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Late 2021 saw the twenty-sixth Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Glasgow, Scotland under the presidency of the UK in partnership with Italy. The COP26 hosted almost 200 countries, which agreed the Glasgow Climate Pact to keep the 1.5°C goal alive and to revisit and strengthen their current emissions targets to 2030. Yet many critical voices declared COP26 a failure, since hopes were ultimately dashed that a commitment would be made to stop burning fossil fuels by 2030.

The later part of 2021 also saw the first session of the fifteenth Conference of the Parties (COP15) to the Convention on Biological Diversity (CBD) take place; the second session of this two-part summit will be held in 2022. The COP15 to the CBD is expected to provide a global biodiversity framework for the conservation, protection, restoration and sustainable management of biodiversity and ecosystems for the next decade.

Since climate change and the conservation of biodiversity are interconnected, both events are of great important to developing solutions and implementation plans designed to meet climate targets and preserve biodiversity. While these two summits showcase the responses on a global political scale, the relevance of the underlying issues is mirrored in the articles of this edition. The contributions explore how the interconnectedness of climate change, biodiversity and human activities impacts protected areas at a regional level.

In the article *Beyond the victim number: faunistic and ecological data from a road-mortality study in the Iron Gates Natural Park, Romania*, authors Severus-Daniel Covaciu-Marcov, Bogdan-Ionuț Lucaci, Alexandra-Roxana-Maria Maier, Achim-Mircea Cadar, George-Adelin Ile, Amalia-Raluca Dumbravă and Sára Ferenți report on the impact of a 154 km long road upon fauna in the area. They observe how mild winters, caused in part by the warm local climate but exacerbated by global warming, affect the activity period of cold-blooded animals, exposing more animals to road mortality.

The study on *Habitat suitability evaluation for Paeonia decomposita, based on a MaxEnt model* by Peihao Peng and Yu Feng predicts the species distribution of *P. decomposita* and supports the establishment of nature reserves to protect endangered plants, since their habitats are severely disturbed by human activities such as livestock grazing, logging, construction of roads and operation of hydropower plants.

The impact of management activities on three Regional Nature Parks in Switzerland is presented by Thomas Hammer, Roger Bär, Albrecht Ehrensperger, Andreas Friedli, Karina Liechti, Astrid Wallner and Thea Xenia Wiesli in *A holistic assessment of the impacts of park management: findings from the evaluation of Regional Nature Parks in Switzerland*. Protected areas face national and international expectations (e.g. to contribute to the conservation of biodiversity, to combating climate change and to the energy transition) and expectations by the local population and actors. These expectations shape the park's strategic goals and management activities, the benefits and impacts of which are evaluated by the authors.

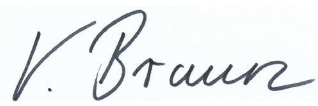
Jessica Oehler gives us an insight into the traditional irrigation system in the Swiss Alps Jungfrau-Aletsch UNESCO World Heritage Site. The irrigation channels are an important cultural-historical element which have produced a structurally rich cultural landscape of high biodiversity but are threatened by more efficient water sprinklers, by the work required to maintain the irrigation system and by the availability of water, which is influenced by climate change.

Sonja Trachsel, Ruth Moser, Birgit Reutz and Rebecca Göpfert introduce the AgriPark project in their article *How can farmers be better integrated into nature parks? AgriPark – Transdisciplinary development of approaches for better cooperation between agriculture and Regional Nature Parks*. Two rounds of workshops were held across three Regional Nature Parks to examine proposed measures aimed at more closely integrating agriculture into Regional Nature Parks in Switzerland. The measures selected include implementing a platform for sharing experiences and incorporating best practices, thematic inputs and coaching support into the process.

Saroj Shrestha, Ang Phuri Sherpa, Sony Lama, Munmun Tamang and Prakash Kumar Paudel report on sightings of Bengal tigers (*Panthera tigris*) in Nepal at higher altitudes in *Tigers at higher elevations outside their range: What does it mean for conservation?*. The authors conclude that factors such as food, scarcity of water and rising temperatures might contribute to the tigers venturing to higher elevations.

A short *Report on the International Symposium of Mountain Studies, part of the 34th International Geographical Congress, Istanbul (16–20 August 2021)* by Alexey Gunya and Fausto Sarmiento introduces 11 presentations delivered at the conference exploring the development of mountain research methodology.

As the impacts of climate change continue to escalate and biodiversity declines due to human interference, protected areas may not be able to buffer these effects. However, such areas present many opportunities that could encourage society to reconsider the issues involved at both local and global levels.



Valerie Braun
co-editor of eco.mont

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Beyond the victim number: faunistic and ecological data from a road-mortality study in the Iron Gates Natural Park, Romania

Severus-Daniel Covaciu-Marcov, Bogdan-Ionuț Lucaci, Alexandra-Roxana-Maria Maier, Achim-Mircea Cadar, George-Adelin Ile, Amalia-Raluca Dumbravă & Sára Ferenţi

Keywords: road-killed animals, Danube River, biodiversity, animal activity, season

Abstract

Road mortality is one of the most obvious forms of anthropic impact upon fauna. The Iron Gates Natural Park is an area of great biodiversity, crossed by a 154 km long road running parallel to the Danube River. To estimate the impact of this road upon the fauna, between March 2019 and February 2020 we monitored road mortality on a monthly basis. We recorded 13,230 road-killed animals, belonging to 71 taxa. The greatest proportion of taxa was killed in early summer and the number of individuals killed peaked in autumn. A spring mortality peak was not observed. Cold-blooded animals were killed year-round, even though they should not have been active in winter in Romania. This is a consequence of the warmer climate of the region compared to the rest of Romania, but also the mild winter of 2019/2020. Mitigation measures such as stopping the construction of new roads would prevent the problem of animal road deaths being replicated in other areas. In addition to the ecological, zoogeographical and conservation value of its findings, our study also warns of a cause-effect link between global warming and an increase in road mortality.

Profile

Protected area

Iron Gates Natural Park

Mountain range

Banat and the Mehedinți Mountains

Country

Romania

Introduction

Road mortality, even at moderate rates, may cause a decrease in some animal populations (e.g. Hels & Buchwald 2001; Gibbs & Shriver 2002; Row et al. 2007; Barbosa et al. 2020). Among vertebrates, the number of victims seems high (e.g. Gerow et al. 2010; Garrah et al. 2015; Santos et al. 2016), but this number is even higher among invertebrates (e.g. McKenna et al. 2001; Baxter-Gilbert et al. 2015; Keilsohn et al. 2018). Road-mortality studies, besides establishing the number of carcasses, sometimes provide other insights, for example indicating the distribution of native or invasive species (Schwartz et al. 2020). If other studies have demonstrated that this is true in general, how does it apply specifically to a particular area of remarkable biodiversity? One region of significant biodiversity in Romania is the Danube Gorge, currently a mountain protected area (Iron Gates Natural Park – IGNP). IGNP is one of the largest protected areas in Romania, sheltering numerous protected species (Rozylowicz et al. 2019). Species with various ecological demands (related to warm sub-Mediterranean areas or associated with cold mountain climates) come into contact with each other here (e.g. Paşcovschi 1956; Covaciu-Marcov et al. 2009; Tăușan & Teodorescu 2017). In the Danube Gorge, mountain species descend to very low altitudes (e.g. Paşcovschi 1956; Covaciu-Marcov et al. 2009; Teodor et al. 2019), despite the region having a warmer climate than other areas of Romania (e.g. Stoenescu et al. 1966; Mândruț 2006). Anthropic activities in the region have a long history: it was an important part of the Roman Empire, with the Romans building a bridge over the Danube in the area (e.g. Păunescu & Butușină 2010; Bara & Kaiser 2015; Mehrotra & Glisic 2015). The Danube Gorge has had a wide network of roads since that period (Ilić et al. 2010). To compound the situation, the construction of the Iron Gates Dam I between 1964 and 1972 had a massive impact on the region, increasing the water level and flooding roads, human settlements and islands (e.g. Mihai et al. 2016; Șelău 2018). The current road has therefore been built higher up, cutting through the sometimes steep slopes and threatening neighbouring habitats (Niculae et al. 2014). However, previous studies offer only limited clues on the effect of road traffic on the fauna in the IGNP (Covaciu-Marcov et al. 2005, 2009; Teodor et al. 2019).

Considering the negative effect of road traffic upon fauna in general (e.g. Baxter-Gilbert et al. 2015; Garrah et al. 2015; Ciolan et al. 2017; Keilsohn et al. 2018) and the biodiversity of IGNP (e.g. Rozylowicz et al. 2019), we presumed that the rich diversity of habitats and species in the region would be reflected in patterns of road mortality. The climatic peculiarities of the region (e.g. Stoenescu et al. 1966; Mândruț 2006), and the warmer and drier weather conditions in south-western Romania over the last few years (e.g. Croitoru & Piticar 2013; Prăvălie 2014; Pravalie et al. 2014; Trif & Oprea 2015) led us to suppose that this climate pattern would result in seasonal changes in road-mortality rates, which presumably would be different from the pattern observed in other areas of Romania (e.g. Ciolan et al. 2017; Covaciu-Marcov et al.

Table 1 – The number of road-killed individuals and average number of vehicles per hour by period and section. The sections were distributed along almost the entire length of the gorge (S1-Orşova, S2-Eşelniţa, S3-Cazanele Mici Gorge, S4-Ponicova, S5-Liubotina, S6-Şviniţa, S7-Cozla, S8-Berzasca, S9-Liborajdea, S10-Gaura cu muscă Cave, S11-Moldova Nouă, S12-Măceşti, S13-Radimna, S14-Divici).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	Total	Average no of vehicles/ hour
March	9	23	19	15	10	16	15	16	26	29	3	55	9	20	**265**	**59.96**
April	65	9	12	9	1	33	65	81	97	16	26	68	19	37	**538**	**65.89**
May	44	66	78	59	32	53	85	90	244	57	37	137	75	57	**1,114**	**89.48**
June	212	72	64	58	75	96	132	239	574	133	38	153	59	27	**1,932**	**134.10**
July	179	59	50	49	48	25	52	63	207	34	47	152	75	65	**1,105**	**183.82**
August	177	61	62	42	23	28	69	85	361	22	118	76	383	170	**1,677**	**125.67**
September	90	27	26	18	26	34	21	20	326	18	48	73	129	99	**955**	**150.37**
October	178	102	64	43	51	106	333	439	455	8	39	262	335	293	**2,708**	**112.27**
November	49	64	16	13	15	267	323	368	358	35	39	216	304	201	**2,268**	**76.77**
December	53	43	36	3	3	19	21	33	123	8	7	21	13	18	**401**	**57.33**
January	18	-	-	1	-	1	5	1	7	-	-	2	-	15	**50**	**64.04**
February	4	2	8	1	1	28	42	40	48	1	5	15	16	6	**217**	**69.41**
Total	**1,078**	**528**	**435**	**311**	**285**	**706**	**1,163**	**1,475**	**2,826**	**361**	**407**	**1,230**	**1,417**	**1,008**	**13,230**	
Average no. of vehicles/ hour	**236.12**	**161.50**	**126.74**	**52.89**	**39.85**	**37.40**	**36.73**	**69.70**	**77.64**	**85.85**	**143.61**	**227.19**	**67.55**	**25.78**	**99.18**	

2017; Popovici et al. 2018) or elsewhere in the temperate zone (e.g. Orłowski 2007; Gryz & Krauze 2008; Mollov et al. 2013; Garriga et al. 2017). In order to verify these assumptions, we set the following objectives: 1. Counting and identifying road-killed animals, 2. Establishing seasonal patterns of mortality, 3. Identifying features of taxa composition determined by the climate of the region.

Material and methods

IGNP is situated in south-western Romania, in the Carpathian Mountains. The road which is the focus of the study has a length of 154 km and runs parallel to the Danube River. Due to its length and the diversity of the neighbouring habitats, we chose 14 sections (S1 to S14) each of 500 m in length. The sections were distributed along almost the entire length of the gorge (S1-Orșova, S2-Eșelnița, S3-Cazanele Mici Gorge, S4-Ponicova, S5-Liubotina, S6-Șvinița, S7-Cozla, S8-Berzasca, S9-Liborajdea, S10-Gaura cu muscă Cave, S11-Moldova Nouă, S12-Măcești, S13-Radimna, S14-Divici). They are surrounded by different habitats with varying degrees of disturbance, distance to the Danube, etc. The road has two lanes, is asphalted and is in a good condition. Field trips were conducted monthly between March 2019 and February 2020. To investigate the 14 sections, two consecutive days were necessary each month; each section was surveyed once a month. The road sections studied were walked simultaneously by several people. The carcasses were identified *in situ*. Most of the vertebrates, especially herpetofauna, were identified to species level, while invertebrates and other badly damaged vertebrates were assigned to supra-species taxonomic levels, as in other studies (e.g. Ciolan et al. 2017; Popovici & Ile 2018). We counted the passing vehicles, expressed later as an average number of vehicles per hour for each section and period of time. Data was collected by month and section. For each data subset, we calculated the relative abundance of road-killed taxa (ratio of the number of road-killed animals belonging to a certain taxon to the total number of individuals) in the sections and periods studied. We thus calculated the relative abundance separately in each section studied for each taxon (with respect to the total number of individuals per section), and separately in each month studied for each taxon (with respect to the total number of individuals per month). Relative abundance is a measure often used in road-mortality studies (e.g., Cicort-Lucaciu et al. 2016; Ciolan et al. 2017; Covaciu-Marcov et al. 2017; Popovici & Ile 2018; Popovici et al. 2018). Taxa diversity was estimated using the Shannon index.

Results

In total, we found 13,230 road-killed animals on the seven kilometres of road studied in IGNP, of which approximately 16% were vertebrates. The number of victims differed by period and section (Table 1). The largest number of road-killed individuals was identified in October (2,708 road-killed animals), and the smallest in January (50 road-killed animals). The section on which the most victims were recorded was S9 (2,826 individuals) and the least S5 (285 individuals). The only instances in which we did not find any carcasses were on six sections (S2, S3, S5, S10, S11, S13) in January (Table 1). The average number of vehicles per hour across all sections over the year was 99.18. The greatest number of vehicles per hour was recorded in the summer and at the beginning of autumn, and

Table 2 – Number of road-killed taxa and taxa diversity (Shannon index – H) in the periods and sections studied. The sections were distributed along almost the entire length of the gorge (S1-Orşova, S2-Eşelniţa, S3-Cazanele Mici Gorge, S4-Ponicova, S5-Liubotina, S6-Şviniţa, S7-Cozla, S8-Berzasca, S9-Liborajdea, S10-Gaura cu muscă Cave, S11-Moldova Nouă, S12-Măceşti, S13-Radimna, S14-Divici).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	Total	H
March	5	9	4	7	4	7	5	6	8	4	2	9	3	7	**23**	**2.37**
April	9	6	7	5	1	7	8	9	10	5	5	7	7	10	**25**	**2.15**
May	20	19	20	23	14	16	19	13	22	16	12	20	16	15	**45**	**2.66**
June	27	22	18	22	17	16	17	19	15	17	9	27	10	13	**50**	**2.53**
July	19	18	16	16	15	11	11	13	13	11	14	14	12	14	**40**	**2.46**
August	16	17	10	13	11	7	16	12	14	10	9	15	13	14	**43**	**2.05**
September	12	8	10	7	10	8	7	8	15	7	15	17	12	9	**35**	**2.19**
October	20	12	15	14	13	17	21	20	17	5	16	14	20	23	**43**	**2.38**
November	10	5	5	9	7	18	19	18	22	11	14	18	15	18	**42**	**2.3**
December	17	13	14	3	2	7	8	6	13	4	5	11	8	7	**34**	**2.81**
January	2	-	-	1	-	1	4	1	5	-	-	1	-	5	**16**	**2.1**
February	3	1	1	1	1	5	6	3	5	1	1	5	4	5	**12**	**1.47**
Total	**47**	**41**	**37**	**47**	**32**	**32**	**44**	**36**	**48**	**28**	**37**	**45**	**36**	**36**	**71**	**2.78**
H	**2.49**	**3.07**	**2.87**	**3.27**	**2.85**	**2.42**	**2.47**	**2.31**	**2.18**	**2.47**	**2.68**	**2.46**	**2.20**	**2.48**		

on the sections situated near the two towns in IGNP, Orșova and Moldova Nouă (Table 1).

The road-killed animals belong to 71 taxa. The actual number of taxa represented could in fact be considered to be higher: where we found just a few individuals from a particular taxon, we grouped these together under other taxonomic umbrellas. For example, under Chilopoda we included several undetermined individuals along with Geophilidae, *Scutigera* and *Scolopendra*, even though these are distinct in terms of their ecology and zoogeography. Orthoptera includes both Ensifera (Gryllidae and Tettigoniidae) and Caeliferae (*Acrida*). In *Coleoptera others*, besides undetermined individuals, we included taxa with fewer than 10 carcasses (Chrysomelidae, Cantharidae, Elateridae, Buprestidae, Tenebrionidae, Silphidae, Lampyridae, Dytiscidae). We did not group taxa in the case of amphibians and reptiles, because we usually identified them to species level and they have conservation value. The number of taxa varied by period and section (Table 2). By period, the largest number of taxa was killed in June (50 taxa) and May (45 taxa), and the smallest in February (12 taxa). By section, the largest number of taxa was recorded on S9 (48 taxa), S1 (47 taxa) and S4 (47 taxa), and the smallest on S10 (28 taxa). Only five taxa were killed in all 12 months (Oligochaeta Lumbricidae, Gastropoda with shell, Gastropoda Limacidae, Diplopoda and Lepidoptera adults). The diversity varied by period and section (Table 2). By period, the highest taxa diversity among road-killed animals was observed in December (H = 2.81), and the lowest in February (H = 1.47). By section, the highest diversity was recorded on S4 (H = 3.27), and the lowest on S9 (H = 2.18). The total diversity was H = 2.78.

Most of the road-killed individuals belonged to Gastropoda with shell (around 21%), followed by Orthoptera (around 16%) and Oligochaeta Lumbricidae (approximately 9%). The relative abundance varied seasonally (Table 3). Earthworms had high relative abundance in the early summer (in June with a relative abundance of almost 30%) and winter (in February with a relative abundance of almost 50%). Different taxa demonstrated high relative abundances at different times of the year: Orthoptera had high abundance in summer and autumn (representing at its maximum around 30% of the total individuals killed per month), *Bufo bufo* in spring (around 12% to 14%), *Pelophylax ridibundus* in summer (around 25%), *Rana dalmatina* in February and early spring (approximately 26% and 8%). The relative abundance of carcasses on the road through IGNP also varied by section (Table 4). Generally, invertebrates were predominant (Orthoptera with a relative abundance of 41% on S1 and Gastropoda (with shell) with a relative abundance of 38% on S12). However, a high relative abundance of a species of vertebrate was identified in two sections: an amphibian species, *P. ridibundus*, represented more than 30% of the total individuals recorded on S11 and a reptile species, *Natrix tessellata*, made up around 10% of the total victims recorded on S10.

Discussion

The road along the Danube causes the death of numerous animals. However, the number of road-killed animals is probably underestimated due to the relatively low carcass persistence of road-killed invertebrates (Skórka 2016) and small vertebrates (e.g. Santos et al. 2011; Teixeira et al. 2013; Silveira et al. 2018; Cabrera-Casas et al. 2020). On the sections of the road studied in IGNP, mostly invertebrates and, among vertebrates, mostly frogs (including many juveniles) were killed. Victims that adhered to vehicles could not be taken into account, as in other studies (McKenna et al. 2001; Baxter-Gilbert et al. 2015). Underestimation is also related to biodiversity of the surrounding area (e.g. Paşcovschi 1956; Rozylowicz et al. 2019): where the number of potential scaven-

Table 3 – Relative abundance (%) of taxa identified in each month of the year (I-XII – January to December); total number of individuals (n) and relative abundance (%) of each taxon.

