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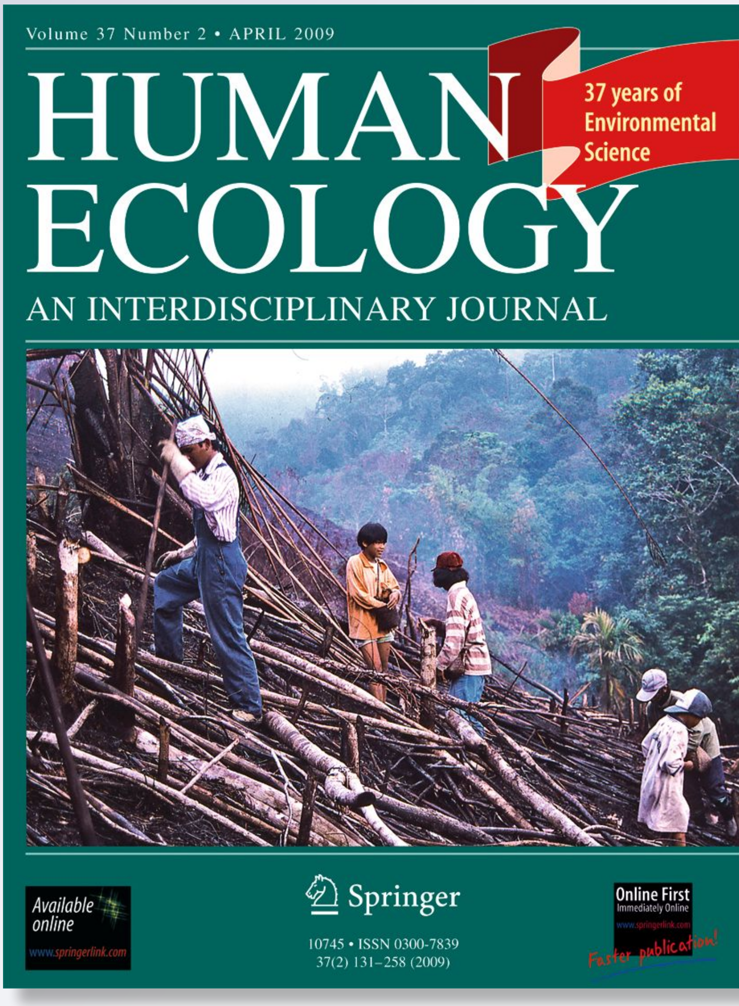

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Can One Animal Represent an Entire Herd? Modeling Pastoral Mobility Using GPS/GIS Technology

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New GPS/GIS technology allows researchers to examine old questions about mobility in pastoral system at multiple spatiotemporal scales, from daily herd movements to annual transhumance orbits (Adriansen and Nielsen 2005; Butt 2011; Butt *et al.* 2009; Coppolillo 2000; Gautier *et al.* 2005; Moritz *et al.* 2010; Sonneveld *et al.* 2009). This research has been conducted with the assumption that one animal is representative of the herd. The question is whether that is indeed the case since cattle herds may consist of animals of different sex, age, breeds, and reproductive status. Kiddy (1977), for example, found that when cows are in estrus they are much more active. There have been a few studies in which multiple animals in the same herd were tracked with GPS devices, but most have been conducted in livestock production systems in which animals roam free (without a herder) in enclosed pastures in the US and UK (e.g., Davis 2007; Stephen *et al.* 2010). Davis (2007) found that one animal could represent the behavior of the animals at the temporal scale of a day in terms of the percentage of time devoted to rest, grazing and travelling but that one animal was not representative of the location of the herd. However, these livestock systems are very different from those of mobile pastoralists in which animals are actively managed by a herder. Butt *et al.* (2009:320) tracked multiple animals within the same herd in a mobile pastoral system in East Africa and showed that the orbit of a single animal is representative of the daily grazing orbit of the entire herd.

Previously we have used GPS/GIS technology to examine grazing behavior and grazing pressure in a mobile pastoral system in the Logone floodplain of Cameroon and found that the speed of an animal is a reliable indicator of grazing behavior (Moritz *et al.* 2010). When the speed of an animal is above 2 km/h, it is no longer grazing and when it is below 1 km/h, it is grazing more intensively (see also Davis 2007:31). We assumed that the grazing behavior of one animal was representative of the entire herd. However, cattle herds consist of animals of different sex, age, breed, and reproductive status. In addition, the social relationships and spatial position of animals within the herd may result in variation in grazing patterns (see also Reinhardt 1982; Stephen *et al.* 2010).

