Allegato 2a_4

Spatial behaviour and activity patterns of male ibex in the Gran Paradiso National Park

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Introduction

One of the major goals in the field of ecology is to identify the factors that determine the distribution and abundance of species, so as to predict future patterns and trends. This can be particularly helpful in developing strategies for the conservation and management of threatened species and populations. To describe the distribution and abundance of species is necessary to analyse the relationships between organisms and their environment, understand how species use space and resources (McLoughlin et al. 2010).

The study of spatial behaviour provides an important model for interpreting the interaction that animals establish with the environment in which they live and with the changes that take place in it. In fact, throughout year the environmental resources undergo qualitative and quantitative changes, which force the individuals to make a choice among the areas in which they can perform their daily activities. The spatial distribution of organisms is driven by the need to maximize the survival and individual fitness (Fretwell & Lucas 1970). Therefore it is expected that the animals will be distributed to optimize the tradeoff between the best energetic resources and the associated risks (e.g. predation, competition, thermal stress). Animals should opt for those areas that improve survival and reproductive success. When different ranges have different seasonal suitability, a seasonal pattern of space use may be established so as to obtain the maximum benefit (Bergerud 1974).

The study of animal activity rhythms is another important tool that can help the researchers to understand the relationships between animals and their environment. Within this framework, it is important to measure organism behavioural responses to specific environmental factors and develop a methodology to assess the deviations from the natural behaviour caused by disturbed conditions (Berger et al., 2003; Scheibe et al., 1999). Now that it is widely accepted that global climate changes are happening, there is a growing demand for accurate forecasts of its effects, and much concerns about its effects on biological diversity. Therefore, the study of climatic factors and their influences on animal behaviour and population dynamics have assumed great relevance.
Here we analyse the spatial behaviour and activity rhythms of the male ibex in Valsavarenche, Levionaz basis, within the Gran Paradiso National Park (PNGP). We describe the characteristics of the areas used by the ibex and we discuss their patterns of daily total activity with particular attention to the influence of climatic variables.

Methods

Study area

The study was carried out in the Gran Paradiso National Park (GPNP; 45°35'N, 7°12'E), in the northwestern Italian Alps. The study area (1,700 ha) lay between 1600 m and 3100 m a.s.l. and consisted mainly of cliffs, slopes, and alpine meadows. Woods (mainly *Norway spruce*, *Picea abies*; *European larch*, *Larix decidua*; *Arolla pine*, *Pinus cembra*) covered less than 15% of the whole area and were not common in the areas selected by ibex. The mainly habitats are secondary pastures or alpine meadows, where the most common grass genera were *Festuca*, *Carex*, *Poa*, *Achillea*, and *Trifolium* (Grignolio et al. 2003; Grignolio et al. 2007). The local climate is temperate, with snowfall mostly occurring from November to April, the warmest period generally occurs from June to September. An automatic station recorded temperature, radiation, precipitation and wind speed data (24 records⁄d, Property of Meteorological Service of Aosta Valley Region).

Data collection

Between the 7th of May and the 28th of June 2013, ten adult male ibex (8-13 years old) were captured by tele-narcosis, using a mixture of xylazine and ketamine according to the method of Bassano et al. (2004). During capture we fitted each male ibex with a GPS radio-collar (GPS PRO Light collar, Vectronic Aerospace GmbH) set to attempt a relocation once every 2 hours. After 7 days from the capture, each collar was set to record the position once every 7 hours.

The radio-collars were equipped by an activity sensor that measure activity in two axes based on the true acceleration experienced by the collar. Axis X measures acceleration in forward/backward motions, axis Y measures sideways as well as rotary motion. Activity is measured four times per second simultaneously on each axis as the difference in acceleration between two consecutive measurements, and is given within a relative range between 0 and 255, characterizing the mean activity/acceleration (Krop-Benesch et al. 2011). Measurements are averaged over a sampling interval of 4 minutes and stored with the associated date and time. Data about spatial behaviour and activity were downloaded from the collars by SMS and by a handheld terminal, using a VHF connection.