Taxa	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	Total	
	%												n	%
Oligochaeta Lumbricidae	7.55	19.14	14.54	29.50	9.50	2.09	0.63	0.22	0.26	13.97	4.00	48.39	**1,176**	**8.889**
Hirudinea	-	-	-	-	-	-	-	-	0.04	-	-	-	**1**	**0.008**
Gastropoda (with shell)	2.26	10.22	30.16	16.61	28.60	29.46	7.64	27.03	17.77	4.24	2.00	0.92	**2,756**	**20.831**
Gastropoda Limax	1.89	28.62	7.36	4.92	5.61	2.09	4.29	9.79	14.11	19.20	4.00	13.36	**1,167**	**8.821**
Araneidae	2.26	-	1.62	0.57	0.27	0.12	0.21	1.14	1.23	7.23	-	-	**130**	**0.983**
Opilionidae	-	-	0.63	0.05	-	-	-	-	0.18	-	-	-	**12**	**0.091**
Scorpionidae	-	-	-	-	0.18	0.06	0.10	0.07	-	0.50	-	-	**8**	**0.060**
Chilopoda	1.51	0.74	0.27	0.83	0.36	0.30	0.84	0.74	2.07	4.99	2.00	-	**132**	**0.998**
Diplopoda	31.32	0.37	1.44	0.31	0.45	0.12	-	13.11	21.21	4.99	2.00	1.84	**975**	**7.370**
Isopoda Oniscidea	-	-	0.09	0.10	-	-	-	0.04	0.22	0.50	-	-	**11**	**0.083**
Odonata	-	-	-	0.31	0.18	0.24	0.42	0.07	0.22	-	-	-	**23**	**0.174**
Plecoptera	-	-	-	-	-	-	0.10	-	-	-	-	-	**1**	**0.008**
Blattodea	-	-	0.18	0.31	-	-	-	0.07	-	-	-	-	**10**	**0.076**
Orthoptera	1.13	-	0.72	10.56	21.90	22.12	31.83	15.88	21.69	8.73	2.00	-	**2,090**	**15.797**
Dermaptera	-	-	-	-	-	0.06	0.10	0.66	0.62	2.24	-	-	**43**	**0.325**
Mantodea	-	-	-	-	-	-	0.10	0.07	0.04	-	-	-	**4**	**0.030**
Coleoptera Carabidae	1.13	0.56	2.69	0.31	0.45	0.18	0.10	0.18	0.75	0.50	-	-	**75**	**0.567**
Coleoptera Scarabeidae	-	0.37	1.53	0.52	1.72	-	0.21	0.15	0.09	0.50	-	-	**58**	**0.438**
Coleoptera Lucanidae	-	-	0.99	0.26	1.00	0.18	0.31	-	-	-	-	-	**33**	**0.249**
Coleoptera Coccinellidae	0.38	-	0.63	0.47	0.18	0.06	-	3.62	5.25	2.99	18.00	-	**258**	**1.950**
Coleoptera Staphylinidae	-	-	0.36	0.10	-	-	-	0.04	0.22	1.00	-	-	**16**	**0.121**
Coleoptera Cerambycidae	-	0.19	0.90	-	0.45	-	-	-	0.04	-	-	-	**17**	**0.128**
Coleoptera Curculionidae	-	-	0.18	0.05	-	-	-	0.07	0.04	1.75	-	-	**13**	**0.098**
Coleoptera Meloidae	3.02	0.19	-	-	-	-	-	-	-	0.25	-	0.46	**11**	**0.083**
Coleoptera others	1.89	-	0.81	0.72	0.36	0.24	0.10	0.59	1.01	4.74	-	-	**95**	**0.718**
Panorpata	-	-	0.72	0.10	-	0.06	-	-	-	-	-	-	**11**	**0.083**
Trichoptera	-	-	-	0.05	-	-	-	0.04	0.13	-	-	-	**5**	**0.038**
Lepidoptera adults	0.38	0.93	1.44	8.95	5.79	2.15	3.77	0.37	0.53	4.74	2.00	0.92	**375**	**2.834**
Lepidoptera larvae	6.04	-	7.45	2.48	1.45	1.85	1.88	0.85	2.03	6.73	-	2.30	**313**	**2.366**
Diptera Brachycera	0.38	-	3.59	2.38	3.17	1.91	1.26	0.89	0.84	0.75	2.00	-	**213**	**1.610**
Diptera Brachycera Tabanidae	-	-	-	1.29	2.62	1.31	-	-	-	-	-	-	**76**	**0.574**
Diptera Brachycera larvae	-	-	-	-	-	-	-	-	-	-	-	1.84	**4**	**0.030**
Diptera Nematocera	-	-	-	0.16	-	0.06	-	-	-	-	-	-	**4**	**0.030**
Hymenoptera Apidae	5.28	1.86	7.54	1.71	1.99	1.43	0.84	0.48	0.26	0.50	40.00	-	**236**	**1.784**
Hymenoptera Bombus	0.38	-	0.90	0.16	0.09	0.06	-	-	-	-	-	-	**16**	**0.121**
Hymenoptera Vespidae	-	-	1.89	1.29	2.35	2.21	5.86	4.25	1.46	0.25	-	-	**314**	**2.373**
Hymenoptera Formicidae	-	-	0.36	0.93	0.27	0.06	0.10	0.07	0.75	-	-	-	**46**	**0.348**
Hymenoptera others	-	-	1.26	0.36	0.54	0.60	0.31	0.07	-	0.50	-	-	**44**	**0.333**
Homoptera Cicadidae	-	-	0.27	0.16	-	-	-	0.22	0.13	-	-	-	**15**	**0.113**
Heteroptera Pyrrhocoris	9.81	-	1.08	0.36	1.36	0.78	0.73	0.85	0.04	1.00	-	-	**108**	**0.816**
Heteroptera others	-	-	-	0.21	0.45	0.30	1.05	7.68	1.41	1.00	2.00	-	**269**	**2.033**
Salamandra salamandra	0.38	0.56	0.09	-	-	-	-	-	-	-	2.00	-	**6**	**0.045**
Lissotriton vulgaris	-	0.37	0.09	-	-	-	-	-	-	0.25	-	-	**4**	**0.030**
Triturus cristatus	-	-	-	-	-	-	-	-	0.04	-	-	-	**1**	**0.008**
Bombina variegata	-	-	-	-	-	-	-	-	0.04	-	-	-	**1**	**0.008**
Bufotes viridis	-	-	-	-	-	0.06	-	-	-	-	-	-	**1**	**0.008**
Bufo bufo	12.45	14.50	1.71	0.31	0.09	0.06	-	0.04	0.26	0.25	2.00	1.84	**151**	**1.141**
Pelobates fuscus	-	0.19	-	-	-	-	-	-	-	-	-	-	**1**	**0.008**
Hyla arborea	-	0.19	-	-	-	-	-	-	-	-	-	-	**1**	**0.008**
Pelophylax ridibundus	-	9.11	1.26	4.40	2.62	25.52	26.91	6.91	2.29	2.00	6.00	-	**1112**	**8.405**
Rana dalmatina	8.68	6.32	0.09	0.72	0.18	-	0.31	0.26	2.03	0.50	-	26.27	**189**	**1.429**
Rana temporaria	-	-	-	-	0.09	-	-	-	-	-	-	-	**1**	**0.008**
***Anura* undetermined**	-	-	0.27	0.05	0.09	0.06	-	0.30	-	-	4.00	-	**16**	**0.121**
Emys orbicularis	-	-	0.18	0.05	-	0.06	-	-	-	0.25	-	-	**5**	**0.038**
Ablepharus kitaibelii	-	-	-	0.10	-	0.06	-	0.11	-	-	-	-	**6**	**0.045**
Podarcis muralis	0.75	0.93	0.45	0.88	0.54	0.54	1.57	0.37	0.18	-	-	-	**73**	**0.552**
Lacerta viridis	-	0.74	0.99	3.11	2.90	2.50	4.61	1.37	0.04	-	-	-	**231**	**1.746**
Anguis fragilis	-	-	0.18	0.05	-	-	-	-	-	0.25	-	-	**4**	**0.030**
Natrix natrix	-	1.30	0.45	0.62	0.54	0.18	0.21	0.15	0.04	-	-	-	**40**	**0.302**
Natrix tessellata	0.38	2.04	2.33	2.07	0.54	0.30	2.41	0.89	0.26	1.75	-	0.46	**150**	**1.134**
Zamenis longissimus	-	0.19	0.09	-	0.18	-	-	-	-	-	-	-	**4**	**0.030**
Dolichophis caspius	-	-	0.09	0.21	0.09	-	-	0.04	-	-	-	-	**7**	**0.053**
Coronella austriaca	-	-	-	0.10	-	0.06	0.21	0.07	-	-	-	-	**7**	**0.053**
Vipera ammodytes	-	-	0.09	0.05	-	-	0.10	-	-	-	-	-	**3**	**0.023**
Reptilia undetermined	-	-	-	0.05	0.18	0.12	-	-	-	-	-	-	**5**	**0.038**

Taxa	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	Total	
	%												n	%
Aves	-	0.19	0.09	-	0.54	0.24	0.42	0.15	0.04	0.50	6.0	1.38	**29**	**0.219**
Mammalia Rodentia	-	0.19	-	0.05	0.09	0.06	0.10	-	-	0.50	-	-	**7**	**0.053**
Mammalia others	-	-	-	-	-	-	0.31	-	0.04	-	-	-	**4**	**0.030**
Mammalia Vulpes	0.75	-	-	-	-	0.06	-	0.04	0.04	-	-	-	**5**	**0.038**
Mamalia Erinaceus	-	-	-	0.05	-	-	-	-	-	-	-	-	**1**	**0.008**
Mamalia Chiroptera	-	-	-	-	-	0.06	-	-	-	-	-	-	**1**	**0.008**
Sum	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	**13,230**	**100%**

Table 4 – Relative abundance (%) of taxa identified in the 14 sections studied (S1–S14). The sections were distributed along almost the entire length of the gorge (S1-Orşova, S2-Eşelniţa, S3-Cazanele Mici Gorge, S4-Ponicova, S5-Liubotina, S6-Şviniţa, S7-Cozla, S8-Berzasca, S9-Liborajdea, S10-Gaura cu muscă Cave, S11-Moldova Nouă, S12-Măceşti, S13-Radimna, S14-Divici).

Taxa	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
	%													
Oligochaeta Lumbricidae	3.15	4.36	10.80	8.04	9.47	12.32	12.90	10.98	15.96	10.80	1.72	6.34	1.48	2.48
Hirudinea	-	-	-	0.32	-	-	-	-	-	-	-	-	-	-
Gastropoda (with shell)	7.98	7.58	8.51	5.14	3.16	8.07	24.59	15.66	27.81	6.65	3.93	38.54	33.45	21.83
Gastropoda Limax	4.17	11.93	5.52	1.93	1.40	20.54	13.93	9.08	10.69	2.49	5.16	7.48	7.34	5.56
Araneidae	3.06	2.27	1.38	2.25	0.70	1.42	1.46	1.56	0.32	-	0.74	0.57	-	0.10
Opilionidae	-	-	-	2.57	-	-	0.09	0.20	-	-	-	-	-	-
Scorpionidae	-	-	0.92	0.64	-	-	0.17	-	-	-	-	-	-	-
Chilopoda	0.83	0.76	0.92	1.61	1.75	1.70	3.27	0.34	0.57	1.66	0.00	0.24	0.92	1.19
Diplopoda	1.02	1.14	4.60	6.43	5.96	5.81	5.76	30.51	1.63	9.14	1.23	2.44	14.18	2.78
Isopoda Oniscidea	0.28	0.19	-	0.32	-	-	0.09	0.27	0.04	-	-	-	-	-
Odonata	-	-	0.23	-	-	-	-	0.14	-	0.28	1.72	0.57	0.07	0.40
Plecoptera	-	0.19	-	-	-	-	-	-	-	-	-	-	-	-
Blattodea	0.56	-	0.23	0.32	-	-	-	0.14	-	-	-	-	-	-
Orthoptera	41.00	16.48	15.86	16.08	21.40	27.05	17.28	11.25	8.28	5.82	12.04	8.86	9.32	27.58
Dermaptera	0.28	0.95	-	0.64	-	-	0.34	0.20	0.32	-	1.23	-	0.35	0.69
Mantodea	-	-	-	-	-	-	0.09	-	0.04	0.28	0.25	-	-	-
Coleoptera Carabidae	0.46	0.76	0.92	4.82	1.40	1.13	0.26	0.68	0.07	0.83	0.25	0.65	0.21	0.50
Coleoptera Scarabeidae	0.56	0.95	1.61	1.61	1.75	0.28	0.17	-	0.25	1.39	0.98	0.49	-	0.40
Coleoptera Lucanidae	0.37	0.76	0.23	3.54	2.81	0.14	-	-	-	0.55	-	-	0.07	0.10
Coleoptera Coccinellidae	0.56	3.79	1.15	0.64	-	0.28	0.43	0.41	4.25	-	0.98	0.24	0.35	7.94
Coleoptera Staphylinidae	0.09	0.19	0.23	0.32	-	-	0.09	0.07	0.07	0.28	0.25	0.41	0.07	-
Coleoptera Cerambycidae	0.09	0.38	0.23	1.29	0.70	0.42	0.17	0.07	0.04	-	-	-	-	-
Coleoptera Curculionidae	0.09	1.52	-	-	-	0.14	-	0.07	-	-	0.25	-	0.07	-
Coleoptera Meloidae	-	-	-	0.64	-	0.14	-	0.07	0.11	-	-	0.24	-	0.10
Coleoptera others	1.86	3.41	0.46	3.22	0.70	0.85	0.43	0.07	0.11	1.66	2.46	0.41	0.07	0.60
Panorpata	0.19	-	-	1.29	0.35	-	0.09	-	-	-	-	0.08	0.07	0.10
Trichoptera	-	-	-	-	-	0.28	0.09	-	0.04	-	-	0.08	-	-
Lepidoptera adults	1.48	1.52	2.53	3.22	11.93	3.40	1.38	2.85	1.38	29.09	6.39	2.03	0.64	0.99
Lepidoptera larvae	3.15	3.60	12.87	3.54	3.51	1.42	1.20	3.39	1.27	0.83	1.72	2.03	1.48	1.69
Diptera Brachycera	1.76	4.36	1.61	4.50	6.32	1.56	0.17	1.22	0.18	2.22	6.14	2.76	1.27	1.09
Diptera Brachycera Tabanidae	2.13	0.95	1.15	0.96	1.40	0.42	0.60	0.14	0.04	-	0.98	1.22	0.07	0.30
Diptera Brachycera larvae	-	-	-	0.32	-	-	0.09	-	0.04	-	-	0.08	-	-
Diptera Nematocera	0.09	-	-	-	-	-	-	-	-	0.28	-	0.08	0.07	-
Hymenoptera Apidae	3.62	2.46	0.69	0.96	1.75	0.42	0.43	0.81	0.07	1.39	3.44	3.82	2.68	4.66
Hymenoptera Bombus	0.09	1.70	0.23	0.64	-	-	-	-	0.04	-	-	0.08	-	0.10
Hymenoptera Vespidae	3.06	5.87	2.53	3.54	3.51	2.12	0.95	3.53	0.78	1.94	5.16	2.76	2.19	2.48
Hymenoptera Formicidae	0.19	0.95	-	5.79	0.35	-	0.69	0.47	0.04	-	0.25	0.24	-	-
Hymenoptera others	0.09	0.57	0.23	2.25	1.40	0.14	-	0.14	0.04	0.28	0.98	1.14	0.28	0.10
Homoptera Cicadidae	0.28	-	0.23	0.32	-	0.42	-	-	0.04	-	-	0.08	0.21	0.20
Heteroptera Pyrrhocoris	0.83	3.79	6.21	0.96	5.96	0.14	0.86	0.07	0.14	-	-	0.08	0.28	1.09
Heteroptera others	5.84	3.98	2.53	1.61	3.86	1.98	1.29	0.47	0.35	0.28	0.49	1.14	2.82	5.46
Salamandra salamandra	-	0.19	-	0.64	-	-	-	-	-	0.83	-	-	-	-
Lissotriton vulgaris	0.19	-	-	-	-	-	-	-	0.04	-	-	0.08	-	-
Triturus cristatus	0.09	-	-	-	-	-	-	-	-	-	-	-	-	-
Bombina variegata	0.09	-	-	-	-	-	-	-	-	-	-	-	-	-
Bufotes viridis	-	-	-	-	-	-	-	-	-	-	0.25	-	-	-
Bufo bufo	1.02	-	0.46	0.64	1.05	-	0.69	0.68	0.04	-	0.25	7.07	0.28	2.18
Pelobates fuscus	-	-	-	-	-	-	-	-	-	-	0.25	-	-	-
Hyla arborea	-	0.19	-	-	-	-	-	-	-	-	-	-	-	-
Pelophylax ridibundus	-	1.14	0.23	0.32	1.75	1.84	4.82	2.24	20.03	8.03	30.96	0.24	16.58	3.77
Rana dalmatina	5.66	1.33	-	2.25	-	-	0.17	-	1.52	-	2.95	3.33	0.99	0.20
Rana temporaria	-	-	-	0.32	-	-	-	-	-	-	-	-	-	-
Anura undetermined	0.83	-	-	-	0.35	-	0.26	-	-	-	0.74	-	-	-

Taxa	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
	%													
Emys orbicularis	-	-	-	-	-	-	0.09	-	-	-	-	0.24	-	0.10
Ablepharus kitaibelii	-	-	-	0.32	0.35	0.28	-	-	0.07	-	-	-	-	-
Podarcis muralis	0.19	0.95	6.90	0.64	0.35	2.27	1.03	-	0.04	-	-	0.24	0.07	-
Lacerta viridis	1.86	6.63	3.45	1.29	2.11	1.56	1.12	1.22	1.70	0.55	2.46	1.54	0.99	1.59
Anguis fragilis	-	-	-	0.32	-	-	0.17	-	0.04	-	-	-	-	-
Natrix natrix	0.09	0.38	-	-	-	0.14	0.26	0.07	0.25	1.11	1.47	0.24	0.49	0.50
Natrix tessellata	0.19	1.14	3.22	0.32	1.05	1.27	1.20	0.54	0.96	10.80	0.25	0.98	0.28	0.99
Zamenis longissimus	0.09	0.19	-	-	-	-	-	-	0.07	-	-	-	-	-
Dolichophis caspius	-	-	-	-	0.35	-	-	-	-	-	0.98	0.08	-	0.10
Coronella austriaca	-	-	0.23	0.32	-	-	-	-	0.11	0.28	-	-	0.07	-
Vipera ammodytes	-	-	0.23	-	-	-	-	-	-	0.28	0.25	-	-	-
Reptilia undetermined	0.09	-	-	-	-	-	0.26	0.07	-	-	-	-	-	-
Aves	0.19	0.19	0.46	0.32	1.05	-	0.43	0.34	0.07	-	0.25	0.33	0.14	0.10
Mammalia Rodentia	0.09	0.19	-	-	-	-	0.09	-	0.04	-	0.25	0.08	0.07	-
Mammalia others	0.09	0.19	-	-	-	-	-	-	0.04	-	-	0.08	-	-
Mammalia Vulpes	-	-	0.23	-	-	-	0.09	-	0.04	-	-	0.16	-	-
Mamalia Erinaceus	-	-	-	-	-	-	-	-	-	-	-	0.08	-	-
Mamalia Chiroptera	-	-	-	-	-	-	-	-	0.04	-	-	-	-	-
Sum	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

gers is high, as observed in studies of other areas (Silveira et al. 2018), carcasses are removed quickly (e.g. Antworth et al. 2005; Schwartz et al. 2018). Furthermore, a warm and humid climate accelerates the decomposition of animal carcasses (Santos et al. 2011). A sample taken at any given moment on a section of this road is therefore likely to be reasonably representative of the actual number of animals killed on this section for a much shorter period than the 24 hours suggested by other studies (Santos et al. 2011; Popovici & Ile 2018).

The huge number of road-killed animals raises a difficult dilemma for IGNP. On one hand, it indicates that mitigation measures should be taken, but on the other hand tourism is one of the most important activities for local human communities (e.g. Ökrös et al. 2014; Brad et al. 2018). Tourism (and the number of vehicles) increases in summer, coinciding with the animals' main period of activity. Increased road mortality caused by an influx of tourists has been observed in other studies (e.g. Seshadri & Ganesh 2011; Jeganathan et al. 2018). Curbing modernization of other roads in IGNP might be the most effective solution and would not affect the equilibrium between the local community and the park. This would at least mean that undisturbed areas could be maintained, as road modernization in forest areas can lead to negative impacts on biodiversity (Ciolan et al. 2017). The high biodiversity of habitats in the vicinity of the road, the road's significant length and its variety of uses across space and time make it difficult to implement any blanket mitigation measures.

We found some road-killed animals in the winter that should not have been active in the cold season. Even if the number of road-killed individuals and taxa was relatively low in the winter, it was larger in December than in March. This is a consequence of a mid-December period which was warmer than March. We even recorded carcasses in January, when night temperatures and sometimes even daytime temperatures were below zero. Moreover, the carcasses belonged predominantly to cold-blooded groups, such as invertebrates, amphibians and reptiles, rather than warm-blooded animals (birds and mammals). Although amphibians and reptiles hibernate in the winter in Romania (e.g. Fuhn 1960; Fuhn & Vancea 1961), amphibians were killed by vehicles in all three winter months and reptiles in December and February. In February, on a rainy day with temperatures of between 7 °C and 8 °C, we identified 57 carcasses of *Rana dalmatina*. In January, a *Salamandra salamandra* was killed; in February, although not on the sections studied, we found another road-killed individual and in December a live one. Thus, in the Danube Gorge in the winter of 2019 / 2020, these animals did not hibernate continuously, instead alternating between dormant and active every few days, exhibiting an activity pattern characteristic of the species in areas further south (Rebelo & Leclair 2003). Dice snakes were killed in December and February in areas with limestone rocks. While *S. salamandra* is a species common in hilly and mountain areas (Fuhn 1960) and which withstands cold conditions (Catenazzi 2016), *Natrix tessellata* is rare even in north-eastern Romania (Cogălniceanu et al. 2013), and yet it was active during two winter months. In addition to herpetofauna, invertebrates such as *Euscorpius carpathicus* and *Scolopendra* were also active in the winter. Winter activity has been observed over recent years in Europe, both in the case of reptiles (Zuffi et al. 1999) and amphibians (Jablonski 2013; Kaczmarek et al. 2018), but this has been in the Mediterranean region or in urban habitats.

The road-mortality data gathered in IGNP goes beyond demonstrating changes in the ecology of some species. Our results are of faunistic and conservation importance for IGNP, at least in terms of the identification of certain road-killed amphibians which have not been observed in the area for approximately 50 years. These species are *Lissotriton vulgaris* and *Triturus cristatus*. In the Danube Gorge, newts had been assumed to be absent due to the steep slopes (Covaciu-Marcov et al. 2009). The two newt species had not been reported in the area since at least as far back as 1971 (Stănescu et al. 2015). In IGNP, *T. cristatus* had been observed only in Orșova, recorded as a specimen in the local high school's collection (Fuhn 1975). After that date, it was recorded in the Locvei Mountains (Covaciu-Marcov et al. 2005), but this was outside IGNP. Identifying a road-killed *T. cristatus* in November was therefore unexpected, even if it was discovered near the previously mentioned locality of Orșova (Fuhn 1975). This shows that habitats favourable to newts still exist near Orșova. Furthermore, the presence of *L. vulgaris* in three sections, including those close to the Danube, show that the region should be searched intensively for newts, which are protected species (O.U.G. 57/2007), thus important for IGNP. Without it being our goal, the road-mortality study therefore led to new records of newts in IGNP. *Ablepharus kitaibelii* was recorded on S9 at Liborajdea, approximately 50 km west of its westernmost known location in Romania as indicated by previous distribution records (Cogălniceanu et al. 2013). Our record therefore became its current westernmost distribution locality in the country, proving its continuous distribution in the region. *Ablepharus kitaibelii* was killed in summer and early autumn on sections surrounded by rocky and forested habitats.

