Brown bear body patches are temporally stable and represent a unique individual visual signature

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Abstract: Patches of color may be used to communicate to conspecifics, mainly in species showing uniform coloration, and may (a) help individuals maintain visual contact, such as between mothers and their young; (b) function as signals of subordination or to frighten rivals; (c) warn conspecifics of approaching predators; and/or (d) signal reproductive condition, health, or genetic quality to potential mates. Intraspecific communication represents one of the major evolutionary forces responsible for the coloration of body parts, but the meaning of many of these signals is still unclear. One of the first steps to understanding whether fur marks have a role in social communication is to understand whether such body patches are stable over time (i.e., whether they represent a unique visual signature for every individual). During the period 1999–2021, we recorded yearly pictures of 7 female (mean no. of monitoring years per bear = 13.6, standard deviation [SD] = 4.6; range = 9–22 yr) and 6 male (mean no. of monitoring years per bear = 9.3, SD = 4.3; range = 5–15 yr) brown bears (*Ursus arctos*) in the Cantabrian Mountains (NW Spain). We show that body mark shapes are stable over time and, because of their uniqueness, might represent a distinctive signature of individuals. Brown bear body marks may act as multicomponent signals, where different features of a given mark may inform about different aspects of the bearer or act as back-ups. For example, a quality-signaling capacity does not preclude the same mark from being used in other functions at the same time, such as individual recognition. Noninvasive techniques helpful for identifying individuals have been developed for estimating population size, reproductive rates, and the survival of several carnivore species. Fur marks that are stable over time can thus be useful in field research (e.g., body marks that are persistent and do not vary over time are an important tool in longitudinal photographic capture–recapture studies).

Key words: body patches, brown bear, camera trap, fur marks, intraspecific communication, *Ursus arctos*, visual capture–recapture, visual communication

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Three evolutionary forces have been invoked to explain fur coloration in mammals (Caro 2005): (1) concealment from predators or prey, (2) diverse physiological considerations (e.g., thermoregulation), and (3) intra-/inter-specific visual communication. Moreover, the most relevant fact about the evolution of animal coloration is that different parts of the body may be subjected to different selective pressures (Caro 2005). Colored body marks are produced by, among other elements, specialized pigment cells (Rosenthal and Ryan 2000) and, generally, the possibility that clearly contrasting fur marks might have a visual signaling function frequently has been overlooked, particularly in crepuscular and nocturnal mammals (Penteriani and Delgado 2017).

Patches of color, rather than overall coloration, may thus be used to communicate to conspecifics mainly in species showing uniform coloration, and may (Caro 2005; a) help animals maintain visual contact, such as between

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mothers and their young; (b) function as signals of subordination or to frighten rivals; (c) warn conspecifics of approaching predators; and/or (d) signal reproductive condition, health, or genetic quality to potential mates. Intraspecific communication represents one of the major evolutionary forces responsible for the coloration of body parts, but the meaning of many of these signals is still unclear (Caro 2005). In fact, the interpretation of the exact meaning of animal body marks is not straightforward. Patches of color might also be used to attract the attention of conspecifics to particular areas of the body (Caro 2005). For example, the association between white spots on the backs of the ears and living in forests, as is the case of some felids, might serve to let young follow their mothers (Caro 2005).

One of the first steps to understanding whether fur marks have a role in social communication (e.g., individual recognition) is to understand whether such colored and/or achromatic body patches are stable over time (i.e., whether they represent a unique visual signature for every individual [Caro 2005]). Together with this important feature, stable fur marks can also be extremely useful in field research (Penteriani et al. 2020). For example, body marks that are persistent and do not vary over time are an important tool in longitudinal photographic capture–recapture studies.

The objective of our study is to evaluate the shape persistence of body patches for those brown bears (*Ursus arctos*) showing them through the use of a long-term data set of camera-trap images. Actually, some bears lack body marks (or, at least, no body marks were discernable from the photos [authors' unpublished data and Penteriani et al. 2021]) but any estimation of the percentage of bears showing marks is not possible with camera traps because bears that do not show fur marks are difficult to identify as particular individuals and, throughout the year and over the years, each bear's size or aspect can change considerably (e.g., when moving from the subadult to the adult phase, or from den exit to the end of the hyperphagia period). Thus, the same individual could be wrongly ascribed to different animals, which would bias any quantitative estimation except when unique injuries can be used to identify individuals (e.g., unique scars, damaged ears). Information reported in previous studies has indicated that brown bears have characteristic body marks that are variable in size and shape on the chest, shoulder, and face (Shimozuru et al. 2017), but no long-term studies on their shape persistence are available. Such individual mark patterns seem not to change seasonally or through the years and, thus, have the potential to be used for individual bear identification.

