7%) and roe deer (n=74; 91,9%) suggesting their different role in *A. phagocytophilum* epidemiology. Moreover, the phylogenetic analysis demonstrated the presence of ecotype I in all wild ungulates sampled species, while ecotype II was only found in roe deer and related ticks.

To date, this is the first report of zoonotic ecotype I in alpine chamois in Italy. This finding, associated with the high prevalence detected in chamois, highlights that this alpine species may not only be involved as an *A. phagocytophilum* reservoir, but it can also harbour zoonotic variants.

Pie charts (left-side) show positive (blue and green) and negative (orange and red) results of screened ungulates and ticks (table below), divided in the two investigated provinces. Maximum likelihood phylogenetic tree* (right-side) based on the *groEL* gene sequences obtained from ungulates (dots) and ticks (triangles); species of origin are color-coded.



*Phylogenetic tree image from Grassi et al., 2021 (Grassi, L.; Franzo, G.; Martini, M.; Mondin, A.; Cassini, R.; Drigo, M.; Pasotto, D.; Vidarin, E.; Menandro, M.L. Ecotyping of *Anaplasma phagocytophilum* From Wild Ungulates and Ticks Shows Circulation of Zoonotic Strains in Northeastern Italy. *Animals* 2021, 11, 310. <https://doi.org/10.3390/ani11020310>).

Severe case of contagious ecthyma in a Balkan Chamois (*Rupicapra rupicapra balcanica*)

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Keywords: contagious ecthyma, Orf virus, zoonosis, Balkan chamois

Contagious Ecthyma is a zoonotic dermatitis caused by the Orf virus of the family Poxviridae. The disease provokes characteristic scabby lesions most frequently found on the mouth and lips, and sometimes but less often on the legs and udder. Morbidity can reach up to 100%, however in the absence of secondary infections lethality is rather low. In this paper we present severe contagious ecthyma in a male Balkan chamois, estimated to be 8 years old. The animal was found dead at the Biokovo Nature Park and transported to the Veterinary Faculty in Zagreb. Dominant gross lesions were scabby formations on the labial and muzzle areas, dental pad, gums, hard palate and tongue. Other organs appeared to be normal. The animal was in poor body condition and advanced autolysis was present. Histological analysis revealed hyperplasia of the epidermis and epithelium of affected areas. The epidermis was mildly eroded and replaced by a thick serocellular crust composed of keratin, proteinaceous fluid, degenerate neutrophils and foreign debris in addition to multifocal parakeratotic hyperkeratosis. Multifocally, epithelial cells contained one or more 2-10 µm intracytoplasmic viral inclusions. The location of the lesions most likely prevented this animal from feeding normally, which led to emaciation and death. To the authors knowledge, this is the first reported case of contagious ecthyma in a Balkan chamois. However, since the majority of infections pass unnoticed due to low mortality and the disease's self-limiting characteristics, one can assume that the virus was probably present in this area prior to our report. The virus can be spread after animals share pastures with infected domestic sheep, or it can be maintained in the wild due to extreme environmental resistance accompanied by potential circulation among the wild chamois population. As a result, the source of infection for this animal still remains unknown.

New data about parasitological status of Balkan Chamois at three mountains in Bulgaria

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Keywords: Balkan chamois, chamois parasites, parasitic infections

The present study aims to obtain new data concerning the prevalence of some helminth and protozoan infections in Balkan Chamois (*Rupicapra rupicapra balcanica*), originating from seven trial areas in Rila, Pirin and Rhodopi mountains, Bulgaria. A total of 275 fecal samples were collected during the period from April to October 2020 year and were processed by flotation technique using saturated sodium chloride (sp. gr. 1.20), routine sedimentation method, Baermann's method and larval cultivation. Eggs or larvae of the parasites belonging to several taxonomic groups were revealed: Phylum Nematoda, represented by eight families such as Trichostrongylidae (*Teladorsagia* spp., *Haemonchus* spp., *Trichostrongylus* spp.), Chabertiidae (*Chabertia* spp., *Oesophagostomum* spp.), Molineidae (*Nematodirus* spp.), Trichuridae (*Trichuris* spp.), Oxyuridae (*Scrjabinema* spp.), Strongyloidae (*Strongyloides* spp.), Gongylonematidae (*Gongylonema* spp.) and Protostrongylidae (*Muellerius* spp., *Neostrongylus* spp., *Cystocaulus* spp., *Protostrongylus* spp.). Phylum Platyhelminthes was represented by *Fasciola hepatica*, *Dicrocoelium dendricum* (Class Trematoda) and *Moniezia* spp. (Class Cestoda, family Anoplocephalidae). The protozoa were represented only by *Eimeria* spp. Research on parasitological status of Balkan Chamois such a wide range is carried out for the first time in Bulgaria.

Tick infestation of Balkan chamois (*Rupicapra rupicapra balcanica*) from the area of Biokovo mountain in the Republic of Croatia

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Keywords: Balkan chamois, ticks, Biokovo, Republic of Croatia

Studies on the tick infestation of Balkan chamois (*Rupicapra rupicapra balcanica*) have not been conducted in the Republic of Croatia thus the aim of the study was to identify tick species from Balkan chamois in the Biokovo area. Sampling was performed during chamois hunting season at altitudes around 1100 meters. In total, ticks were present on 20 (62.5%) out of 32 animals examined after hunting. After morphological determination, ticks were subjected to genetic characterisation. After the PCR, a section of the 16S rRNA gene and COX 1 segment were sequenced. Six different tick species from 68 collected have been detected, of which the species *Ixodes gibbosus* (36.76%) was the predominant one followed by *Rhipicephalus bursa* (19.11%), *Ixodes hexagonus* (16.17%), *Ixodes ricinus* (13.23%), *Haemaphysalis punctata* (10.29%), and *Dermacentor marginatus* (4.41%). Adult ticks *H. punctata* and *D. marginatus* were recorded, adults and nymphs of *I. ricinus* and *I. hexagonus*, and only *R. bursa* nymphs. All developmental stages were recorded from *I. gibbosus*. The highest number of ticks including *I. ricinus*, *H. punctata* and *I. gibbosus* were collected in October while *I. hexagonus* was detected only in November. *D. marginatus* was mostly in January and *R. bursa* only in October. *I. ricinus* was commonly found attached in the neck area while *H. punctata* in the loin area. *I. gibbosus* and *I. hexagonus* were mostly attached on the head. *D. marginatus* was recorded only on the abdomen, and the species *R. bursa* only on the head (ears). The highest infestation rate on a single animal was 22 ticks of two species *I. gibbosus* (17) and *R. bursa* (5) while the largest number of tick species on a single animal was three including *I. ricinus*, *I. gibbosus*, and *H. punctata*. Further studies are needed to assess the impact of ticks and pathogens they can transmit to health status of chamois.

Results of a restocking project and influence of sarcoptic mange on Prealpi Giulie Regional Park chamois population (NE ITALY)

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Keywords: Alpine chamois, chamois disease, chamois mortality, Prealpi Giulie Regional Park

Before the establishment of the Prealpi Giulie Regional Park in 1996, chamois populations in Northeast Italy were highly endangered due to many years of over-hunting and poaching.

Between 1998 and 1999, the newly instituted Regional Park together with some hunting districts, carried out one of the largest restocking projects in the Alpine area (Genero F., 1997). 55 chamois from the Alpi Marittime Regional Park (Cuneo, Italy) were released within the protected area. While all of them were ear tagged, 25 were equipped with radio tracking devices. 75% of the animals remained within the Park boundaries and this led to an unexpected increase in their numbers. After 14 years, the park's chamois population had grown to a total of 600 individuals. From 2012 to 2015 the population was affected by a sarcoptic mange epidemic, which had spread to the Park area from the east (Slovenia). The impact of the disease was not as bad as expected: a 30% mortality was recorded over a period of 4 years. On the other hand, the Ibex population living in the same area was strongly affected and more than 75% of the colony's animals perished. It can therefore be concluded that the chamois population in the Julian Prealps has shown a strong resistance to sarcoptic mange. Currently (2020), censuses results confirm that the population is healthy and has perfectly recovered the numeral consistency it had reached before the epidemic outbreak.

Severity of infections of Tatra chamois by lungworms (*Muellerius capillaris*)

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Keywords: *Rupicapra r. tatrica*, *Muellerius capillaris*, lung nematodes

Muellerius capillaris is the most common lung parasite in Europe. Occurs in small domestic ruminants (sheep and goat) and wild ruminants: many deer species as well as chamois. This parasite requires snails as intermediate hosts. The lesions are typically localized in the dorsal areas of the caudal lung lobes. Invasion result varies in signs from almost no signs to a pneumonia. The aim of the study was to estimate prevalence and infestation of the chamois lungs by *Muellerius capillaris*. Lungs samples were collected from 26 chamois found dead in Polish Tatra National Park and Slovak Tatra National Park. All examined animals were found death during winter/spring season (1st December- 31st April). The lungs were stored frozen until examination. Severity of infection was estimated using morphological examination of lungs and numbers of *Muellerius* larvae (L1) in three lung lobes/parts: cranial, middle and caudal. Lung samples were weighed, homogenized and examined at 100 magnification. Results were expressed as the number of larvae per gram lung tissue. Identification of parasite based on morphology of larvae. In all cases of chamois lungs, the observed macroscopic lesions included multiple subpleural 3 – 12 mm nodules as well as diffuse interstitial lesions, mainly localized in the diaphragmatic lobes mainly on the dorsal side. Prevalence of L1-positive feces in examined animals was 100%. Mean number of L1 was 167.6, 310, 2384 parasite/g of cranial, middle and caudal lung tissue respectively. Study shown that prevalence and infestation of *M. capillaris* is very high in Tatra chamois population. Moreover, the amount of lung tissue rendered inactive in heavy infections was considerable. Results of our study indicated that invasion of *M. capillaris* should be monitored as an potential factor, which could have influence on population of Tatra chamois.