The peculiarities of the Danube Gorge in terms of the presence of certain mountain animals at low altitudes (e.g. Pașcovschi 1956; Covaciu-Marcov et al. 2009; Teodor et al. 2019) were also noticeable. *Salamandra salamandra*, *Bombina variegata* and *Rana temporaria* were killed even below an altitude of 100 m, which is lower than the altitude at which they usually occur in Romania (Fuhn 1960). Some road-killed species are protected (O.U.G. 57/2007), including almost all herpetofauna species, certain invertebrates (*Lucanus cervus*), etc. Others, such as *E. carpathicus*, are endemic to Romania (Fet & Soleglad 2002). Anthropically favoured species, such as bees, were also killed on sections surrounded by beehives, as was the case in other studies (Cicort-Lucaciu et al. 2016). Bees were killed even in January: despite temperatures falling below zero at night, the sun warmed the hives enough during the day to activate some bees.

The usual two-peak pattern (spring and autumn) of road-mortality rates (e.g. Gryz & Krauze 2008; Ciolan et al. 2017; Garriga et al. 2017) was not observed in IGNP. Fluctuations in the number of individuals and taxa killed had different periodicity. The number of individuals identified reached a maximum in the autumn (October and November), while the maximum number of taxa was recorded in June. A second, less pronounced peak was observed in the number of individuals in June and in the taxa richness in October and November. Both the number of individuals and the number of taxa killed increased between the cold and the warm season. However, unusually the number of road-killed individuals did not exhibit a spring peak, which is normally the most significant (e.g. Orłowski 2007; Orłowski et al. 2008; Ciolan et al. 2017). In IGNP, the autumn peak was driven by the deaths of snails and orthopterans, which are affected in different ways by the same local meteorological conditions. As snails prefer humidity, they were activated by the warm autumn rains, and because they move slowly and cover only short distances, they were killed in large numbers. Increased road mortality of snails following rainy days has also been observed in other areas (Jeganathan et al. 2018). Orthopterans, for their part, like heat; they are commonly associated with steppe areas (Radu & Radu 1967) and are particularly prone to traffic deaths in summer (Ciolan et al. 2017). The grasslands and high temperatures in IGNP helped keep them active in the autumn and there were even road-killed orthopterans recorded in December. Atypical mortality peaks were observed in some other taxa too. Among amphibians, the usual spring peak (e.g. Orłowski 2007; Orłowski et al. 2008; Ciolan et al. 2017) shifted to summer, when many *P. ridibundus* juveniles were killed. This is a result of the road's vicinity to the Danube.

In addition to highlighting the huge number of road-kill victims in IGNP, the results demonstrate the necessity for road-mortality monitoring, at least in this area, even in the cold season. The large number of victims recorded, along with the negative impact on wildlife, shoud provide motivation for new studies. The road through IGNP may be a useful focus for other studies which examine the carcasses of road-killed animals. Such uses of road-killed vertebrates' carcasses have been mentioned recently in studies concerning feeding ecology, parasites, morphology and age structure (e.g. McAllister et al. 2016; Kolenda et al. 2019a,b; Vafae Eslahi et al. 2017; Ile et al. 2020; Maier et al. 2020). The road could also be used as a source of samples in the case of invertebrates, including rare species, such as *E. carpathicus*. Another conclusion that can be drawn from the study is that the mild winter exposed animals to road mortality in a period in which they should not have been exposed. In the case of salamanders, the findings of this study seem to support the suggestion that global warming will affect their activity period (Catenazzi 2016). This highlights another, hitherto ignored, negative facet of climate change, namely the increased exposure of animals to road mortality. The extension of their activity period due to this warming will expose more animals to traffic over a longer period. We cannot predict the exact effect of these milder winters on this fauna, which has already been impacted by road mortality. The points discussed in this study demonstrate the important part played by road-mortality studies in various contexts and the many conclusions that can be drawn in relation to human-nature interaction.

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A holistic assessment of the impacts of park management: findings from the evaluation of Regional Nature Parks in Switzerland

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Keywords: management effectiveness, evaluation of parks and large-scale protected areas, Regional Nature Parks, Switzerland

Abstract

In Switzerland, Regional Nature Parks are required to undergo an impact assessment after ten years of operation, in order for the federal government to award the *Park of National Importance* label for a further ten years and for the government, relevant canton and communes to continue to provide financial support for the park's operation. To this end, is there a convenient way of identifying and holistically assessing the impacts of park management activities on the goals of the parks and the overarching targets of parks policy in Switzerland?
Based on experience gained from the evaluation of three Regional Nature Parks, we have developed a framework model for the holistic evaluation of such parks and present it here for discussion.

Profile

Protected area

Regional Nature Parks

Chasseral, Diemtigtal and Gantrisch

Mountain range

Alps, Switzerland

Introduction

A broad discussion of how to measure the effectiveness of park management can be found with reference to the keywords *Protected Area Management Effectiveness (PAME)* (Coad et al. 2015; Ferreira et al. 2018; Hockings et al. 2006, 2015; Leverington et al. 2010a, 2010b, 2010c; Nolte et al. 2010; Oldekop et al. 2014). The discussion began with the implementation of the Convention on Biological Diversity (CBD) and initially focused on the question of how to determine the effects of measures aimed at protecting biodiversity and achieving the goals of the Convention (Coad et al. 2015). The spotlight also fell initially on issues related to improving management processes (for example, involving local actors). The international conversation widened to include the question of how to measure management impacts for UNESCO Biosphere Reserves (Ferreira et al. 2018), prompted by the fact that Biosphere Reserves, unlike strict protected areas, play a role in socio-economic development as well as conservation. With the ongoing debate on sustainable development and the emerging view that many protected areas offer multiple socio-economic and cultural benefits for the region in addition to their ecological contribution, it is now widely recognized that management impacts also need to be considered and assessed with the bigger picture in mind (Hockings et al. 2015). The discussion has turned to how the impacts of protected areas can be measured holistically, for example from a sustainable development perspective (Ferraro & Hanauer 2015; Ferraro & Pressey 2015).

The discussions reflect the fact that parks are usually confronted with multiple – often very diverse – economic and social expectations on the part of local stakeholders, even if the parks belong to the same IUCN category (Hammer et al. 2016). In Switzerland, Regional Nature Parks (RNPs) must undergo an impact assessment at the end of a ten-year operating phase in order to apply for renewal of the *Park of National Importance* label and a subsequent ten-year operating phase (Swiss Parks Network 2021). A key question in this respect is how to assess the impacts of park management activities holistically, i. e. in relation to the overall objectives and those of the parks policy, in a manner commensurate with the means available (Plachter et al. 2012; Ferraro & Hanauer 2015; Ferraro & Pressey 2015).

The aim of this paper is to construct and justify a framework model for the holistic evaluation of a specific type of Swiss park, namely RNPs, based on experience evaluating the impacts of management activities at three parks. The framework model is intended to be used to design impact assessments for this and similar types of park, to derive relevant questions and to frame the results.

The model is based on our experience evaluating the three RNPs in the canton of Bern: Chasseral, Diemtigtal and Gantrisch (see Figure 1). These three parks were selected because the Canton of Bern decided to evaluate them together instead of individually and to develop an appropriate method for this purpose. In this paper we present, in turn, the Swiss concept of RNPs, the evaluation design, the results of the evaluation and lessons for the holistic evaluation of RNPs in Switzerland. We then explain the framework model and formulate conclusions.

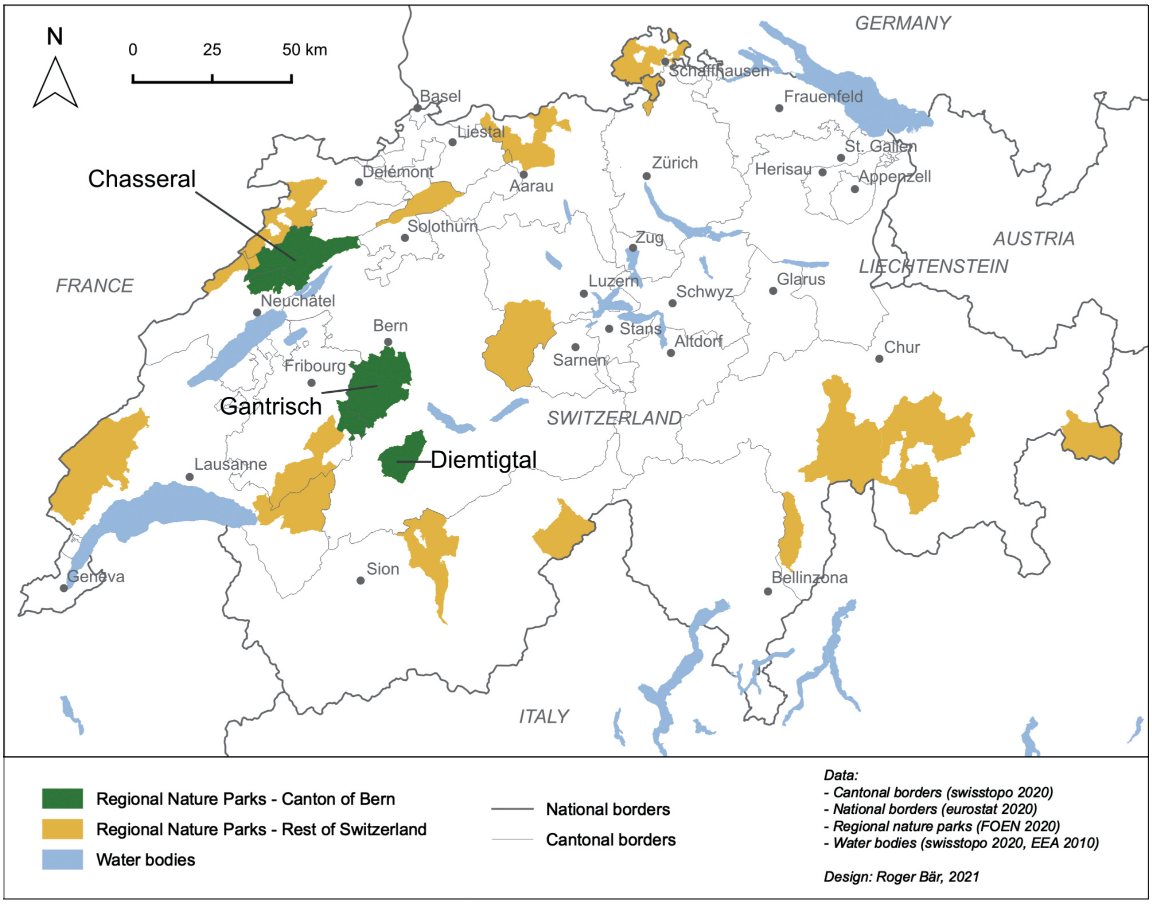

Figure 1 – Regional Nature Parks in the canton of Bern (green) and in the rest of Switzerland (yellow).

The Swiss concept of Regional Nature Parks

Legislation governing RNPs and the cantons concerned is laid down in the Federal Act on the Protection of Nature and Cultural Heritage (NCHA) and in the Parks Ordinance (ParkO) (Federal Assembly of the Swiss Confederation 1966 / 2020; Swiss Federal Council 2007 / 2018). Table 1 summarizes the main requirements contained in the legislation in relation to park areas and the establishment and operation of the parks. These include obligations relating to minimum size, quality of natural and cultural environments, spatial planning safeguards, participation of local residents, companies and organizations in the establishment and management of the park, composition and organization of the park authority, the role of the responsible cantons and the goals to be pursued. The main features of the Swiss concept of RNPs are as follows:

- A RNP is usually composed of several communes. The communes involved in the park set up a *park authority* on which they are represented and have a majority of the votes.
- In close consultation with the canton, the park authority draws up a ten-year *charter* on the operation and quality assurance of the parks. The charter contains the strategic goals and a management plan for the ten years and serves as the park authority's strategic steering instrument.
- To implement the charter, the park authority and the canton, in consultation with the federal government, draw up a four-year *programme agreement.* This agreement specifies, among other things, which projects are to be implemented and how funds are to be used; it lays out the proportions in which the communes, relevant canton(s), federal government and other actors will contribute financially and with other services.
- The park authority appoints a *park management body* which is responsible for the operational implementation of the strategic goals and the programme agreement.
- To apply for recognition and support from the federal government, the park communes have to demonstrate that the majority of the population living in the park supports the establishment of a park.
- If the federal government approves the application for recognition as a RNP, it awards the *Park of National Importance* label to the park authority for a period of ten years.

The Swiss concept of RNPs is characterized by the need to demonstrate the local population's approval for the establishment of a RNP.

The *Park of National Importance* label belongs to the park authority and thus to the park communes. The communes pursue strategic goals, which are imple-

Table 1 – Legislation governing the Regional Nature Parks (RNPs) in Switzerland (NCHA Art. 23g; ParkO Art. 15, 19-21, 25-28).

General requirements for Regional Nature Parks in Switzerland
A RNP in Switzerland is a large, partially populated area of at least 100 km² of high natural and scenic value, whose buildings and facilities blend into the landscape and townscape. It must include the entire area of the communes in which the park is located and is characterized in particular by the following: - the diversity and rarity of native animal and plant species and their habitats; - the outstanding beauty and distinctiveness of the landscape; - a low degree of disturbance of the habitats of native animal and plant species and of the landscape and townscape by buildings, facilities and uses made of the park; and - the uniqueness and exceptional quality of the cultural landscape, and sites and monuments of cultural and historical significance.
Overall Goal 1: Conservation and enhancement of nature and landscape
The following should be carried out to maintain and improve the quality of nature and landscape in a RNP: - preserve and as far as possible enhance the diversity of native animal and plant species, the habitat types and the landscape and townscape; - for native animal and plant species, enhance and connect habitats, especially those that require special protection; - preserve and strengthen the character of the landscape and townscape in the event that new buildings and facilities are built in the park or new uses made of areas of the park; and - reduce or eliminate, when the opportunity arises, existing encroachments on the landscape and townscape by buildings and facilities in the park or uses made of areas of the park.
Overall Goal 2: Encouraging sustainable business activities and promoting the marketing of the park's products and services
To encourage sustainable business activities, the RNP should, in particular, - ensure that local natural resources are used in an environmentally friendly way; - promote the regional transformation of raw materials and marketing of products produced in the park; - promote services with a focus on nature-based tourism and environmental education; and - support the use of environmentally friendly technologies.
Further requirements
- The cantons shall support local efforts to establish and maintain parks and shall ensure that the population in the communes concerned can participate in an appropriate manner. - There must be a park authority that has a legal form, a park management body and resources that can guarantee the establishment, operation and quality assurance of the park. The communes to which the park area belongs must be properly represented on the park authority. - The park authority must ensure the participation of the population in the establishment and operation of the park and enable the participation of interested companies and organizations in the region. - The charter to be drawn up by the park authority must stipulate how the natural, scenic and cultural values of the park are to be preserved, what measures to enhance and develop the park should be taken, how land-use related activities carried out by the communes are to be aligned with the requirements of the park and how human and financial resources are to be deployed. - The park must be protected by spatial planning policies. The authorities entrusted with planning shall adapt the land use plans according to the requirements of the park. In addition, the federal office concerned (Federal Office for the Environment, FOEN), shall a) together with the park authorities, the relevant cantons and the research funding institutions, ensure that research on parks, where it concerns several parks, is coordinated, and b) ensure cooperation and knowledge transfer among Swiss parks and internationally.

mented on the ground by a park management body. The park management body itself has no legislative powers. This has implications for a holistic assessment of management impacts: in addition to the legislative requirements at national and cantonal levels, the expectations of the local population and other stakeholders must also be taken into account. Some stakeholders (not just in Switzerland), for example, regard nature parks as *model regions* of sustainable development and have corresponding demands that go beyond the legal requirements (Dinica 2016; Hammer et al. 2018; Romagosa et al. 2015).

The Canton of Bern and the park authorities provided financial resources for the evaluation, but these were limited, so it was not possible to conduct wide-ranging, comprehensive research. In order to measure – or at least estimate – the impacts of park management activities, we therefore had to develop an approach that was commensurate with the means available.

Evaluation design

The federal government provides guidelines for the evaluation of *Parks of National Importance* (FOEN 2014 / 2019). According to the guidelines, three analyses are to be carried out. Firstly, an analysis should be conducted showing what significant changes (e.g. social, political) have taken place in and around the park since the start of the operating phase and what implications these changes have had in relation to park management. Secondly, it should be determined to what extent the legally prescribed overarching goals and the strategic goals formulated by the park have been achieved. And thirdly, an overall assessment of the management effectiveness should be carried out, which will also demonstrate the implications for the future direction of the charter and park management activities.

The evaluation of the three RNPs in the canton of Bern (mid-2018 to end of 2019; Bär et al. 2020) was based on these guidelines and, as far as possible, designed as a transdisciplinary research project. Scientific responsibility lay with the Centre for Development and Environment (CDE) of the University of Bern. An advisory group consisted of representatives of the Canton, the three RNPs, the Swiss Park Research Coordination Office and a private consultancy. Their task was to provide constructive criticism and guidance in relation to the planning, implementation and analysis of the evaluation.

Table 2 – Example of the operationalization of the legally prescribed overall goal Conservation and enhancement of nature and landscap *by one of the three Regional Nature Parks in the form of a strategic goal and several outcome and output goals.*

Overall goal	Strategic goal	Outcome goals	Output goals
Conservation and enhancement of nature and landscape	Maintain, develop and, where appropriate, enhance natural, landscape and cultural values	Foster the quality of landscapes and habitats	At least 3 ha of habitats should be enhanced per year
			At least three landscape management measures will be carried out every year in different habitats
		Foster the quality of settlement areas and townscapes	A programme of measures for the enhancement of sites and landscapes will be completed by 2015
			The measures should be implemented annually in line with the programme
		Foster unique and valuable cultural and scenic assets	At least one cultural camp should be held each year until 2021
			Special cultural events and activities should be held
			A signage scheme should be implemented to label cultural assets
			Communes should sign up to light pollution guidelines enabling the park to be recognized as a "star park"
		Foster the diversity of species and habitats and their interconnectedness	The area, distribution and development of habitats should be known
			At least three technical reports on the matter should be published each year
			A solution should be found that respects the legal framework in this area and takes into account the various interests involved
			Measures should be implemented aimed at promoting and raising awareness of most of the species recorded in the park
			Threatened species should be recorded
		Ensure sustainable engagement with nature and culture	At least 500 people should complete the block course on the subject of water
			Awareness-raising measures should be carried out

The evaluation design was based on the standard model of policy evaluation, as advocated by the International Union for Conservation of Nature (IUCN) (Hockings et al. 2015, p. 900–902) and as used, in a modified form, by the Swiss Federal Office for the Environment (FOEN) as a framework for evaluation (see Figure 2). This model essentially distinguishes between the following four elements: inputs (available resources), processes (implementation in the form of activities and measures), outputs (services and products provided) and outcomes (results and impacts).

Our methodological design made it possible to identify outputs and outcomes and to assess related objectives based on criteria and indicators. Where possible, we derived the criteria and indicators from the objectives and other specifications set out in the respective management plans of the three parks. However, indicators could only be determined for two parks, because one of the three management plans contained almost no quantitative targets. In this case, the criteria alone were used to assess the outputs and outcomes. As the three parks operationalized the overarching goals for all parks in different ways, we had to define specific criteria and indicators for each park to assess their outputs and outcomes. Table 2 shows an example of how a park has operationalized an overarching goal.

The evaluation was also designed to take into account specific characteristics of each park. We therefore analysed existing data and previous studies relating to the nature parks and carried out park-specific surveys, interviews with local actors and workshops.

Evaluation results and lessons for the holistic evaluation of Regional Nature Parks in Switzerland

The results of the evaluation of the three RNPs in the canton of Bern have been published in a synthesis report (Bär et al. 2020). These can be summarized as follows: Across all three parks, about two thirds of the output and outcome goals were achieved or even surpassed. The remaining objectives were achieved only partially or not at all, for various reasons, or no reliable statements could be made on their achievement. The park management body succeeded in implementing a range of measures and projects that had positive impacts.

Overall, we found that park management bodies' options for action were, in line with the resources available to them, severely limited in regard to the strategic goals formulated by the respective park authorities to achieve the goals specified in the legislation, and the very wide-ranging, and in part contradictory, social demands. Park management can contribute to gradual changes by cooperating closely with local and regional actors and by informing, raising awareness, initiating, advising, motivating, networking and providing support. Park management can also create incentives for action, such as awarding its own certification label for products produced in the park that meet certain standards, organizing competitions or offering attractive opportunities for volunteers. But what park management can effectively achieve depends very much on local circumstances such as local authorities, local policies, the existence of various local and regional actors and their willingness to cooperate, and the funding available.

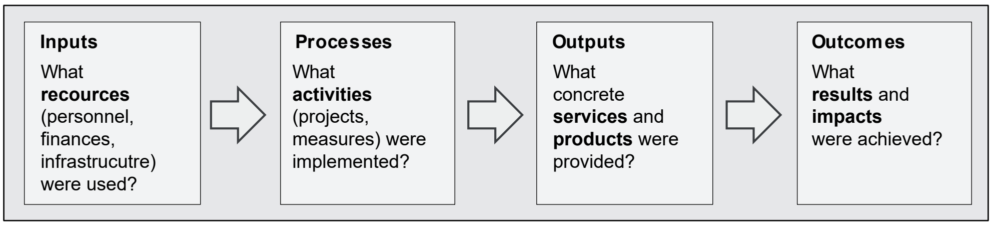

Figure 2 – Standard model for the evaluation of the impact of management activities on parks (adapted from Hockings et al. 2015, p. 901).