Research of feral and free-ranging cattle has shown that they are intensely social animals that develop affinities for others in the herd and spend time with those preferred partners (Reinhardt and Reinhardt 1981; Bouissou *et al.* 2001). Positions of individuals in the herd have been shown to relate to matrilineal relations (Reinhardt 1982; Bouissou *et al.* 2001). However, in unfamiliar situations and in situations in which cattle are driven by herders, dominance, age, sex, level of habituation to the stimulus, and levels of biological need seem to play a larger role in herd position (Reinhardt 1982; Bouissou *et al.* 2001). For example, lactating cows tend to lead the herds at dusk when they return to the settlements where their calves remained during the day (see also Rathore 1982), while dominant animals tend to lead the group in an unfamiliar situation like entering a dip tank (Reinhardt 1982), but there seems to be some variation across different breeds of cattle (Bouissou *et al.* 2001). It is reasonable to assume that these biological differences and complex social interactions would result in different movement patterns for different individuals in the herd (see also Kondo 2011).

In interviews, mobile pastoralists in our study argued that there were no major differences in grazing behavior between animals of different sex, age, breed, reproductive status, or

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dominance, but they noted that there were differences in behavior related to an animal's habitual position in the herd. The cattle that are in front during movements, the *hooreeji* (from *hoore*, "head" in Fulfulde), were said to be always eager to move on to other pastures and have their heads and noses up in the air more frequently than the *baawooji* (from *baawo* "back") in the back (see also Reinhardt 1982). Pastoralists noted that the position in the herd is heritable and that there was no correlation between dominance and position in herd (see also Reinhardt 1982:259–261). Because pastoralists noted that there are behavioral differences between *hooreeji* and *baawooji* during daily movements, we used this criterion to examine whether there are significant differences in individual grazing behavior over the course of a day and whether one animal can represent the grazing patterns of the whole herd. To examine these questions we put multiple GPS tracking devices on different animals in two separate herds in two different locations in the Logone Floodplain in the Far North of Cameroon.

Study Area and Population

The Logone Floodplain, called Yaayre in Fulfulde, is flooded by the Logone River and its branches from September until November. After the water recedes in December, thousands of Arab and FulBe pastoralists from Cameroon, Nigeria and Niger move with more than 200,000 cattle into the floodplain making it one of the most important dry season grazing lands in the Chad Basin. Many remain there until the start of the rainy season in June, while others move south to the grazing lands that surround Lake Maga. Pastoralists find nutritious regrowth and surface water in the floodplain far into the dry season, when surrounding pastures have dried up. At the start of the rainy season, pastoralists return to the higher elevated dunes of the Diamaré or their respective countries.

The vegetation in the floodplain consists primarily of perennial grasses and is relatively homogenous in terms of forage quantity and quality because of the extreme flatness of the area resulting in only limited spatial variation in flooding depth and duration (Scholte 2007). There is a weak coupling between herbivore densities and vegetation as the predominantly perennial vegetation is controlled by flooding depth and duration and naturally protected against overgrazing because up to two-thirds of the biomass is stored underground. In addition above ground biomass is generally inaccessible to livestock during the flooding for 6 months of the year (Scholte 2007).

The population of mobile pastoralists who go on transhumance to our study area in the Logone Floodplain comprises approximately 1,000 households divided over about 130 camps and includes Suwa Arabs and FulBe, subdivided in Jamaare, Mare, Alijam, Adanko, and Anagamba. The different FulBe groups are endogamous and have their own dialect, cattle breed, houses, and marriage system. Our surveys show that about 30 % of the herds are under contract and owned by absentee owners, although the percentages vary by group (for example, 47 % for Alijam versus 12 % for Arabs).

Methodology

In this study we tracked seven animals in two herds for 1 day each during the hot dry season of 2011. We asked the herders to indicate which animals were *hooreeji*, *baawooji*, or *cakaaji*, (from *cakacaka* "in the middle") and put three GPS devices on *hooreeji*, two on *cakaaji*, and two on *baawooji* in each herd. Herders said there was little difference in behavior between *cakaaji* and *baawooji*. Unfortunately we lost tracks due to technical failure, and so we ended up with four tracks for an Arab herd in Ngelleehon and five tracks for a FulBe herd in Misde. We used the Garmin DC 20 in combination with the Garmin Astro 220 to track the daily herd movements of cattle. The DC 20 records geographic coordinates at 3-second intervals if the animal is moving. When the animal is not moving the GPS does not record spatial information until the animal is moving again or after 1 min (whichever comes first). The device also records distance, speed, true direction, and elevation. We downloaded the data via the Astro 220 into Garmin's MapSource software and exported the data to ArcGIS 9.3 from ESRI and GraphPad Instat (version 3.1 for Mac) for statistical analyses.