Data Analyses

Spatial behaviour - Analysis focused on GPS positions taken by the radio-collars. From these data, we removed any location with a dilution of precision (DOP) greater than 10. The resulting data were imported into a GIS software (ArcMap Version 9.3, ESRI). We examined the characteristics of areas used by the male ibex throughout the period of data collection (May 2013 – April 2014) using a high-resolution digital terrain model (DTM, with space resolution of 10 meters).

Activity patterns - Analysis focused on daily mean activity. Consequently, for each male and for each day of data collection we calculated the mean of activity on the X axis and on the Y axis measured by the activity sensors in the collars. The X daily mean and the Y daily mean activities were summed. The resulting activity value was used as dependent variable in a Generalized Additive Mixed Models (GAMMs) considering individual identity as random factor. We included in the models the meteorological data (temperatures, radiations, precipitations and wind speed) to account for effect of climatic factors that could influence ibex activity. To account for temperatures effects we inserted in the models alternatively daily mean, minimum and maximum temperatures. Moreover, we modelled the season changes by estimating the effect of the day of the year (Julian day) to account for potential endogenous variation of ibex activity patterns throughout the year. To check for multicollinearity between the explanatory variables, we calculated the variance inflation factors (VIF) for each of them. As radiation and temperatures measures were found to be highly auto-correlated, they were used alternatively in different models. We ranked and weighed the alternative models using the minimum AIC criterion (Symonds and Moussalli 2011).

Results

During the period of data collection we obtained a total of 4859 validated localisations and 1360 daily activity values. For two males (ID 12228 and ID 12335) we had a long data series, for the others we had data for limited periods, depending on the period of working of each GPS radio-collar (see Table 1, 2 and Fig.1-4 for detailed information). One ibex (collar ID 12229) died in the 4th of October 2013.

GPS-collar ID	Age of the male	Total number of localizations												
		May 2013	Jun 2013	Jul 2013	Aug 2013	Sep 2013	Oct 2013	Nov 2013	Dec 2013	Jan 2014	Feb 2014	Mar 2014	Apr 2014	Total
12227	8		141	54										195
12228	9	94	111	95	96	100	96	67	83	60	50	68	51	971
12229	13	99	90	91	86	90								456
12230	9		27	154	4									185
12231	9	95	114	87										296
12232	9	110	96	50										256
12233	11		26	294	95	96	78							589
12234	9	131	93	95	4									323
12235	8		134	96	98	99	95	77	81	72	55	81	49	937
12236	11	133	95	101	98	100	99	25						651
Total		662	927	1117	481	485	368	169	164	132	105	149	100	4859

Table 1: Number of recorded localizations per ibex male in each month of data collection.

GPS-collar ID	Age of the male	Total daily activity values												
		May 2013	Jun 2013	Jul 2013	Aug 2013	Sep 2013	Oct 2013	Nov 2013	Dec 2013	Jan 2014	Feb 2014	Mar 2014	Apr 2014	Total
12227	8		25	17										42
12228	9	9	30	31	31	30	31	30	31	31	28	31	17	330
12229	13	17	30	31	31	1								110
12230	9		2	24										26
12231	9	10	30	31	31	12								114
12232	9	22	30	17										69
12233	11			31	31	30	16							108
12234	9	23	30	31	2									86
12235	8		24	31	31	30	31	30	31	31	28	31	16	314
12236	11	23	30	31	31	30	16							161
Total		104	231	275	188	133	94	60	62	62	56	62	33	1360

Table 2: Number of recorded daily activity values per ibex male in each month of data collection.