Multiorgan injuries in Tatra chamois; following fall from height and in avalanches

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Keywords: *Rupicapra r. tatrica*, injuries, mortality, fall, avalanches

Injuries from fall from height are well known and described in human medicine. However, in veterinary medicine, such reports are rare. The aim of this study was to present the characteristic of multiorgan injuries do to the fall from height or in avalanche. We described cases of multiorgan injuries of Tatra chamois *Rupicapra rupicapra tatrica* which died as a result of fall from height or in avalanches over the 10 years (2010-2019). The fall took a place from a height of about 150 m or more. The material consisted 12 specimens of Tatra chamois. Animals were subjected to X-ray examination and then necropsy. All examined animals were in good condition. The chamois showed different spine fracture, mainly of the thoracic vertebrae, paravertebral rib fractures with ruptures of the intercostals muscles and tearing off the end of the distal ends of ribs with penetration of the thoracic cavity. In 7 cases there was diaphragms rupture with displacement of forestomach (4 cases) or intestine (2 animals) into thoracic cavity. Fractures of the limbs were presented in 5 cases. There were numerous hematomas in the organs, and ruptures of heart, liver, kidneys and lungs with emphysema. There was no fractures in the skull (except horns). The direct cause of death in all animals were multiorgan injuries as a result of fall from height or in avalanche.

Gastrointestinal parasites of Balkan Chamois (*Rupicapra rupicapra balcanica*) in Mount Timfi

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Keywords: Balkan Chamois, Gastrointestinal parasites, Mc-master test, Mount Timfi

The Balkan Chamois (*Rupicapra rupicapra balcanica*) is one of the seven subspecies of the *Rupicapra* genus. The total population size of Balkan Chamois in Greece is estimated between 1180 and 1605 individuals. The aim of this study was to determine the prevalence of gastrointestinal parasites of Balkan Chamois using quantitative fecal examination. To the best of our knowledge, a similar study has not been conducted before in Greece.

The study area is located in Timfi Mt at the northwestern part of the Pindus mountain range in Greece, covering 25,896 ha. It is a mountainous area within an elevation range between 412 m and 2497m. Mount Timfi hosts the largest Chamois population in Greece.

A total of 66 fecal samples were collected between May and August (2020) from various locations throughout the mountain. The samples were examined within a few hours after collection and when this was not possible, they were refrigerated. Sample analysis was conducted using the Modified McMaster test on 2 g of feces suspended in 28 ml of flotation solution (NaCl, SPG 1.2). Enumeration of parasites was conducted with an optical microscope using McMaster slides.

The most common parasite detected was *Eimeria* sp. The *Eimeria* oocysts were found in 98,5% of the samples tested (AVG=7.432 OPG). Eggs of Trichostrongylidae were detected in 73.8% of the samples (AVG=285 EPG), *Moniezia* sp in 12,1% (AVG=20 EPG), and those of *Nematodirus* sp in 6% (AVG=3 EPG). None of the samples was positive for *Trichuris* sp.

The parasitological examination that was conducted indicates that the Balkan Chamois population of Mount Timfi is exposed rather heavily to parasites, which implies heavy parasitic load of the local ranges and/or high level of transmission between individuals. The results of this study indicate that measures should be taken to decrease the parasitic load both of animals and ranges.

02 | Management & Conservation



Chairman: Juan Herrero

Management and conservation of chamois (*Rupicapra* spp.). So far so good, but what is around the corner?

Festa-Bianchet, M. [keynote speaker]

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Keywords: harvest management, *Rupicapra*, chamois monitoring

Globally, chamois are doing better today than 50 years ago. Numbers, range and harvest have all increased, although some local populations have declined. What is in store for the next 50 years? Climate change appears as an increasing threat, but its effects are complex, may vary according to local environment, and are still poorly understood. Land use changes may have both positive and negative effects. Conservation of distinct populations and subspecies may become increasingly problematic as ranges expand and extralimital releases affect genetic distinctiveness. Increasing numbers and range of large predators and new competitors may pose additional ecological and, especially, societal challenges. Harvest management that accounts for ecology, evolution and changing societal influences will continue to be challenging. Reliance on science, cooperation with social scientists, and continued long-term monitoring will be required to ensure the continuation of this success story.

Random encounter model to estimate density of Balkan chamois

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Keywords: camera trapping, mountain ungulates, REM, *rupicapra balcanica*, ungulate density

Reliable estimation of wildlife density and population size is the crucial basis for the successful implementation of wildlife management and conservation. As a non-invasive and easily affordable tool, camera traps are commonly used to monitor wildlife. However, estimating population density using camera traps is challenging, but several methods conducted on individually recognizable species have shown good performance, such as spatial capture-recapture and mark-resight. Conversely, methods for estimating population densities of unmarked species using camera traps are still developing. One of these methods is called "Random Encounter Model (REM)" and, to our knowledge, has never been used to estimate densities of mountain-dwelling ungulates. In this study, we tested the REM to estimate the density of Balkan chamois (*Rupicapra r. balcanica*) in a Mediterranean habitat, Mountain Biokovo. We proportionally placed 25 camera traps throughout the known range of the population distribution (ca. 55 km²) at the intersections of 2-km grid cells to meet the assumptions of REM. Prior to data collection, population density was estimated by visual counts on sample plots in August 2020. Cameras were operational between July 2020 and September 2020 and active throughout the 24-hour period. We obtained 279 independent events of chamois from 2503 camera trap days. Other variables required to calculate density were speed (1.62 ± 0.21 km/day), detection distance (5.56 ± 0.20 m) and detection angle ($1.16 + 0.05$ radians). The density estimate obtained by REM resulted to be 20.65 ± 5.27 ind/km², slightly higher but not significantly different (Wald test, $p = 0.61$) than the reference value: 17.33 ± 3.64 ind/km². The CV value of 0.25 obtained by REM was satisfactory, considering low number of trap-sights. Therefore, REM has shown comparable results to visual counts and may have potential for estimating density of mountain ungulates, especially in mountainous areas with dense vegetation cover where other approaches are inadequate.

Estimate the population of chamois (*Rupicapra r. rupicapra*) on the Italian Alpine arc (2009 – 2014)

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Keywords: Chamois, Italian Alpine arc, population estimate

The Ungulates Commission UNCZA (Unione Nazionale Cacciatori Zona Alpi) on March 2012 started a survey whose object was to estimate the population of chamois (*Rupicapra r. rupicapra*) of the Italian Alpine arc.

The survey has been carried out within the 24 provinces of the Italian Alpine arc from 2009 to 2014. The study area has been divided into three alpine macro-regions (western, central and eastern). Data concerning the estimate of the chamois population have been gathered (official census) and concerning the number of the animals culled. The data gathering and processing have been done using the Excel sheet.

As for the chamois's demographic picture, an increase of the animals has been recorded, from 119,042 (year 2009) to 124,847 (year 2014) with a 4,8% increase. The cull of chamois has recorded an annual average of 12,924 culled animals (10,51%). Compared to the three Alpine macro-regions, the estimated population increased from 32,632 individuals (2009) to 38,463 (2014) with a 17,9% increase and an annual average of the animals culled of 3,103 individuals. In the central area there has been an increase from 15,520 individuals (2009) to 18,343 individuals (2014) with an 18,1% increase and an annual average the animals culled of 1,344 individuals. There has been a 4% decrease from 70,884 (2009) to 68,041 (2014) with an annual average the animals culled of 8,477 individuals in the eastern area.

The demographic picture points out a stable presence of the chamois on the Italian Alpine Arc. Two regions (Piemonte and Trentino Alto Adige) constitute over 60% of the entire population of the study area. The data concerning the animals culled are uniform and coherent with the reference literature. It's desirable, at a methodological level, a computerisation of the national data bank to be able to update it and be able to examine it quickly to improve the fauna conservation policies.

Fig. 1

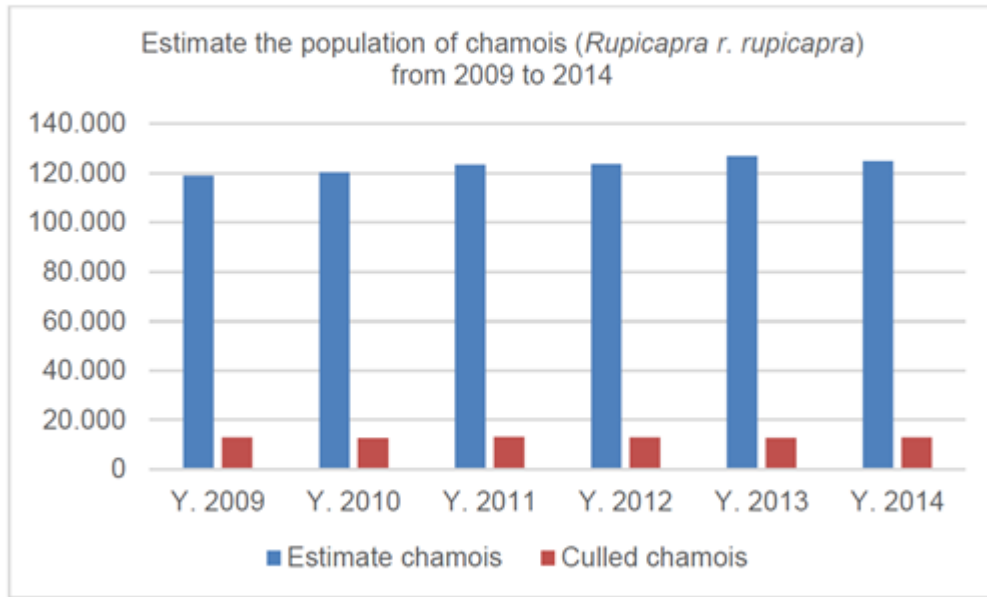


Fig. 1. Estimate the population of chamois (*Rupicapra r. rupicapra*) from 2009 to 2014

More than just count data: estimating chamois density and distribution using spatial capture-recapture modelling

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Keywords: population density, density gradients, genotyping, sex-ratio, wildlife management

Estimating population size and determining which factors contribute to density gradients are key ecological questions and essential for management, yet challenging to quantify. At the edge of their distribution range, alpine chamois (*Rupicapra rupicapra rupicapra*) are facing heterogeneous habitat conditions which ultimately affect local population densities. We estimated and compared density for chamois in two study areas of the Bavarian Alps which differ in their habitat composition and the intensity of human land use. We used a spatial capture-recapture analysis (SCR) based on systematic faeces collection and genotyping. In our model, we accounted for variation in sampling effort as well as sex-specific differences in detectability and space use. To test for the effect of habitat composition on local densities, we included different covariates (e.g., elevation, canopy cover). Estimated chamois densities ranged from 3 up to 19 individuals per 100ha and chamois density increased with elevation. However, we observed a high amount of variation in densities within and between the study areas and sexes. Male and female chamois densities differed along elevation gradients and habitat openness. For example, higher male densities were observed in intermediate elevations whereas female densities tended to increase in areas above the tree line. Our results indicate that the availability of typical alpine habitat components (high elevation, rocks, steep terrain) is a strong determinant for local densities in our study areas. We discuss how potential constraints in space use caused by anthropogenic factors and interspecific interactions could further explain the observed spatial variation in density. Gaining a better understanding of the relationship between habitat and chamois densities is crucial for sustainable management of this species. SCR, combined with non-invasive genetic sampling, not only provides accurate estimates of population size, but also allows testing for variation in density.