The evaluation of the three RNPs in the canton of Bern showed that a rule-book approach quickly reaches its limits. Regional complexity and the ten-year operating phase form a dynamic monitoring context which a static approach is not well-suited to reflect. In order to identify the main lessons learned, we examined the experiences associated with the evaluation of the three RNPs in a working session. In this session, we were able to refer to various discussions held during the evaluation process. The findings from the six workshops (two workshops per park) held to assess the output and outcome goals with the park management bodies and other local actors proved to be particularly valuable. In particular, the following insights were gained and challenges identified:

The evaluation is a learning process

During the evaluation, we found that the actors involved in the process discussed issues and gained insights; these can be interpreted as learning processes and are thus relevant for both park management and research purposes. Assessing the impact of park management activities in the way we have done is therefore an integrated transdisciplinary research and learning process that differs substantially from, for example, clearly delineated evaluation formats such as evaluation research, self-evaluation and external evaluation, while at the same time combining the strengths of these approaches. Throughout the process, the three park management bodies, researchers, one representative from each of the Canton of Bern, Park Research Switzerland and a non-governmental organization, and other local stakeholders participated in the six workshops in the three RNPs. Involving a wide range of actors in this manner provides differentiated knowledge of the context, enables adaptation of the evaluation to local conditions and leverages knowledge of the park management body's scope of action.

A differentiated methodological design is needed for the evaluation

Identifying and assessing outputs and outcomes is demanding. The assessment cannot be designed solely in relation to resources and process. Contextual factors such as communal, cantonal and national policies, and the park management body's scope of action, are essential to reduce attribution gaps in explaining the causal relationship between the resources, process factors, outputs and outcomes. In addition, not all output and outcome objectives, criteria and indicators were adequately formulated at the beginning of the ten-year operating phase, so that it was not sufficient to consider only the criteria and indicators originally defined.

Some developments are difficult to observe and identify

Various developments such as changes in biodiversity and landscape and the effects of awareness-raising and educational measures are difficult to determine and quantify. Although we came to the conclusion that park management activities make significant contributions to achieving outcome goals, this does not necessarily mean that the environmental, social and economic situation in the Bernese Nature Parks improved in all relevant areas during the operating phase.

Adaptive management is systemic

RNPs contribute to developments that are significant from a sustainability perspective but were not originally planned in the charter. These include, for example, contributions to strengthening regional cooperation and regional identity. In a dynamic region, a nature park must be able to respond to changing social demands. Simply ticking off previously formulated output and outcome goals and indicators does not do justice to circumstances on the ground.

Aspects of process design must be included in the evaluation

Governance structures that enable local and regional actors to take initiative and participate are essential for the success of a RNP. On the whole, RNPs are *soft* steering instruments of sustainable development with limited capability and means. However, they can indirectly influence the ongoing development of *hard* underlying institutional aspects (e.g. spatial planning), and thus prepare the ground for substantial changes towards sustainability.

A framework model for the holistic assessment of Regional Nature Parks in Switzerland

Based on the lessons learned from the evaluation of the three Regional Natural Parks in the canton of Bern, we propose a differentiated framework model

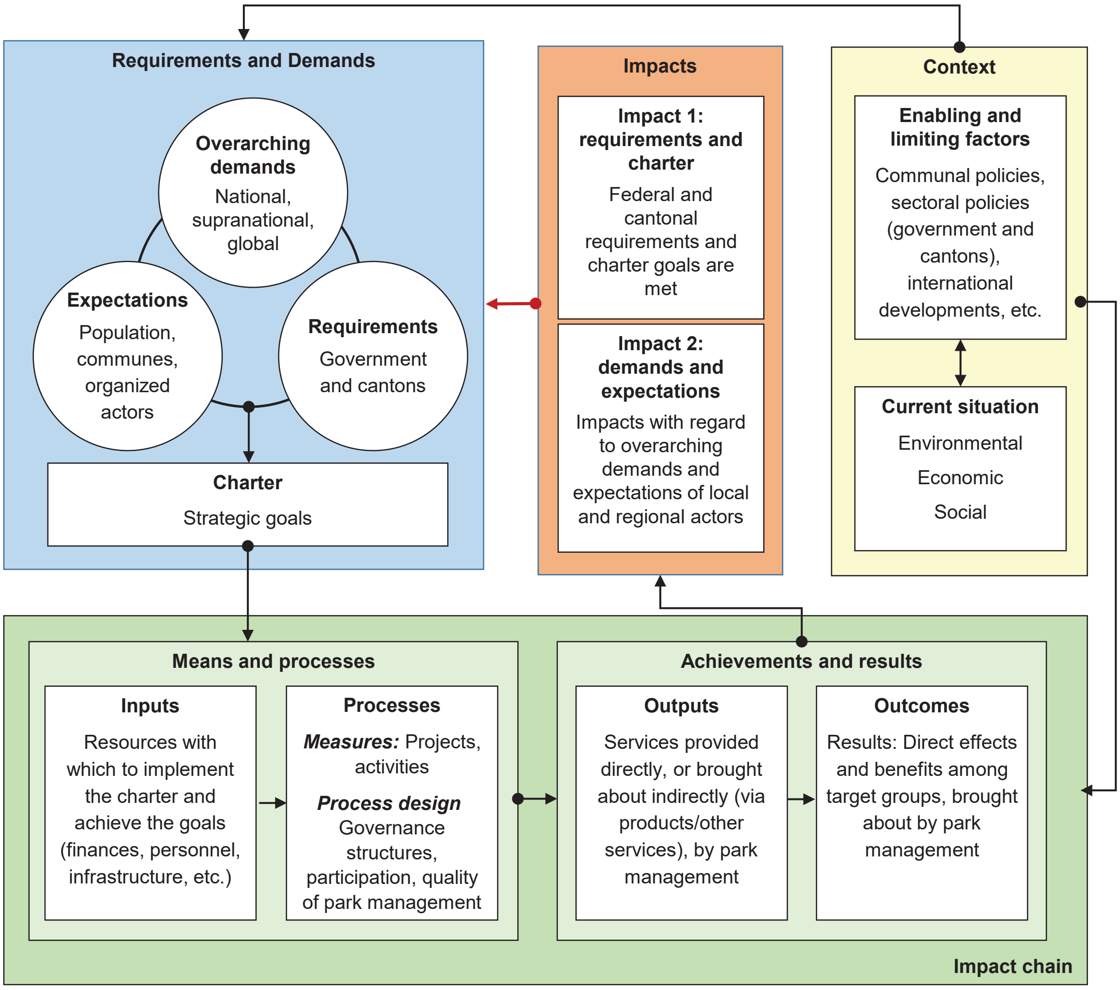

Figure 3 – Model for evaluating the impacts of management on Regional Nature Parks in Switzerland: The blue box shows the requirements and demands. These are composed firstly of the general national and international expectations of protected areas (e.g. contribution to the conservation of biodiversity), which are not necessarily laid down in law (e.g. contribution to combating climate change and to the energy transition). Secondly, these and possibly other expectations are specified in national and cantonal legal provisions (requirements). Thirdly, the local population and other local actors have expectations of the parks, which are all incorporated into the charter as a normative framework for park management. The charter in turn provides the framework for the means and processes (arrow from blue to green box) that are part of the standard model (inputs, processes, outputs, outcomes) shown in Figure 2 (green box). The inputs and processes determine which outputs and outcomes are produced. The context (yellow box) also has a significant bearing (arrow from yellow to green box) on these outputs and outcomes. The outputs and outcomes have effects (arrow from the green to the orange box) on the context and the requirements and demands (arrows in red). The effects on the context also feed into changes in the requirements and demands (arrow from the yellow to the blue box).

for the holistic assessment of RNPs in Switzerland (see Figure 3). This model is intended to encourage consideration of all essential elements right from the initial development of an evaluation, to help us think about them in a networked way and to enable the corresponding evaluation questions to be formulated (see Table 3). Compared to the standard model shown in Figure 2, it demonstrates significant refinements:

First, the proposed framework model places much greater importance on processes (second element in the standard model in Figure 2 and second element in the impact chain in Figure 3) by giving strong weight to process design in addition to measures. What park management can achieve depends largely on what governance structures are in place, how local and regional actors are involved and can participate, and the quality of park management. It therefore makes sense, in addition to the actual projects and other activities, to relate the process design in particular to the outputs and outcomes in the area of implementation and also to assess the process design itself.

Second, the extended framework model presents outcomes in a more differentiated way. Whereas in the standard model (see Figure 2) results and impacts are considered together, the extended model (Figure 3) divides them into direct effects (direct effects and benefits among target groups brought about by park management, described in Figure 3 as *outcomes* and broader-ranging effects (described in Figure 3 as *impacts*).

Table 3 – Example of a questionnaire for evaluating the impacts of management activities on Regional Nature Parks in Switzerland.

Questions about the services provided ("Outputs") and the results achieved ("Outcomes")
What outputs are provided directly by park management activities and what outputs are brought about indirectly with the help of projects and activities (e.g. products, services)? Have the output goals been met? What are the direct effects brought about in the target groups and target assets (including in relation to land use, landscape and nature? Have the outcome goals been met? If the output and/or outcome goals were not met, what are the reasons for this? Were the output and outcome goals commensurate with the resources available? How have contextual factors such as communal policies, cantonal and federal sectoral policies, and international developments influenced outputs and outcomes?
Questions about the impacts (Impacts 1 and 2)
To what extent have the federal and cantonal requirements been met and the strategic goals set out in the charter achieved? (Impact 1) Have adequate contributions been made to fulfilling overarching national, international and global demands (e.g. to mitigating climate change) and to fulfilling local expectations (e.g. preservation of jobs)? (Impact 2) If federal and cantonal requirements and the goals set out in the charter have not been met: What are the reasons for this? What influence did contextual factors have? What are the main changes in the park area in environmental, economic and social terms that have resulted from all outputs, outcomes and impacts of park management? (Impacts on the current situation)
Questions about the use of resources and the implementation process
Have the available resources (including finances, personnel, infrastructure) been used appropriately and in line with the strategic goals set out in the charter? Did the measures implemented (e.g. projects, activities) achieve the intended outputs and outcomes? Were the measures adequate and appropriate to achieve the outputs and outcomes? Have appropriate governance structures been established for the implementation of the measures and have appropriate participation processes been designed? Have the measures been accompanied by an adequate quality of park management?
Questions about refinements to the charter and the federal and cantonal requirements based on the evaluation results
What need is there to adapt the strategic goals in light of current and expected overarching demands, expectations of local actors and requirements of the federal government and the canton? What are the recommendations regarding future measures, process design and the use of resources to achieve the strategic goals? What are the recommendations regarding the ongoing development of federal and cantonal requirements?

Third, the extended model supplements the standard model by providing a coherent framework that includes both the context and the requirements and demands. This consists of: (a) feedback loops (*Impacts* in the orange box and red arrows, Figure 3), through which the outputs and outcomes influence the requirements and demands (blue box) and the context (yellow box) via their impacts and thus continuously reshape the evaluation framework; and (b) requirements and demands at different levels (blue box). Through their interplay, these elements form a dynamic framework, the understanding of which is indispensable for a contextual evaluation that leads to helpful recommendations. The importance of these elements for an evaluation is described below:

Feedback loops

These are at the heart of the framework model, as they reveal changes in the park's context and the expectations of the actors in that context (and beyond); these feedback loops should therefore be seen as part of the context rather than as an external construct. This subtlety is essential because it implies that a dynamic goal is an integral part of the context and that this requires park management to be adaptive.

Impacts

The impacts represent the changes achieved. Capturing them is key, since an evaluation is concerned particularly with identifying and assessing the actual changes achieved. Here we distinguish on the one hand between impacts that relate to requirements and demands, i.e. those that concern, among other things, the requirements of the federal government and the canton, the expectations of the population and other actors, and the goals set out in the charter (blue box, Figure 3). On the other hand, we distinguish between impacts on the context (yellow box), such as changes brought about by enabling and limiting factors, and changes in the sustainability dimensions of environment, economy and society. The elements distinguished in the blue and yellow boxes are intended to help classify the changes identified.

The same applies to the elements distinguished in the Impacts box. In principle, it makes sense on the one hand to identify the impacts in terms of the federal and cantonal requirements and the charter objectives (orange box, Figure 3: *Impact 1: requirements and charter*), which is a crucial part of evaluating a RNP. However, as explained above, the parks face further demands from a national, supranational and global perspective and expectations of local and regional actors, which is why it makes sense to also identify impacts related to the role of RNPs as model regions for sustainable development. In the case of the latter, questions should also be asked about the *soft* effects, such as changes in regional identity, in sustainability awareness or in forms of cooperation, which are difficult to identify but are of fundamental importance for sustainable development. Central to the understanding of the framework model and the design of evaluations is that Impacts 1 and 2 generate an effect with regard to the ongoing development of the charter, the requirements of the federal government and the relevant canton, the contextual conditions, the expectations of local and regional actors, and the overarching demands on RNPs:

Expectations and requirements

These shape the content of the charter at the start of the operating period (see below). It is therefore necessary when formulating the charter to consider which overarching societal effects (Impact 2, e.g. energy transition, reduction of the use of natural resources, increase in the quality of life, sustainable mobility) are to be achieved through the measures aimed at achieving the strategic goals in the park area (Impact 1). For the evaluation, however, this also means that expectations and requirements are to be understood as dynamic elements, as became evident in the evaluation of the Bernese Parks: the priorities that were set out in the charter had changed ten years later. For example, adaptation to climate change, which may have been viewed with scepticism ten years ago, is now much more important, be it for winter tourism or for agriculture.

Context-specific factors

As the consideration of contextual factors is essential for an appropriate assessment of management effects, these take on a framing function in the model. Two types of factor can be distinguished in this respect: first, the region's current situation (environmental, economic, social) and second, the enabling and limiting factors. The contextual factors influence the overarching demands on RNPs, the requirements of government and canton, and the expectations of local and regional actors and thus the formulation of the charter. They also influence the inputs, implementation process, outputs and outcomes, and thus, indirectly, the impacts. The impacts in turn lead to changes in the context, and the altered context consequently influences the demands, expectations and requirements, which in turn influence the inputs and the implementation process.

Strategic goals

Finally, the strategic goals set out in the charter are based on the requirements of the federal government and the relevant canton, and the expectations of local and regional actors. The services provided to the park management body and their strategic use are also described in the charter. These services also represent the inputs that are available to the park management body for the operational implementation of the charter. In the context of an evaluation, the temporal context in which these goals were formulated must not be forgotten, and the difference between priorities at the time the goals were set, intermediate priorities and priorities at the time of evaluation (for example, changes in priority that arise due to a change in legislation) must be taken into account.

Discussion

Using the extended framework model for an evaluation takes greater effort than using the standard model. The extended model requires a consistent immersion in the context of the relevant park; it is more than a matter of checking off indicators and quantifying outputs and outcomes. It places high demands on everyone involved, especially researchers. They must be able to enter into a process with an uncertain outcome, integrate the perspectives of all actors and maintain high scientific standards.

On the other hand, such an evaluation also offers significant added value, namely the design and implementation of a joint learning process which can support the region as a whole in its transformation towards sustainability. The evaluation can demonstrate which lessons can be learned from the implementation process up to that point – to what extent park management has contributed to fulfilling the requirements set out in the charter, to achieving the strategic goals (Impact 1) and the overarching societal demands (Impact 2) – and what its future contributions should be. We believe that carrying out an evaluation based on the proposed framework model serves as a learning tool for the park management and the other actors involved in the evaluation of the relevant park which makes it possible to deal with fundamental questions that go well beyond the minimum evaluation results required by the authorities.

It is essential that this process is participatory. For without the broad involvement of local actors, there is no opportunity to engage in a joint learning process. In the evaluation of the three Bernese Nature Parks, it would have been useful to involve the local population and other stakeholders more extensively, for example in discussions on the future role of a RNP and the scope of action granted to the park management body, especially with a view to creating a good basis for taking the charter forward.

Based on experience gained from the evaluation, we can conclude that understanding the evaluation of the charter as a comprehensive learning tool enables park authorities and park management to engage in a process with the local actors, take a critical look back at previous activities and develop forward-looking visions for sustainable development in the region.

We consider the creation of a differentiated hierarchy of objectives with corresponding criteria and indicators along the impact chain of outputs, outcomes and impacts to be a useful guide both for park management and for carrying out an evaluation. Impact 2 (desired impacts with regard to overarching demands and expectations of local and regional actors) can reflect, in particular, how park management wants to contribute to overarching social sustainability goals beyond the immediate strategic goals of the RNP, i.e. to goals that are not included in the core mission, but that various actors expect RNPs to fulfil as models of sustainable development. It is important that appropriate monitoring systems are set up at the beginning of the implementation phase so that corresponding data can be accessed during the evaluation phase.

As we discovered, the strategic objectives of the Bernese Nature Parks were only partially taken into account in communal, regional and cantonal planning and consultation procedures, and in sectoral policies. It would be valuable to find ways for park authorities and park management to become more involved in the ongoing development of the institutional framework (including sectoral policies) at communal, regional and cantonal levels and to be regarded as important actors in this respect.

Given the observation that park management's options for action are very limited in terms of actually fulfilling its strategic goals, it is essential to place increased focus on the strengths of the RNPs, when formulating – and communicating about – the charter. The evaluation showed that the strengths of these parks lie especially in awareness-raising and educational measures, initiation and (non-material) support of projects, motivation and networking of actors, and cooperation with actors from the local to cantonal and national level. Although difficult to quantify and qualify, such soft measures certainly promote regional change towards sustainability. They focus on changing the preconditions for action. RNPs already take on a variety of mediating and bridging functions between different actors. Park management can thus be seen – and promoted – as coordinators of regional change (see Hammer & Siegrist 2016). However, this does not exempt park management from presenting and communicating quantifiable outputs and outcomes to ensure visibility of their direct achievements, as this is of fundamental importance for the acceptance of RNPs by local populations (Michel & Wallner 2020).

The question arises whether the framework model can also be used for evaluations of the effects of park management activities in other countries. The answer depends in particular on the purpose of the park in question, the objectives of the evaluation, and the requirements of the authorities and any international organizations involved. However, we believe that evaluations of parks with a broad mandate in terms of sustainable development can be inspired by this model.

Recommendations

We found a degree of contradiction between the legal stipulations of the federal government and the cantons, the level of funding available and the scope of action of park management on the one hand – and, on the other, the image of RNPs as model regions of sustainable development, as postulated by the federal government and supported by social actors. In reality, the scope for RNPs to exert influence is limited. To fulfil their role as model regions, their opportunities for exerting influence at communal, regional and cantonal levels should be expanded and they should, for example, be more closely involved in policymaking.

This would require adjusting the requirements set by the government, and the scope of action of the park authorities and park management, to enable the latter to better incorporate their strategic goals into policy processes. One possibility is to expand the legal requirements of the government and the Canton of Bern. For example, RNPs could be required to show in their charters how they intend to deal with overarching demands and expectations in relation to sustainable development that are not explicitly defined by law. This would enable the evaluation to show what RNPs contribute, for example, to sustainability strategies at both communal, cantonal and national levels and globally (e.g. Sustainable Development Goals, SDGs).

However, expanding the legal requirements is also a balancing act for RNPs if their resources are not increased accordingly, their scope of influence expanded and their status as actors of regional change revalued. This requires the support of the federal government and the relevant cantons, communes, population and other local actors. RNPs in the canton of Bern – and thus also park policy – could take a step in this direction for the next ten-year operating phase, to really fulfil their role as model regions of sustainable development.

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Habitat suitability evaluation for *Paeonia decomposita*, based on a MaxEnt model

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Keywords: Paeonia decomposita*, MaxEnt, habitat, suitability evaluation, Sichuan province*

Abstract

Paeonia decomposita is on the IUCN's Red List of endangered species, and occurs only in the northwest part of Sichuan Province, China. For the effective protection of the species, it is important to evaluate the suitability of potential habitats for *P. decomposita* and natural factors that influence the species. Based on the actual distribution points of *P. decomposita* in northwest Sichuan from 2016 to 2018, the Maximum Entropy Model (MaxEnt) was used to analyse the main factors affecting its habitat, and to predict suitable habitats. The results show that: (1) the model has high accuracy and is suitable for the prediction and evaluation of habitat suitability for *P. decomposita*; (2) temperature, slope, precipitation and moisture index will all greatly affect *P. decomposita's* distribution; (3) the areas that are potentially suitable for *P. decomposita* are mainly in Mianyang, Aba, Ganzi and Liangshan, which are greatly affected by human activities; effective protection measures have not been taken. It is proposed that new reserves for the introduction of *P. decomposita* should be established in areas of high or moderately high suitability. A programme of cultivation of this rare species should also be set up.

Introduction

Paeonia decomposita (Fang 1958) is a rare and endangered plant endemic to China (Fu, 1991; Xia et al. 2017), on the IUCN's Red List of endangered species. Its distribution area is very narrow: the plant is found only in northwestern Sichuan province (Editorial Committee of Flora of China 1997), mainly in the arid valleys of the rivers Dadu and Min, and grows in the grasslands or shrub at altitudes ranging from 2,200 to 3,100 m (Hong et al. 2017; Zhou et al. 2018). *P. decomposita* is an ideal choice for the development of new peony varieties. Peonies are appreciated not only for their flowers; peony seed oil has culinary uses, and nutritional and medicinal properties; peony root extracts also have medicinal properties (Yang et al. 2015). In recent decades, *P. decomposita* has become endangered and is likely to become extinct if not protected, due to the excessive exploitation of the plant, the destruction of its habitat conditions caused by a large number of hydropower stations, and its biological characteristics, such as the low germination rate of seeds under natural conditions (Jing & Zheng 1999).

The evaluation of habitat suitability for a species usually uses a species distribution model (SDM), which analyses the relationship between the actual species distribution area and environmental variables, and through the use of algorithms predicts the possible distribution area (Du et al. 2021). At present, the Maximum Entropy Modelling of Species' Geographical Distribution (MaxEnt) is one of the most commonly used niche models (Yang et al. 2020). Compared with other niche models, such as GARP (Genetic Algorithm for Rule-set Prediction), Bioclim (Bioclimatic Prediction System), Donmai (Domain Model) or ENFA (Ecological Niche Factor Analysis), MaxEnt needs only a small sample size and has a higher prediction accuracy (Wan et al. 2020). It is therefore widely used in modelling potential suitable areas and priority protected areas for rare and endangered plants, such as *Kingdonia uniflora*, *Taxus yunnanensis* or *Davidia involucrata* (Qu et al. 2018). The reliability of the model makes it suitable for informing the protection plan of related rare species, and to some extent also the planting of economic species.