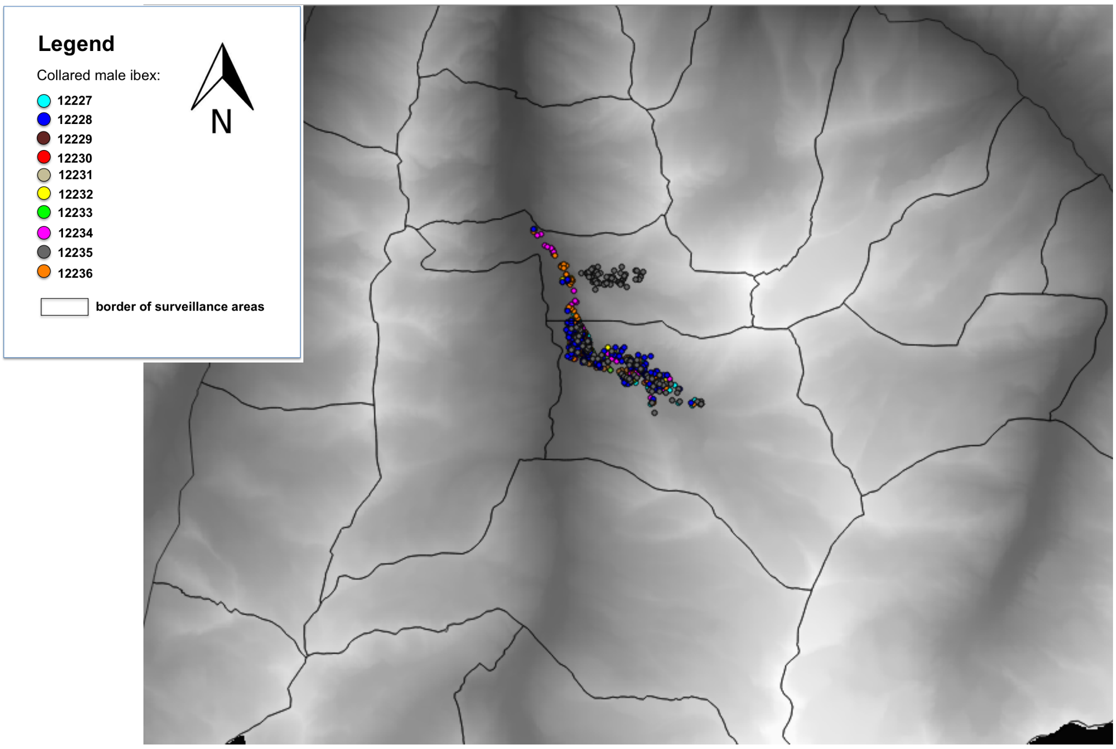

Figure 1: Map of the study area in Valsavarenche Valley (Gran Paradiso National Park) and GPS-locations of male ibex during spring

