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ORIGINAL ARTICLE

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Changes in unit structures and infanticide observed in Arsi geladas

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Abstract In 1989 a new gelada baboon (*Theropithecus gelada*) population was found in Arsi, on the opposite side of the Rift Valley to that of the known gelada populations of Semien and Showa. Previous comparisons of units of the band at Gado Goro, Arsi, in the same season in consecutive years, indicated that unit structure is less stable among Arsi geladas as compared to the Semien population. Gelada units of the band at Gado-Goro were studied for 7 months in order to investigate the processes of social changes. Changes in unit structure were observed. Provisioning was carried out for 1.5 months at the beginning of the 7-month study period, in order to capture and obtain blood samples from the geladas. Following this, changes in male leadership of some units were observed, presumably as a consequence of the capture. However, natural changes also occurred. One change in unit structure occurred after a female gave birth, and changes in another unit occurred after the disappearance of the leader male. These changes involved female desertion of a unit, her subsequent transfer to a male unit, and culminated in the formation of a unit consisting of one female and one male. One successful and one attempted case of unification of units, and one case of change of a unit leader male are reported. These changes occurred among eight resident units in a period of 7 months (196 female months). Though the types of social changes were not much different from previous observations in Semien National Park, their frequencies seemed to be much higher. The characteristics of Arsi gelada social changes are proposed to be related to the small size of the units. We also describe a new confirmed case and one suspected case of infanticide, as well as one case of abortion at the time of male leader change.

Keywords Abortion · Gelada baboons · Herding · Infanticide · Social change

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Introduction

A new population of gelada baboons (*Theropithecus gelada*) was found in Arsi in 1989 on the opposite side of Rift Valley to the well studied gelada populations of Semien and Showa, Ethiopia (Crook 1966; Dunbar and Dunbar 1975; Kawai 1979; Mori and Belay 1990). This population is estimated to have separated from other northern populations about 350,000 years ago (Belay and Shotake 1998), and are living at much lower altitudes than the Semien population.

Though gelada unit structure was found to be stable in Semien (Dunbar 1979; Mori 1978, 1979; Ohsawa 1979), we discovered that the unit structure of Arsi geladas was unstable, by comparing unit compositions of the Gado-Goro band in three separate surveys (Mori et al. 1999). It was necessary, however, to observe the processes of social change over a longer term study. To this end, we conducted a 7-month study from November 1995 to May 1996. We reported previously that the unit size was small in Arsi geladas (Mori et al. 1999). We hypothesized that this is a result of sub-division of the units by males who were originally accepted in the unit for defense against leopards. However, another process of formation of small units was found, and characteristics of small units in relation to social changes are discussed.

Methods

Study at Gado-Goro village

The main study site was at Gado-Goro village situated along the Robe river in Arsi. The study was conducted over 143 observation days from 3 November 1995 to 16 May 1996 (196 days) with intermittent absence from the site. The study is divided into four periods: Nov + Dec, 40 days (3–15 November 1995, 21 November–6 December 1995, and 8–18 December 1995); Jan + Feb, 45 days (10–21 January 1996, 27 January–28 February 1996); Mar, 30 days (12 March–10 April 1996); and Apr + May, 24 days (23 April–16 May 1996).

The cliff observed was W-shaped (Fig. 1) and the way the area was named and the name and composition of each unit follows a former study (Mori et al. 1999). The composition of each unit is listed in Table 1. We observed the NN and NS areas continuously using telescopes. Observation of SN and SS was conducted once every 1 or 2 h, by 5-min scans by telescope. Nonresident units were observed only when they visited the above area. A more detailed methodology is given in a previous report (Mori et al. 1999).