We created maps in ArcGIS to examine visually whether animals followed the same orbit (Figs. 1 and 2). This showed, for example, that animal #4 was not staying as closely to the other three animals in the Ngelleehon herd (see Fig. 1). The reason is that the animal is from another herd. When we conducted our study, two herds were taken to pasture by one herder because the other herder had a day off. We found this out only when we were following the herd and asked the herder about the distribution of the animals.

We calculated descriptive statistics for the two herds to examine whether there were any differences in speed and distance that animals covered during the day (Tables 1 and 2). We used a nonparametric ANOVA to determine whether there are any significant differences in average speed (and thus grazing behavior) between *hooreeji*, *cakaaji* and *baawooji* by comparing the animals' average speed for every five minute-period over the course of the day.

We also examined how much space animals in the herd occupy by calculating the maximum distance between the tracked animals at five-minute intervals (Table 4) and

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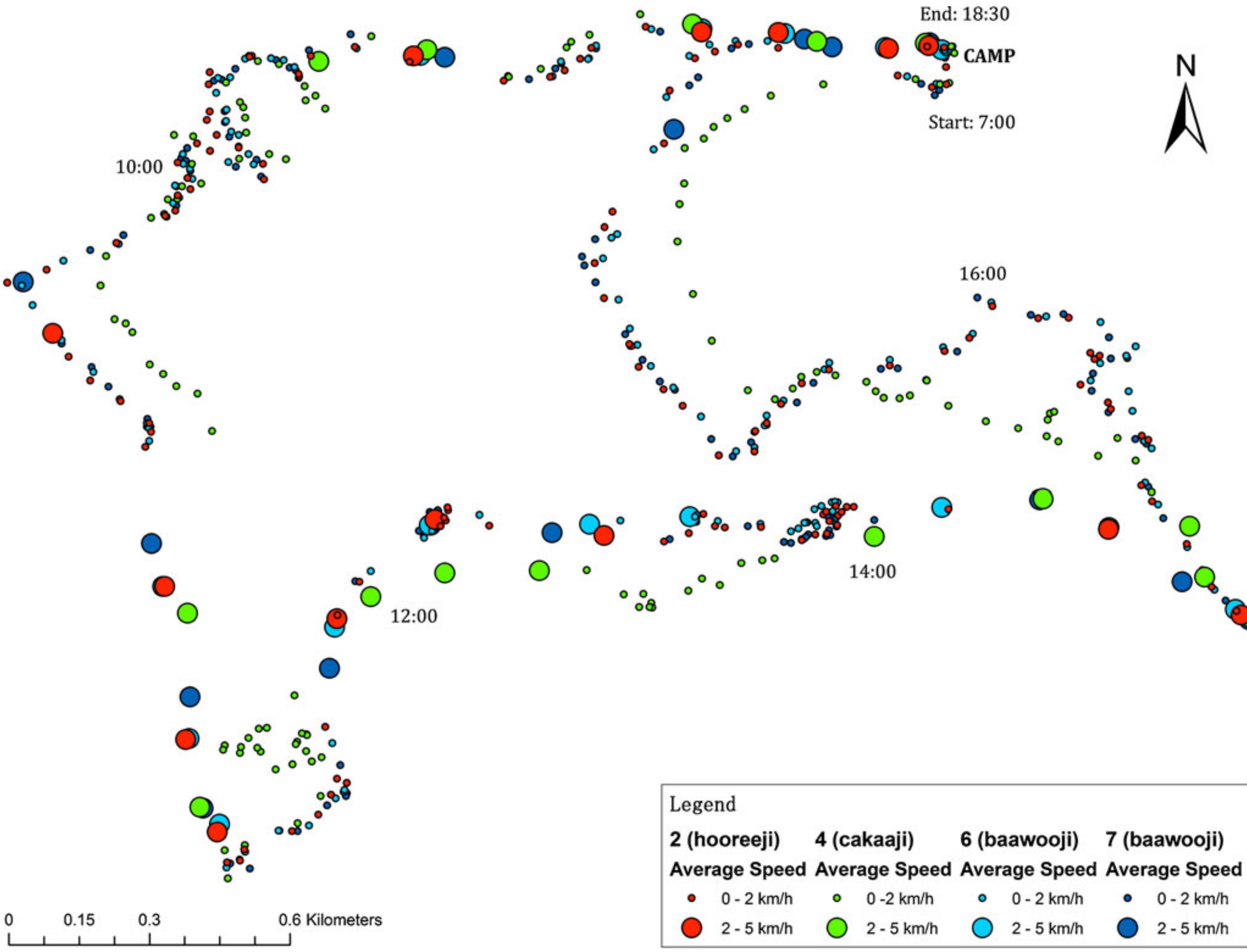