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

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Keywords: count data, hunting bag, sex ratio

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 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. The example of the Oberallgäu region shows that for a discussion to be neutral and objective, two independent data sets are necessary.

Monitoring of the Balkan chamois in Frakto Forest in the Rodopi Mountain-Range National Park (RMNP). A collaboration of a management body, expert scientists and an environmental NGO

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Keywords: chamois, conservation, monitoring, population, demography

The Management Body of the Rodopi Mountain-Range National Park in collaboration with expert scientists, implemented in 2014-2015, the monitoring of the Balkan Chamois (*Rupicapra rupicapra balcanica*) in the RMNP. During the period 2016-2018, the BC continued to be monitored, with emphasis in the Frakto Forest area, with the collaboration of the Management Body and the environmental NGO “Balkan Chamois Society”. The objectives of the monitoring were to record the population status of the species and its demography along with the evaluation of the main threats and pressures that affect the BC population. Predefined line-transects and observation from vantage points were conducted systematically the years 2015, 2016 and 2017. Additionally, records of tracks and droppings and audiovisual material from trail-cameras were used. At the autumn 2015 and 2016 surveys, a minimum of 135 and 153 individuals were counted, whereas in 2016 the population was consisted from 33% males, 36% females, 7% yearlings and 24% kids. At the July 2017 survey, a birth rate of 0,37 was estimated, that is 40 newborns of the total estimated population (n=148). The major threat to chamois survival in RMNP is considered to be poaching. At least four incidents with poachers, three from the neighbor country, Bulgaria, with stripe rifles and other guns were recorded. The results of the BC monitoring is proving the positive impact that a collaboration of a MB and an environmental NGO expert in wildlife management, can have.

Chamois Management in Central Serbia with Special Reference to the Tara National Park

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Keywords: *Rupicapra rupicapra*, reintroduction, population, trophy

This paper presents the status and management of chamois in the region of Central Serbia (cc 56,000 km²) from 2011-2019. Although suitable habitats for this autochthonous species exist across Serbia, specific habitat requirements coupled with poaching and overexploitation in the past reduced both its range and population density. According to the data of the statistical survey on hunting (Form LOV-11, municipal level, www.stat.gov.rs), as well as the database of the Forest Directorate (hunting ground level), a synthetic chamois distribution map was prepared which showed a positive population trend over the study period (2011 - 520 ind., 2019 - 725 ind.). Spontaneous migrations from existing population centers (in the Đerdap National Park and Lazarev Gorge protected area) to new habitats in eastern Serbia, as well as an implemented project of reintroduction on Mt. Stolovi (Municipality of Kraljevo) were mainly responsible for this trend. In the hunting year 2019/20, 68 individuals were planned for culling, of which 70.6% in the "Tara National Park", and the rest in the eastern part of central Serbia ("Zlatske šume - Crni vrh" managed by PE "Srbijašume" - 26.5%; "Orlovica" managed by the hunting association from Despotovac - 2.9%). The population of chamois in the "Tara National Park" (western part of central Serbia) is especially important for the status of the species. This special purpose hunting ground has a unique natural population, recently (spring 2019) estimated at 380 individuals. From 2011-2019, 198 chamois were culled in this hunting ground (N♂ = 105; N♀ = 93). Their age ranged from 1 to 15 years (mean = 6.6), while trophy values ranged from 21.4 to 103.8 CIC points (mean = 84.4). In order to improve the current population status in Serbia, competent state authorities are planning a series of reintroduction projects in several localities with developed reintroduction baseline plans, primarily in western and southeastern Serbia.

Chamois management considering important species and habitats in Natura2000 site Biokovo and Rilić

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Keywords: chamois, management, golden eagle, lead poisoning, Natura2000

Appropriate species management in Natura2000 sites can be challenging because different important species can have different response on the same activity. The very same activity that improves one species status can also push other species status downhill. In Natura2000 sites, where those statuses are clearly defined and are part of the legal obligation, all actions that are negatively effecting the important species are thus considered illegal. Such potential conflicts in the Natura2000 sites HR5000030 Biokovo and HR1000030 Biokovo and Rilić were checked for all the important habitats and species. Both scenarios, chamois considered a game animal or strictly protected species (implemented for *spp. balcanica* in the native range) were considered. Chamois is medium sized non-specialized herbivore living in small densities in the areas with natural predators and the pronounced direct negative effect on any species in such circumstances is rare. Management of the important species and habitats in both the Natura2000 sites promotes open and/or mosaic habitats what also benefits the chamois. The habitats management for a majority of the important bird species especially benefits the chamois as it directly increases grazing possibilities and decreases predation because of less scrubland cover. Several potential conflicts were registered, the most pronounced being lead poisoning of Golden Eagles but also already challenging management of the local wolf population that suffers because of gene pollution.

The National Action Plan for Balkan Chamois in Greece. A step forward for the subspecies prosperity

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Keywords: Action Plan, Balkan chamois, *balcanica*, conservation

Balkan Chamois (*Rupicapra rupicapra balcanica*) in Greece has a scattered and fragmented distribution, with a population size around 1500 individuals. Hellenic Ministry of Environment accomplished during 2018-2020 a study regarding the National Action Plan for BC in the framework of the LIFE-IP Project "Integrated Actions for Conservation and Management of Natura 2000 Network Areas, Species, Habitats and Ecosystems in Greece (LIFE16 IPE/GR/000002).

The purpose of NAP is to contribute towards ensuring the survival of the BC by improving the species' Conservation Status at a national level, turning its current 'U2- I' status into 'U1- I'.

The major threat for the BC survival is poaching, followed by the construction and use of roads, livestock breeding under certain conditions, population fragmentation and genetic isolation, disturbance due to hunting, tourism and mountain sports, mineral extraction and climate change, whereas populations on the border with neighboring countries are adversely affected by interventions from other countries.

Its main objectives involve the implementation of those measures that would safeguard and enhance the population size and the geographical distribution of the BC, at local and national level. Specific objectives concern the BC population, its habitat characteristics, its distribution and range, its critical zones and ensuring the connectivity between isolated populations.

A series of actions are proposed which are grouped into seven sets of Measures: Population Conservation & Improvement, Conservation and Improvement of Habitat Status, Preservation/ Extension of Geographical Distribution and Reduction of Fragmentation, Institutional Framework (Legislation and Policy), Monitoring and Research, Public awareness and environmental education, International cooperation.

The implementation of the NAP is expected to culminate in a significant reduction on the intention of the current pressures on the species, bringing along a 40% population increase (with a 6% annual increase), a 10% increase in its geographical distribution and a reduction of the current fragmentation levels.

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

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Keywords: Monitoring, Census, Rupicapra, Oberallgaeu, Bavaria

Monitoring of the European chamois (*Rupicapra rupicapra*) is compulsory for states which hunt this species. In Bavaria usually game harvest statistics are used for this purpose. This is 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 system of the living chamois population. 18 chamois habitats were defined, considering natural structures like massifs and known chamois trails. Each habitat unit is assigned a coordinator, organising the systematic count of chamois. 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 estimate of the percentage observers think the animals seen are, in relation to the animals assumed in the habitat unit. In that way, personal experience about the area is integrated. This is mostly important for areas with high forest coverage. The census is done between September and October. Five groups are recorded: “buck”, “doe”, “yearling”, “fawn” and “unknown”. This new approach to chamois monitoring indicates, that the population of about 3.000 chamois in the Oberallgaeu mountains is fairly stable since 2014, the first year of data.

This method gives information not only on population size, but also sex ratio as well as reproductive performance and long-term development of the population. It allows, to bring the discussion about the state of preservation of the Oberallgaeu chamois population to an objective level. The experience so far shows that this method of monitoring can be used in other areas that have not yet a good and practical monitoring of chamois in place.

How many are they? Uncertainties in the wildlife management of alpine chamois (*Rupicapra r. rupicapra*)

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Keywords: Chamois, Alps, block census, accuracy

Block census is the method most commonly used for monitoring chamois populations. However, the biology of the species and the necessity of a large number of field operators make its practical application sometimes challenging. For these reasons, a study was carried out to investigate whether it was possible to reduce the census sampling effort, without losing the quality and representativeness of the estimates.

Through the analysis of census data from the alpine hunting district C.A.CN2 "Valle Varaita" in the period 2004-2018, the aims of the study were: i) to evaluate if a census conducted on representative sample areas, with trained observer groups, is as accurate as a census carried out on the whole species range, ii) to assess whether the estimated population parameters from the census operations are in the normal range defined for the species and, iii) to evaluate the effectiveness of observers in covering the sample areas assigned.