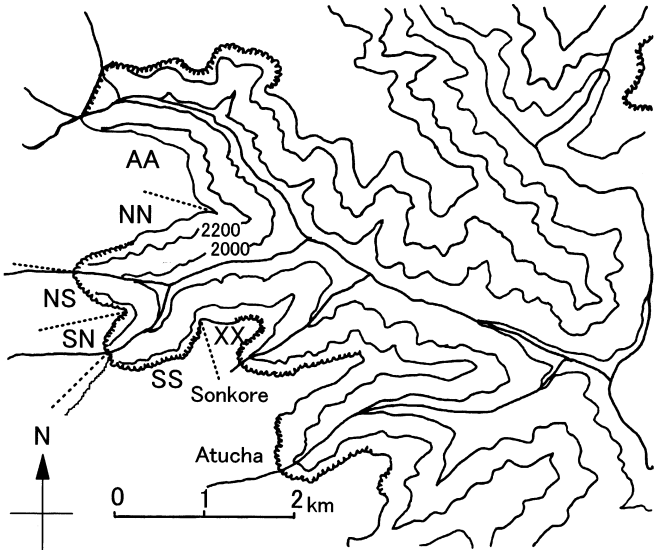

Fig. 1 Map of the study area

Study at other sites along the Robe river

G. BELAY habituated three gelada units and one male group at Robe-Ademtu, and two units at Robe-Temama (see Fig. 2 in Belay and Shotake 1998). He provisioned geladas from November 1995 to 19 January 1996, in order to capture them to take blood samples, at Robe-Ademtu, 3 km north east of Gado-Goro village, (9 km along the cliff edge). Then he shifted to Robe-Temama, 6 km north of Gado-Goro village, (21 km along the cliff edge) to take blood samples from 2 to 28 February 1996.

Results

Factors affecting social changes

Two factors affected the social changes that occurred during the study period:(1) the effect of capture and release, and (2) the seasonal change of moving ranges of units.

The effect of capture and release

Provisioning was conducted from 10 to 15 November 1995, and from 22 November to 18 December 1995. On 18 December, geladas were captured in a large trap and blood samples were taken. The units present at the site when trapping occurred were the male group, (= C5), and two one-male units, C6 and C10. The 20 captured animals included most members of C5 except for two – three adult males, one –two adult C6 males, one C6 female with a black infant, and the leader male of C10.

Two adult males among the captured were clearly identified by external characteristics; the leader of C10, Kiba, and the 2nd male, Kunchikire, of C6. As the second male of C6 was in the trap, we think it highly likely that the leader male of C6 was also captured.

Seasonal change of moving ranges of units

After crop harvesting on the plain ended in the middle of January, geladas were less frequently chased away by

Table 1 Age-sex composition of each unit of gelada baboons (*Theropithecus gelada*) at Gado Goroin January 1996

Units	M	F	I	J(1)	J(2)	J(3)	J(4)	Pub	Ad	Sub-M	Total
C1	1	3		3	1						8
C2	1	1									2
C3	1	4		3							8
C4	1	3		1							5
C5	2	1		2	2	1		4	2	1	15
C6	3	3	1			1					8
C7	1	5	1		3						10
C8	1	6	1	3		1					12
C9	1	3		1	2						7
C10	1	2		1							4
C11	1					4		5	1		11
C12	1	3				1		1			6
C13	1	3	2								6
C14	1	3	1	1	2						8
Sum of C1-C10	13	31	3	14	8	3	0	4	2	1	79
	Within unit AD♀/AD♂ 2.21			Whole AD♀/AD♂ 2.21			J = Inf∼J(3) J/AD♀ 0.9			J = Inf∼J(4) J/AD♀ 0.9	

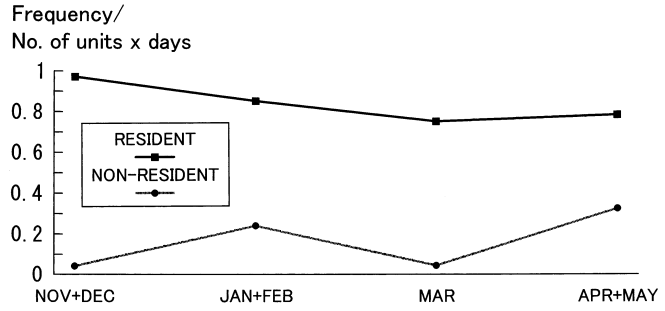

Fig. 2 Frequency of resident and non-resident gelada baboon (*Theropithecus gelada*) units observed inside the Gaodo Goro area. Ratio of staying in Gado Goro area by gelada units (resident or non-resident) was calculated as: total observed days of all (resident or non-resident) units in Gado Goro area / (the observation days) x [number of (resident or non-resident) units]}

