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The social network structure of a dynamic group of dairy cows: From individual to group level patterns

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ABSTRACT

Social relationships have been shown to significantly impact individual and group success in wild animal populations, but are largely ignored in farm animal management. There are substantial gaps in our knowledge of how farm animals respond to their social environment, which varies greatly between farms but is commonly unstable due to regrouping. Fundamental to addressing these gaps is an understanding of the social network structure resulting from the patterning of relationships between individuals in a group. Here, we investigated the social structure of a group of 110 lactating dairy cows during four one-month periods. Spatial proximity loggers collected data on associations between cows, allowing us to construct social networks. First we demonstrate that proximity loggers can be used to measure relationships between cows; proximity data was significantly positively correlated to affiliative interactions but had no relationship with agonistic interactions. We measured group-level patterns by testing for community structure, centralisation and repeatability of network structure over time. We explored individual-level patterns by measuring social differentiation (heterogeneity of social associations) and assortment of cows in the network by lactation number, breed, gregariousness and milk production. There was no evidence that cows were subdivided into social communities; individuals belonged to a single cluster and networks showed significant centralisation. Repeatability of the social network was low, which may have consequences for animal welfare. Individuals formed differentiated social relationships and there was evidence of positive assortment by traits; cows associated more with conspecifics of similar lactation number in all study periods. There was also positive assortment by breed, gregariousness and milk production in some study periods. There is growing interest in the farming industry in the impact of social factors on production and welfare; this study takes an important step towards understanding social dynamics.

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1. Introduction

In the UK dairy industry there is considerable diversity in the way animals are grouped and managed; group sizes and stocking density vary greatly across farms, and regrouping cows during lactation (based on yield or parity etc.) is common practice. Numerous studies have demonstrated the negative welfare and productivity consequences of regrouping, including reductions in milk yield, feed intake, rumination and lying times, and increased aggression between cows (Hasegawa et al., 1997; Hultgren and Svensson, 2009; Raussi et al., 2005; von Keyserlingk et al., 2008). Agonistic interactions such as threat gestures, chasing and head butting, often result in displacements from resources, but can escalate to prolonged (and more injurious) fights. The latter are less frequent in stable social groups (Reinhardt and Reinhardt, 1981) as a well-established dominance hierarchy shortens agonistic events or prevents them through active avoidance, profiting both dominant and subordinate animals (Gurney and Nisbet, 1979).

Within a stable social group many cows form preferential social bonds, which may differ between activities such as feeding or social grooming (Gygax et al., 2010; Reinhardt and Reinhardt, 1981). Preferred social partners can influence status in the social hierarchy (Reinhardt and Reinhardt, 1981) and their presence or absence can affect stress responses (McLennan, 2012). Social grooming can be used as an indicator of affiliative relationships among social

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animals (Boissy et al., 2007; Wasilewski, 2003), with the strength of social bonds often reflected by the degree of grooming between individuals. Social grooming is believed to have a calming effect on cows (Sato et al., 1991; Sato and Tarumizu, 1993), and plays a role in reducing social tension and maintaining social stability (Benham, 1984; Boissy et al., 2007; Sato et al., 1993). Interestingly, social grooming has been linked to production; it has been positively correlated with both milk yield and weight gain in past studies (Arave and Albright, 1981; Sato et al., 1991). The social preferences of cattle are also reflected in their spatial proximity to others in the group (Bouissou et al., 2001), thus the ability to maintain suitable inter-individual space is important to cows (Bøe and Færevik, 2003). In fact, Miller and Wood-Gush (1991) suggest the lower levels of agonistic behaviour exhibited by cows at pasture (compared to indoor-housed cows) is due to a greater opportunity to avoid others.

As the dairy industry becomes more aware of the impact the social environment can have on welfare and production, there is growing demand for information on optimal size, stocking density and composition of dairy cow management groups. In order to begin answering questions on the most effective social conditions for cattle, we first need to accurately measure and understand their social dynamics and group structure. Social network analysis (SNA) has been developed to quantitatively measure and analyse the structure of groups and patterns caused by dyadic social interactions (Croft et al., 2008). A network is made up of nodes (individuals; cows in this case) and edges (interactions; association time in this case). We can calculate statistics for individuals in the network such as 'degree' (number of edges for a given node) and 'betweenness centrality' (number of shortest paths between pairs of individuals that pass through a particular individual) (Krause et al., 2009). These methods allow us to study non-random patterns of association, and detect differences in group structure that may be linked to individual attributes (Croft et al., 2008). SNA is becoming more popular in the field of animal behaviour, however its potential for improving animal welfare in captive populations is currently underappreciated, with only a handful of empirical studies to date (e.g. rhesus macaques; McCowan et al. (2008), Atlantic salmon; Cañon Jones et al. (2010), pigtailed macaques; Flack et al. (2006), domestic chickens (Abeyesinghe et al., 2013)). Though few, these examples establish very promising applications of SNA in animal management and have been centred on reducing aggression and improving social cohesion. They suggest an important future role for SNA in animal welfare science (Koene and Ipema, 2014).