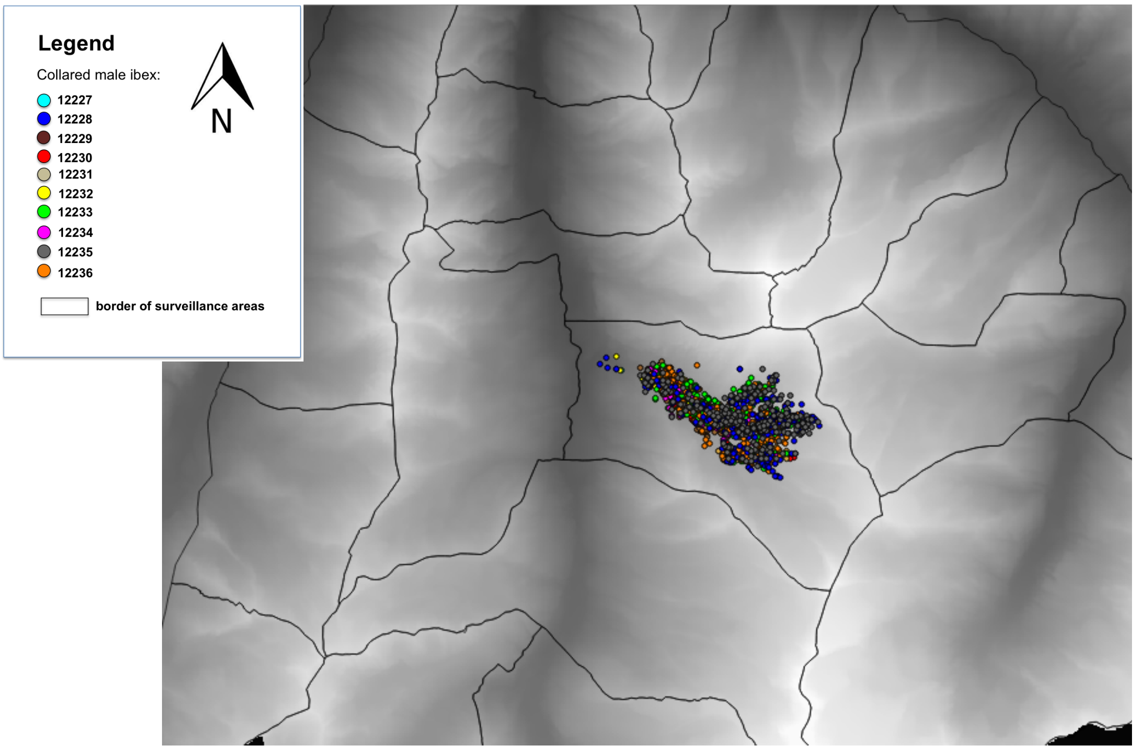

Figure 2: Map of the study area in Valsavarenche Valley (Gran Paradiso National Park) and GPS-locations of male ibex during summer

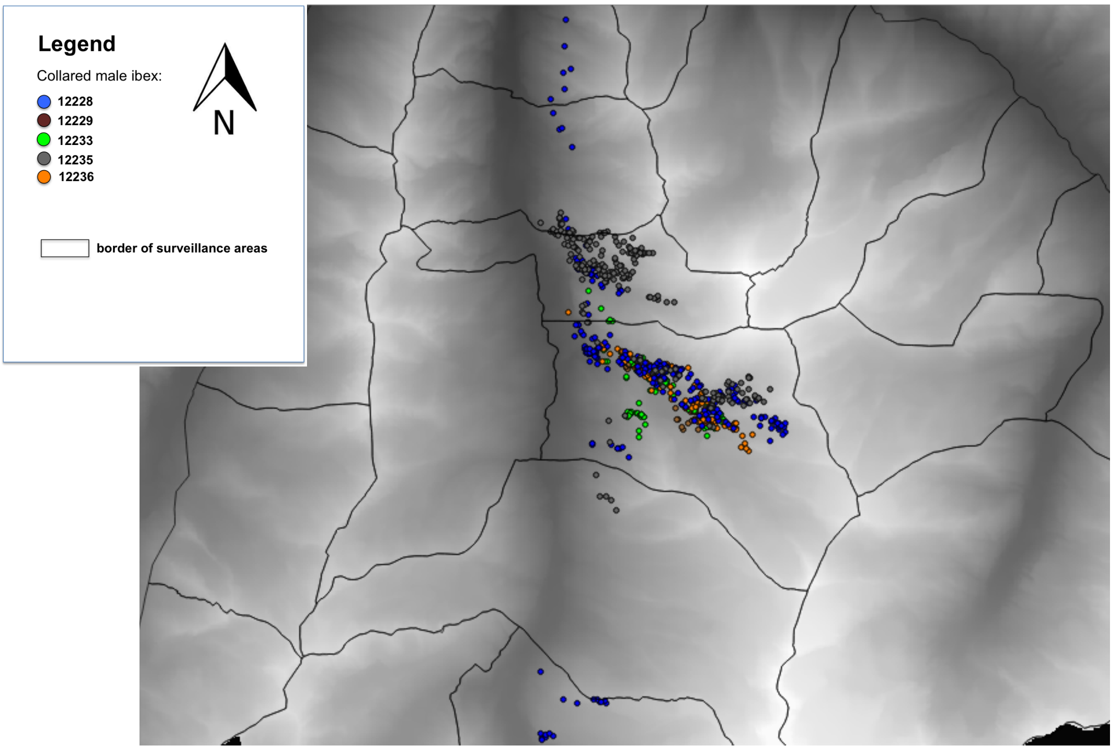

Figure 3: Map of the study area in Valsavarenche Valley (Gran Paradiso National Park) and GPS-locations of male ibex during autumn