farmers. At the same time the dry season continued and drinking water for geladas became more scarce. Geladas tended to go far into the plain away from the cliff edge, and units tended to go beyond their normal moving range in November and December. The area from NN to SS is considered to be the moving range of the Gado-Goro band (Mori et al. 1999), and units that always stayed in this area are regarded as resident. Units were divided into resident units (C3, C4, C5, C6, C7, C8, C9, C10) and nonresident units (C1, C2, C11, C12, C13, C14) (Mori et al. 1999). Among the resident units, only the male group (C5) crossed from NN to AA in November and December. Seasonal change in unit movement was evaluated to determine how frequently resident units moved outside of NN-SS, and how frequently nonresident units moved inside this area (Fig. 2). Over the periods Nov + Dec and Mar, nonresident units came into NN-SS, less frequently, but their visits increased in the periods Jan + Feb, Apr + May. Resident units gradually increased their movements away from the area over the study period. As movements outside of the normal range by unit males or the unit increases, the chance for social change is also expected to increase.

Social changes

As nonresident units visited observation areas intermittently and for rather short durations (typically a few days), we could not identify detailed social changes among them. The following observations are concerned only with resident units, C3–C10.

Effect of capture

C10 This unit was originally composed of 1xM + 2xF + 1xJ(0–1); where M (adult male), F(adult female), J(0–1)(juvenile of 0 to 1-year old). The leader male of this unit had a clear external identifying characteristic, i.e. the left lower canine was always showing, and he was named Kiba. He was identified when captured on 18 December. We left the study site with the blood samples the day after the capture and when observation resumed on 29 December, we found two adult males in the unit. The former leader male, Kiba, had by that time become the second male of the unit. This situation continued up to 17 January, when the unit was observed to have only the alpha adult male; Kiba was not seen again. The juvenile was observed up to 13 January, but had disappeared by 15 January. The number of females did not change during the study period.

C6 This unit had two adult males at the start of the study period. The second male, Kuchikire, had been the former leader, but had become the second male because of injuries inflicted by a leopard (Mori et al. 1997). Kuchikire was captured on December 18, 1995, together with a female with a black infant who was one of the three adult females of the unit. In all probability, the leader male was also captured. On the first observation day after the capture, 29 December, we noted that the unit had three adult males. This situation continued until 15 January 1996. The black infant of C6 disappeared between 12 and 15 January. The mother had got injuries from her middle finger to the palm of her left hand and on the palm of the right hand, and another female also had an injury on the outer side of the left ankle. These injuries did not appear to be consistent with injuries inflicted by a leopard, Verreaux's eagle or other predator. However, they did closely resemble injuries in another case (described below) where one of us (B. Belay) actually witnessed a male gelada attack and kill an infant in the Robe-Temana group.

The number of adult males increased to four only between 17 and 19 January. During this time, adult females were made very anxious by any movement of the adult males, and the leader male repeatedly chased a male that frequently approached his group. As we could not identify the former leader male, it is difficult to say whether the leader change took place. However, we presume that it occurred on the day of capture, as another male joined as the effect of the capture. Then the level of conflict among males increased after the incident of infanticide, which led to the presence of one more adult male. The number of adult males stayed at three from 20 January to 18 February, and then one adult male disappeared, leaving Kuchikire as the second male of the unit. A solitary male who appeared between 15 and 25 March, tried to approach C6, and behaved in a friendly manner with Kuchikire. We presume that this male was the former unit leader.