Fig. 1 Orbits and grazing speeds of individual animals in the Ngelleehon herd. Animal #4 (in green) is from another herd

how far the different animals were from the center of the herd (Table 1). Finally, we examined whether there is a correlation between the animals' speed and herd space using a multiple regression.

Results

The maps with the orbits of the two herds show that the animals are essentially following the same path, except for animal #4 in the Ngelleehon herd (Fig. 1) and that the animals in the Misde herd are particularly close to each other (Fig. 2). The figures also show, with few exceptions, the animals seem to be moving at similar speeds over the course of the day.

The descriptive statistics for the two herds show that there is relatively little difference between the average speed of the animals and the percentage of time that the animals are grazing in the two herds (Table 1 and 2). The nonparametric ANOVA we conducted of animals' speed confirms that there are no significant differences between the different animals (*hooreeji*, *cakaaji* and *baawooji*) within the Misde (Kruskal-Wallis Statistics KW=2.785, P value 0.5943) and Ngelleehon herds (Kruskal-Wallis Statistics KW=0.06119, P value 0.9699).

However, the small differences in speed cumulatively result in larger differences in terms of total distance traveled per day for individual animals. For example, in the Misde herd, animal #1 (*hooreeji*) traveled more than 1,200 m more (8 % of the total distance) over the course of a day than animal #5 (*cakaaji*)(Table 2). In the Ngelleehon herd we find only a difference of 230 m (and the difference between animal #4 and the other animals is only 600 m or about 5 % of the total distance)(Table 1). However, overall there are no clear differences in speed, grazing behavior, and distance covered between *hooreeji* and *baawooji*.

The inclusion of animal #4 in the Ngelleehon herd resulted from miscommunication between the herder and us. However, the advantage is that the results underscore that herds are relatively tight social and spatial units and that

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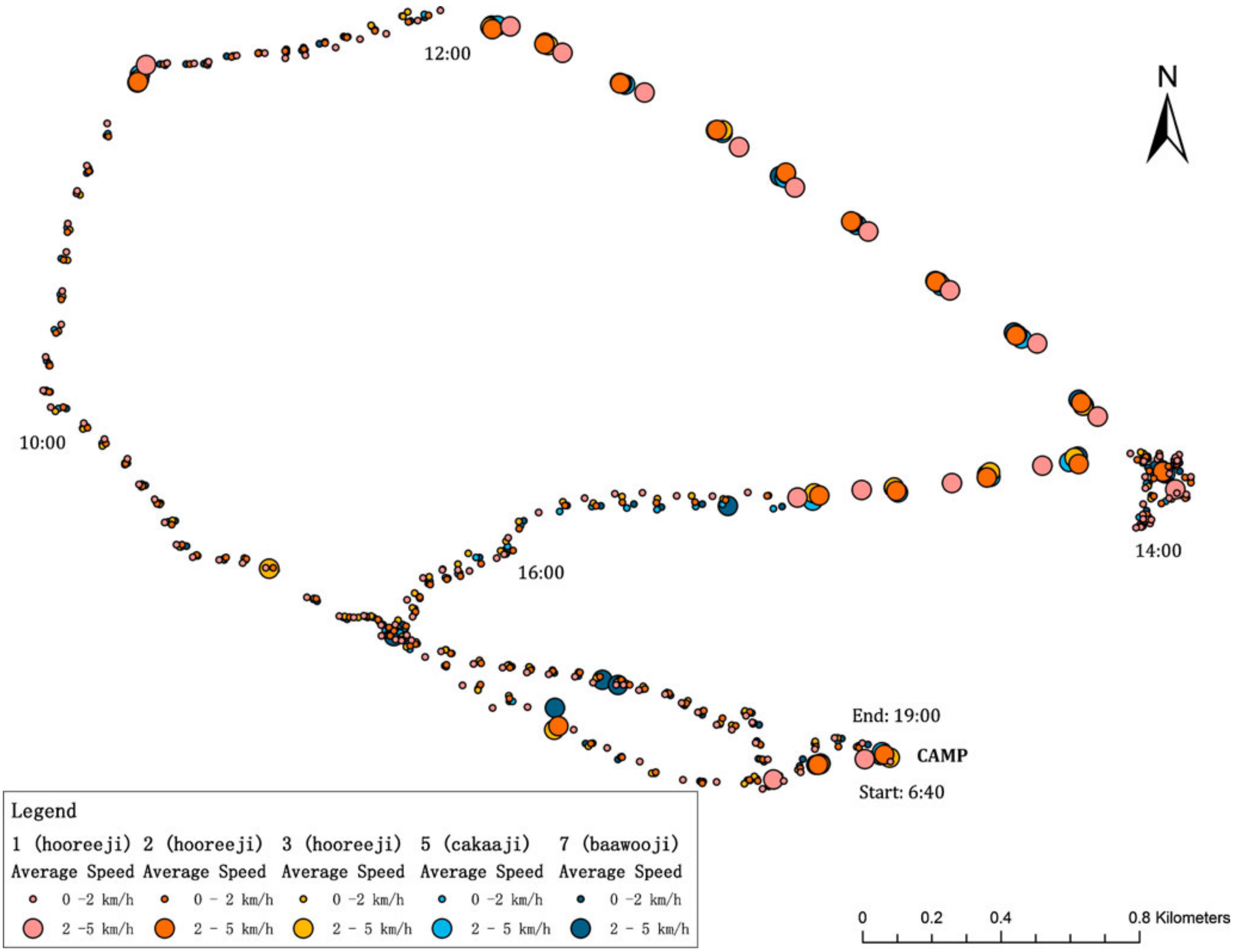