In short, the MaxEnt model has many advantages, and we therefore used it to analyse the impact of environmental factors on *P. decomposita*, predict suitable habitat, and provide scientific advice for determining priority protection areas for *P. decomposita*.

Materials and Methods

Current distribution of species

Information on the distribution of *P. decomposita* was obtained from three field surveys that we carried out from 2016 to 2018, in Sichuan Province, China, at longitude 97° 21' 57" E ~ 108° 31' 58" E, and latitude 26° 03' 57" N ~ 34° 19' 13" N. The longitude, latitude and altitude of a total of 52 distribution points were recorded. Before analysis, we used R package spThin version 0.1.0 (Aiello-Lammens et al. 2015) to check the spatial autocorrelation of all distribution points. Finally, 11 distribution points of *P. decomposita* were retained for the creation of the MaxEnt model (Figure 1).

Environmental variables and preconditioning

Climate has been reported to be the most significant factor affecting species' geographical distributions (Jochum et al. 2007). For our study, climatic variables were obtained from the Data Registration and Publication System of the Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (http://www.resdc.cn/DOI) (referred to hereinafter as the DRPS), with a resolution of 500 m × 500 m. The dataset we downloaded, based on mete-

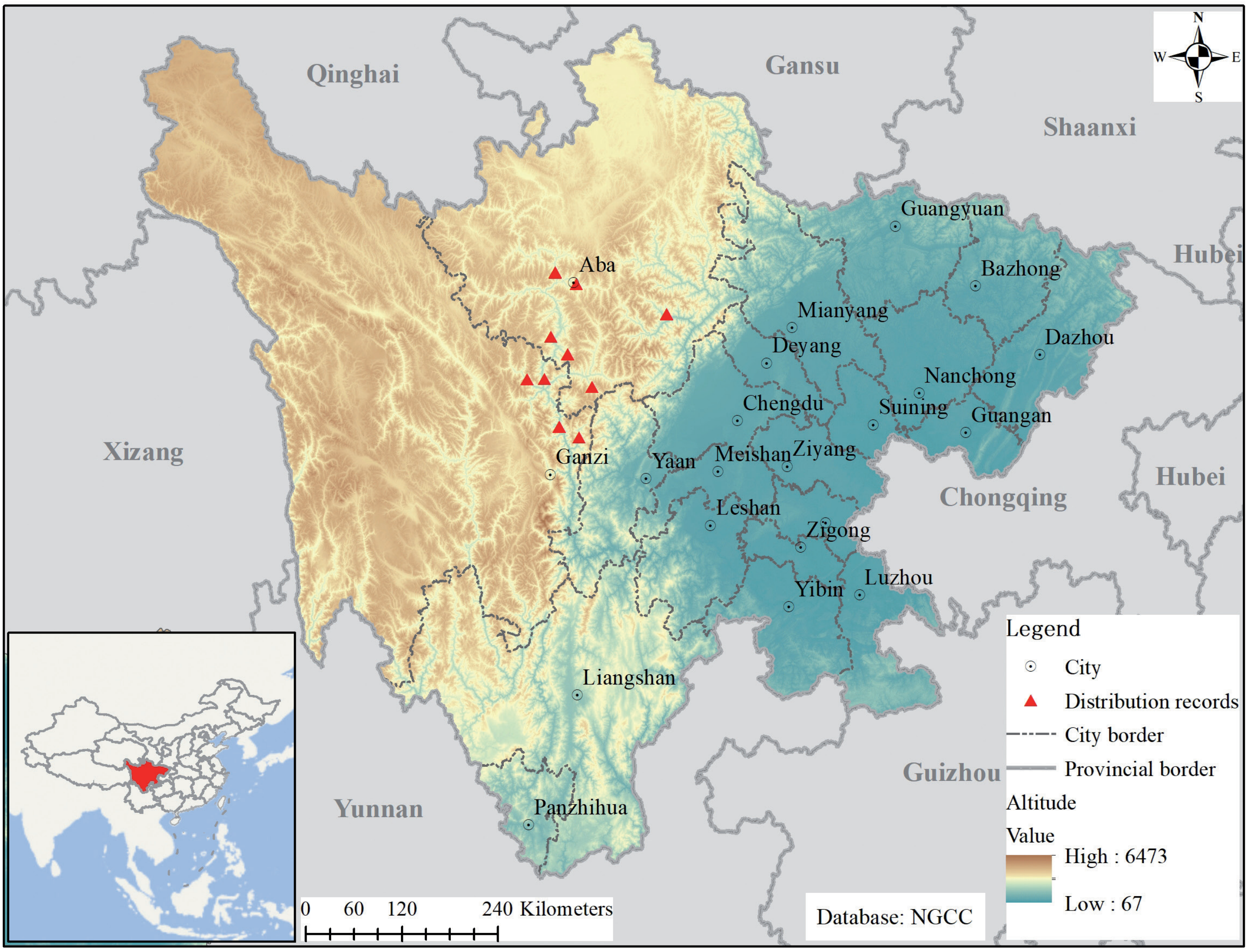

Figure 1 – Distribution records of Paeonia decomposita *in Sichuan province.*

orological data from 1 915 stations in China, included mean annual temperature, mean annual precipitation, the sum of the annual temperatures above 0°C, the sum of the annual temperatures above 10°C, the aridity index and the humidity index (Table 1).

Topography is also an important factor that determines vegetation growth, especially in mountainous areas, where solar radiation, soil moisture and surface rivers are all affected by topography (Zhou et al. 2018). Topographic data included slope gradient, slope direction and slope position (see Table 1), obtained from the Geospatial Data Cloud (http://www.gscloud.cn/), with a resolution of 90 m.

Vegetation cover is one of the most important monitoring indicators that reflects the quality of land surface ecosystems and environments (Sun et al. 2019); vegetation cover can be represented numerically by the Normalized Difference Vegetation Index (NDVI). The annual NDVI for 2018 was obtained from the DRPS (http://www.resdc.cn/DOI), with a resolution of 1,000 m.

We processed all the above data and distribution points of *P. decomposita* in ArcGIS 10.2, and projected all data to the unified coordinate system (WKID: 3857, WGS_1984_Web_Mercator_Auxiliary_Sphere). All data was clipped with the boundary of the Sichuan administrative region in order to obtain the variable layers of the study area.

The existence of multicollinearity among the environmental variables used to predict species distribution may adversely affect the prediction results (Wan et al. 2020). Therefore, we performed a Pearson correla-

Table 1 – Environmental variables related to the distribution of Paeonia decomposita.

Description	Source	Unit
Mean annual temperature	DRPS http://www.resdc.cn/DOI	°C
Sum of temperatures above 0°C		°C
Sum of temperatures above 10°C		°C
Aridity index		-
Moisture index		-
Mean annual precipitation		mm
Slope gradient	The Geospatial Data Cloud http://www.gscloud.cn/	°
Slope direction		°
Slope position		-
Annual NDVI of 2018	DRPS http://www.resdc.cn/DOI	-

Table 2 – Environmental variables used in this study and their percentage contribution to species distribution.

Environmental variables	Percentage contribution
Mean annual temperature	34.0
Slope gradient	25.1
Mean annual precipitation	21.2
Moisture index	10.9
Annual NDVI in 2018	5.6
Aridity index	2.9
Slope direction	0.4

Table 3 – Percentage of areas with Paeonia decomposita *in the main distribution areas.*

Habitat suitability	Distribution areas [km²]	Proportion [%]
Unsuitable	437 762.30	89.93
Low habitat suitability	26 796.99	5.51
Moderate habitat suitability	15 774.69	3.24
High habitat suitability	6 438.46	1.32

tion analysis (SPSS V20.0) on environmental variables, and deleted the variables whose correlation coefficient was greater than 0.8 (Yang et al. 2020). To run the maximum entropy model software (MaxEnt V3.3.3), we chose *do jackknife to measure variable importance* (this is a built-in feature of the software), and deleted the variables whose contribution rate was 0 (Ma et al. 2020). Finally, we reserved 7 environmental variables to predict the potential distribution area and evaluate habitat suitability for *P. decomposita* (Table 2).

Model description

Maximum entropy theory can be understood as follows: a species will spread as far as possible to other areas when suitable conditions prevail, and will finally be distributed almost uniformly (Phillips et al. 2006). Based on this theory, we used MaxEnt software to predict species distribution (http://biodiversityinformatics.amnh.org/open_source/maxent/). After using the *jackknife* function (as described above), three-quarters of the species distribution data were identified for use as training data for the model; the remainder were used for model validation (Du et al. 2021). The MaxEnt software needs only two groups of variables – sample variables (species distribution) and environmental variables – to establish the potential distribution model of a species. Finally, we used ArcGIS 10.2 to convert the results file generated by the MaxEnt software into raster format for further analysis.

Evaluation of the model's results and habitat suitability

The evaluation of a model's results is an important step in constructing a model of the potential distribution of a species. The most commonly used evaluation method is the Receiver Operating Characteristic curve (ROC). The horizontal axis of the ROC curve is the false positive rate, and the vertical axis is the true positive rate. The area under the ROC curve is the AUC value, which can reflect the value of the diagnostic test directly. The ROC curve was not affected by the diagnostic threshold, and the accuracy of the two diagnostic tests could be comprehensively compared. The AUC value was between 0.5 and 1.0. The closer the AUC value is to 1, the better the model's performance and the greater the reliability of the results (Swets 1988; Vanagas 2004). Finally, the output of the MaxEnt software for the probability of species distribution was converted into the habitat suitability index for species distribution, which is between 0 and 1. We used the sensitivity-specificity and sum maximization approach to determine the threshold, which we considered superior to other threshold partitioning methods (Jiménez-Valverde & Lobo 2007). The threshold value of the existence probability of *P. decomposita* was 0.53; an area giving a value of less than 0.53 is considered unsuitable as a habitat area. Therefore, the habitat suitability index for *P. decomposita* was reclassified into four different grades, using the ArcGIS reclassification tool: unsuitable (0–0.53), low habitat suitability (0.52–0.65), moderate habitat suitability (0.65–0.77), and high habitat suitability (0.77–1.0).

Results

Model evaluations

The MaxEnt software was used to predict the potential distribution of *P. decomposita*; the ROC curve evaluation results gave an AUC value of 0.863 (see Figure 2). According to the AUC evaluation standard, the result of the model was accurate and considered *excellent*. An AUC value of more than 0.85 (which is far greater than the AUC value in the case of random prediction) indicates that the model is adequate for evaluating habitat suitability for *P. decomposita*.

Important environmental variables

The results of the MaxEnt model's jackknife test showed that mean annual temperature (explaining 34.0% of variation), slope gradient (explaining 25.1% of variation), mean annual precipitation (explaining 21.2% of variation), moisture index (explaining 10.9% of variation) and annual NDVI in 2018 (explaining 5.6% of variation) were the main variables affecting distribution of *P. decomposita*; the cumulative contribution rate reached 96.8% (Table 2). In other words, even if the influence of just one single environmental variable on the distribution of *P. decomposita* is considered, the variable contains important information.

The response curves drawn by the MaxEnt model reflect the impact of environmental variables on the distribution of *P. decomposita*. The horizontal axis of the response curve is the variation range of the environmental variables, while the vertical axis is the probability of the existence of *P. decomposita* (Figure 3). The

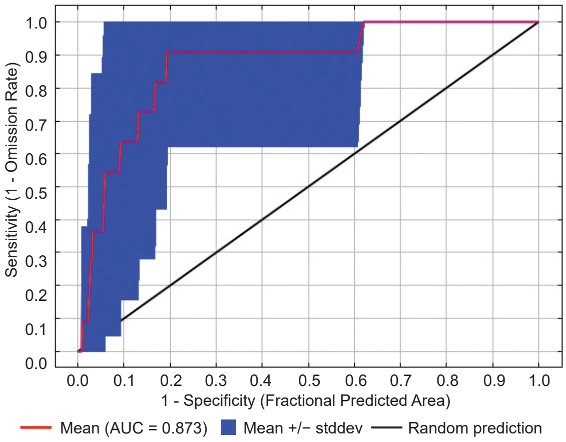

Figure 2 – Reliability test of the distribution model created for Paeonia decomposita.

greater the probability, the more suitable the range of variables is for the survival of *P. decomposita*. Our results show that when the probability of existence is greater than 0.53, the corresponding variable range is suitable for the survival of *P. decomposita*. The mean annual temperature range suitable for *P. decomposita* is 4.5 to 15.0°C; the greater the slope gradient, the greater the probability of *P. decomposita*'s existence, and the most suitable gradient is greater than 60°; the mean annual precipitation range suitable for *P. decomposita* is 180–990 mm, and with an increase of mean annual precipitation, the existence probability of *P. decomposita* decreases; the moisture index range suitable for *P. decomposita* is −25 to +68. In addition, the mean annual temperature was 8°C, the slope gradient was 6–65°, the mean annual precipitation was 180–350 mm, and the moisture index was 0, which is the combination of environmental variables that provides the most suitable habitat for *P. decomposita*.

Potential distribution of *Paeonia decomposita*

Habitat suitability of *P. decomposita* was classified in ArcGIS, and the results can be seen in Figure 4. These show an area of high habitat suitability for *P. decomposita* in Sichuan Province of 6 438.46 km^2; the area of moderate habitat suitability was 15 774.69 km^2; the area of low habitat suitability was 26 796.99 km^2; all other areas were unsuitable. The areas calculated amount to 1.32%, 3.24%, 5.51% and 89.93% of the total area of Sichuan Province respectively (computed using the zonal statistics tool in ArcGIS 10.2) (Table 3). Areas of high and moderate habitat suitability were considered to be viable for *P. decomposita*. Combined, these equate to just 4.56% of the total area, and only a few are located in existing nature reserves.

The areas of high habitat suitability for *P. decomposita* were mainly to the north of Mianyang city, in the southwest and northeast of Aba Autonomous Prefecture, and in the east of Ganzi Autonomous Prefecture. The areas of moderate habitat suitability were found mainly north of Mianyang city, in the southwest and northeast of Aba Autonomous Prefecture, in the east of Ganzi Autonomous Prefecture, and in the east of Liangshan Autonomous Prefecture. They are distributed mostly along the upper reaches of the Yalong, Dadu, Min and Fu rivers, or along their tributaries (Figure 5).

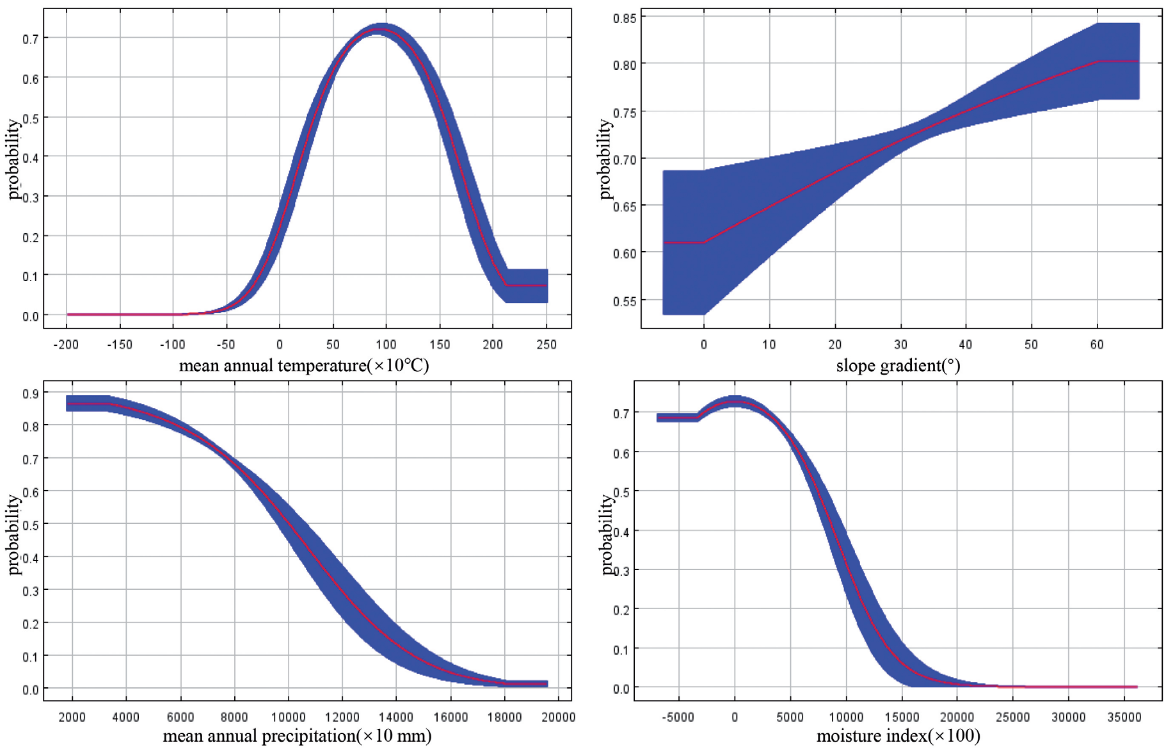

Figure 3 – Response curves for the probability of the presence of Paeonia decomposita.

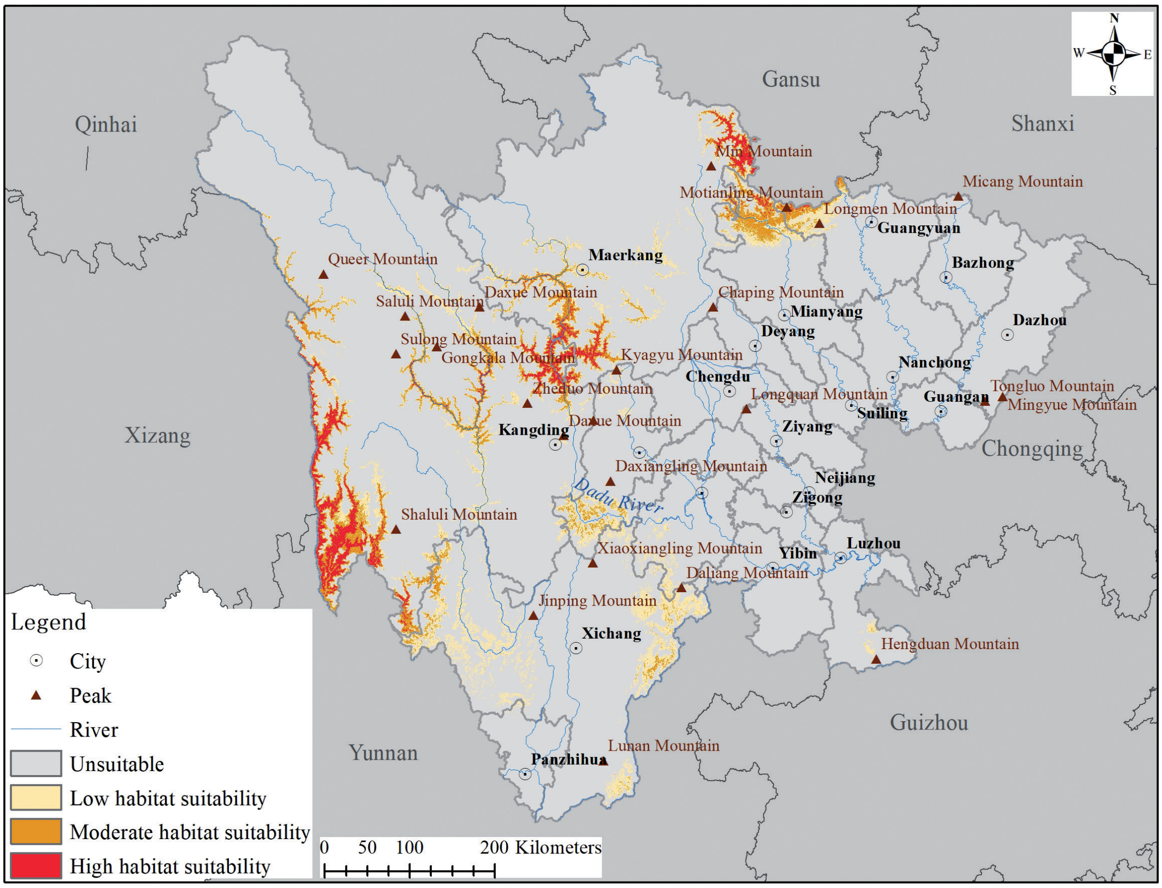

Figure 4 – Current and potential habitats for Paeonia decomposita *in Sichuan.*

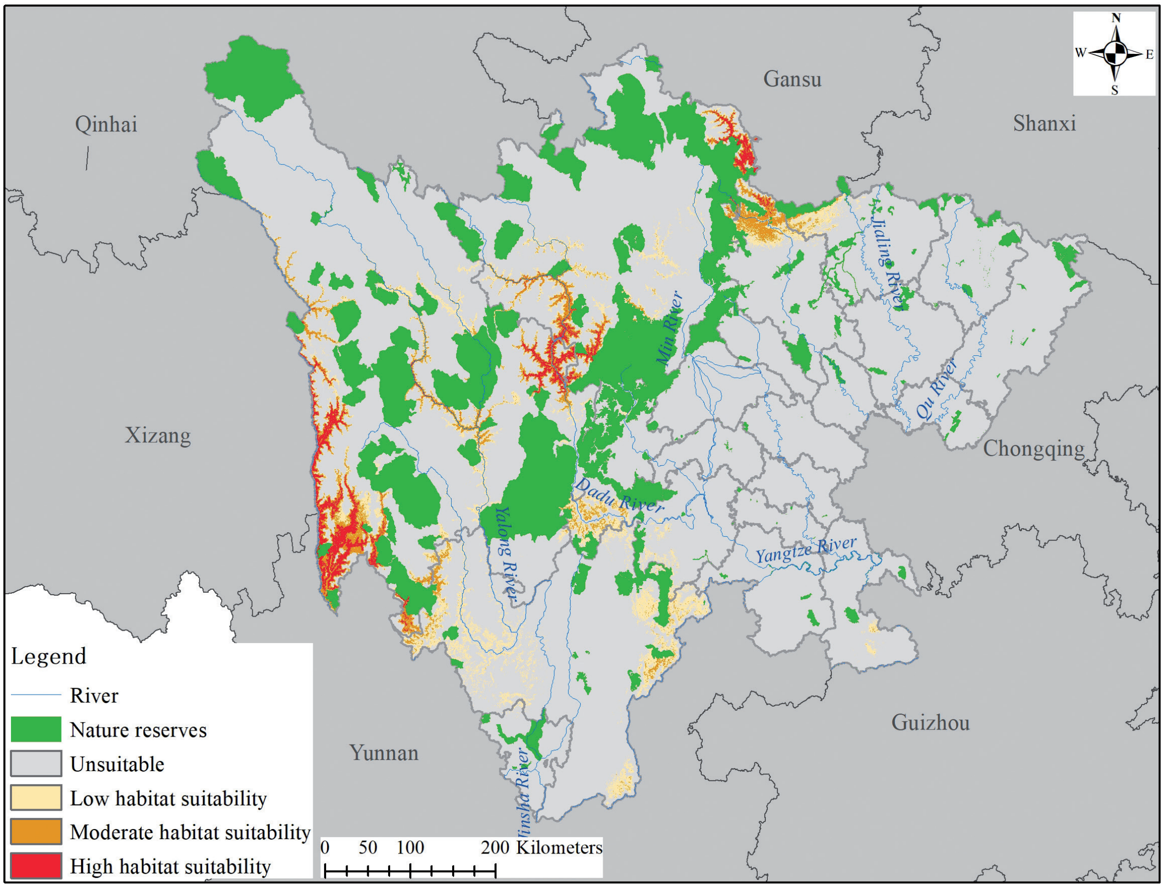

Figure 5 – The relationship between suitable habitat areas for Paeonia decomposita *and nature reserves.*

Discussion

P. decomposita is an endemic species in China. It is an important part of the local ecosystem and an important traditional medicinal plant, growing among the shrubs of arid valleys in northwest Sichuan province. In recent years, human activities such as engineering construction and logging have had a great impact on *P. decomposita* and its habitat (Hong et al. 2017). To prevent its extinction, suitable habitats of the species must be identified, using a niche model, and the species must be protected.