Birth of a new infant

C3 This unit consisted of 1xM + 2xF + 1xYF + 1xJ (0–1) at the start of the study period, where YF stands for a young adult female. One adult female with a J(0–1) tended to separate herself from the other two females. In one extreme case the two parties were separated by

500 m for 3 h. The leader male did not show herding behavior, but placed himself between the two parties, and associated preferentially with the female with J(0–1). On 16 February 1996, the female who associated with the young adult female gave birth to an infant. The adult male subsequently started to follow the female with the new infant. On 23 February, 1 week after the birth of the infant, the female with the J(0–1) disappeared leaving C3 group composition at1xM + 1xF + 1xYF + 1xInfant. A female with a J(0–1) was found with the male group (C5) on 12 March 1996, and we supposed this female and J(0–1) were those from C3. We observed two adult females from 12 to 24 March in the all male group. After that we could not confirm the presence of two adult females at the same time in the male group, partly because this group always separated into two parties (see below). On 3 April, an adult male and one adult female were spotted together and the leader male of C3 repeatedly attacked this male. As the only other couple found in this area was C1 which never approached other units, we concluded that the couple that had this interaction with C3 was a newly formed unit involving the former female of C3.

Chain reaction 1

Gado-Goro male group (C5) This group had many adult males and one adult female, and shared characteristics with both all male groups and one male units. The number of adult males and juveniles was always changing in this unit (Table 2), with a mean group size of 16 (range 12–21), and it seemed to serve as a buffer group where adult males and juveniles could join freely. There was, however, a core membership; i.e. one identified male, Tosaka, with a characteristic feature of crown hair, one adult female, and juveniles. This core membership was stable since the former study period, February 1995. Whereas core members always moved together, some adult and subadult males separated from the group from time to time.

After 19 March 1996, the members of this unit frequently separated into two parties, one of the core members, and the other of adult and subadult males together with older adolescent males. The timing of this separation occurred 1 week after 12 March arrival of the adult female from C3. As the relationship between Tosaka and the other female was stable, this split must have been triggered by the immigrant female. Since a new couple emerged on 3 April, we suppose that the immigrant female had been herded by one male of the male group, thereby forming a new couple. Though we could not confirm the presence of two adult females at the same time in the male group after 24 March4, we suppose the immigrant female must have been in one of the branch parties of this group until 3 April. On 31 March, C3 and the male group (C5) left NN and went to AA (out of the observed area), but two subadult males and one older adolescent male remained on NN. On 3 April, when the core member of the male group, Tosaka and one female with juveniles returned to NN, they were associating with C3. The previously mentioned new couple also came back together. This combination of units suggests that they associated because of the immigrant female from C3. Any conflict over the female should have ended when she was taken by the male to form a new couple. The two subadult males and an older adolescent male lost the competition over her, and separated. After their separation from the male group, they were constantly chased by unit males, and maintained a long distance between them and the units.

The number of adult males in the middle of March was always five, but by 4 April one adult male was missing.

On 3 April, the core members of C5 and C3 spent the night together. The only female of C5 and the females of C3 interacted, exhibiting both antagonistic and grooming behaviors. On 5 April, the core members, Tosaka + 1xF + 1xJ(0) + 1xJ(1) + 2xJ(2) + 2xJ(3), spent the night with C3, while other C5 juveniles separated from them at night. Tosaka and the leader male of C3 fought on the evening of 6 April and the juveniles of C5 separated from the core members and C3, and moved instead with C7. On 8 April, the core members of C5 decreased to four, Tosaka + 1xF + 1xJ(0–1) + 1xJ(1), and moved together with C3. Tosaka became the second male of the integrated C3 and C5-units. C5 juveniles mainly associated with C7, but they sometimes associated with Tosaka, or C6. Thus, the male group of Gado-Goro dissolved, and the composition of the integrated C3 and C5 units became 2xM + 2xF + 1xYF + 1xJ(0–1) + 1xInfant. This new unit remained stable to the end of the study period.