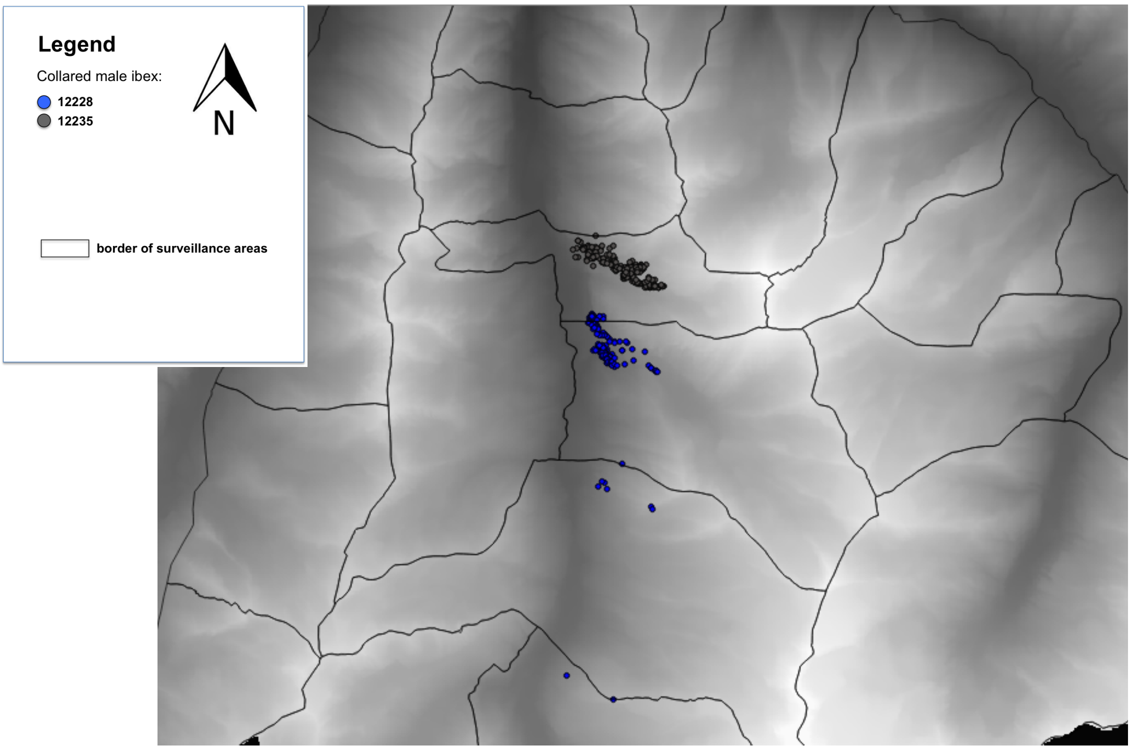

Figure 4: Map of the study area in Valsavarenche Valley (Gran Paradiso National Park) and GPS-locations of male ibex during winter

Spatial behaviour

Results on spatial behaviour analysis showed that in summer the ibex males used areas at higher altitudes, just above 3000 meters (Fig. 5), and the areas most exposed to the West, North and North-West (Fig. 6). In spring males reached the pastures at lower altitudes (mean=1650) and areas exposed to West, Nord-West and South-West. The areas facing East, South-East and North-East were exploited less frequently throughout all the year. In contrast, males were located most in Western and South-Western areas (Fig. 6). No differences were found in the seasonal distribution of males with respect to the slop of used areas (Fig. 7).