In this study, we quantified the social network structure of a group of lactating dairy cows, collecting association data using spatial proximity loggers. We corroborated this method by determining how well associations measured by the proximity loggers matched agonistic and affiliative interactions recorded during behavioural observations. We predicted that data collected by the proximity loggers would closely resemble affiliative interactions, but would not resemble agonistic interactions. Group-level structure was measured by testing for communities, betweenness centralisation, and assessing network stability over time. We investigated individual-level structure by determining whether individuals formed socially differentiated relationships, and by assessing the extent to which cows were assorted by attributes (lactation number, breed, gregariousness and milk production).

2. Methods

2.1. Animals and housing

The study was carried out on a commercial dairy farm in Devon, UK from November 2012 to June 2013, in the form of 4 one-month data collection periods (see Table 1). The farm comprises a 1045 m^2 (approx.) barn with straw yard housing and a voluntary milking system operating two Delaval robotic milking units. A total mixed ration was fed twice daily (approx. 9am and 5pm) at a feed barrier and additional concentrate feed was provided during milking and at an out-of-parlour feeder. At any given time the milking group contained between 106 and 113 lactating cows. Due to year-round calving, group structure was dynamic with cows entering and leaving depending on calving and drying off dates, in addition to sale or culling. The total number of unique cows present throughout the study was 134. The group was of mixed breed though the majority were Holstein-Friesian (see Table 1 for more details on cows included in the study). A charolais bull was added to the milking group on 07-05-13, and was therefore present within the fourth period of data collection only.

Although managed and housed as a single milking group, pasture access was regulated (via electronic collars) based on each cow's stage of lactation. Cows were restricted to the barn in the early part of their lactation, however after both testing positive for pregnancy and when milk yield dropped below a threshold of approximately 26 litres, they were also given free access to pasture. All cows were thus able to mix when inside the barn, but there were physical constraints to group synchrony when any cows with access chose to enter the pasture. As this affected some cows' ability to associate, we incorporated this management factor into all null models used in our analyses.

Individual attribute data (lactation number, breed, last calving date and milk yield) were downloaded from the on-farm computer system (Delpro). The number of days in milk (DIM) for each cow was determined as the number of days from the last calving date to the first day of each data collection period. We summed the daily milk yield over each data collection period for each individual.

2.2. Spatial proximity loggers

The proximity loggers used in this study were manufactured by Sirtrack Ltd (New Zealand), and are supplied as ready-made collars to attach around cows' necks (model E2C181C). These devices broadcast unique identification codes over an ultra-high frequency (UHF) channel while simultaneously searching for the ID codes of others within a pre-set distance range. Each logger is able to detect up to eight others simultaneously; recording its ID, the date, start and end time of the contact and its duration. The detection distance may be altered by users, by adjusting the power setting of a UHF coefficient range (0–62). The duration that any two loggers need be separated for an encounter to terminate ("separation time") can also be adjusted prior to deployment. Here, proximity loggers were set to a UHF value of 47 (which logged contacts at 1.5–2 m in pilot tests using collared horses) with a separation time of 120 s. Due to memory fill rate we deployed and removed loggers on four occasions so that data could be downloaded, hence we divided our analyses into four data collection periods (hereafter referred to as deployments 1–4).

2.2.1. Proximity logger data handling

Data collected by proximity loggers consisted of dyadic associations over time. We summed the duration of all associations between dyads within each deployment period and these values were used to construct social networks. As advised in previous studies (Drewe et al., 2012; Prange et al., 2006) we removed all 1-s contact records from the database prior to analysis, as these are considered unreliable, occurring sporadically when individuals are at the edge of the detection range (Drewe et al., 2012; Prange et al., 2006). Only loggers that functioned fully (both sending and receiving signals) for the whole deployment period were

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