Despite some critical issues related to the method applied, to climatic conditions and to the establishment of a protection area, within the study period, that has reduced the hunting territory, the analyzes confirmed i) a good correlation of the values observed in the sample areas with the rest of the species range in the alpine district and ii) the effectiveness of the observers in covering the sample areas assigned. However, some important issues were highlighted by the comparison between the estimated population parameters from the census operation and those described for the species. Our results confirm the possibility of limiting the monitoring of alpine chamois within sample areas without losing in estimation accuracy.

Current Status and Management of Chamois in the Alpine Range

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Keywords: Alpine chamois, EU Bird and Habitat Directive, FFH-Status report, Monitoring, Management decisions

The framework conditions regarding the management of the Alpine chamois *Rupicapra rupicapra* in the affected EU member states and Switzerland were compared between the different countries. This included questions about the habitat, size and structure of the chamois populations, along with guidelines for harvest management including their consequences and implementation pertaining to the listing of the chamois in Annex V of the European Union (EU) Habitats Directive.

The responsibilities for planning, management, evaluation and reporting are regulated differently among countries in the range of the Alpine chamois. A basic prerequisite for achieving sustainable harvest management in accordance with the Habitats Directive status of the Alpine chamois is a viable monitoring system. It would be sufficient to carry out censuses on a random basis (mark-recapture of certain individuals) or on specific areas (reference areas). However, in any case it is necessary to achieve long-term data sets based on a consistent sampling protocol. Existing monitoring approaches must be extended in order to map population trends in more densely wooded habitat areas. In contrast to other areas along the Alpine range, Austria and Germany, have no management structures for meaningful and obligatory monitoring developed and implemented. This can lead to a harvest management not in accordance with the requirements of the Habitats Directive.

In all cases it is advisable to always use a balanced and participatory approach to harvest planning and when deciding on management strategies that affect the Alpine chamois in its range.

Chamois on Velebit, 50 years after reintroduction

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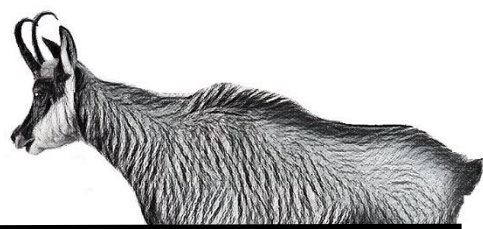
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Keywords: Chamois, Velebit, population dynamics, reintroduction

Counting game is an important part of long-term monitoring and determining the population dynamics with the objective of conservation and management. The aim of this paper was to show the state of population in Velebit area fifty years after reintroduction. The trends of population within the protected parts of Velebit were compared with population trends of the rest of Velebit where chamois is hunted game. Data on the counted numbers were taken from the central hunting records, hunting news, management plans for national parks, nature parks, registered mortality. Based on data, the density and certain multi-year trends within microlocations were calculated. It has been established that the chamois on Velebit, after reintroduction procedures in the 1970s, shows constant progress in population. The increase in the number is also supported by the expansion of population and the appearance in localities where it did not exist in the past. The analysis of microlocations shows that the increase in numbers is highest in the southern part of Velebit, within the protected part of Paklenica National Park. A weaker increase in numbers is present within the second protected part of Northern Velebit National Park, and the regression model of the development of this protected part follows the trend of chamois population in the hunting grounds of Velebit. The reasons may be different, although the habitat area of Paklenica National Park where the increase in numbers is highest does not differ significantly from the rest of the coastal slopes of Velebit. Abundance is affected by natural mortality, predator mortality and hunting. It can be assumed that the impact of predators throughout Velebit is seasonally the same as natural mortality, the conclusion remains that hunting mortality is a limiting reason for a slightly weaker increase in the number of Velebit compared to Paklenica National Park.

03 | Genetics & Systematics



Chairwoman: Sabine Hammer

Molecular data advance understanding of chamois evolutionary history, conservation, and management

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Keywords: molecular markers, *Rupicapra*, phylogeography, conservation, management

The evolutionary background of the genus *Rupicapra* is complex and still unclear, although scientists have been trying to clarify the phylogeography and taxonomy of the genus by using molecular data for nearly three decades. However, in spite of several hypotheses that have been proposed, rejected, and/or re-evaluated, no agreement has yet been reached on the monophyly or polyphyly of chamois or on the number of (sub)species in this genus.

Morphological and behavioural data had recognised two chamois species, i.e. *Rupicapra rupicapra* and *Rupicapra pyrenaica*, which are further divided into seven and three subspecies, respectively. But the picture became more complicated by molecular controversy concerning the subspecies subdivision based on morphological and behavioural traits/characters. While nuclear markers provided some support for this classification, mitochondrial DNA identified the nominal species as paraphyletic. Maternally inherited markers in chamois revealed a distinct substructuring of the maternal gene pool into regional mitochondrial DNA phylogroups with restricted gene flow between adjacent populations, suggesting a history of expansion and contraction during Pleistocene glacial-interglacial dynamics that led to the alternation of connection and isolation of populations. Such structuring was later confirmed by a combination of mitochondrial regions and differs from the pattern observed by nuclear markers (microsatellites, mitochondrial pseudogenes, and introns). Although revealing a similar division into geographically structured clades, this finding more closely resembles a subdivision of g. *Rupicapra* into subspecies based on morphological characters and highlights a complex population history strongly characterized by male-biased dispersal, as confirmed by Y chromosome lineages.

Past and present translocations of chamois for hunting purposes, either from different populations or even subspecies, have increased the risk of losing this unique differentiated gene pool. Majority of these actions have been carried out without prior knowledge on the taxonomic status of the individuals involved, introducing an additional confounding effect. Therefore, translocations of chamois should be avoided in the future or at least carefully planned, i.e. individuals should be genotyped before releasing in another environment, and genetic monitoring should be implemented across different populations. We must keep

in mind that when having viable populations, it is important to maintain local adaptation and the unique gene pool, and hence avoid gene introgression among different evolutionary lineages.

Spatial genetic structure of chamois *R. r. rupicapra* in a fragmented population in southwestern Germany

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Keywords: genetic structure, mountain-ungulate, reintroduction, microsatellites, continental German uplands

Rupicapra was a resident game in the German Black Forest up to the 14th century. Shortly afterwards the species was exterminated probably by overhunting. In the 1930s, a limited number of chamois originating from the Austrian Alps were reintroduced to the Black Forest. According to hunting bag data of recent decades the chamois population in the German federal state Baden-Württemberg has increased but is characterized by strong geographic variation. In Baden-Württemberg 11 occurrence areas of chamois are currently reported, mainly continental regions, however little data is as yet available. Furthermore, the German report of the Council Directive 92/43/EEC only contains relevant data for Rupicapra from alpine areas. In 2017/18 a pre-study was implemented to receive information about the interconnection of chamois populations between the German Black Forest and Swiss Jura by comparing sequences of mtDNA. The present study will use microsatellite markers to provide information about the spatial genetic structure of chamois in Baden-Württemberg and their interconnection, including migration routes and dispersal barriers. We expect a genetic interchange between the populations caused by long-distance exchange. This hypothesis is supported by sightings and hunted chamois out of known core areas.

From October 2019 to January 2021, muscle tissue samples of 161 chamois from Baden-Württemberg were collected and georeferenced by participating hunters. Sampling will be continued until and including 2022. We tested 27 microsatellite markers using 48 muscle tissue samples from chamois originating from 3 different European locations. From these we selected a final marker set of 16 microsatellite loci (with a

mean number of 9.30 alleles/ locus) for the genotyping process. Preliminary results about the spatial genetic structure of Baden-Württemberg chamois are expected in April 2021.

The results will be an important contribution towards the lack of data of chamois in the continental areas of southwestern Germany and the 92/43/EEC guideline.

A multi-omics approach to the conservation and management of the Alpine chamois

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Keywords: ancient DNA, DNA metabarcoding, metataxonomics, species interaction, management

The Alpine chamois is a charismatic species of alpine pastures above the treeline, an increasingly fragmented habitat as a result of climate warming. It has been suggested that mountain agricultural practices further degrade chamois habitat, influencing, together with translocations, restocking and overharvesting, its distribution, population demography and genetic structure. There is also increasing resource overlap with red deer and domestic animals, reducing the quantity and quality of available pasture, or forcing chamois displacement to suboptimal areas. These behavioral changes could also influence microbiota diversity and composition affecting an individual's ability to adapt to these environmental changes and impacting health, survival, and fitness.

To interpret the relative importance of demographic and evolutionary processes, patterns of variation in mtDNA and selected nuclear genes (Y-chromosome and nuclear introns) of 60 museum specimens are being analyzed using a 'target enrichment' method. Analysis of mtDNA markers of 70 modern samples (on the basis of 54 haplotypes previously identified) will be completed, and comparison of historical and modern data will be used to ascertain how past events may have impacted the current genetic structure of the species.

Finally, 520 fresh fecal pellets were collected for chamois, red deer and domestic sheep from multiple areas characterized by different levels of species interaction: no geographical overlap of chamois with red deer or sheep; overlap with red deer; overlap with red deer and sheep. DNA metabarcoding will be used to understand if and how overlap can induce changes in chamois diet; metataxonomics will be applied to the same fecal pellets to study changes in gut microbiota composition and investigating future ability of the animals to adapt to changing environment. Our results will contribute to a better understanding of historical and modern impacts of natural and human-mediated processes on Alpine chamois populations with the prospect of developing new management guidelines.

Biokovo genetic story after more than half a century from the reintroduction

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Keywords: Biokovo, *Rupicapra rupicapra balcanica*, SSR loci, reintroduction

Literature, historical and archaeological data confirm that chamois once lived in the Biokovo Mountain (first records ca. 12 thousand years ago). The population became extirpated in the early 20th century due to many reasons such as overhunting, poaching, competition with and disturbance by livestock. The population was later reintroduced (1964-1969), 48 individuals were released from the neighbouring mountains in Bosnia Herzegovina (BIH). The main objective of this study was to determine the accuracy of historical data on the origin of the Balkan chamois population on Biokovo Mountain and to assess the population genetic status of both the initial and translocated populations 56 years after the reintroduction. We used 16 microsatellite loci to analyse the genetic structure of Balkan chamois populations. We screened three populations from BIH: Prenj (12), Čvrsnica (12) and Čabulja Mountains (5), and one from Biokovo Mountain (20). Independent analysis of the BIH populations in STRUCTURE revealed a clear separation of the population of Prenj from the populations of Čvrsnica and Čabulja, with the latter two forming a single population. This suggests the Neretva River and the highway M-17 may be effective barriers for the species as they constitute a genetic boundary. By including the Biokovo population in STRUCTURE analysis, it built a separated cluster. This divergence may be due to the historical founder effect and more recent genetic drift due to isolation, and local adaptation. Interestingly, we report a considerable genetic similarity between the Biokovo and Čvrsnica-Čabulja populations. This suggests that the Biokovo population may have multiple origins, not only from Prenj Mountain, as primarily assumed based on both available literature and personal communications.