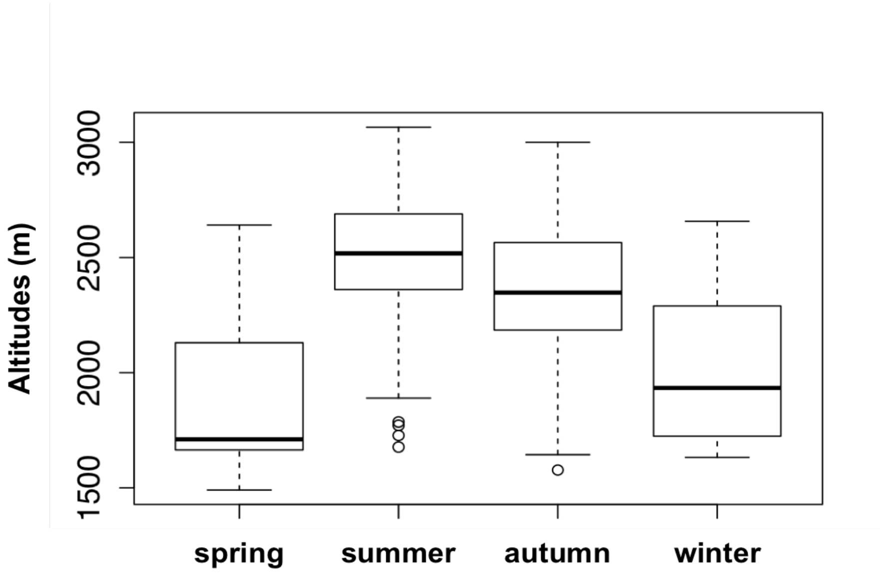

Figure 5: Seasonal distribution of altitudes of areas used by males ibex in the Gran Paradiso National Park from May 2013 to April 2014.

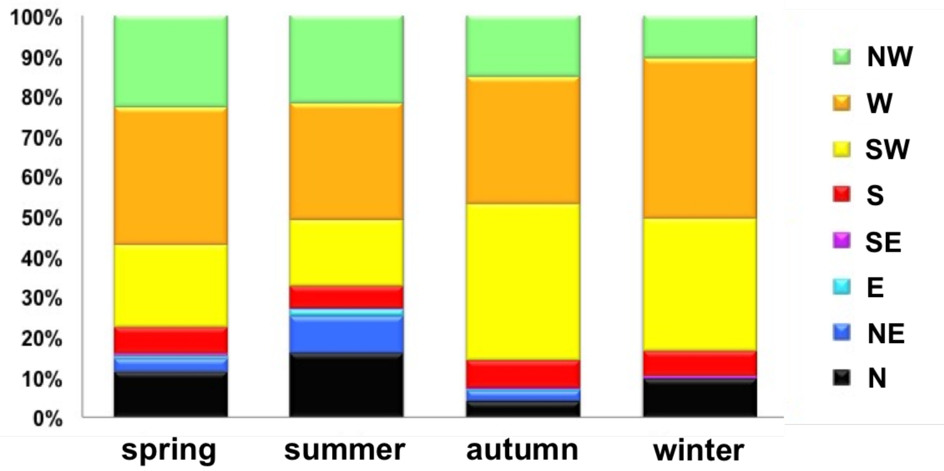

Figure 6: Proportion of use of areas with respect to their exposition (N: north, NE: north-east, E: east, SE: south-east, S: south, SW: south-west, W: west, NW: north-west) by male ibex during each season in the Gran Paradiso National Park from May 2013 to April 2014.

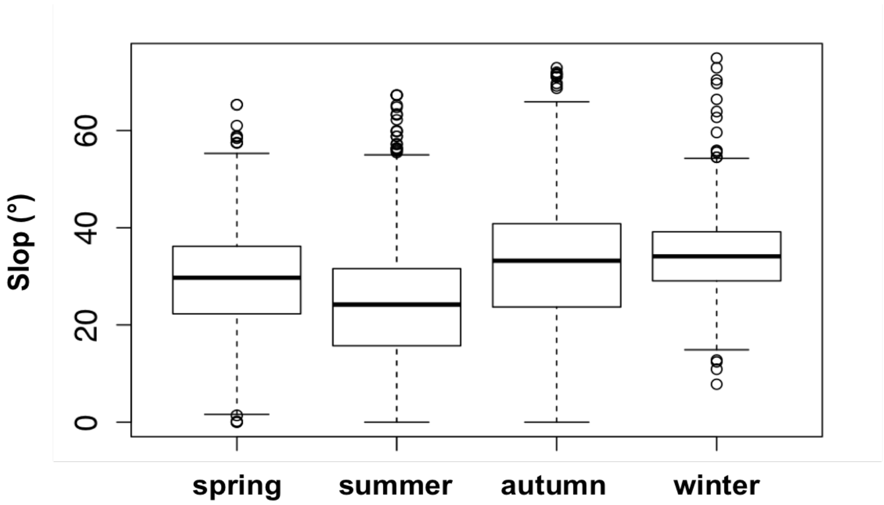

Figure 7: Seasonal distribution of slop of the areas used by males ibex in the Gran Paradiso National Park from May 2013 to April 2014.