MaxEnt is a superior method of species distribution prediction (Elith et al. 2006). We used MaxEnt software to predict the potential distribution area of *P. decomposita* and to classify habitat suitability. We analysed the contribution of each environmental variable to the MaxEnt model and ranked it using jackknife. The ROC curve was used to evaluate the applicability of the MaxEnt model, and the AUC value was used to judge the model's reliability. The results show an AUC value of 0.863, which means that the performance of our model is *excellent* (Vanagas 2004), and the model can reliably be used to predict habitat suitability for *P. decomposita*.

The areas of high and moderate habitat suitability for *P. decomposita* measured 6,438.46 km^2 and 15,774.69 km^2 respectively, accounting for 1.32% and 3.24% of the evaluation area. The niche of *P. decomposita* is thus very small. Some studies have shown that the results of the MaxEnt model simulation may be over-estimates of the actual situation (Hernadez et al. 2008; Boubli & Lima 2009). This means that the area suitable for *P. decomposita* may be smaller than the modelled results. The most suitable combination of environmental variables for *P. decomposita* was a mean annual temperature of 8°C, a slope gradient of 60 to 65°, a mean annual precipitation of 180 to 350 mm, and a moisture index of 0, demonstrating further the very limited area suitable for *P. decomposita*, which has very strict requirements for growth. Previous research has demonstrated that the distribution of *P. decomposita* is affected by temperature, precipitation, slope gradient and other factors (Xia et al. 2017; Hong et al. 2017).

The MaxEnt simulation results showed that areas of high and moderate habitat suitability for *P. decomposita* were located mainly to the north of Mianyang, southwest and northeast of Aba, east of Ganzi, and east of Liangshan, mostly along the Yalong, Dadu, Min and Fu and their tributaries (Figure 5). These river valleys are also the main residential areas, and so are greatly affected by human activities. Generally, in the same habitat area, banded distribution has a longer perimeter, a larger range of contact with external disturbance, and is subject to more external influence (Yang et al. 2020). The field investigation found that the *P. decomposita* distribution area was strongly disturbed by human activities such as grazing, logging, construction of roads, and hydropower plants. The attractiveness of the plant and its medicinal value also lead to its serious depletion in the field and difficulty in protecting it. In addition, the plant's biological and seed-germination characteristics (Jing et al. 1995; Jing & Zheng 1999) have also led to natural regeneration difficulties in *P. decomposita*. Its current precarious status may therefore be the result of both internal and external factors.

Results from earlier research showed that human activities contributed significantly to species endangerment (Schemske et al. 1994). In recent years, a large number of hydropower stations have been built in western Sichuan province, which often causes irreversible damage to the habitat of *P. decomposita*. Therefore, protection of *P. decomposita* needs to be carried out *ex-situ*, for which the most difficult problem is to identify the most appropriate habitat areas among those with high or at least medium suitability.

The construction of nature reserves, as one of the main protection measures for endangered plants, would be a good way to provide in-situ protection for *P. decomposita*. Areas of high to moderate suitability for *P. decomposita* occupy only 4.56% of the total area of Sichuan province, and only a small proportion are located within existing nature reserves (Figure 4 and Figure 5). We therefore suggest that areas of high or moderate suitability for the species should become potential priority protection areas, to be included in nature reserves areas, or that new reserves should be established to effectively protect *P. decomposita*. Artificial breeding and cultivation of *P. decomposita* should also be encouraged in areas of high or moderate habitat suitability. In addition, the precise ecological status of *P. decomposita* should be determined promptly, and ordinary people should be encouraged to participate in its protection to avoid extinction.

Conclusions

The mean annual temperature, slope gradient, mean annual precipitation and moisture index greatly affect *P. decomposita's* distribution. The best combination of environmental variables for *P. decomposita* was: mean annual temperature of 8°C, slope gradient of 60–65°, mean annual precipitation of 180–350 mm, and moisture index of 0. *P. decomposita* has a narrow distribution area. The areas suitable for the species are very few and mostly outside existing nature reserves. It is important to set up new nature reserves for *P. decomposita* and to carry out artificial cultivation in areas of high or moderately high suitability. Taken together, our conclusions about areas suitable for *P. decomposita* will provide a theoretical reference to protect the species.

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The UNESCO World Heritage Swiss Alps Jungfrau-Aletsch – protecting the cultural landscape by preserving the traditional irrigation system in the Upper Valais

Jessica Oehler

Keywords: World Natural Heritage, Swiss Alps Jungfrau-Aletsch, Upper Valais, traditional irrigation system, cultural landscape, cultural heritage preservation

Abstract

The Great Aletsch Glacier and world-famous peaks of Eiger, Mönch and Jungfrau make up the core of the UNESCO World Heritage Swiss Alps Jungfrau-Aletsch (SAJA), which was designated as a UNESCO World Heritage site in 2001, the first Alpine World Heritage designation. The natural and cultural landscape is very diverse due to its climatic differences and high altitudinal gradients. One extraordinary cultural element of the landscape in the UNESCO World Heritage SAJA is the traditional irrigation system. It mainly provides irrigation for meadows and vineyards, creating small-scale and species-rich habitats for animals and plants. As a result of agricultural structural change and workload, the traditional irrigation techniques are endangered and are being replaced by sprinkler systems or, in some cases, abandoned completely. The project *Preservation of Traditional Irrigation in the Upper Valais* served to detect areas still traditionally irrigated and to discuss challenges, solutions and perspectives with local actors and experts to develop a concrete action plan. Possible solution approaches proposed are: a) financial compensation; b) platform and volunteering; c) institutionalization; d) education and training; e) awareness raising; f) Expert Commission Irrigation Landscape Upper Valais Sun Mountains.

Profile

Protected area

UNESCO World Heritage Swiss Alps Jungfrau-Aletsch

Mountain range

Alps

Country

Switzerland

Introduction

The UNESCO World Heritage Swiss Alps Jungfrau-Aletsch (SAJA) is one of the most spectacular mountain landscapes in the Alps (see Figure 1 & 2).

A total area of 824 km^2, the UNESCO World Heritage SAJA covers almost all of the Bernese Alps in the territory of the cantons of Bern and Valais (Figure 4). About 90% of the World Heritage area is covered by rocks and ice, and the area hosts the largest contiguous glaciated area in the Alps.

The mosaic of natural habitats combined with adjacent cultural landscapes is responsible for the rich biodiversity. 60% of all animal, fungal and plant species that occur in Switzerland are found in the region, made up of 7,200 species. Compared to the entire country, this is above average and of inestimable value.

The fascinating combination of natural and cultural landscapes has contributed significantly to the designation as UNESCO World Heritage Site in 2001. SAJA thereby fulfils three out of four possible criteria for World Natural Heritage sites (see Table 1).

This article describes the contribution of the SAJA management centre to the preservation and restoration of an important cultural-history element of the cultural landscape, the traditional irrigation system, and the project *Preservation of the Traditional Irrigation in the Upper Valais*. The explanation of the traditional irrigation system is based on *Einblicke-Ausblicke*, a regular

Figure 1 – Oeschinensee. © R. Schmid

Figure 2 – The Grand Aletsch glacier. © R. Schmid

Table 1 – UNESCO criteria.

Criteria	Description
VII	The extraordinary scenic and aesthetic appeal of the region, which has frequently been attested to throughout cultural history.
VIII	The importance of the high-mountain region and its glaciation as a source of geological data and a witness to climate change.
IX	The importance of the region as a dynamic (due to glacier fluctuations) alpine and sub-alpine habitat rich in diversity.

publication to inform the population about the development of the World Heritage Region.

Traditional irrigation – a cultural heritage with a future?

One extraordinary cultural landscape element in the UNESCO World Heritage SAJA is the traditional irrigation system, which was created over hundreds of years in the Valais and can be traced back at least to the 13th century (UNESCO-Welterbe SAJA 2020).

The Valais is one of the driest regions of Switzerland because of the rain shadow effect (see Figure 3). In order to ensure water supply through generations, an irrigation system based on the water channels – variously called *Suonen*, *les bisses*, *Wasserleiten*, etc. – was developed (Figure 5). Water is transported via these channels from higher to lower altitudes, primarily for the irrigation of meadows, vineyards and orchards. The water is generally diverted from streams fed by springs, snowfields and glaciers. As a result, the channels can supply water from spring to autumn – in times when precipitation is low, evaporation is high, and the natural water supply for agriculture is insufficient (Bär & Liechti 2020).

As Leibundgut & Kohn (2014) described, traditional irrigation is a complex land and resource management system. In the past, and to some extent still today, the water associations (*Geteilschaften*) have regulated the maintenance of a water channel. A member (*Geteile*), who owns a piece of land that can be irrigated by a water channel, has the right to take water, but also the obligation to contribute to the maintenance of the water channel (UNESCO-Welterbe SAJA 2020).

According to the cantonal inventory of 2018, there are more than 180 water channels, of about 740 km length in total. Of these, about 130 km are located in the World Heritage Region (Kanton Wallis 2018).

Multiple significance of traditional irrigation

The main function of traditional irrigation is the irrigation of agricultural areas (UNESCO-Welterbe SAJA 2020). In addition to its agricultural significance, traditional irrigation also has many other functions (Rodewald 2010; Liechti 2015). It has influenced the ecosystem and produced a structurally rich cultural landscape of high biodiversity (Leibundgut & Vonderstrass 2013; Melliger et al. 2014). The minerals in the glacier water act as natural fertilizer and supply soils and plants with valuable nutrients (UNESCO-Welterbe SAJA 2020). The slope irrigated landscape of the Valais and the hiking trails following the course of the water channels are an attractive hiking and landscape experience for visitors. Water channels are also slope stabilizing and serve as fire and flood prevention by regulating and draining surface water. The spectacular constructions, the collective management and the traditional irrigation techniques are also valuable expressions of cultural history (Figure 5 & 6). In this way they play a significant role for regional identity and are a valuable cultural heritage (Bär & Liechti 2020).

The project *Preservation of the Traditional Irrigation in the Upper Valais*

This project investigated the complex water management system to find out more about challenges and solutions. The project was supported by *Bundesamt für Umwelt, Fonds Landschaft Schweiz* and *Stiftung Landschaftsschutz Schweiz*. Together with local residents

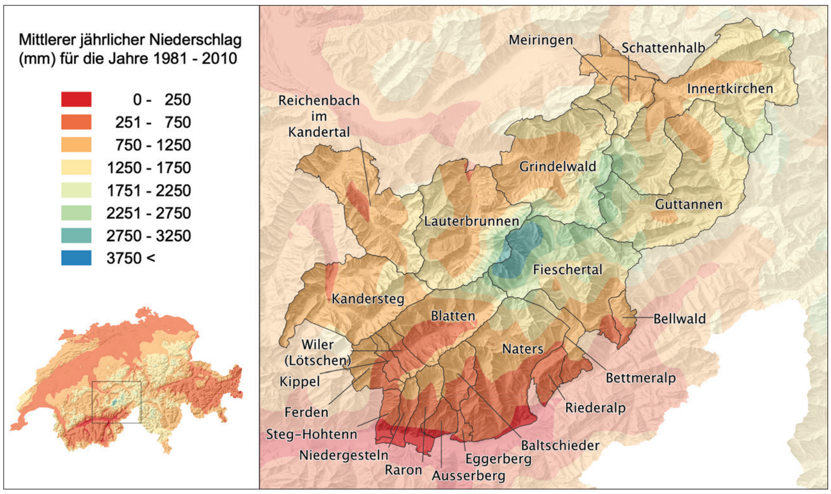

Figure 3 – Annual mean precipitation (Bär R.; data from: Meteo Schweiz, Normwert-Karte für den Niederschlag 1981–2010).

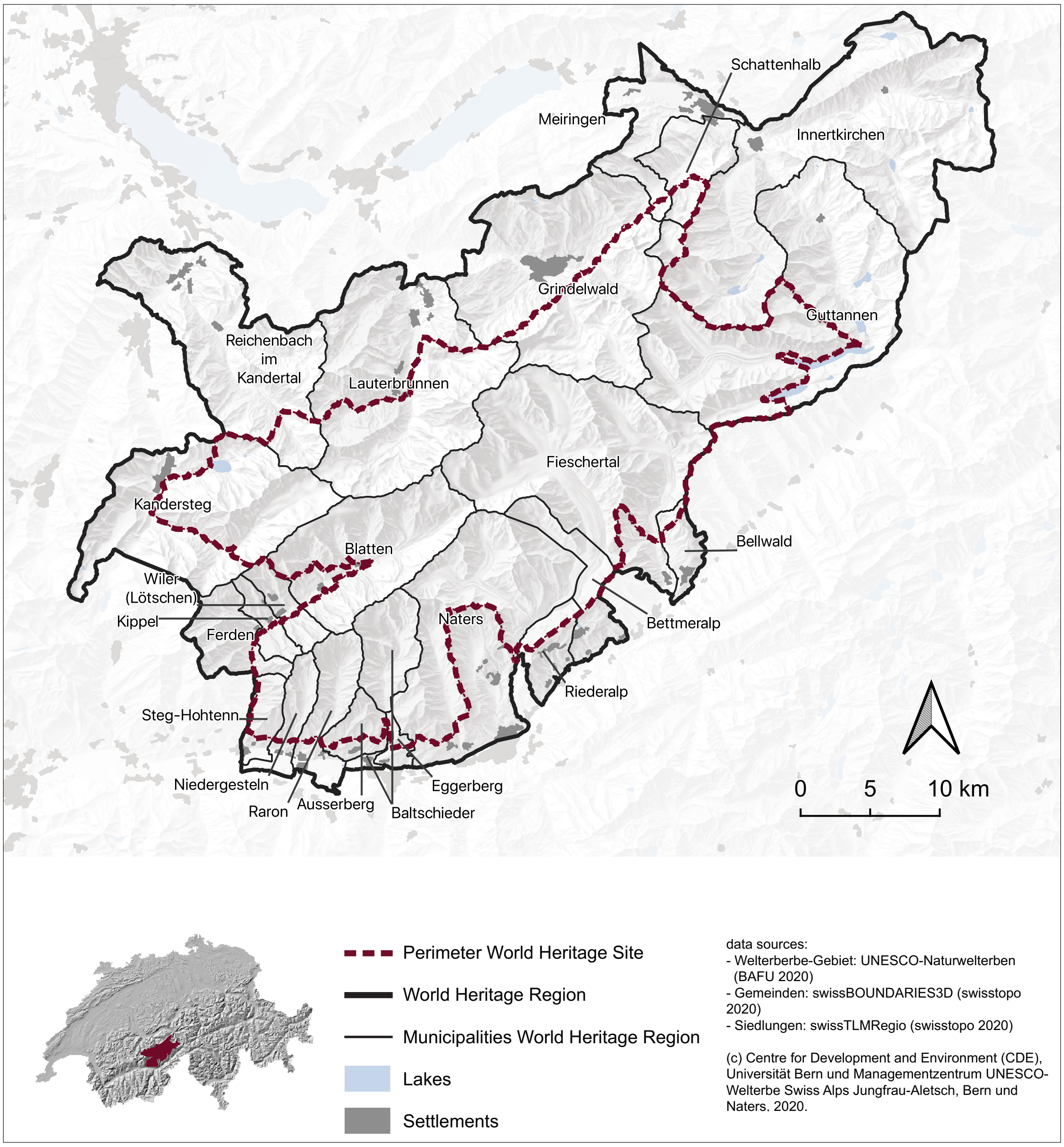

Figure 4 – The UNESCO World Heritage Swiss Alps Jungfrau-Aletsch (SAJA).

(especially farmers), cantonal authorities and the University of Bern, an inventory of traditional irrigated areas in Naters was created and a concrete action plan for the preservation of the traditional irrigation developed.

Challenges and perspectives

The following section showcases the challenges identified in the workshops and interviews with farmers and experts.

The centuries-long practice of collective water use can serve as a model for the sustainable use of a scarce resource. However, its future is now uncertain (Bär & Liechti 2020). The water associations are breaking up. The biggest challenge is the amount of time needed to keep up traditional irrigation: The farmer has to be present the whole time to distribute the water, which is difficult for part-time farmers (UNESCO-Welterbe SAJA 2020). In addition, many members don't participate in the joint maintenance day, preferring instead to pay a certain amount. The young lose interest in agriculture, so some farms give up and the water associations lose members.

This combination of agricultural structural change, workload and less awareness means that the traditional irrigation techniques are endangered and are being replaced by sprinkler systems, or in some cases, abandoned completely (Bär & Liechti 2020).

Moreover, climate change influences water availability. The consequences are difficult to estimate (UNESCO-Welterbe SAJA 2020).

It is expected that these dynamics will continue in the future, particularly with climate change, the expected drier summers and the altered availability of

Figure 5 – Suone Wyssa. © R. Schmid

Figure 6 – Traditional irrigation. © K. Liechti

glacier water. This results in a conflict of goals: the technical simplifications, especially the operation of sprinkler systems, make water use and work more efficient. At the same time, a valuable form of cooperation, a traditional craft and knowledge system and landscape qualities are lost – and with them a part of the cultural heritage and regional identity (Bär & Liechti 2020).

Solutions to the challenges of traditional irrigation

In the project a concrete action plan with possible solutions was developed. One option to support farmers who irrigate their land traditionally could be to compensate them better for the more elaborate work financially and to conclude a contract. In addition, a financial incentive could be offered to the people who help on the joint maintenance day. Within the prevention of natural hazards, some of the maintenance could be taken on by forest districts. Other possibilities include work assignments with volunteers and school classes to support the water associations. The discussions also pointed to the importance of raising the awareness of the population for the cultural value of the water channels and the traditional irrigation as well as of education and training for its preservation (UNESCO-Welterbe SAJA 2020).

Several measures were taken to support the preservation of the traditional irrigation in Naters. A contract should be made with the farmers to ensure sustainable and targeted maintenance of the areas. In cooperation with the municipality and the interested communities, SAJA is setting up an agency platform to serve as an overview page and planning tool. It provides information and manpower for the annual maintenance of the water channels. SAJA also supports the communities of the water channels with the annual maintenance projects through groups of volunteers. In addition, an in-depth study on irrigation in Naters with specific planning of measures to deal with the problems identified in the present study is planned in a next step (UNESCO-Welterbe SAJA 2020).

Also, the international appreciation of the cultural heritage is important to support traditional irrigation systems. The program Traditional Irrigation as Cultural Heritage of Europe should preserve traditional irrigation for the future. Traditional irrigation systems should receive the status of immaterial cultural heritage of the UNESCO. Different actors are involved to demonstrate how shared water use can be used for future sustainable joint property management (Bär & Liechti 2020).

Conclusion

The traditional irrigation channels are an important cultural-historical element in the landscape of the Upper Valais and have high priority in the canton of Valais and especially in Naters. This important role of this system comes from its various uses and its significance for ecology, economy and society. The project Preservation of the Traditional Irrigation in the Upper Valais was initiated to contribute to the preservation of the cultural landscape. It identified various challenges and discussed possible solutions with local actors to develop a concrete action plan.

Preservation of the water channels and traditional irrigation is a holistic task and depends on the commitment of numerous contributors. Only when everyone participates, will it be able to preserve this World

Infobox

824 km² World Heritage area
1,629 km² World Heritage region
23 communities: 15 in the Upper Valais and 8 in the Bernese Oberland
9 peaks above 4,000 m a.s.l.
Finsteraarhorn the highest at 4,273 m
About 50 peaks are above 3,500 m
About 350 km² are glaciated areas
With a length of 20 km, the Great Aletsch glacier is the biggest and longest glacier of the Alps
88% are unproductive and vegetation-free areas

Cultural Heritage in the Upper Valais in the long term (UNESCO SAJA 2020).