Genetic makeup of Slovak chamois: new methods, new insight?

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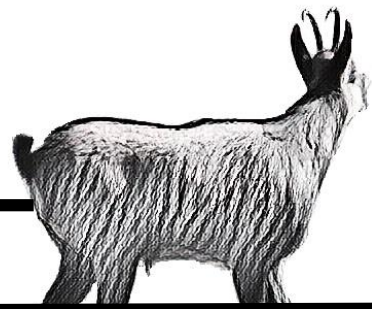
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Keywords: *Rupicapra rupicapra tatrica*, hybridization, genetic structure, genomics, Slovakia

Two subspecies of Northern chamois, non-native Alpine chamois (*Rupicapra rupicapra rupicapra*) and endemic Tatra chamois (*R. r. tatrica*), inhabits four mountain ranges in Slovakia. Non-invasive samples of faeces as well as available tissue samples were collected (mainly in years 2006-2009) and four types of genetic markers (20 nuclear microsatellites, *SRY* marker for sex identification, *DRB* gene of MHC class II and mitochondrial DNA marker) were analysed with the aim to describe in detail population genetic structure and genetic variability of all Slovak chamois populations. Low genetic variation and high level of inbreeding were found in all populations, the least variable being the native bottlenecked Tatra chamois population in the Tatra Mts. with only one MHC allele. Introduced Alpine chamois showed greater variation, despite originating from few founders. Male-biased introgressive hybridization between the introduced back-up Tatra chamois population in the Low Tatra Mts. and both Alpine chamois populations was detected, with a direction of gene-flow from Alpine to Tatra chamois. The native Tatra chamois population in the Tatra Mts. represented pure Tatra subspecies with no genetic signs of contact with Alpine individuals.

Currently, after almost 15 years, there is an opportunity to complete the study by applying high-throughput genomic methods. Extension of the analyses to a genome-wide level will enable to assess genetic variation, inbreeding, effective size of populations and patterns of gene-flow between populations with significantly higher resolution. These parameters are of conservation importance and can serve as a base for identification of potential threats and/or benefits of introgressive hybridization. However, is it possible to extract DNA from chamois droppings in a quality sufficient for genomic analyses? What genotyping system is best to use to ensure comparability of chamois data between laboratories? And there are also other issues. Therefore we appreciate an opportunity for discussion given by the conference.

04 | Behavior & Ecology



Chairman: Francesco Ferretti

Climate change and Alpine chamois

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Keywords: body mass, climate change, life history, population recruitment, *Rupicapra rupicapra*

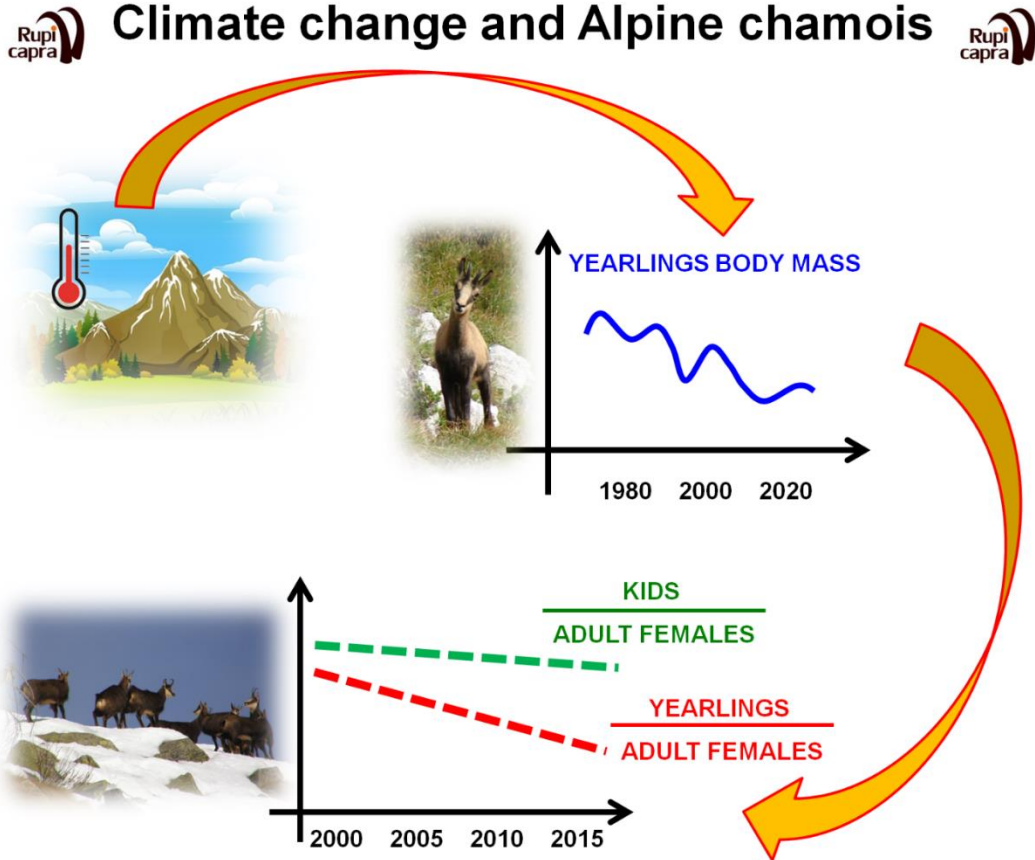
Climatic and environmental changes have impacted species in a variety of ways, including affecting population dynamics.

Alpine chamois (*Rupicapra rupicapra*) populations in some areas of the Alps are declining. Thus, it is interesting to assess the influence of climatic factors on the biology of this species.

In a study conducted in the Swiss Alps, Alpine chamois activity rhythms proved to be strictly related to temperature, with a strong decrease of activity connected to temperature above 10-15 C°. In the Gran Paradiso National Park (Italy), we showed that temperature variation influenced chamois behaviour. Specifically, we found strong evidence for an effect of temperature, independent of time of day, on both altitude use and time spent foraging.

An analysis of 35 years of eviscerated weights from yearlings hunted in Trento province (Italy) showed a significantly negative trend linked to population density and warming temperatures during spring and summer. At the same time, we examined initial recruitment (i.e., the ratio of kids to adult females) and net recruitment (i.e., the ratio of yearlings to adult females) from 2001 to 2015. Initial recruitment was relatively unaffected by climate change, declining slightly over the study period. Net recruitment strongly declined throughout the study period, consistent with the slight decline of initial recruitment and the negative effects of increasing summer temperatures on the survival of kids during their first winter. These negative effects seemed to outweigh the positive effects of climate change, even in a species strongly challenged by winter conditions.

As a future research perspective, the analyses of stress hormones and parasitic loads under different temperatures, and the study of movement strategies linked to microclimatic conditions will be useful to evaluate the impact on individuals caused by climatic changes.



Apollonio et al. 2021 - marcoapo@uniss.it
 III International Rupicapra Symposium

Climate change can impact Alpine chamois populations decreasing limiting net recruitment by reducing kids' survival during winter and can impact on the body condition of surviving yearlings. As temperature increase is a continuous process whether snow cover decrease is not, the costs of a steady lower availability of high-quality food is not compensated by an irregular reduction of limiting factors as snow cover.

Spatiotemporal variability of body masses in Alpine chamois in Slovenia

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Keywords: Alpine chamois, body mass, capital breeder, rut-related changes, reproductive investment

In the absence of abundance/census data, body masses and their trends have been used for decades as indicators in adaptive management of wild ungulates in Slovenia. However, the spatiotemporal context is often neglected in the analyses, i.e. neither interannual variability and seasonal changes nor various environmental factors affecting body mass are adequately considered. This is particularly crucial in polygynous species, where the body mass of individuals and the average body mass in a population can change significantly between and within years in different sex and age classes. In Alpine chamois (*Rupicapra rupicapra*), a typical capital breeder, during the rut adult males lose on average >15% of the pre-rut body mass, but presumably invest in reproduction an amount of energy that varies among individuals and/or among years. In this species, which typically lives in a harsh mountainous environment, the rutting season is just before winter. Therefore, females also experience a high reduction of body mass during the rut (approx. half that of males), and rut-related seasonal changes of body masses are likely dependent on habitat characteristics and weather conditions. However, there is a lack of data on seasonally varying patterns of body mass of Alpine chamois as well as on the influence of the key environmental factors which also affect interpopulation variability of body masses.

To fill this gap in knowledge, we analysed body masses of all chamois harvested throughout Slovenia in the period 2011–2020 (22,067 individuals with body mass available), covering a range from 3.0 kg for some fawns to 37.5 kg in a 5-year-old male. We determined the influence of age, year (i.e., weather conditions) and environment (by comparing different populations) on seasonal changes in body mass of both sexes over the period August–December. In this way, we described characteristics of growth and body development in juveniles and subadults, and assessed variation in the investment in reproduction and

subsequent recovery in both sexes. Furthermore, we pointed out that a high spatiotemporal variability and a complex influence of different environmental factors crucially limit the potential of body mass as a reliable indicator for adaptive management of Alpine chamois.