Fig. 2 Orbits and grazing speeds of individual animals in the Misde herd

this is not simply the result of the herder's management of the herd, but also because strong social bonds have developed between animals (Bouissou *et al.* 2001; Krätli and Schareika 2010; Reinhardt and Reinhardt 1981). When we include animal #4 in the Ngelleehon herd we find that there are significant differences in speeds between the animals (Kruskal-Wallis Statistic KW=14.527, with a P value of 0.0023) in which only the paired comparisons with animal #4 show significant differences. It is clear that animal #4 walks to the beat of a different herd even though the two herds were managed by the same herder that particular day.

Table 1 Descriptive statistics for animals in Ngelleehon herd

	Min speed (km/h)	Max speed (km/h)	Average speed (km/h)	0–2 (km/h) (grazing)	2> (km/h) (no grazing)	Total distance (km)	Total time (h:m)	Average distance from herd center (meters)
2 (Front)	0.10	4.69	1.03	90 %	10 %	11.86	11.30	24.7
4 (Middle)[1]	0.18	5.14	1.07	90 %	10 %	12.29	11.30	NA
6 (Back)	0.12	4.72	1.02	89 %	11 %	11.69	11.30	20.6
7 (Back)	0.06	4.61	1.05	88 %	12 %	12.09	11.30	24.0
Herd average	0.12	4.79	1.04	89 %	11 %	11.98		23.1

[1] Animal #4 is from another herd

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Table 2 Descriptive statistics for animals in Misde herd

	Min speed (km/h)	Max speed (km/h)	Average speed (km/h)	0–2 (km/h) (grazing)	2> (km/h) (no grazing)	Total distance (km)	Total time (h:m.)	Average distance from herd center (meters)
1 (Front)	0.12	3.95	1.30	88 %	12 %	14.82	11.20	21.3
2 (Front)	0.07	3.76	1.22	87 %	13 %	13.78	11.20	16.5
3 (Front)	0.05	3.97	1.24	86 %	14 %	14.08	11.20	16.8
5 (Middle)	0.05	3.83	1.20	88 %	12 %	13.62	11.20	14.5
7 (Back)	0.07	4.61	1.26	84 %	16 %	14.26	11.20	15.5
Herd average	0.07	4.02	1.24	87 %	13 %	14.12		16.9

The spatial organization of the animals in the herd was examined by looking at the amount of space the herd occupies at one time. To do this we calculated the maximum distance between the tracked animals at five-minute intervals (Table 3) as well as the distance of each animal from the center of the herd (calculated as the centroid of the locations of all observed animals) (Table 1). The average distance between animals was about 51 m for the Ngelleehon herd and 42 m for the Misde herd. Butt *et al.* (2009:320) found that the animals in Maasai herds were within a standard deviation of 30 m from each other, which they argue is the average width of medium-sized herds in mobile pastoral systems. Our findings show herds in our study occupy more space as well as that there is considerably more variation in herd space over the course of the day, for example from a minimum distance of 5 m to a maximum of 250 m in the Ngelleehon herd (Figs. 3 and 4).