Table 2 Fluctuation of membership of the male group (C5). Number of adult and sub-adult males

Month	Number of observation days	Number of adult and sub-adult males						Males/day
		1	2	3	4	5	6	
Nov 1995	11	0	3	1	1	4	2	4.1
Dec 1995	7	1	2	0	2	2	0	3.3
Jan 1996	6	0	2	1	0	2	1	3.8
Feb 1996	11	0	0	1	2	4	4	5.0
Mar 1996	10	0	1	0	2	7	0	4.5

Disappearance of a leader male and abortion

C9 The distal half of the tail of the leader male, Shippokire, of this unit was noticed to have dropped off in November 1995, so this unit could be identified very easily. Though this unit was resident of SN–SS, it was also found in the southern area, of XX, around Sonkore and Atucha (Fig. 1). We observed C9 up to 10 April, but we were away from the study area between 11 and 22 April. On 23 April we could not find the leader male, Shippokire, but did find a unit with the same age-sex composition as C9 at SN. On 24 April, many units of Atucha band came from the southern area to our study site but we still could not find Shippokire. A unit of same age-sex composition as C9, however, was still present. This unit remained in SS after Atucha band had gone back south on 25 April. As this unit was tolerant of observers, we concluded that the leader male of C9 had changed. One of the females carried a bundle, which proved to be a dead infant. The dead body was covered with black hair, and was small and thin. The corpse was fresh, being still soft, and we believed that a late stage fetus had aborted. The female did not carry the dead body the next day. The new leader male proved to be Kiba, the former leader male of C10 who lost his status because of the capture. Shippokire appeared to have been ill before his disappearance, so we surmise that he may have died.

As C9 and C10 units had always moved together on SS, it seemed plausible that the former leader of C10 had become the new leader of C9.

Chain reaction 2

Rearrangement of C9 and C10 units Between 10 and 16 May, many units of Atucha band came from the south to stay in the study area. C10 and C9 units stayed and moved together on the cliff face of SN, and did not associate with other units on the plain. This phenomenon was first noticed on 13 May. Females of C10 tried to follow Kiba, the leader male of C9. Kiba the former leader male of C10, and these females still seemed attracted to him.

On 15 May, when C9 and C10 units moved together, three females of C9 were observed to aggressively encounter two females of C10 on the cliff face. On this day, the male of C10, Stepm, tried to approach the females of C9. Both Kiba and the larger Stepm sat near the C9 females. Stepm was groomed by a female of C9, while Kiba sat 2 m away from the grooming pair. On 16 May, Stepm moved together with females of C9, and conducted control attacks on females who approached Kiba. Stepm attacked and bit Kiba, causing bleeding under the nose. Kiba consequently became the second male of C9. Females of C10 sat 15 m apart from C9, but the two males sat closer to C9.

As our observations terminated on 16 May, we do not know if the integration of these two units continued.

Infanticide observed at another area in Arsi

We have reported previously that infanticide occurs among Arsi geladas (Mori et al. 1997). A second clear case of infanticide was observed at Robe-Temama, but it occurred under provisioning.

G. Belay started provisioning at Temama on 2 February 1996 and at that time the unit lacked an adult male (3xF + 1xJ(3) + 1xJ(2) + 1xJ(1) + 2xBrown Infant). This unit was without an adult male for 8 days until an adult male joined the unit on 10 February. Two days later, on 12 February, infanticide occurred. During afternoon session of provisioning at around 1700 hours, G.Belay heard loud defensive vocalizations from the females, and he saw the leader male pulling an infant from the back of a female. The male grabbed the neck of the infant, and took it from its mother. The mother sat facing the male who held the infant, and the other females and juveniles sat surrounding the male. The mother grasped both shoulders of the male with both hands, and bit his cheek while the females and juveniles pushed at the male with their hands. The male retreated down the cliff. It was difficult to clearly observe the infant, because the other geladas were constantly in the way. At 0830 hours next morning, the mother carried the dead infant.

On 14 February, A. Mori observed the corpse and the mother. The body of the infant had been bitten in three areas. The injury to the left side of the breast was most serious, being 10-cm long, and a few ribs could be seen from outside. The mother also had injuries, one was a 4-cm cut just under the right elbow and, the other was a 3-cm injury on the proximal right palm. We observed blood stains on the right cheek of the adult male which supposedly killed the infant, but could not see any injury because of his long cheek whiskers. The victim's mother had kept a distance from other members of the unit during the 10 days of observation prior to the attack.