Woodlands buffer the climate-induced decline of body mass in a mountain herbivore

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Keywords: Body mass, chamois, climate change, *Rupicapra rupicapra*, temperature

Climate change affects key life history traits, such as body mass, reproduction, and survival in numerous species. Animal populations inhabiting mountain habitats are adapted to extreme seasonal environmental conditions, but are also expected to be especially vulnerable to climate change. Studies on mountain ungulates typically focus on populations or sections of populations living above the tree line, and populations inhabiting forested habitats are largely understudied. Here, we investigate if forested areas can mitigate effects of climatic change on life history traits by evaluating the interactive effects of temperature and habitat characteristics on body mass variation in the Alpine chamois *Rupicapra rupicapra rupicapra*. We examined data of 29,235 yearling chamois collected from 1993 - 2019 in 28 mountain ranges in the Austrian Eastern Alps, characterized by different proportion of forest cover. Our results show that the temporal decline of chamois body mass is less pronounced in areas with greater proportion of forest cover. For chamois living in forest habitats only, no significant temporal change in body mass was detected. Habitat-dependent variation in body mass was largely explained by the interaction between spring temperatures and forest cover, supporting the role of woodlands as thermal buffer against the effects of increasing temperatures on life history traits in a mountain ungulate. This study strongly suggests a buffering effect of woodlands against effects of climate change. Assessments of the consequences of climate change on the life history traits and population dynamics of mountain-dwelling species should thus consider the plasticity of the species with respect to the use and availability of different habitat types.

Movement plasticity in an iconic mountain ungulate

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Keywords: movement plasticity, trade-offs, seasonality, GPS telemetry, wildlife management

Movement is the behavioural mechanism that links the multi-scale process of resource selection. For example, fine scale movements can occur during daily activities, e.g. in response to depletion of forage patches. At larger scales, migration may occur in seasonal environments. In the case of ungulate migration, recent research underlines that this phenomenon is flexible and most ungulates display a behavioral plasticity of migration 'tendency' in response to favorable conditions. Assessing which factors shape intermediate behaviors between the endpoints of the migration gradient is the key to understanding ecological plasticity in migratory behavior. Here we analyse movement behaviour with a focus on seasonal migration in Alpine chamois (*R. r. rupicapra*) using GPS data from 16 adult chamois (males = 7, females = 9, collected between 2018 and 2021) in the Bavarian Alps. For the analysis of individual movements we employ a combination of the net squared displacement rate (NSD) and the GIS-extension MigrO. We test for plasticity in migratory status and tactics. Further, we quantify finer-scale movement behavior such as excursions to microsites. 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. 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 may be misleading. Understanding plasticity in movement behavior will improve monitoring efforts, management and provide insights to evaluating potential negative effects, especially those associated with changing climate.

The Bavarian chamois (*Rupicapra rupicapra*) – master of adaptation with regard to energy supply

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Keywords: Energy, rumen content, rumen volume, crude nutrients

The condition of the Bavarian chamois populations has been a subject of heated debate for several years now, and the debate is based on relatively little data on how the chamois population is actually faring. 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 = 182) in the alpine region in Bavaria in 2017. Among other parameters, the energy content and crude nutrient composition of the ingested food were determined, as well as the weight and volume of the rumens.

We were able to determine that adult chamois have an average energy density of 4400 kJ/kg DM at their disposal in their habitat. According to Hüppop [1], the chamois has a basal metabolic rate of 2463 kJ/day and an energy consumption of 9372 kJ/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 [2], the energy supply can be seen to be more than adequate at any period of the year. One adaptation to the lower-energy season is the increased mass of the rumen filling. In winter, the animals have more content in the rumen than in summer, despite a smaller rumen volume. The energy requirement is met by compensating for a decrease in the quality or availability of the energy with an increase in the mass of the rumen filling. 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.

Disentangling demographic effects of red deer on chamois population dynamics

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Keywords: Alpine chamois, density dependence, interspecific competition, population dynamics, survival rates

Investigating the impact of ecological factors on sex-and age-specific vital rates is essential to understand animal population dynamics and detect the potential for interactions between sympatric species. We used block count data and autoregressive linear models to investigate variation in birth rate, kid survival, female survival, and male survival in a population of Alpine chamois *Rupicapra rupicapra* monitored over 27 years within the Stelvio National Park, Central Italian Alps, as function of climatic variables, density dependence, and interspecific competition with red deer *Cervus elaphus*. We also used path analysis to assess the indirect effect of deer abundance on chamois growth rate mediated by each demographic parameter. Based on previous findings, we predicted that birth rate at [t] would negatively relate to red deer abundance at year [t-1]; survival rates between [t] and [t+1] would negatively relate to red deer abundance at year [t-1] and to the interactive effect of winter precipitation at [t+1] and chamois density at [t]. Our results showed that birth rate was positively related to spring-summer precipitation in the previous year, but this effect was hampered by increasing red deer abundance. Kid and female survival rates were negatively related to the combined effect of chamois abundance and winter precipitation. Male and female survival rates were negatively related to lagged red deer abundance. The path analysis supported a negative indirect effect of red deer abundance on chamois growth rate mediated by birth rate and female survival. Our results suggest that chamois population dynamics was largely explained by the synergistic effect of density dependence and winter harshness, as well as by interspecific competition with red deer, whose effects were seemingly stronger on the kid-female segment of the population.

Comparison of stress responses between sympatric Alpine chamois and red deer in a protected area

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Keywords: Glucocorticoid metabolites, red deer, stress, Swiss National Park

Due to species-specific adaptations to different habitat types, chamois and red deer occurring in sympatry at high elevations may show contrasting physiological responses to potential stressors. We examined fecal glucocorticoid metabolites (FGMs) in sympatric Alpine chamois (n=742) and red deer (n=1649) from fresh samples collected in the Swiss National Park with respect to weather, digestibility of forage and human disturbance. Sampling took place at the same locations every two weeks over 4 years. FGM concentrations were determined by enzyme immunoassay. In both species, FGM concentrations were highest in mid-winter and lowest in mid-summer. Numbers of hikers crossing the sampling area on a designated trail in summer (automatically counted by a pyrosensor) had no effect on FGM concentrations in either species. Instead, both chamois and red deer showed a physiological stress response to drought conditions during summer and increasing snow height in winter. In chamois, the response to snow height was additionally modulated by humidity, in red deer by temperature, with greater humidity and lower temperatures, respectively, leading to increased stress. While low forage digestibility was correlated with higher FGM concentrations in red deer in winter and – though only at the lowest elevation sampling area - in summer, it showed no effect on chamois in either season. The main interspecific difference in stress responses was thus related to forage digestibility with chamois apparently better adapted to low quality forage than red deer, but more sensitive to humidity during winter. While the former result is surprising considering the two feeding types (both mixed, but with chamois more on the browsing side), it may reflect the better adaptation of chamois to seasonally poor forage conditions in mountain environments. This would also be in line with the chamois' higher sensitivity to humidity in winter, i.e. more atypical conditions for alpine habitats.

Alternative reproductive and spatial tactics in male Alpine chamois

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Keywords: mating behaviour, spatial behaviour, mating opportunities, territoriality, intra-sexual interactions

Ungulates show great variability in alternative reproductive tactics (ARTs) in relation to individual or environmental factors. Different cost-benefit trade-offs could occur in relation to the adoption of each ART, possibly influencing also spatial behaviour. Understanding differences in key aspects of behaviour (e.g., space use) and life-history (e.g., reproductive success and survival), amongst individuals adopting different ARTs, would help explain their evolution and coexistence in a population. We collected data on mating behaviour of 31 marked adult male Alpine chamois *Rupicapra rupicapra rupicapra* during 5 rutting seasons (early November-early December, 2011-2012 and 2015-2017) and their spatial behaviour throughout the years. Amongst them 15 have been classified as territorial (T) and 16 as non-territorial (NT). No individuals changed ART over the years, with the only potential exception of an old male which lost its territory during its last rut. Moreover, we reported a previously undocumented occurrence of different patterns of spatial behaviour across T males. Fifty percent of these individuals had overlapping or continuous winter and summer areas, whereas the others moved between different areas (immediately after the rut, in winter, or in summer-autumn). Data suggest differences neither in age nor in the frequency of intra-sexual aggressive interactions between males adopting different ARTs. T males, which are known to be dominant over NT ones in aggressive interactions, consistently showed greater indices of mating opportunities than non-territorial ones. Data support that ARTs may be fixed in male chamois, which may adopt a conservative mating strategy, i.e. a less intense and less energetically demanding competition amongst males compared to that of highly dimorphic species, and probably different spatial strategies, to maximise survival.

Geodiversity can drive alternative life history tactics: Alpine chamois as a case study

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Keywords: body mass, geological substrate, horn, life history, *Rupicapra rupicapra*