Finally, we examined whether there was a correlation between the average speed of the animals in the herd and herd space. When herds are moving at higher speeds, e.g., when moving to the watering place or returning to the corral, we observed that they occupy less area then when they are slowly grazing and each animal moves at its own pace. However, we found the opposite to be true when we conducted a multiple regression of average speed and distance at five-minute intervals; herds occupy more space when moving at higher speeds (Table 4).

Table 3 Herd space for the Ngelleehon and Misde herds

	Minimum	Maximum	Mean	SD	N
Ngelleehon	5.4 m	252.3 m	51.3 m	37.0 m	136
Misde	8.0 m	202.9 m	42.4 m	28.7 m	136

Herd space is measured as the maximum distance between the animals that we tracked. We did not include animal #4 in the analysis of the Ngelleehon herd

Discussion

When we compared animal movements we did not find any statistically significant differences in speed between animals that are in the front of the herd (*hooreeji*) and those in the middle and back of the herd (*cakaaji* and *baawooji*) despite observations from pastoralists and researchers (Reinhardt 1982; Sato 1982) that there are behavioral differences between these animals. Our analysis shows that the movements, speed, and grazing behavior of one animal are indeed representative of an entire herd in pastoral systems in the Far North Region of Cameroon.

The main limitation of our study is the sample size: two herds in the dry season in the Logone Floodplain. However, we do not think this threatens the validity of our findings. Our observations of other herds in the floodplain indicate that the movements of these two herds are representative of herding in the dry season (Moritz *et al.* 2010). Moreover, we expect even less variation in grazing behavior and herd space in the rainy season when pastoralists are in the forested savanna and herders keep their animals close because of limited visibility. In the floodplain, on the other hand, herders can see for miles, as there are practically no trees, and herds roam more freely over more space.

The foremost goal of our study was to examine whether one animal can represent the grazing behavior of the entire herd in pastoral systems; however, our study has also implications for our understanding of herding in pastoral systems. Our findings show that the daily movements result both from the herder's management as well as the social dynamics of the animals in the herd.

First, one of the main reasons why one animal is representative of the herd is herders' active management. The herders decide—to some extent together with the animals in the herd—when and where the cattle will eat, move, and water (see also Dwyer and Istomin 2008). This sets pastoralists' herds apart from wild herbivores as well as cattle roaming free in enclosed pastures. The role of the herder and the importance of herding, *ngaynaaka* in Fulfulde

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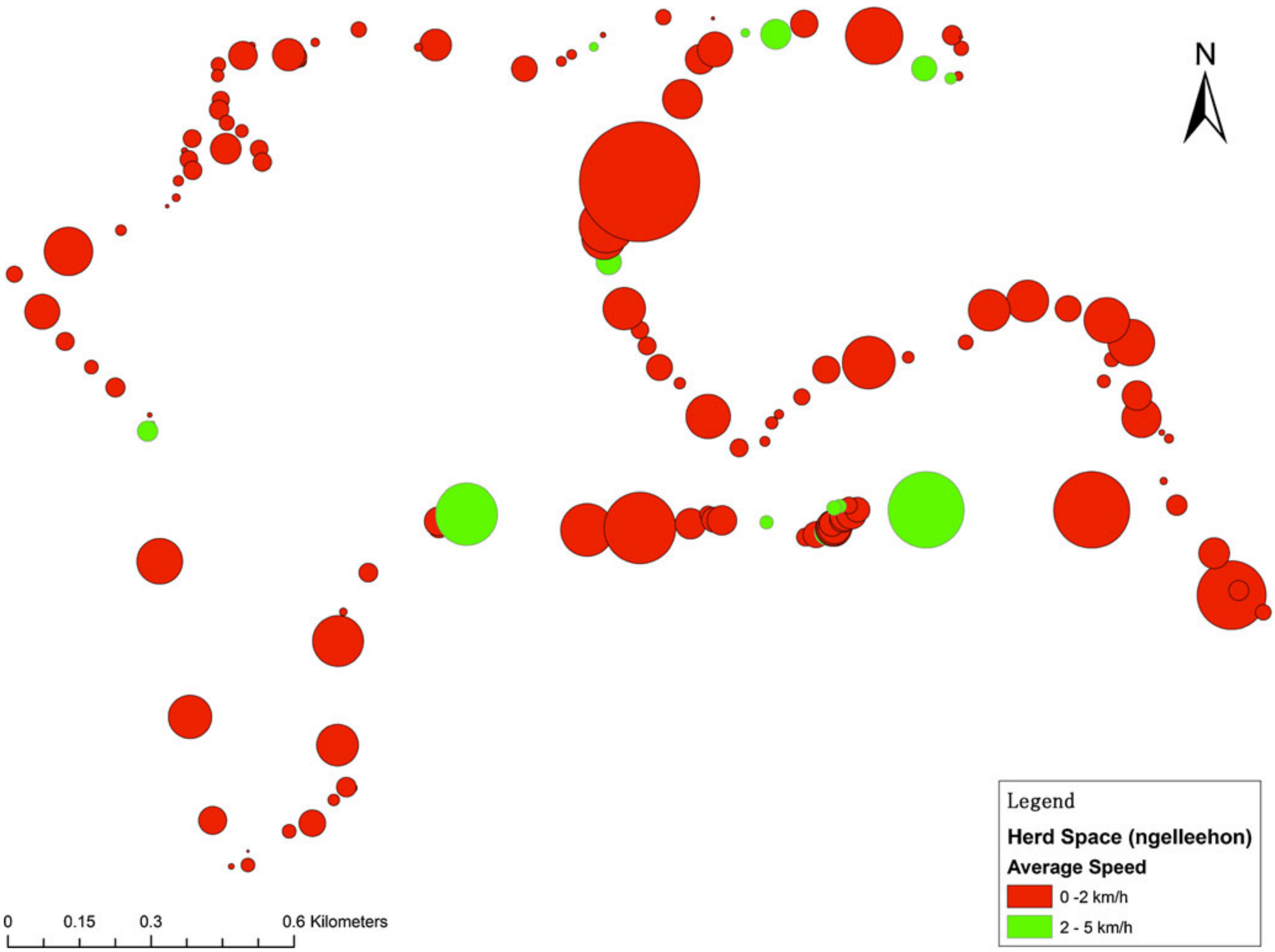