Material and methods

Study area

The study area encompasses the distribution range of the Cantabrian brown bear population in the areas of Somiedo and Belmonte, located in western Asturias, Northwest Spain. In particular, the extent of the study areas was ca. 500 km^2 during the 1998–2009 period, and ca. 800 km^2 from 2010 to 2022. The study area extends along the Cantabrian Mountains, at an average altitude of ca. 1,100 m above sea level. The climate of the region is oceanic, more continental and drier along southern slopes and temperate and more humid on northern slopes (Ortega and Morales 2015). The region is mainly covered by forests, shrublands, and farmland. The forests on southern slopes are mainly composed of semideciduous and evergreen oaks (*Quercus* spp.), whereas the northern slopes host mostly deciduous forests (*Fagus sylvatica*; *Q. robur*, *Q. petraea*; *Betula* sp.; Mateo-Sánchez et al. 2016). Nonforested areas are covered with shrubs such as broom (*Cytisus* spp.) and heather (*Erica* spp., *Calluna* spp.); while above the tree line, berry shrubs such as bilberries (*Vaccinium myrtillus*) appear (Pato and Obeso 2012, Mateo-Sánchez et al. 2016). Most bear habitat patches are embedded in a matrix of cultivated areas with a high density of transport routes and human settlements, where the main economic activities are livestock breeding, recreational activities, mining, and timber harvesting (Zarzo-Arias et al. 2019).

Camera-trap monitoring of individual bears

We began camera-trap monitoring in 1998 with 3 analogical TrailMaster Olympus DLX 20 (TrailMaster, Lenexa, Kansas) camera traps, to which 7 analogical Canon BF-8 (Canon, Inc., Tokyo, Japan) camera traps were added in 1999 (total = 10 camera traps/yr). During the period 2000–2009, 3 analogical TrailMaster and 15 analogical Canon Prima BF-8 camera traps were used every year. Starting from 2010 all camera traps (Cuddeback Capture [Cuddeback, De Pere, Wisconsin] and Reconyx [Holmen, Wisconsin]; $n = 15$) were digital. Then, starting from 2012, Scout Guard SG550V (Scout Guard, Leo District, Slovenia) and Minox DTC600 (Minox GmbH, Wetzlar, Germany) camera traps replaced the Cuddeback and Reconyx traps, whereas from 2016 to 2022 only Bushnell Trophy Cam (Bushnell Corporation, Overland Park, Kansas) and Browning Dark OPS (Browning Arms Company, Morgan, Utah) camera traps were used (total = 30 camera traps/yr). Half of the camera traps monitored footpaths throughout the whole year, while the other half were removed during the winter because they were located in high-elevation mountain areas where bear presence was scarce or nonexistent. Camera traps were active 24 hours/ day and with a time lapse between each shot of (a) 20 seconds for TrailMaster Olympus DLX 20; (b) 30 seconds for Canon Prima BF-8 and Cuddeback Capture; (c) 8 seconds for Scout Guard SG550V and Minox DTC600; and (d) 1 second for Reconyx HC600, Bushnell Trophy Cam, and Browning Dark OPS. We determined the sex of individuals from external reproductive organs, swollen mammae, and the presence of cubs.

Results

During 1999–2021, we recorded yearly pictures of 7 females (mean no. of monitoring years per bear = 13.6, standard deviation [SD] = 4.6; range = 9–22 yr) and 6 males (mean no. of monitoring years per bear = 9.3, SD = 4.3; range = 5–15 yr). During a systematic monitoring period ranging from a minimum of 5 years to a maximum of 22 years/bear, the shape of brown bear body patches never changed (Fig. 1 and Supplemental Material Files 1–13). Body mark stability over the years was always accompanied by individual uniqueness of patch patterns (i.e., every bear had a mark that was different from the ones that we were able to monitor through our camera traps; Supplemental Material Files 1–13).