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How can farmers be better integrated into nature parks? AgriPark – Transdisciplinary development of approaches for better cooperation between agriculture and Regional Nature Parks

Sonja Trachsel, Ruth Moser, Birgit Reutz & Rebecca Göpfert

Keywords: participation, acceptance, sustainable development, agriculture, protected areas, Regional Nature Parks, Switzerland

Abstract

In the AgriPark project, a transdisciplinary approach was used to develop ways of integrating agriculture better into Regional Nature Parks. It revealed that there are no ready-made solutions and longer processes involving a wide range of stakeholders are needed to develop closer cooperation between parks and agriculture.

Profile

Protected area

Regional Nature Parks Binntal, Gantrisch and Schaffhausen

Mountain range

Alps, Switzerland

Introduction

Agriculture is an important player in Regional Nature Parks (RNPs) in Switzerland. Farmers cultivate land and contribute with their activities to the improvement of biodiversity and the protection of landscapes, at the same time RNPs provide farmers with opportunities to further develop their farm businesses, for example, through the creation of cooperation projects or sales opportunities for agricultural products and services. However, farmers are frequently not ready to take advantage of these opportunities and to participate in RNP projects because of scepticism about the concept and usefulness of RNPs (Butticaz 2013; Haggenmacher 2017; Humer-Gruber 2016). The question that therefore arises is: How can farmers be convinced of the benefits of RNPs and the opportunities they offer? Currently there is no overview of tried and tested approaches for integrating agriculture better into RNPs that could be made available to agricultural advisory services and RNP managements.

Transdisciplinary methodological approach

Approaches to improve cooperation between agriculture and RNPs were developed in the *AgriPark* project using a transdisciplinary research methodology. The project team included experts from research (Zurich University of Applied Sciences ZHAW) and from the Swiss Association for the Development of Agriculture and Rural Areas, AGRIDEA, thus ensuring the link between research and practice. At the strategic level, project partners from the Federal Office of Agriculture, cantonal agricultural advisory services and the Network of the Swiss RNPs gave their feedback on the project. At the operational level, stakeholders from the three partner RNPs, Binntal, Gantrisch and Schaffhausen, were involved in workshops as part of the preliminary study as well as in the development of approaches for better cooperation between agriculture and RNPs. These approaches will be made available to the agricultural advisory services and RNP management teams.

The *AgriPark* project was divided into two phases (see Figure 1). In the first project phase quantitative and qualitative data were collected in the three Swiss partner RNPs, Binntal, Gantrisch, Schaffhausen. 1) An online survey was conducted in spring 2019 in the three RNPs by means of convenience sampling. Any farmer that was eligible for direct payments and had an e-mail address could take part. 509 farmers answered the questionnaire, at least in part, with a response rate of 36%. Participants were asked if their farm was run by a man or a woman. 89% of those who answered this question indicated a man as primary farmer (n = 279) and 71% a woman as secondary farm manager (n = 173). From this we concluded that the majority considered themselves as managing the farm as a couple. 2) Semi-structured interviews were also conducted in all three RNPs. To include different perspectives, the following stakeholders were interviewed in winter 2018 / spring 2019 using purposive sampling: 13 interviews with male farmers and 4 with farming couples, interviews with 5 female and 2 male representatives of the RNP management teams and with 4 male and 1 female representative(s) of the cantonal agricultural advisory services.

In the second phase we developed step by step approaches for a better integration of agriculture in RNPs. The results from the survey and interviews

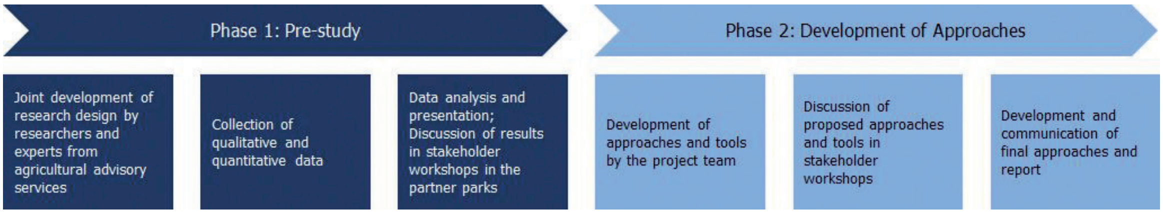

Figure 1 – Process of the AgriRNP Project, (own illustration).

served to elaborate paths of action. These were then discussed and further developed in two rounds of workshops in the participating RNPs and a further RNP in French-speaking Switzerland. Representatives of the RNPs, agriculture and agricultural advisory services were present at all of the workshops.

To develop possible approaches, we worked with *human-centred design*, a creative, problem-solving process for developing innovative ideas that puts people and their problems and needs at the centre (IDEO.org 2015). In addition, Dave Snowden's Cynefin Framework served to classify problems and possible solutions depending on their context. While complicated problems can be solved with expert knowledge, complex problems need participatory approaches (Snowden et al. 2007).

Results of the pre-study and paths of action

The results showed that most farmers tend to assume the benefits of a RNP for agriculture as rather low. Nor do they rate their knowledge of the RNPs very highly. The analysis of the guided interviews indicates that the RNP managers need to do a lot of communication work to convince farmers to participate in the RNP. Figure 2 illustrates a RNP's possible agriculture-related activities and how farmers rate them according by significance (for more results, see Trachsel et al. 2020).

1st path of action: Knowledge of needs and creation of proximity

Our research revealed that the relations between farmers and *their* RNPs differed from RNP to RNP. Factors influencing these relations were the history of the RNP, existing regional development projects, size of the RNP, and implemented agricultural projects in the RNP. Accordingly, activities in the RNPs were rated differently in the different RNPs. For instance, *information on funding opportunities for agriculture* (Figure 2) was very important for 46% in Binntal RNP (n = 11), but for only 16% in Schaffhausen (n = 128). Consequently, in order to ascertain farmers' most pressing needs, RNP managers must develop close relations with farmers and gain their trust.

The survey and interviews suggest that the more contact farmers have with the RNP management, the more positively they judge the RNP's actions and achievements. Figure 3 shows: 58% of farmers who take advantage of RNP activities agree with the statement *RNP XY contributes to the good image of agricultural products and services in the RNP*, compared to only 38% for farmers who do not participate in any RNP activities.

2nd path of action: Promotion of agricultural products & services

The results of the online survey and the guided interviews showed that the farmers saw the RNP's

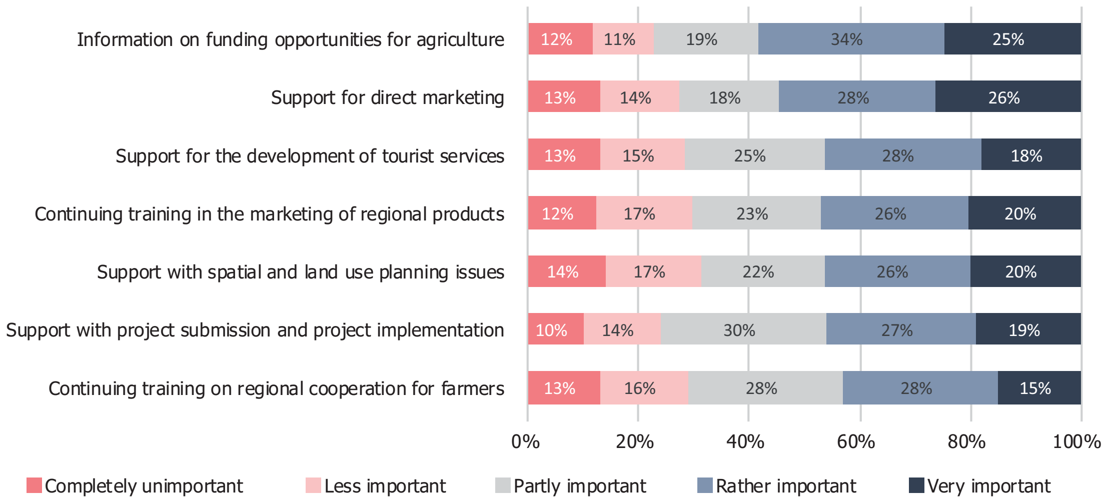

Figure 2 – Frequencies of the answers regarding the importance of different possible Regional Nature Park (RNP) activities for agriculture in the three RNPs (n = 330). Based on the results, we derived six paths of action showing where most action is needed or where there is potential for farmers to be better integrated into RNP activities.

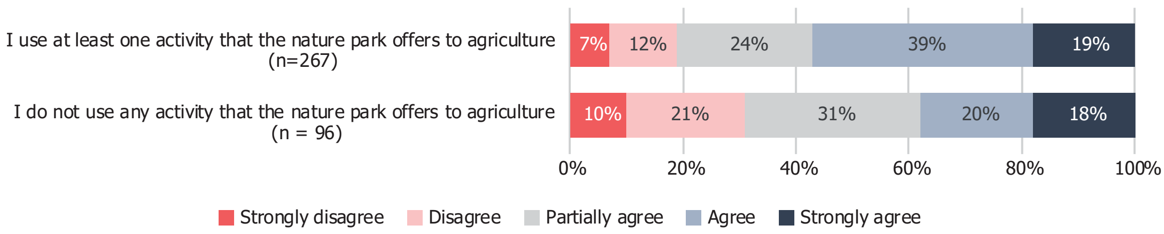

Figure 3 – Evaluation of the statement Regional Nature Park (RNP) XY contributes to the good image of agricultural products and services in the RNP and participation in at least one of the RNP activities (n = 363), (illustration by the authors).

contribution to the image and promotion of regional agricultural products as an important advantage (see Figure 3). Representatives from agriculture and RNPs considered communication about regional products one of the main tasks of a RNP and saw further potential to enhance RNP activities in this area. Many were in favour of the Swiss RNP product label, but they would like to see its implementation simplified.

3rd path of action: Creation of regional value chains

According to our results, farmers hoped that RNPs would be able to support the creation of regional value chains and new sales opportunities that would increase their margins. The interviewed farmers considered it an important role of RNPs to act as mediator and networker when creating these regional value chains. The questions that arise are: How could farmers who do not yet sell products locally profit from value chain creation? And how could farmers who are already successful in direct marketing also benefit from the RNP?

4th path of action: Use of agricultural support instruments

The evaluation of the online survey confirmed that in all three RNPs the majority of the interviewed farmers participated in projects that support them in preserving biodiversity and traditional cultural landscapes and also bring them direct financial benefits as a result of being linked to the direct payment subsidy system: 84% Binntal (n = 13), 73% Gantrisch, (n = 201) and 57% Schaffhausen (n = 139). From these results it can be deduced that RNPs should clarify to what extent they could communicate or use agricultural support instruments in order to more successfully involve the agricultural population in RNP activities.

5th path of action: Communication between farmers and RNP management

Our results indicate that farmers should be provided with (even) more information about the options for involvement, participation and development. From the online survey it was clear that farmers consider

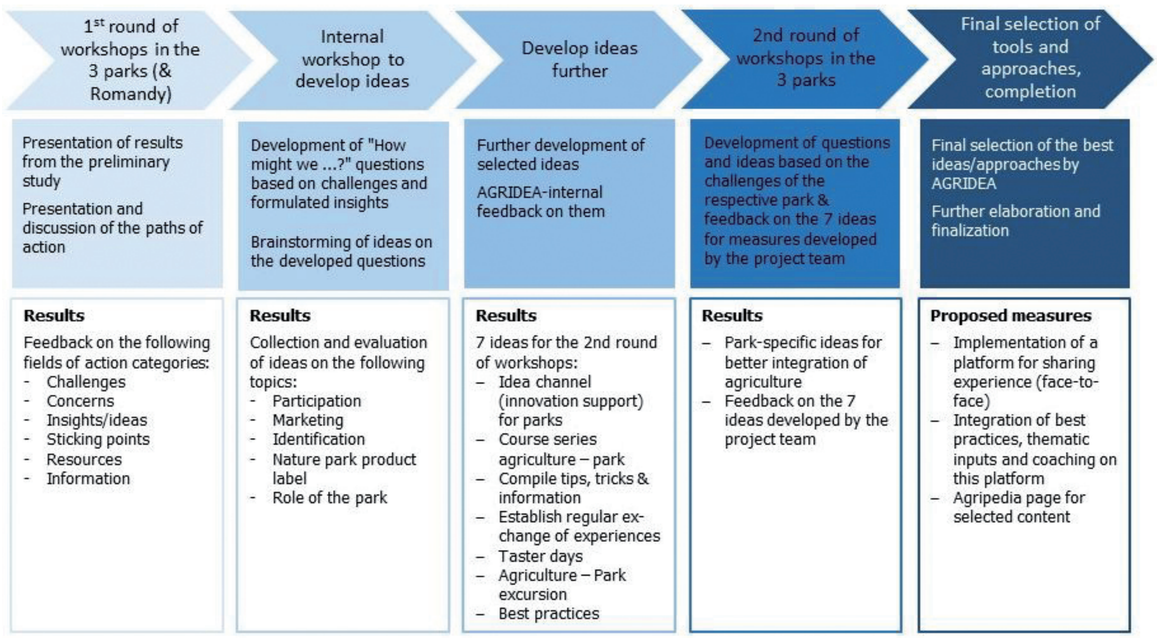

Figure 4 – Illustration of the process for developing approaches to better integrate agriculture into Regional Nature Parks and the concrete results from each individual step in the process.

their level of knowledge about the RNP to be rather low. 66% of the respondents declared that they felt only partially or ill-informed about the activities of the RNP (n = 363). Therefore it would be useful to know how farmers could be better informed about the RNP, taking into account their interview responses that indicated they do not have sufficient time to obtain information themselves.

6th path of action: Structural integration

According to the results from the guided interviews, structural integration of farmers in RNPs is an important approach to enhance cooperation between RNPs and *their* farmers. In addition to the integration of agriculture into the existing bodies of the RNPs, the sort of organizational structures that already exist in some of the three RNPs that are specifically aimed at the agricultural population would certainly help to achieve this goal.

Results from the 2nd phase: Development of approaches

In an initial round of workshops, the results of the pre-study and the paths of action were presented and explored in greater depth (see Figure 4). Challenges and sticking points as well as insights and initial ideas for solutions were established that then served as a basis for the development of concrete approaches.

These first workshops already provided the impetus for initial activities in the RNPs: For example, two ideas from the workshop in Gantrisch RNP were implemented: 1) establishing contact between the RNP management and the agricultural advisory services, and 2) holding a workshop to specify opportunities for collaboration.

The challenges and ideas discussed in the first workshops served as a basis to develop possible approaches that could be used to integrate agriculture better into several RNPs. For this purpose, based on jointly identified challenges, insights and then questions were formulated. Afterwards we formulated ideas in response to these questions, with the most promising ideas being further developed. In this way, a total of seven ideas for possible approaches emerged, ranging from educational measures to sharing experiences and support for innovation (for all 7 ideas of the 2nd round of the workshop, see Figure 4) for the 2nd round of the workshops. Presentation of the above-mentioned seven approaches and joint evaluation of them in these workshops.

Exchange instead of ready-made approaches

One of the developed approaches received more support than the others – the platform for regular sharing of experiences between stakeholders from agriculture and the RNPs. Since many of the other ideas discussed in the second round of workshops, such as the presentation of best practices, elements from the course series, excursions, etc., could be integrated into such an exchange platform, it was decided to drop the idea of developing more tangible approaches and to focus on the implementation of this platform, which is being organized by AGRIDEA and the Network of Swiss RNPs. A first event took place under the title *Cooperation as an Opportunity* on 7 September 2021 in Gantrisch RNP.

In addition, a simple online publication was created that presents the project, the developed paths of action and possible approaches for better integration of agriculture into RNPs, which can be expanded in future, if needed.

It is not surprising that the decision was made in favour of a platform for regular sharing of experiences. According to our results, the integration of agriculture into RNPs is a complex challenge for which there are no ready-made, one-size-fits-all solutions. In such a context, the main challenge is to bring together a wide range of stakeholders who work together to find appropriate solutions; a task that should be understood as an ongoing process. From this point of view, a regular platform for sharing experiences will hopefully create a suitable framework to develop a variety of solutions for better integration of agriculture into RNPs.

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Tigers at higher elevations outside their range: What does it mean for conservation?

Saroj Shrestha, Ang Phuri Sherpa, Sony Lama, Munmun Tamang & Prakash Kumar Paudel

Keywords: conservation, higher elevations, Himalaya, Mahabharat range, presence, tiger

Abstract

Nepal's population of endangered Bengal tigers *(Panthera tigris)* is on the rise. In recent years, the presence of tigers has been documented at higher elevations. The objective of this study is to explore the possible reasons for the tigers' presence at the higher elevations. It is critical that these high-altitude habitats for tigers be further explored and protected. The study points out the importance of the Mahabharat range and a longitudinal conservation gradient approach in Nepal. Apart from this, it is imperative to assess the density of tigers and tiger prey in the area. Even though high-altitude ecology may be suitable for tiger growth, the formulation of a high-altitude tiger conservation action plan with effective coordination between stakeholder organizations and concerned departments is of great importance.

Tigers are an apex species of the terrestrial ecosystem and exist in a precarious state throughout their range. The tiger is a globally endangered species (Goodrich et al. 2015). In the past, the tiger once existed as nine subspecies, now reduced to only six subspecies that exist in the wild. The subspecies Bengal tiger *(Panthera tigris)* has the largest population and is restricted to South Asia, namely Bangladesh, Bhutan, India, and Nepal (Global Tiger Initiative 2010). In the past century, *P. tigris* numbers have plummeted from 100,000 to below 3,500. Presently, wild *P. tigris*' habitat covers approximately 1.2 million km^2 in 13 Tiger Range Countries (TRCs) (Global Tiger Initiative 2010). Faced with decreasing *P. tigris* populations, TRCs in 2010 proposed doubling *P. tigris* populations by 2022, from a global estimate of ~3,643 in the year 2010 to ~5,845 by the year 2022 under the Global Tiger Recovery Program (Global Tiger Initiative 2010). *P. tigris* are listed as endangered on the Red List of threatened species by the International Union for Conservation of Nature (IUCN) and under Appendix I by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). In Nepal the National Parks and Wildlife Conservation Act, 1973, classified *P. tigris* as a protected species.

India, along with Bhutan, Nepal, Russia and Indonesia, has successfully recovered wild *P. tigris* populations. In recent years, *P. tigris* have been recorded at higher elevations outside of their usual habitat (Figure 1). For example, presence of *P. tigris* was recorded from 3,602 m at Arunachal Pradesh and at 3,274 m in Uttarakhand in India, 4,038 m in Bhutan and 3,165 m from Nepal (Adhikarimayum & Gopi 2018; Bhattacharya & Habib 2016; Tempa et al. 2019). Similarly, the presence of *P. tigris* was documented at higher elevations in Nepal (i. e., 2,500 m) and in far-western Nepal bordering on Nanda Devi National Park in India, Uttarakhand. A camera trap also recorded *P. tigris* in Eastern Nepal at 3,165 m (Red Panda Network 2020) bordering on Singalila National Park in India, North Sikkim. *P. tigris* are not the only species that are being sighted at previously unheard-of altitudes. There have definitely been sightings of several species at higher altitudes. Scientists have also noted an upwards movement of the mountain-dwelling pika *(Ochotona roylei* and *O. macrotis)*. Within a 46-year interval, the Pika habitat has moved up by 200 m (Koju 2018). Another study, conducted on the clouded leopard *(Neofelis nebulosa)* in 2020 in the Langtang area, found the elusive animal surviving at 3,498 m (Can et al. 2020). Previously the animal had been found only at 2,300 m. Another study revealed that the house crow *(Corvus splendens*) has been moving up by 136 m annually on average from 2,000 m to 4,200 m in Mustang district in Nepal (Acharya & Ghimirey 2013). This study concluded that climate change seems to be a possible reason behind this upward movement. And this kind of movement of wildlife has not just been witnessed in the mountains of Nepal. It has also been found with the red panda *(Ailurus fulgens)*, Assam macaque *(Macaca assamensis)*, flying squirrel *(Pteromyini)*, Himalayan crestless porcupine *(Hystrix brachyuran)*, Himalayan goral *(Naemorhedus goral)*, Himalayan palm civet *(Paguma larvata)*, Himalayan serow *(Capricornis thar)*, leopard cat *(Prionailurus bengalensis)*, leopard *(Panthera pardus)*, marbled cat *(Pardofelis marmorata)*, northern red muntjac *(Muntiacus vaginalis)*, yellow-throated marten *(Martes flavigula)*, red fox *(Vulpes vulpes)*, wild boar *(Sus scrofa)*, and the Himalayan black bear *(Ursus thibetanus)* (Red Panda Network 2020).

