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Leadership linked to group composition in Highland cattle (*Bos taurus*): Implications for livestock management

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ABSTRACT

Animals kept for livestock or conservation form strong cohesive groups when foraging and moving, in the same way as their wild counterparts. Collective decision-making involves making compromises by consensus to maintain group cohesion and synchronisation. This type of consensus can be observed during collective movements, when a leadership can emerge. In a distributed leadership, many group members may initiate collective movements but some individuals initiate more frequently than others and are more frequently followed by their conspecifics due to socio-demographic factors such as age, sex or dominance. In this study, we focused on organisation and leadership in the collective movements of semi-wild groups of Highland cattle (*Bos Taurus*). Highland cattle being often used in eco-pasture, studying leadership emergence and the use of space by animals may improve livestock and pastureland management. We studied nine different compositions (i.e., same location but with transfers of individuals) of four groups over a six-month period. The group sizes ranged from nine to 21 individuals. Results revealed that leadership is widely distributed in Highland cattle groups, with some individuals initiating more often than other group members. Indeed, in large groups, some group members never initiated movements. The number of followers within a movement was particularly influenced by the age of the initiator, its social centrality and dominance, but was also affected by the increase of pre-departure activities. This study also shows the influence of several variables on the joining rank of individuals during movement progression, such as age and social centrality. Finally, social centrality and the number of followers explained the departure latency between two individuals. Here, we proposed how these findings can help manage livestock.

1. Introduction

Humans keep some animal species captive as livestock on farmland, or for conservation purposes (Boyland et al., 2016; Ramos et al., 2016). Even if these animals may have food provided ad libitum for all or a part of the year and no longer face predation, they still show the same strongly cohesive behaviour as their wild counterparts due to strong evolutionary pressures. Indeed, humans have chosen mainly social species for livestock or conservation purposes, because this sociality facilitates the maintenance of herd cohesion, making it easier to find the groups in pastureland and coordinate movements such as transhumance (Butt et al., 2009).

Group living provides many well-known advantages (Krause and Ruxton, 2002). Particularly, sociality allows protection against predators in prey species such as ungulates through communal defence (Sillen-Tullberg and Leimar, 1988) but also through shared vigilance (Pays et al., 2014). Living in groups also leads to better information sharing and improved efficiency when seeking food (Danchin et al., 2004). However, there are also disadvantages to group living, such as food competition (Gore, 1993; Sterck et al., 1997) and increased pathogen transmission due to proximity between conspecifics (Godfrey et al., 2009; Nunn et al., 2006). One of the major disadvantages is the wide range of different and sometimes conflicting individual needs within the group. These conflicts of interest can lead to group fission (meaning the permanent split of the group into at least two new groups), a phenomenon which can have a negative impact on group members, especially when there is a high predation risk (Conradt and Roper, 2005; Sueur et al., 2011b). In order to maintain spatial and temporal cohesion, group members therefore need to synchronize their activities and make collective decisions (Conradt, 2011). Collective

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decisions might be easy to observe in the context of group movements, meaning when a group move from one location to another one without doing other activity than moving.

Collective decision-making allows a compromise to be reached amongst group members through communication mechanisms. This consensus is shared when several individuals, i.e. the majority of group members, are involved in decision making (Bourjade and Sueur, 2010; Conradt, 2011; Conradt and Roper, 2007; Sueur and Petit, 2008a). In the process of movement departure, several phases or periods are important in the decision making: the pre-departure period, the initiation and the following process. The pre-departure period is a period before the departure of the initiator and of the followers in which some individuals may indicate their readiness to go through activity increase (Ramseyer et al., 2009c,d), intentional movements or even voting behaviours (King and Sueur, 2011; Ramos et al., 2015). The time of this period as well as the number of individuals involved in this period influence the number of followers (Bourjade and Sueur, 2010). After the initiation, some individuals might also be important in the decision process such as the first follower: its identity and its behaviour may influence the initiation success (Ramseyer et al., 2009c,d; Sueur and Petit, 2008a, 2010). This is why a decision to move is collective as it often implies the participation of several individuals. The fact that several individuals participate to a decision is defined as shared consensus. Shared consensus, also called distributed leadership, has been shown in the African buffalo (*Syncerus caffer*, Prins, 1996), the European bison (Ramos et al., 2015), and many other animal species (Conradt and Roper, 2005). However, in some cases, a group member may play a more important role in the group decision to move, either by initiating more movements or by being followed by more of its conspecifics more frequently (Pyritz et al., 2011). In this case, this individual is considered as a leader (Van Vugt et al., 2008). Leadership process might have deep implications in dairy production as for the entrance order of cows in the milking parlour (Grasso et al., 2007; Polikarpus et al., 2015, 2014).