Fig. 3 Herd space and average speed of the Ngelleehon herd. The diameter of the circles is the distance between the tracked animals that were farthest away from each other. This figure does not include animal #4, which was from another herd

(Bonfiglioli 1981), is highlighted by the fact that compared to cattle roaming free in enclosed pastures in temperate climates, cattle in pastoral systems spend much more time grazing and travelling (to forage resources). Davis (2007) found that the Iowa cattle in his study spent 58.7 %, 40.4 % and 0.9 % respectively resting, grazing, and travelling during eight-hour observation periods, while for cattle in our study the percentages were 0 %, 88 %, and 12 % respectively. The high percentage of time devoted to grazing shows that herders are actively managing the herd to ensure that the animals have access to high quality forage in an environment where grazing resources are more limited (compared to Iowa). Herding (*ngaynaaka*) is labor-intensive practice that requires great skill and expertise and that allows pastoralists to efficiently exploit the spatiotemporal heterogeneity in grazing resources in arid and semi-arid grazing systems (see also Krätli and Schareika 2010).

The second reason why one animal is representative of the herd is the social behavior of cattle. The social dynamics among animals in the herd are complex and shape their daily movement (Reinhardt 1982; Sato 1982), which was revealed by the accidental inclusion of animal #4 in the Ngelleehon herd. The animals in the herd form a tight social community with strong bonds based on kinship and friendships, a gendered hierarchy with dominant males and females, and leadership roles, for example, the *hooreeji* leading the herd to pastures (see Bouissou *et al.* 2001; Krätli and Schareika 2010; Reinhardt 1982; Reinhardt and Reinhardt 1981). Pastoralists expertly exploit these social dynamics and are able to control the herds with calls to specific animals and occasional threats to others (see also Krätli and Schareika 2010; Lott and Hart 1977).

One of the herds in this study was under contract and managed by a hired herder and while hired herding has been associated with unsustainable management practices in the literature (for a review see Moritz *et al.* 2011), we did not find significant differences in movements and grazing behavior between the two herds. Mobile pastoralists