Discussion

Here, we have shown that the body marks of brown bears are stable over time and, because of their uniqueness, might represent a distinctive signature of individuals. However, to date, we still lack the support of DNA-based individual identification to confirm long-lasting stability of bear body patches and we remain uninformed about the possibility that (a) similarities in body marks might exist between related bears, and (b) such body marks might be more frequent in one sex. If coloration is sexually selected, color patches should be expected only in one sex, mainly in polygynous species where males compete intensely over females (Caro 2009), as do brown bears (Swenson et al. 2021). However, we demonstrated here that single-sex color patches are not the case in brown bears. A potential function and importance of brown bear visual signaling through fur marks might also be explained by taking into account that this species relies highly on both chemical and visual communication on and around rubbing trees (Clapham et al. 2013, González-Bernardo et al. 2021, Penteriani et al. 2021, Revilla et al. 2021) because direct contact among individuals is infrequent and mostly limited to the mating period (Swenson et al. 2021). Thus, individual recognition through body patches of color might allow an individual to, for example, tailor its behavior in aggressive interactions with familiar opponents (Chaine et al. 2018). Brown bear body patches are of limited extent, so the possibility of them having some physiological and physical function (e.g., patches are involved in regulating body temperature; Caro 2005) does not seem likely. Finally, we cannot discard the function of these patches as possibly being quality-dependent expressions of color patterns (Pérez-Rodríguez et al. 2017), and assessing a potential quality-signaling role of bear patches will require an understanding of the factors determining differential expression of color patches between high- and low-quality individuals. However, the different reliability mechanisms proposed here do not necessarily need to be mutually exclusive and fur marks may act as multicomponent signals (Harper 2006). It is important to highlight here that, even if a trait is present in only a fraction of the individuals of a population, the possibility of an adaptive significance in such a trait might still exist because inter-individual differences in coloration traits can signal, for example, individual status, fitness and good genes, genetic heritage and individual recognition, environmental features, mother–offspring similarity, and parasite resistance (Blest 1957; Roulin et al. 1998, 2000, 2001; Niecke et al. 2003; Almasi et al. 2012; Penteriani et al. 2015; Roulin and Randin 2016; Tietgen et al. 2021). As a final point, all of these issues represent interesting research avenues for future studies and, depending on their results, it may be possible to formulate hypotheses about the functions of brown bear body patches. However, attempts to generate and test predictions concerning the function of brown bear body patches through experimental approaches have met with difficulty. Additionally, brown bear body patches do not follow any species-specific generalized patterns, as is the case for other ursid species such as the sun bear (*Helarctos malayanus*; Penteriani et al. 2020) and the Asiatic black bear (*Ursus thibetanus*; Higashide et al. 2012).

Noninvasive techniques helpful for identifying individuals have been developed for estimating population size, reproductive rates, and survival of several carnivore species, including brown bears, black bears (*Ursus americanus*), and Asiatic black bears (Higashide et al. 2012, Shimozuru et al. 2017). Identifications based on fur coloration patterns and marks are relatively simple, cost-effective, and easy to perform; therefore, they have an advantage in field studies in cases where invasive techniques may be detrimental or unfeasible (Higashide et al. 2012, Shimozuru et al. 2017). Not all brown bears show distinc-

Fig. 1. Two examples of the stability of the body marks of female and male brown bears (*Ursus arctos*; see Supplemental Material File 1 for the entire set of pictures of these 2 individuals, as well as for the pictures of the 13 bears—7 females and 6 males—monitored by camera traps). A. Best images of a female monitored from 2000 to 2021 in the Cantabrian Mountains (NW Spain). B. Best images of a male monitored from 2014 to 2021 in the Cantabrian Mountains (NW Spain).

tive body marks (i.e., this fur trait is only shown by an unquantifiable portion of the individuals in our study population [authors' unpublished data and Penteriani et al. 2021]); therefore, the lack of these marks is a factor that limits individual identification through this noninvasive means. However, individual markings are still applicable to many individuals of a population and, thus, can represent an additional piece of information for the study of brown bear populations.

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Supplemental materials

Supplemental Files (1–13). Stability and uniqueness of the body marks of 7 female (mean no. of years = 13.6; range = 9–22 yr) and 6 male (mean no. of years = 9.3; range = 5–15 yr) brown bears (*Ursus arctos*), as recorded by camera traps during the period 1999–2021 in the Cantabrian Mountains (NW Spain).