This propensity to be a leader is not only influenced by socio-demographic factors such as the age and sex of individuals, but also by their dominance rank or their social centrality/role (Jacobs et al., 2011; Sueur and Petit, 2008b). Most studies show that age has a great influence on leadership. Older individuals have more knowledge and experience (McComb et al., 2011), and initiate more movements than younger group members, such as in European bison or in semi-wild cattle (Ramos et al., 2015; Reinhardt, 1983). In some species, dominant individuals also play a more important role in collective decisions than their subordinates (Petit and Bon, 2010). However, results are contradictory in cattle with studies showing a link between leadership and dominance (Dickson et al., 1967; Reinhardt, 1983; Sato, 1982) but one study at our knowledge not showing a link between the two variables (Ramseyer et al., 2009c,d). This last study was done however on a group of heifers having the same age. The nutritional needs of group members also seem to increase the likelihood that they will initiate a movement (Sueur et al., 2010). Indeed, individuals with higher nutritional requirements, such as bigger males in Chacma baboons (Sueur, 2011) or lactating females in zebras (Fischhoff et al., 2009) initiate more movements than their conspecifics. In ungulates, these differences in needs between males and females lead to sexual segregation (Conradt, 1998; Ruckstuhl, 2007).

Bovines are a remarkable taxa that is known to form very large groups in the wild, showing extraordinary collective phenomena such as the migration of wildebeest (*Connochates taurinus*, Williamson et al., 1988) and American bison (*Bison bison*, Bamforth, 1987) in large fission-fusion herds. However, not only wild bovines live in large groups; domestic bovines also show this behaviour and are of particular interest, mainly in pastoralism and farmland economic activities. Knowing how bovines move in their environment and being able to predict their movements is very useful for conservation biology or for livestock management (Bishop-Hurley et al., 2007; Holdo et al., 2011; Ramos et al., 2016). Researchers have studied leadership in American bison (McHugh, 1958) and in European bison (Ramos et al., 2015), but also in domestic species such as zebus (Reinhardt, 1983) and domesticated cattle (Della-Rossa et al., 2013; Dumont et al., 2005; Ramseyer et al., 2009c,d; Šárová et al., 2007, 2010). Results showed that leadership in all these groups and species is not individual, but distributed. In European bison, adult females are more likely to initiate movements whilst juveniles very rarely do so (Ramos et al., 2015). Many ungulate species form stable clusters of kin relatives or affiliates (Archie et al., 2006; Bercovitch and Berry, 2010; Lazo, 1994). The postures of animals and the dispersal state of the group influenced the success of an initiation. In domestic cattle, an increase was observed in activity during the pre-departure period (Ramseyer et al., 2009c,d). A study by Dumont et al. (2005) in groups of grazing heifers showed that although most group members did initiate movements, one specific individual was particularly observed as the leader within different groups of individuals that shared the same characteristics (age, sex, origins).

However, all of these previous studies on domesticated ungulates were performed on one group, or were performed on several groups that had specific group compositions (e.g. only females). Given the different factors influencing leadership in bovines, it is important to study how group composition affects the probability that some individuals will become leaders. In this study, we aimed at studying collective decision-making and the emergence of leadership in several group compositions of semi-wild Highland cattle. This breed is particularly suitable for eco-pasture (management of lands using animals) due to its resistance to cold temperatures and its non-selective diet. Many French natural reserves and national parks have imported Highland cattle in order to maintain ecosystem biodiversity. The resulting number of cattle populations with different group compositions enables researchers to carry out a large study and attain a better understanding of the behaviours underlying the use of space and collective decision-making in the context of group movement. In this study, we specifically want to understand how socio-demographic traits of cattle (sex, age and dominance rank) influence the leadership as group compositions in previous studies conducted in impossibility to disentangle the effects of these traits. As for other bovines, we expected to find a distributed leadership with:

1.) Adult females initiating more movements than other individuals, and with a higher success rate (more followers to a movement);
2.) Dominant individuals initiating more movements than other individuals, with a higher success rate;
3.) Females initiating more movements and having a higher success rate;
4.) We also expected social relationships to have a strong influence on following behaviour;
5.) Intentional movements during the pre-departure period were also expected to influence the number of followers in a group movement.

2. Material & methods

2.1. Ethical note

This study was based on the observation of animals, and no handling or invasive experiments were involved. Our study was approved by our research institution (Institut Pluridisciplinaire Hubert Curien). It was carried out in full accordance with its ethical guidelines and complied with European animal welfare legislation. Every effort was made to ensure the welfare of the animals and minimize disturbance by researchers present in the field.

2.2. Observation sites and study subjects

We studied four groups of Highland cattle subject to composition