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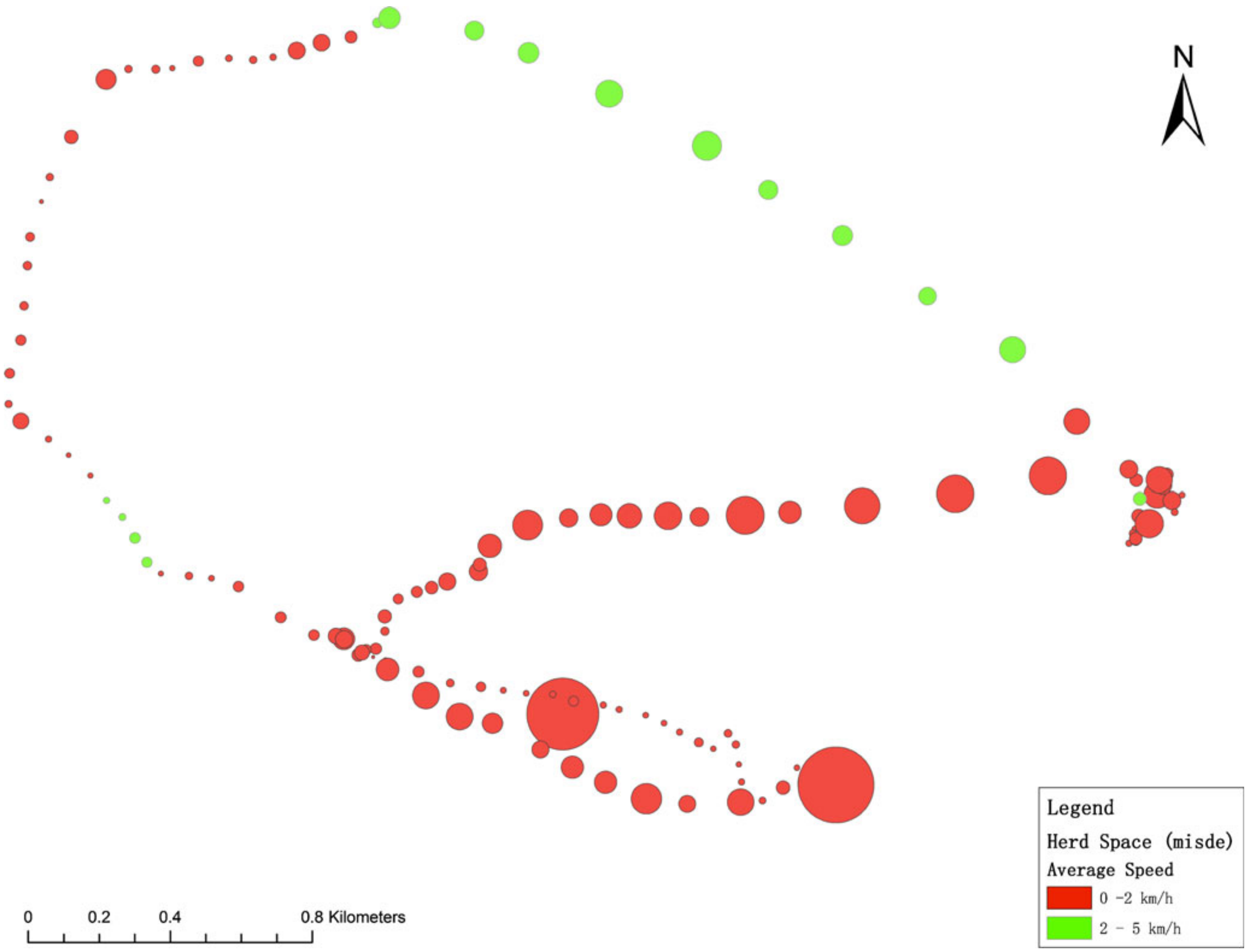

Fig. 4 Herd space and average speed of the Misde herd. The diameter of the circles is the distance between the tracked animals that were farthest away from each other

unanimously agreed that hired herders are as committed to herding excellence (*ngaynaaka*) as independent herders; knowing whether someone is a hired herder does not tell you anything about the care for and condition of the animals (Moritz *et al.* 2011:281). Moreover, even had we found differences, they would not necessarily be due to herder management. The differences in grazing behavior could also have been due to the social behavior of cattle as herds under contract consist often of animals from different sources that may not yet have formed a cohesive social group.

Our study shows that despite the complexities of the interplay between herders' management and cattle's social behavior tracking one animal with GPS is a valid method to study movements and grazing behavior of an entire cattle herd in mobile pastoral systems.

Table 4 Multiple regression of speed and herd space in Ngelleehon and Misde herds

	R squared	*P* value	Herd space 1 km/h	Herd space 2 km/h	Equation
Ngelleehon	28.63 %	<0.0001	51 m	66 m	DISTANCE = 34.889 + 15.802*SPEED
Misde	29.09 %	<0.0001	37 m	57 m	DISTANCE = 17.465 + 19.959*SPEED

The table shows that higher the speed of the animals, the greater space they occupy. When animals are moving slower than 1 km/h they are grazing intensively and when they are moving faster than 2 km/h they are no longer grazing

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