Discussion

Infanticide

In the infanticide observed in Robe-Temama, females supported the mother against the adult male. Notably, the injuries of the mother were to the palm and limb which suggests that the injuries that two females of C6 had at the time of disappearance of an infant were caused by infanticide. The injuries to the females were similar in both cases, and they were not considered to be caused by predators, such as a leopard or a Vereaux's eagle. Thus, up to now, three cases of infanticide have been noted among Arsi geladas, confirming that infanticide occurs more frequently in Arsi geladas than among those of Semien (Mori et al. 1997). The present cases of infanticide presumably occurred after a leader male change which differs from the previously reported case.

It is interesting that abortion also occurred in the present study after a leader male change. Spontaneous abortion has been reported among geladas (Mori and Dunbar 1985), and Dunbar (1984) hypothesized that it developed as a strategy against infanticide.

Characteristics of changes in unit structure

We reported previously that changes in unit structure occurred more frequently among Arsi geladas than among the Semien population (Mori et al. 1999), though we did not elaborate on the processes of social change. Various types of changes were observed during the subsequent 7-month study on eight resident units consisting, in total, of 27 adult females.

Although the first two cases of changes in unit structure were precipitated by capture, parturition and the disappearance of an adult male also induced social changes. Social changes continued as a result of chain reactions. One female deserted from a unit and transferred into another unit. The female was subsequently herded by a male to form a new unit. This transfer rate is one in 189 female months. This rate is higher than that of the E- and K- herds at Gichi, where no female transfer was observed in 437 female months, and only one in 1764 ($=196\times9$) female months occurred in Sankabar (Dunbar 1979). One successful and one attempted integration of units were also observed. Integration of units did not succeed in Semien, although one attempted integration was observed in Gichi (Mori 1979).

The social changes of natural origin occurred in the last 3 months, March, April, and May. Emigration of resident units from the study area increased from March, and immigration of nonresident units increased in April and May. We suspect that social changes were related to the overall increase in activity of units in these months.

In a previous paper, we indicated that the size of the unit is smaller in Arsi than Semien, and also that each unit moved more independently in Arsi (Mori et al. 1999). The male group, C5, included three–four adult males and three adult females in the previous study period, from 6 December 1994 to 18 February 1995, and had a sub-unit of one male and two females which was not found in the present study period (Mori et al. 1999). Relationships between the core members of the present study were already established at that time. The adult male, Tosaka, was observed to carry a J(1) on his back, and showed protective behavior toward females in the previous study period. We judged Tosaka to be the former leader male of the unit that had been invaded by males. We proposed that the sociological process of forming a small unit proceeds as follows: (1) a number of males are accepted into a unit for defense against leopards; (2) subunits develop inside the unit; and (3) the unit is subsequently divided into small units.

We can add two types of social changes which arise from small unit size. Small units could easily be integrated, and even small units could be abandoned by females, despite the suggestion that the benefits of leaving a large unit increase for lower ranking females who experience decreased reproductive success in large units (Dunbar 1984). The deserted female was finally taken by a male in the C5, and a small unit was formed. Through division of a unit and integration of units, a unit is not always expected to be formed by blood related females among Arsi geladas. If a unit is not formed by blood related females, the role of males in the integration of the unit will be important, particularly the males' ability to herd females.

The characteristics of a male group

The male group behaves as a challenger to the leader male of one male units in both hanuman langurs and patas monkeys (Sugiyama 1965; Ohsawa et al. 1993). However, the male group, C5, of geladas in the Gado-Goro band, which was composed of a number of adult males, juveniles and an adult female, was not a challenger. Instead, this male group was a buffer group which accepted animals not accepted in one male units. It served as a buffer group even for the deserted female from C4. The males of this group did not show herding behavior toward the female of their own unit, though a close tie was observed between Tosaka and the only female. When the female from C3 joined the male group, males started herding this female and the male group consequently divided and dissolved, with a small unit, being formed with the deserted female. Interestingly, the dominant male did not adopt the strategy of chasing away other males in C5, although this tactic is commonly employed for take overs in other species (Sugiyama 1965; Ohsawa et al. 1993).

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