Activity patterns – The best model, with the lowest AIC, included: daily mean temperature, daily mean precipitation values and he Julian date. Wind speed was found to not significantly affected males daily activity. Results showed that throughout the year the average daily activity of the ibex followed a hump-shaped pattern, with a maximum of activity around the middle of July and minimum values in the month of February (Fig 8). The average daily activity was also significantly influenced both by the daily temperatures and precipitation. In particular, the males' activity decreased linearly with increasing temperature values (β = -0.15 ± 0:04, P <0.001) and with increasing daily precipitations levels (β = -2.46 ± 0:37, P <0.001).

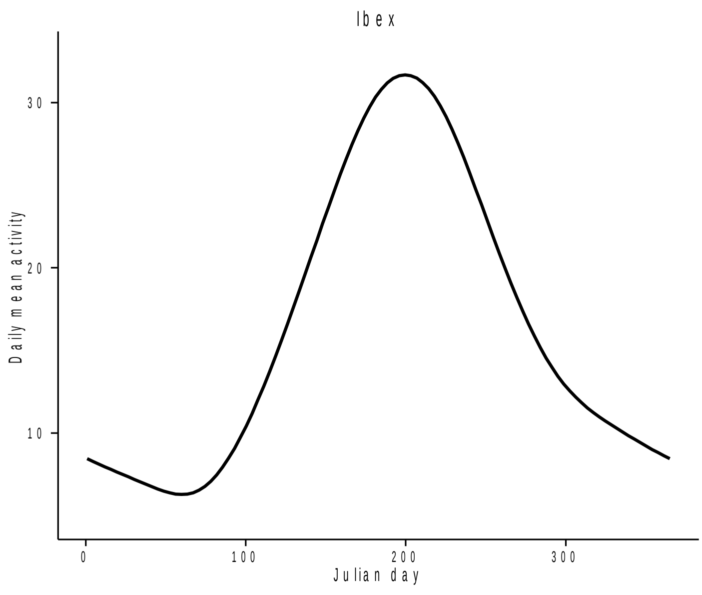

Figure 8: Individual daily activity predicted by the most-supported generalised additive mixed model for male ibex (including the individual as a random effect): as a function of the day of the year (Julian day), including a smoothing effect with a spline.

Conclusions

The analyses on spatial behaviour showed that collared male ibex undertook altitudinal migrations. They used the areas at the bottom of the valley in spring and they moved at the higher altitudes during summer. In autumn they increased their movement pattern, as they used the areas most distant from the core study area. The GPS data confirmed that ibex are a gregarious species, as all collared males' locations were grouped together both in spring and in summer (when we had data from the 10 males).

The results on both spatial and activity patterns showed that climatic factors are of great importance in determining the behaviour of the ibex. As expected, in the hottest season (summer) animals used the areas where they can find the lowest temperatures (higher altitudes and north, north-west facing). Air temperatures negatively affected ibex daily activity: during hot day males were less active. Also precipitation seemed to have importance in determining activity levels, males reduced their total daily activity with increasing precipitation levels. In contrast to our expectations, during the winter season there has not been an increase in the use of areas with greater slope, where the snow tends to smell more quickly and therefore where ibex can move more easily and find greater forage availability. It is important to highlight that only two animals had working collars during winter. Hence, these results could be strongly influenced by the individuality of these two males and not be suitable to extrapolate general information on the ibex behaviour.

These preliminary findings suggested that climatic factors affected ibex behaviour, in that temperature and precipitation influenced both spatial and activity patterns. It will be of great importance to develop further investigations on the possible effects of global climate change. In the future it will be necessary to obtain large and long data series. By means of these datasets it will be possible to implement analyses on ibex resource selection and step selection. Ibex and other Alpine ungulates may provide sensitive indicators to the advance effects of global climate change, and thus these populations need careful monitoring in the future.

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