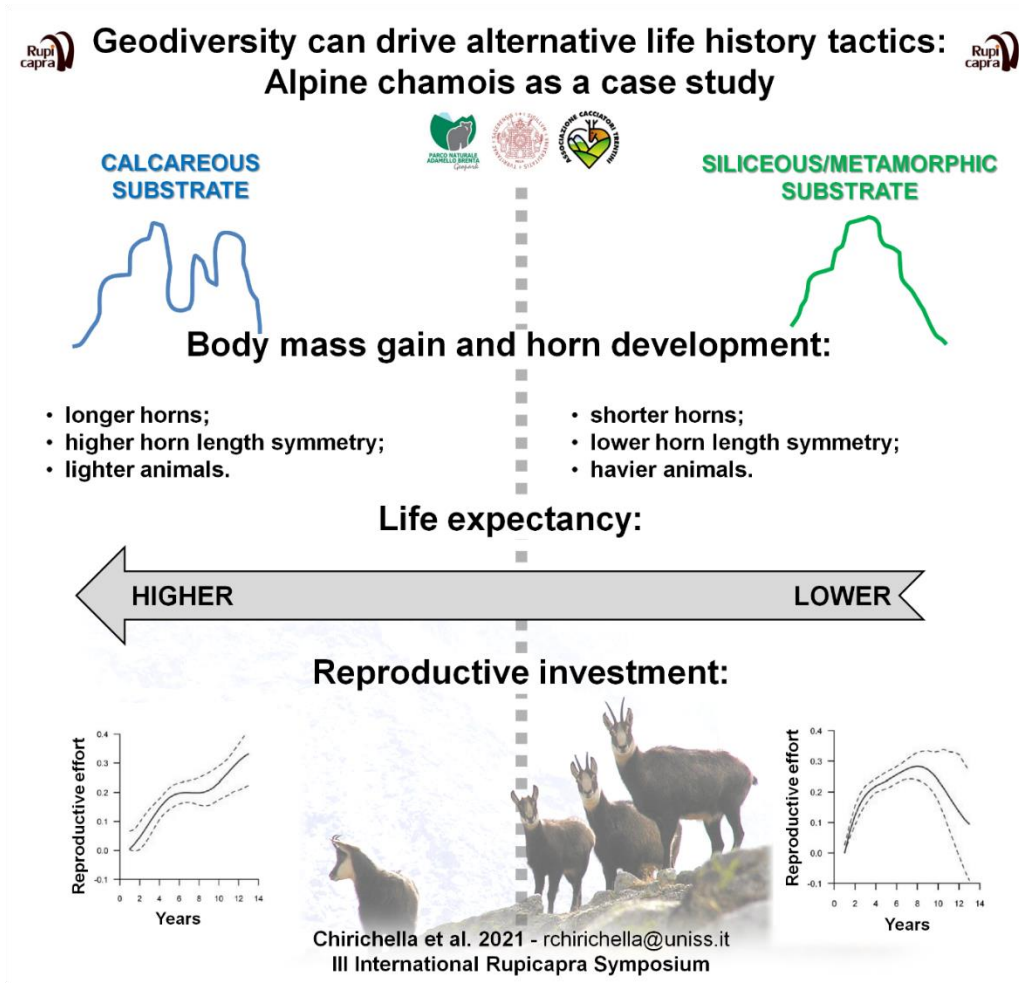
In ungulates, ecological factors can reveal key information on individual life histories and can have important evolutionary consequences. In analysing factors commonly thought to play a role in these processes, researches have so far neglected the possible influence of the geological features.

With special reference to species living in extreme environments, Alpine chamois is an ideal case study to investigate how the geological substrate can drive growth investment, affect the reproductive life histories and promote body mass senescence. We took into consideration a broad range of ecological factors that are expected to affect Alpine chamois body condition and analysed how the substrate (calcareous, siliceous or metamorphic) could modify body mass gain/loss and horn growth (i.e. length and developmental stability).

We analysed data from over 28,000 animals legally culled during 10 hunting seasons (2010-2019) in 28 hunting districts with different geological substrate in the province of Trento (6,212 km²; Italian Alps).

We found a key role of calcareous substrate in promoting horn growth and horn length symmetry. Moreover, contrasting results in body mass gain in calcareous areas revealed a differential investment in body mass and horn length according to different geological features. Heavier animals lived on the siliceous substrate. Vegetation communities growing on siliceous substrates in the Italian Alps show a higher resistance to winter conditions than vegetation of higher quality growing on calcareous substrate, ensuring constant trophic level availability in different environmental conditions. Available data confirmed that females experienced a later senescence than males, in accordance with a greater energy expenditure undergone by males in rut period. However, even in this case long-lived animals were related to calcareous areas, while siliceous substrate shortened life expectancy. According to males reproductive effort, terminal investment may only occur in areas with lower rates of body mass senescence.

In conclusion, we described a strong effect of geodiversity into promoting the use of alternative life history tactics in this species.



Does the geological substrate drive growth investment, reproductive life histories and body mass senescence in Alpine chamois?

We described a strong effect of geodiversity into promoting growth investment and body mass senescence. Long-lived animals were related to calcareous areas. According to males reproductive effort, terminal investment may only occur in areas with lower rates of body mass senescence.

Designed for coping with the cold, the challenge for chamois in a warming world

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Keywords: seasonality, energy expenditure, fat reserves, global warming

Chamois inhabiting high Alpine areas are exposed to harsh winter conditions. For a long period, they experience a shortage of food supply, low ambient temperatures, and a high snow pack hindering movements. To study how chamois cope with such conditions, we equipped free-living animals in an alpine area of upper Austria with a self-constructed telemetry system enabling continuous recording of heart rate as a measure of energy expenditure, of body temperature, locomotor activity, and GPS-positions over two years. Further, we analysed long-term data from necropsy of individuals hunted or found dead.

We found that chamois reduce their metabolic rate during winter to about half of the summer level, similar to other alpine ungulates as ibex, or red deer. They accomplish this reduction by lower locomotor activity, shrinkage of visceral organs, and, most importantly, by tolerating a lower body temperature. However, even the considerably lowered energy expenditure during winter cannot be covered from food intake. Survival depends on the use and a sufficient amount of body fat reserves. As a result, the annual trough of body mass and a critical depletion of fat stores is reached at the end of winter. Particularly prime age males are prone to late-winter starvation and death because of the high energy demands of rutting at begin of winter. The remarkable abilities of chamois to cope with cold apparently imply a low tolerance of heat. Our results show that chamois are in thermoregulatory troubles already at moderate temperatures, presumably impairing the replenishment of body fat reserves during summer. This may well explain why populations shrank on a large geographic scale over the past 20 years, when temperatures increased particularly at high altitudes. However, there are areas in the Alps where chamois populations grew during the same period. This may indicate the existence of different thermoregulatory phenotypes, possibly evolved under differing selection regimes in southern or northern glacial refugia.

Summer activity budgets of chamois in relation to heat, food and disturbance constraints

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Keywords: activity budgets, hidden Markov models, heat stress, foodscape

Alpine herbivores such as chamois, are capital breeders and need to maximise energy accumulation during summer. Food acquisition is limited by the time required to find resources, the need to process food, risk avoidance related to predation or human disturbance and abiotic constraints such as thermal stress or terrain configuration. In heterogeneous mountain landscapes, individuals may adopt different behavioural tactics for maximising food intake whilst coping with these constraints. Our aim was to tease apart the roles of food quality and quantity, human disturbance and thermal stress on daily time budgets, assessed from GPS data collected every 20 min on 25 chamois females during July and August. Using Hidden Markov Models applied to the speed of their movements and turning angles, we classified the activities of the chamois in three behavioural states supposed to represent resting-ruminating, foraging, and relocating periods. Chamois spent on average 30% time resting, 42% foraging and 28% relocating. The level of human disturbance (density of hiking tracks in a home range) did not influence time budgets of chamois. Chamois responded to thermal stress by relocating more during the hottest days, if shaded areas (forest or north facing slopes) were available inside their home range. Otherwise, individuals increased the time resting during hot days. Higher heterogeneity in resource quantity was associated with more time spent by chamois relocating in July, suggesting that quantity of resources may drive foraging decisions when edible resources are of good quality. In contrast, individuals relocated less in August when heterogeneity in resource quality increased, independently of resource quantity in their home range. Given our results, and as climate change should modify plant phenology (hence quantity and quality of resources) and the occurrence of hot days,

future changes may alter chamois energy balance, which in fine may have repercussions on individual performance.

Does horn size matter?

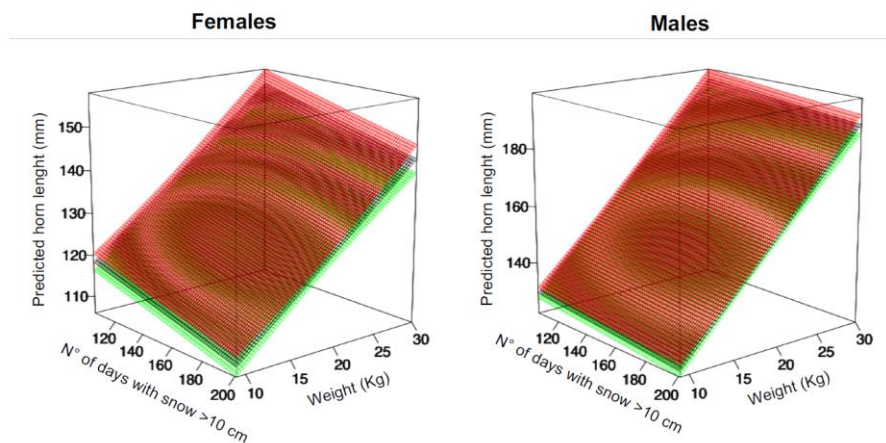
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Keywords: Body size, Compensatory growth, Secondary sexual traits, Weapons

Animal weapons are one of the most studied morphological traits, particularly in Artiodactyla. Since in polygynous species males with larger weapons tend to be more successful in gaining access to females, researchers focused on horn size. Recently, in basal species with limited horn size, weapons size was supposed to have reduced or null effect on life history traits. We examined the effect of intrinsic and extrinsic factors on the length of the second and third segment of chamois horns (*Rupicapra rupicapra*) to test how intensively environmental conditions affected weapon growth and whether compensatory growth occurred. We showed that horn length is isometric to body size, although male horns grew more quickly. Such ecological factors as snow and forage availability affected weapon length, though mildly, and no sign of compensatory growth was detected. We inferred that chamois mainly use horns as armament in intrasexual interactions, but their length is not a key element since its growth remains isometric, at least in suboptimal ecological conditions. In species without extreme weapons, the handicap caused by longer horns is likely not compensated by an increase of individual fitness.



Environmental conditions significantly affected horn growth in Alpine chamois, but their effect on the actual horn length was shown to be negligible. Snow cover, the factor with the strongest effect, caused a maximum variation of only 0.5 cm (3.3%) in the second horn segment in males.

Age-related development of trophy value in both sexes of Alpine chamois across different Slovene environments

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Keywords: Alpine chamois, trophy value, CIC points, horns, population management

In adaptive management of wildlife populations, trophy value is proposed as a reliable indicator for assessment of both population dynamics/status and the effects of management actions. Furthermore, trophy value and understanding of its development are important for management *per se*, as in some game species trophies reach high prices at the market and represent the main income for population managers. In Europe, this is particularly true for the Bovidae family, like the northern/Alpine chamois (*Rupicapra rupicapra*). In contrast to deer species, in which antlers are usually worn only by males and the assessment of the value of their trophy can be highly subjective as well as biologically irrelevant (i.e., inclusion of various subjective traits such as colouration, tines' number and their sharpness, coronet height, and general appearance), the horn value indicated by CIC points is a very objective measure, based primarily on measurable traits (height, length, circumference), and reflects the lifelong investment of individuals of both sexes of chamois in the development of this interesting structure.