In Nepal, *P. tigris* enjoy an exalted status because they are considered sacred and spiritually evolved. Nepalese people generally had a positive attitude toward *P. tigris* conservation and were willing to accept some losses of livestock, but not human casualties. (Bhattarai & Fischer 2014). Nepal has been a pioneer in *P. tigris* conservation since it established protected area systems. *P. tigris* are a priority species for tropical and subtropical ecosystem conservation in Nepal. Until the mid-20th century, *P. tigris* in Nepal were distributed along the contiguous lowland forests on the slopes of the Siwaliks, Bhabar and alluvial grasslands

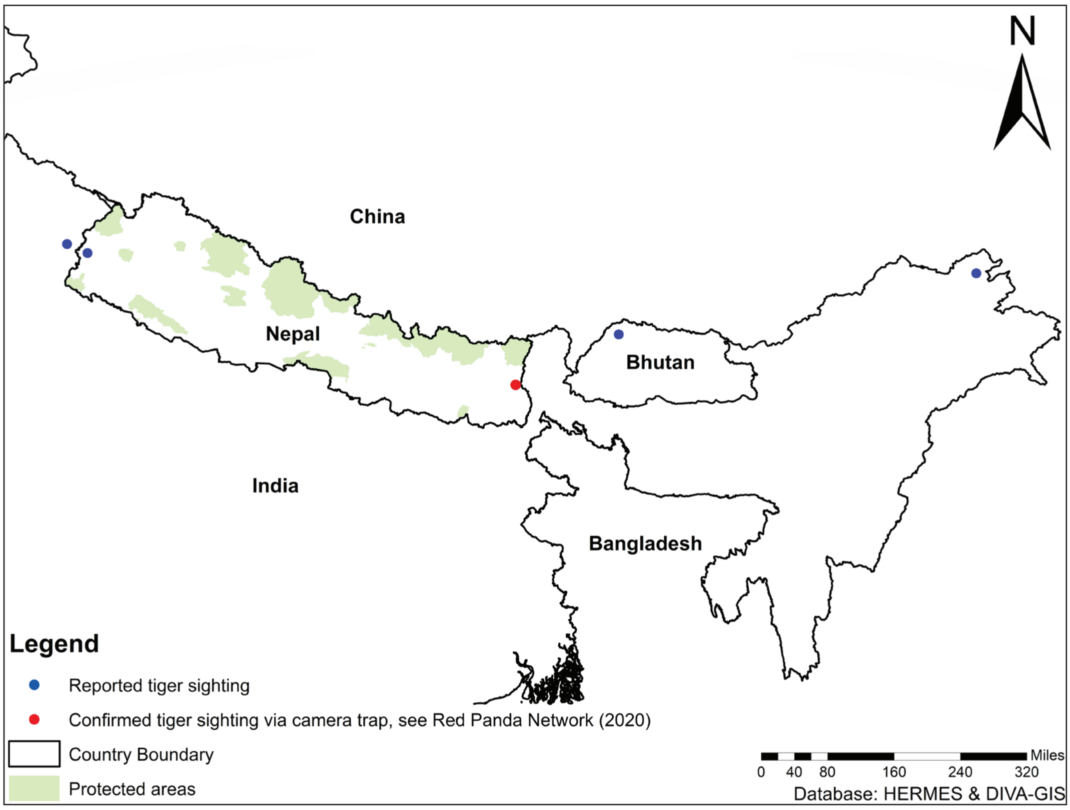

Figure 1 – Panthera tigris *sightings at high altitudes in Hindu Kush Himalaya.*

and riverine forests of Nepal (Smythies 1942; Gurung et al. 2006). *P. tigris* distribution is currently largely limited to five protected areas of the Terai Arc Landscape (TAL), including: Chitwan National Park, Parsa Wildlife Reserve, Bardia National Park, Banke National Park and Shuklaphanta Wildlife Reserve.

Conservation activities in Nepal aim to connect several protected areas with habitat corridors to facilitate the movement and dispersal of wildlife primarily along the east-west corridor at lower elevations. TAL in Nepal is critical for doubling the *P. tigris* population. In Nepal, TAL covers 24,710.13 km^2 across 18 districts and extends from the Bagmati River in the east to the Mahakali River along the western border with India. Apart from these protected areas, various national and community forests serve as *P. tigris* habitats that enable habitat interconnectivity and allow their dispersal. Previously the Bagmati River was considered the eastern boundary of *P. tigris* distribution in Nepal. In Nepal, *P. tigris* have been confined largely to the lowland habitat (below 1,000 m elevation) in the forests on the slopes of the Siwalik Range (1,000 to 1,500 m) (Miehe et al. 2016) up to the Bagmati River in the east. However, recent sightings of *P. tigris* across Nepal at higher elevations raise some critical questions that need to be addressed: a) Did these *P. tigris'* seen at higher elevations just stray from their natural habitat? b) Does individual plasticity play a role in the occurrence of these *P. tigris'* seen at higher elevations? c) Did a reduction in the prey population, scarcity of water, or elevated temperature force *P. tigris* to move higher? d) Do these higher elevations historically harbor *P. tigris* as folklore suggests?

The Nepal Himalaya is divided into six biographic and bioclimatic zones in north–south direction: 1) Terai (the northern edge of the Indo-Gangetic plain), 2) Siwalik (Churia) range, 3) Mahabharat range, 4) Midlands, 5) Himalayas, and 6) Inner Himalayas and Tibetan marginal mountains (Figure 2). Each of these zones has distinct altitudinal variation, slope, and relief characteristics, as well as climatic characteristics (Figure 3). The Mahabharat range (also known as mid-hills), south of the Himalayan range and north of the Siwalik range, is a critical physiographic region in Nepal. The Mahabharat range rises higher than the Siwalik hills and reaches an altitude of 3,000 m (Hagen 1998). The Mahabharat is an east-west running mountain range. The Mahabharat has a subtropical climate at low elevations and temperate climates at higher elevations. It is well developed in eastern and central Nepal and underdeveloped in western Nepal. Since the mid-1990s, Nepal's mid-hills have seen forest cover increase significantly as a result of community forestry. Moreover, mid-hill areas in Nepal have also witnessed a decline in human population due to out-migration and low birth rates. All these factors might have also resulted in *P. tigris* and other animals coming back in the mid-hills. Present frequent sightings of *P. tigris* in this range might not be just a fluke. All these sightings might suggest that this range is also an important hotspot for *P. tigris* and other wildlife populations that need to be protected. Or *P. tigris* might venture up into

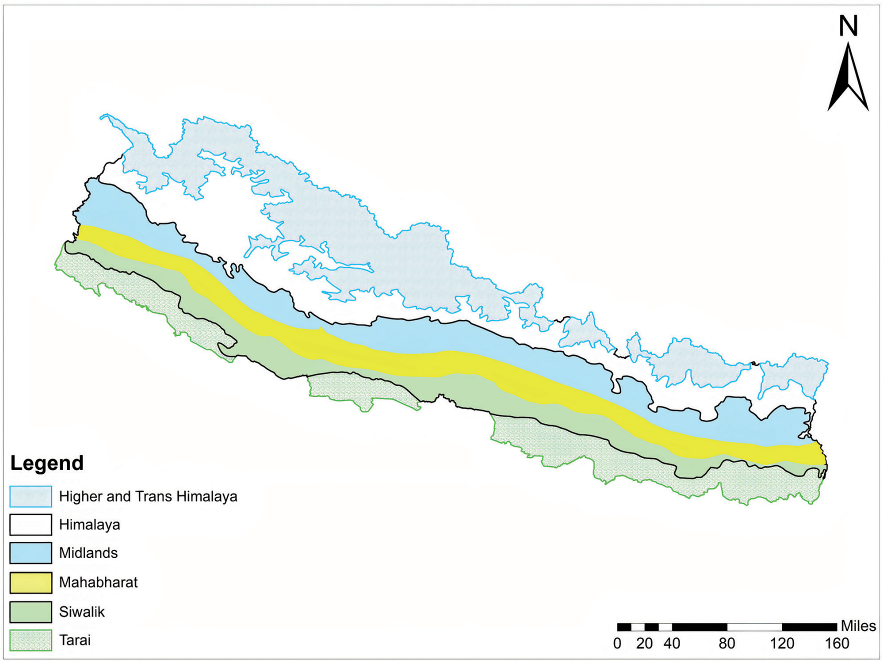

Figure 2 – Physiography of Nepal. Data source: GIS Database of Nepal available at MENRIS-ICIMOD (http://geoportal.icimod.org/downloads)

higher elevations in search of food. Additionally, a reduction in the density of prey in the Terai, scarcity of water and rising temperatures might have contributed to make *P. tigris* venture into higher elevations.

All these suggest the importance of the Mahabharat range and of a longitudinal conservation gradient approach in Nepal. Most wildlife research in Nepal focuses on Terai or the high Himalaya, with the mid-hills usually left out. Therefore it is critical that these high-altitude habitats for *P. tigris* be further explored and protected. Apart from this, a detailed assessment of the status of *P. tigris* and *P. tigris* prey densities in the region is imperative. Although high-altitude ecology may be suitable for *P. tigris* growth, the formulation of a high-altitude *P. tigris* conservation action plan is of vital importance, with effective coordination between stakeholder organizations and departments concerned. In addition, habitat corridors must be structurally and functionally connected for the long-term viability of *P. tigris* populations in the region. Apart from this, the protection of *P. tigris* requires a transboundary approach that includes actions on a landscape, local, state, national and international scale. Developing landscape-level monitoring mechanisms, mobilizing resources and intensive monitoring of *P. tigris* are essential. At international level, bilateral cooperation, regional cooperation, trans-border protection and joint assessments are needed among Nepal, India, Bhutan, Bangladesh and Myanmar in the region for sustainable *P. tigris* conservation.

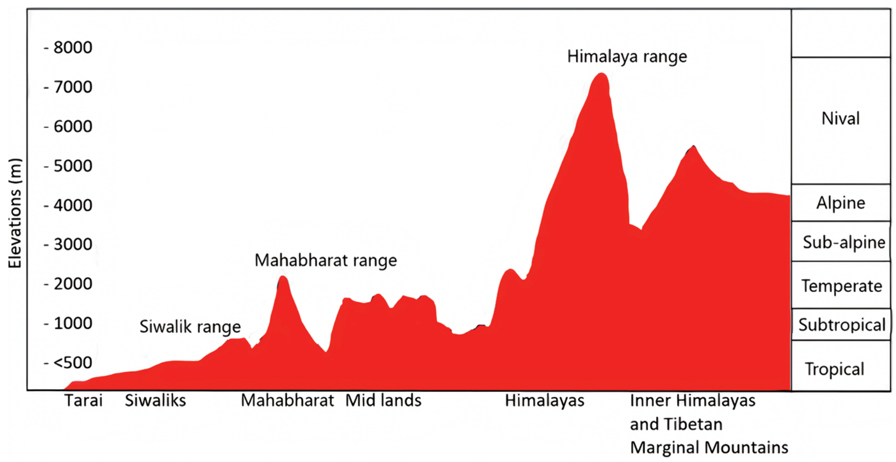

Figure 3 – Biographic and bioclimatic zones of Nepal. Adapted from Paudel et al. (2012)

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Report on the International Symposium of Mountain Studies, part of the 34th International Geographical Congress, Istanbul (16–20 August 2021)

Alexey Gunya & Fausto Sarmiento

Abstract

The 34th International Geographical Congress was held online from 16 to 20 August 2021. Its main themes were strengthening our collective response to global problems and building *bridges between continents*. The International Geographical Union Commission of Mountain Studies (IGU-CMS) organized an International Symposium of Mountain Studies (Istanbul) as part of the congress, with 11 presentations over three different sessions. Three explored the development of mountain research methodology (montology), which underpins the advancement of mountain science. These focused on: montology as applied to mountain conservation; getting to grips with urbanization; and the reality of periglacial geographies. Other topics covered by the presentations included disciplinary methods of ecosystem dynamics, land-use change, transhumance, climate change model simulations of terraced landscapes, conservation of flagship species and mountain responses to extreme weather scenarios. The IGU-CMS also presented its plans for an edited book series on montology and announced the launch of its first volume (Montology Palimpsest: A Primer of Mountain Geographies) in time for next year's IGU Paris 2022.

The range of participants and topics at the 34th International Geographical Congress reflected the current state of geography, which is influenced by global trends: environmental change under the influence of climate factors, diffusion of digital technologies into all spheres of life, pandemics, migration crises, etc. The overarching themes of the congress were strengthening our collective response to global problems and building *bridges between continents*.

In his keynote lecture, Professor Mike Meadows called geography the *"science of sustainability"*, and the core objective of geography *"the study of the relationship between humans and the environment"*. He argued that, perhaps more than any other scientific discipline, geography makes a significant contribution to understanding human-environment relations, as demonstrated in the following areas: 1) hazard and risk research, 2) human impact studies, 3) Earth system science, 4) remote sensing and GIS, 5) environmental history, 6) landscape studies. This interaction between physical and human geography is evident in the study of mountains. The results of studies in the world's mountain systems were presented in several sessions at the congress. Of particular note was the International Symposium of Mountain Studies, with 11 presentations given over three sessions.

Three presentations explored the development of mountain research methodology (*montology*), which underpins the advancement of mountain science. The presentation by the Chair of the Commission of Mountain Studies, Professor Fausto Sarmiento (USA), focused on aspects of practical montology (*Applied Montology: Critical Biogeography of Andean Treelines and the Humboldtian Paradigm on Satoyama Landscapes*). Montology, as a complex science of mountains, where the issues of the relationship between humans and the mountain landscape with all the ensuing consequences (the transformation of mountain ecosystems, the influence of natural and destructive processes, the cultural heritage of mountain peoples and civilizations, etc.) are systematically considered, is a vivid expression of modern trends in geography.

The presentation by Andreas Haller and Domenico Branca (Austria) examined the prospects for studying urban areas in mountain regions (*Ideas on Urban Montology: Periurbanization, Verticality, and Ecological Complementarity in the Peruvian Andes*). They proposed a new direction of research – *urban montology*. In contrast to traditional montology, which assumes a homogenous rural landscape, urban montology focuses on the study of dense urban space in the mountains.

Meanwhile, the presentation by Yuri Golubchikov (Russia), *A Holistic Approach to High-Latitude and High-Altitude Regions of the World*, outlined the opportunities for combining studies of high-latitude and high-altitude regions of the world within the framework of a new direction in geography – *periglacial geography*.

Two presentations provided an overview of the state of mountain research at country level (Turkey and China). The Turkish mountains were the focus of the presentation by Neslihan Dal and Barbaros Gönençgil (*Description of Mountains and Mountainous Areas in Turkey*). It was emphasized that Turkey is a mountainous country, characterized by a wide range of mountain landscapes and development problems inherent in mountainous areas. Barbaros Gönençgil was head of the organizing committee for the congress and is an active member of the IGU Commission of Mountain Studies. The review of mountain research in China made by Dunlian Qiu (*Mountain Research in China*) showed that mountain research in China is represented in many universities and academic institutions, including the Chinese Academy of Sciences. Dunlian Qiu is the editor of one of the world's leading journals for mountain research (*Journal of Mountain Science*). It should be noted that in the context of dynamic changes in the mountains of the world, such reviews of other mountainous countries would be very useful.

Lynn Resler (USA) explored a classic theme in mountain geography (*Phytotopographic Interactions in Three Mountain Environments and Potential Pathways for Ecosystem Development*). She explained how a study focusing on various regions of the United States demonstrated significant variability in alpine vegetation across different mountain environments. It should be noted that such studies are still central to mountain geography, with links to Carl Troll's mountain geoecology. Another study in a similar vein, *Current Trends of Landscape/Land Cover Change of Protected Areas of North Caucasus (Case Study of Alanya National Park)* (N. Alekseeva, A. Cherkasova, Russia) was presented. The presentation emphasized that the main changes in the middle mountains are related to land use transformation, and in the high mountains to climate change.

Transhumance and mountain terrace farming are typical mountain practices. It should be noted that their relevance continues to be significant. This is evidenced by the announcement of a special issue of the journal *Mountain Research and Development* on transhumance. A. Gunya presented a report (co-authors I. Kerimov, U. Gairabekov, H. Zaburaeva, Z. Gagaeva, Y. Karaev) entitled *Contemporary Transhumance in the North Caucasus: Chances and Risks for Sustainable Development*, focusing on an assessment of the migration of livestock between high-altitude zones. It was noted that the scale of transhumance has declined sharply over the past thirty years. Modern transhumance is based on family associations and tribal alliances, with grazing regulated by traditional institutions and market relations.

A report on arable mountain terraces in the Caucasus Mountains (*Caucasus Mountain Agricultural Terraces*) was presented by Idris Idrisov (co-authors N. Ryabogina, A. Borisov, Russia). The speaker noted that agricultural terraces are most widespread in the Eastern Caucasus. They are highly resilient parts of the landscape and can be used in modern environmental model simulations.

The survival of high-altitude communities that rely on niche biological products was discussed in Sanjeev Poudel's (Australia) presentation on *Community-Based Management of "Himalayan Gold" (Caterpillar Fungus) in Remote Landscapes of Dhorpatan Hunting Reserve, Nepal.* Local communities, in order to prevent people from outside the area collecting caterpillar fungus, have developed their own rules for access to the mountain environments concerned. This ensures that revenues from the sale of the caterpillar fungus are guaranteed and pressure on mountain ecosystems is reduced.

An important aspect of mountain research related to extreme weather events was discussed in a presentation by Kenichi Ueno (Japan) entitled *Perspectives of Mountain Studies in the Coming World of Extreme Weather*. Significant climate change is accompanied by a decrease in the ability of the world's population to withstand impending risks. The way out of this predicament is education and training, not only using conventional approaches, but also by developing adaptation strategies.

The International Symposium of Mountain Studies demonstrated that in modern conditions we must pursue new approaches, and develop existing ones, for studying mountainous countries. At the meeting of the IGU Commission of Mountain Studies, held immediately after the symposium, it was noted that there is a need for analysis to provide an overview of the state of mountain research globally. It was also agreed that a similar symposium should be organized for the IGU Centennial Congress Paris 2022 to maintain the momentum and drive mountain geography forwards. The IGU-CMS has also signed a contract with Springer Nature Switzerland for the publication of an edited book series on montology, which will help take the message worldwide. Several volumes will be published with the first, entitled *Montology Palimpsest: A Primer of Mountain Geographies*, scheduled for release next year. The intention is that this volume will constitute an updated textbook of mountain geography almost a decade after Price et al. (2013).

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7th National Austria Symposium in Vienna, 7–9 September 2022

In September 2022, the 7th Nationalparks Austria Symposium will take place in Vienna, Austria. Research in and about protected areas is once again brought into focus. Lectures, discussions, poster sessions and excursions are also part of the programme. More information available on: https://symposium.nationalparksaustria.at

International Mountain Conference 2022 (#IMC2022) in Innsbruck, 11–15 September 2022

In September 2022, the IMC2022 will take place in Innsbruck, Austria. The key goals of the conference are to synthesize and enhance our understanding of mountain systems, in particular their response and resilience to global change. More information available on: www.imc2022.info/

3. Schweizer Landschaftskongress, 8–9 September 2022

In September 2022, the 3rd Swiss Landscape Congress will discuss challenges such as the biodiversity and climate crises for the landscape in Switzerland. Representatives from practice and politics, research and teaching are invited to participate in the dialogue and develop solutions. More information available on: https://landschaftskongress.ch/

EuroMAB Meeting 2022 in Bad Kleinkirchheim, 12–16 September 2022

The Nockberge Management and the Austrian MAB Committee invite managers of UNESCO Biosphere Reserves (BRs), scientists and representatives of institutions and associations connected to and working with BRs to join the EuroMAB 2022 in the Nockberge Region of the BR *Salzburger Lungau and Kärntner Nockberge* in Carinthia in Austria. More information available on: www.euromab2021.at

How much hydropower is ecologically sustainable?

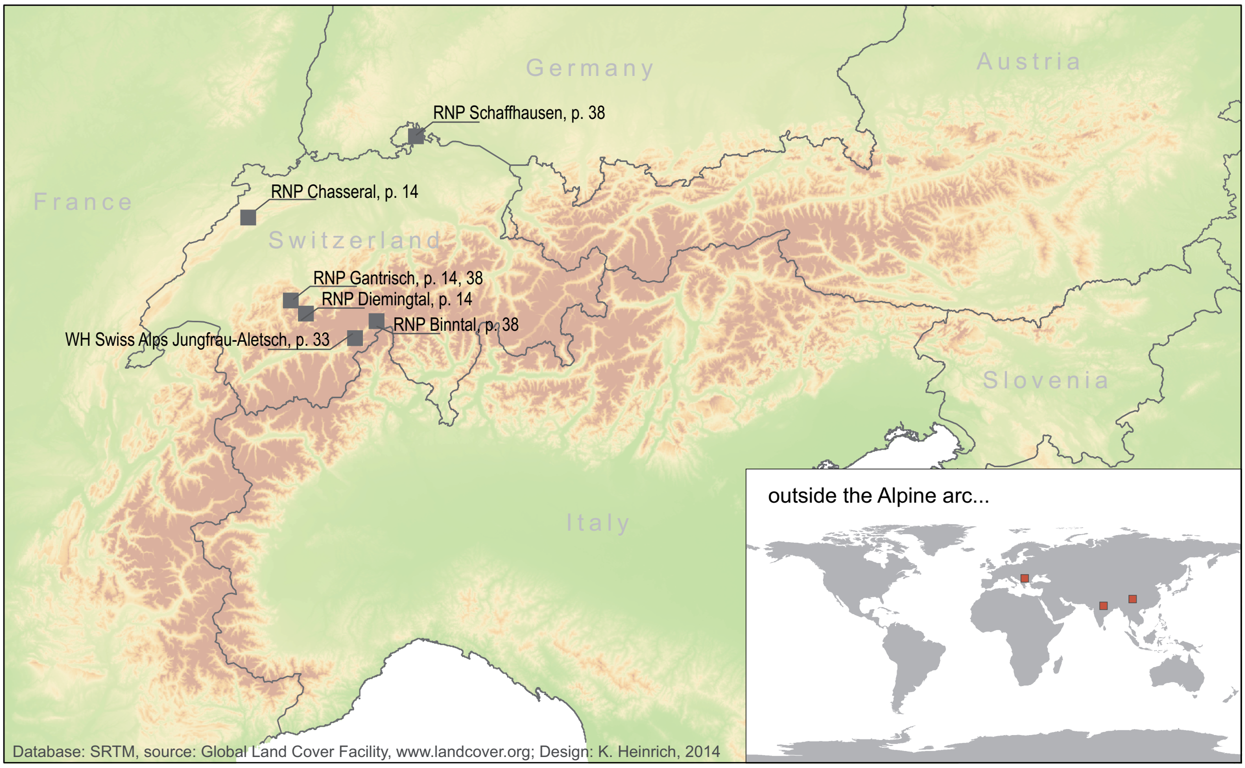
CIPRA has published a position paper with detailed technical demands on the use of hydropower in the Alps. More information available on: www.cipra.org/en/news/how-much-hydropower-is-ecologically-sustainable

Wanted: pioneering renovations and new buildings

The *Constructive Alps* architecture prize is entering its 6th round: buildings that contribute to achieving the *net zero* climate goal can be submitted until the end of January 2022. More information available on: www.constructivealps.net

Parks discussed in this issue

Abbreviations: RNP – Regional Nature Park; WH – UNESCO World Heritage; p. – page



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