However, knowledge on age-related development and the influence of environmental factors on horn development in Alpine chamois is very scarce. Therefore, we took the advantage of a unique and very large Slovenian dataset on all individuals either harvested or found dead nationwide between the 2011 and 2020 (17,975 chamois with available CIC points), covering the age range from fawns to a 23-year-old individual, with trophy values of up to 111.48 CIC points for females (13-year-old) and 120.70 pints for males (12-year-old), respectively. Using spatiotemporal Bayesian Generalized Additive Models, we determined the influence of individual (age, body mass) and selected environmental factors on trophy score in both sexes throughout the species' range in Slovenia. In addition, we compared standardized trophy values of harvested individuals with those that died due to diseases (scabies, diarrhea, pneumonia) and injuries, and thus assessing the existence of selective hunting pressure on individuals with either low quality trophies (in subadults) or high-quality ones (in adults). Through our analyses, we confirmed a great potential of

Slovenian databases on harvested ungulates, including chamois, for management purposes as well as for understanding the evolution of the fascinating horn structures on their heads.

Usefulness of chamois horn lengths as a population index – an example on three chamois populations of different cohorts in Croatia

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Keywords: Dinaric Alps, hooks, trophy measurement, ANCOVA

Northern chamois is autochthonous wild ruminant species in Croatia. Majority of its Croatian population is distributed in Dinaric region. In the past some populations are disappeared and during 1960s and 1970s years of 20th century hunters reintroduced the species in middle and southern part of Dinaric Alps. At the end of 20th century some research revealed chamois horn (hook) length from the first 3 years of life, is relatively reliable population index. Those, from the practical point of view, the question is how reliable are data from hunting trophy evidence as population index? Hunting trophy measurement in Middle Europe has relatively long tradition and in some countries (including Croatia) hunting trophy measurement is obligated. Thus relatively huge evidence of measured hook could improve chamois management. In the paper we tested usefulness of 1 168 horn lengths (773 males and 395 females) from 3 main population (Risnjak – Alpine chamois, Velebit – hybrid population and Biokovo – Balkan chamois) according to cohorts.

The anthropogenic risk avoidance hypothesis applies to the Balkan Chamois (*Rupicapra rupicapra balcanica*): an ecological overview from a Natura 2000 site in Greece

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Keywords: climate change; conservation; demography; disturbance; ENFA; habitat selection; hunting; poaching; seasonal range; roadless areas

Balkan chamois (*Rupicapra rupicapra balcanica*) is a protected species with an Inadequate-Bad (U2) conservation status in Greece and its hunting is prohibited since 1969. We investigated the seasonal range use pattern, demography and habitat selection of the species in Timfi Mountain (Natura 2000 site). We used 1168 observations obtained from six seasonal surveys (2002: four seasons, 2014 and 2017: autumn) to perform an ecological-niche factor analysis (ENFA), using 16 environmental and human-disturbance variables. The species had an annual range of 6491 ha (25% of the study area), followed the typical range-use pattern, and presented the minimum core area during the rutting season (autumn). Timfi Mt hosted 469 individuals in 2017, increasing by 3.55 times in the period 2002-2017. The species selected higher altitudes during summer and autumn, pinewoods over broad-leaved woods as winter grounds, and it avoided south-facing slopes. Our results supported the anthropogenic risk avoidance hypothesis; the species always selected remote areas away from roads, human settlements, and hunting grounds. Hunting ban areas cover 16.5% of Greece, and 40% of the species distribution area falls within it. A national conservation policy is needed towards maintaining and increasing roadless areas and hunting-ban areas within Balkan chamois range nationwide.

Positive effect of spring advance on the diet quality of Pyrenean chamois

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Keywords: Global warming, phenology, *Rupicapra pyrenaica pyrenaica*, Near-Infrared Spectroscopy, Cuticle Microhistological Analysis

Changes in vegetation phenology related to global warming are having alarming effects on the life history traits of many herbivore species. Such changes are particularly critical in alpine ecosystems, where strong climate limitations on plant growth make seasonal synchronization imperative for the growth, reproduction and survival of herbivores. However, despite the pivotal role of resource-use strategies on the performances of such species, few studies have still explicitly assessed the mechanistic impact of climate change on their diets. We aimed at filling this gap by studying the effect of spring onset on the dietary composition and quality of Pyrenean chamois (*Rupicapra p. pyrenaica*), considering density-dependent processes and age- and sex-specific differences in foraging behaviour. Using an exceptional long-term (24 years) direct individual-based dietary monitoring, we showed that ongoing earlier onsets of spring are leading to an earlier access to high-quality forage and therefore a higher diet quality at a fixed date, without apparent changes in diet composition. We also showed that at high densities, intraspecific competition deteriorated diet quality by driving animals to feed more on woody plants and less on nutritious forbs and graminoids. Finally, we observed a higher diet quality in older animals, suggesting an increasing experience in resource selection with age. By assessing the mechanical effects of global warming on the dietary patterns of

herbivore species, this study is an essential step for predictive models aiming at understanding the ongoing ecosystem consequences of the global climatic crisis.

Investigation of vitality in selected Bavarian chamois populations

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Keywords: Chamois, vitality, physical constitution, reproduction, Bavaria

The chamois (*Rupicapra rupicapra*) is one of the most important game species in Bavaria. Factors like climate change and tourism are increasingly reshaping the alpine habitat. For this reason, it has been the focus of public and scientific attention in the recent years. The aim of this study is to obtain data regarding physical condition, age structure and reproduction of the chamois population under study.

Samples were collected from several areas in Bavarian Alpine regions during hunting season from 2016/17 to 2019/20. The study comprised of slightly more than 200 animals for which data regarding age, weight and several other factors was systematically recorded. Among other things, the kidneys were analysed to determine the kidney fat index (KFI). This was statistically evaluated in conjunction with the weight data. In addition, the reproductive organs of female chamois were examined which involved the macroscopic examination of the uterus for embryos and the ovaries for corpora lutea.

The study included all ages from juvenile to adult animals. The increase in body weight reached at its peak most until the age of about 3.5 years. The heaviest male individual weighed about 28kg (age 9 years), the heaviest female was 3 years old and weighed about 24kg (field dressed weights). Gravidity could only be detected from a weight of approx. 17kg. From a weight of over 17kg, about 70% of the females showed signs of gravidity. From 4 years of age, between 66-100% showed signs of gravidity. The oldest individual in which an embryo could be detected had an age of 13 years while the oldest individual with a corpus luteum was 17 years old.

The data collected on body condition and reproduction indicate populations with good vitality. The study was funded by the Bavarian State Forests and the Berchtesgaden National Park.

Modelling Suitable Habitats for Alpine Chamois in Bavaria (Germany)

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Keywords: *Rupicapra rupicapra*, Habitat suitability model, management decisions, wildlife refuges, Northern Alps

The habitat of chamois *Rupicapra rupicapra* in mountainous and partly wooded areas is managed to various degrees for agricultural and forest purposes. Therefore conflict of interests may occur and a decreasing tolerance by management authorities towards wildlife and its impact on their habitat can interfere with sustainable management goals for the species. The Alpine region comprises most of the range of Alpine chamois in Bavaria. There is growing public awareness about the management of chamois and the conflicting interests in its habitat. Since 2020 Alpine chamois is listed on the Warning list of the Red List of Germany.

We built a Suitability Model for summer and winter habitat of the species in the Bavarian Alpine range based on model parameters that were earlier established and evaluated in Western Austria, in Vorarlberg. Model components were: altitude, exposition, steepness, solar radiation during summer and winter months, and vegetation cover.

We compared land sections with an without intensive touristic use and land use projects across areas with an expected high degree of habitat suitability for chamois based on topographic and biological characteristics. Especially forestry projects change habitat parameters on local scale and establish zones of intensive and year-round culling of chamois on large scale.

Based on the SI Index for chamois, we built an easy to use GIS tool to define wildlife refuge areas for chamois, that can integrate different degrees of land use and management options and can contribute to prevent the threat of further putting on risk of overexploitation and habitat loss the Chamois population along the German part of the northern Alps.

Functional responses in habitat selection by Alpine chamois

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Keywords: habitat selection, faecal pellets, trade-offs, dimorphism

Understanding the relationship between mountain ungulates and their habitat is important to wildlife management and has gained even more relevance with an increased interest in anticipating the potential effects of landscape changes and human impact in alpine environments. Habitat selection can be influenced by resource availability, sex, predation risk, anthropogenic disturbance, seasons, and by the scale of selection studied. Resource selection functions (RSF) use a statistically rigorous framework to measure habitat selection by examining use or avoidance of a resource relative to its availability. We studied habitat selection of Alpine chamois (*Rupicapra r. rupicapra*) in two study areas in the Bavarian Alps with contrasting environmental conditions and varying degrees of human impact. Non-invasive, systematic faecal pellet sampling and subsequent genotyping was applied to sample chamois presence. Using an RSF-framework, we tested for the effects of abiotic and biotic factors on habitat selection at the landscape scale in spring and autumn. To account for sex specific differences in habitat selection we included random factors in our models. Chamois habitat selection was strongly driven by topographic variables, especially elevation and terrain ruggedness in both study areas. Habitat selection was positively affected by further distances to roads, even though the response differed in strength between study areas. We detected differences in selected vegetation types between the study areas due to their varying availability. Our results suggest differences in the habitat selection between male and female chamois, especially with regard to topography. On average female habitat selection was stronger affected by the trade-off between forage and risk. Internal model validation (k-folds cross validation) confirmed good predictive power of our models. Based on non-invasive sampling, our results contribute to a better understanding of chamois habitat selection in human altered landscapes.