Wealth-dependent and interdependent strategies in the Saami reindeer husbandry, Norway

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1 This is the accepted version of the paper and as such may differ from the final corrected proof which can be accessed at http://dx.doi.org/10.1016/j.evolhumbehav.2012.05.004.
It has been argued that decisions in relation to choosing strategies to a large degree depend on an organism’s state. For nomadic pastoralists, wealth is an important state variable, since it has been argued that differences in observed behaviours reflect alternative strategies dependent on varying socioeconomic circumstances. From a game theoretical point of view, however, strategies are also interdependent, i.e. the choice of a strategy cannot be made wisely without considering what other actors are doing, since the outcome of a given strategy is not only dependent on individual state but also on the strategies of others. This study investigated to what degree slaughter strategies in the Saami reindeer husbandry are both state dependent and interdependent. The main findings in this study was that: (1) the probability; (2) the amount; and (3) the type of animal slaughtered was to a large degree influenced by both individual herders’ herd size and the number of animals slaughtered by neighbouring herders. Moreover, this study also found that kinship represents a coordinating principle since the degree of genealogical relatedness had a positive effect on the slaughtering strategies adopted by herders.

Keywords: Tragedy of the commons; Prisoners’ Dilemma; Cooperation; Kinship; Reindeer abundance; Wealth.
1.0 INTRODUCTION

1.1 State dependent strategies

It has been argued that decisions in relation to choosing strategies to a large degree depend on the organism’s state (e.g., McNamara and Houston, 1996) and for nomadic pastoralists some measure of wealth (e.g., herd size) may be an important state variable. Differences in observed herder behaviours among nomadic pastoralist may, for example, reflect alternative strategies aimed at achieving similar objectives dependent on varying socioeconomic circumstances (Borgerhoff Mulder and Sellen, 1994). Grandin (1983:240), for example, argues that a herder with 400 animals have different options available than one with 4. In a model investigating how household wealth should be divided between small stock and camels in order to maximise long term household viability, Mace & Houston (1989) found that while it paid off for relatively poor pastoral households to maximize small stock, this changed above a certain threshold of wealth where it paid off to invest in camels. In another study, Mace (1993) found that wealthier pastoralists use flexible herd management strategies to accommodate long-term household survival by controlling breeding rates of sheep. This practice can be explained by the cost of reproduction, especially during occasions of harsh weather conditions where the survival rate of neonates and even pregnant and/or lactating females can be substantially lowered (Bårdsen et al., 2010; Bårdsen and Tveraa, 2012; Tveraa et al., 2003; Bårdsen et al., 2011). Poor households cannot engage in this practice since they have no choice but to increase herd size. Moreover, Borgerhoff Mulder & Sellen (1994:214) argues that rich herders among the Kipsigis and Datoga often extend livestock as gifts to clansmen or neighbours having an emergency. While this practice reduces wealthy households’ short term access to livestock and livestock...
products, it may increase long term household survival through delayed reciprocity, a strategy that is only available to wealthier households (Borgerhoff Mulder and Sellen, 1994:214; see also Moritz et al., 2011). Grandin (1983:241-2, Table 2) has presented evidence that indicate that in Kenya percentage off take is negatively related to wealth, but that wealthy household have greater per capita slaughter. In other words, wealthy households slaughter a larger number of animals but proportionally less of their herds than poor households.

1.2 Interdependent strategies

While wealth seems to be an important state variable affecting production strategies in several pastoral societies, decisions in relation to, for example, the number of animals to slaughter also have to be made in relation to the actions of neighbouring herders because the outcome of a given strategy is not only dependent on the herders’ own state but also on what others are doing (Schelling, 1980; see also Axelrod, 1984; Dixit and Skeath, 2004; Colman, 1995; Wydick, 2008). In general terms, this interdependency lies on a continuum with pure coordination at one end (convergent interests) and pure conflict at the other end (divergent interests, Schelling, 1980:86).

1.2.1 Mixed motives: Prisoners’ Dilemma and the tragedy of the commons

Nevertheless, most situations lies somewhere in between these two extremes where individuals are faced with incentives both to cooperate and compete. A case point is Hardin’s (1968) concept of ‘the tragedy of the commons’ since it captures the social dilemma inherent in utilizing communally owned resources: all herders would be better off by
cooperating to restrict herd size and consequently preserve the common grazing area, but individuals can do better by taking advantage of the cooperative efforts of others.

The tragedy of the commons is an example of a Prisoners’ Dilemma and Hardin (1968) observed that Prisoners’ Dilemma problems occur in many, if not most, situations that call for some kind of collective sacrificial restraint or action, but where the underlying incentive lies in gaining and individual advantage through a lack of individual restraint (Wydick, 2008:27-8). In short, the Prisoners’ Dilemma captures a broad class of settings in which the welfare of the individual and the welfare of the group are in conflict with another (Wydick, 2008:28). Thus, decisions in relation to the number of animals to slaughter also have to be made in relation to the actions of other herders. This is especially pertinent in areas with common pastures, such as e.g. the reindeer husbandry in Finnmark, where pasture access to a large degree is dependent on herd size (Riseth et al., 2004). Larger herds use more extensive pasture areas and may thereby exclude other herds from grazing in the same area. In such a system a unilateral strategy of slaughtering many animals have negative implications if everybody else slaughters few or no animals. In other words, in areas where pastures are common, decisions in relation to slaughter can be expressed as a tragedy of the commons: individuals perform better by adding additional animals on the common pastures since the cost of overexploitation is shared by all users while the benefits of increased herd size is accrued to individual herders (Næss and Bårdsen, 2010). One way of achieving such a benefit is to restrict slaughter.
1.2.2 Kinship – evolutionary aspects of cooperation

In general terms, benefits not easily obtainable by individuals may be available to cooperating groups (Axelrod, 1984). The problem, as illustrated by the tragedy of the commons, is related to “free riding” where individuals that can benefit from cooperation can do better by exploiting the cooperative behaviour of others (Axelrod, 1984:92).

From an evolutionary point of view important mechanisms facilitating cooperative behaviour are kin selection and inclusive fitness (see e.g. Hamilton, 1964; Alvard, 2003; for a review, see Griffin and West, 2002). Other prominent mechanism facilitating cooperation are (1) reciprocity (Trivers, 1971), (2) signalling (Smith and Bird, 2005), and (3) punishment (Axelrod, 1986). Moreover, (4) asymmetry in social relations have been argued to play a part in the emergence of cooperative social institutions (Richerson et al., 2003; see also Borgerhoff Mulder and Coppolillo, 2005), where some individuals have both the means and the incentives to enforce e.g. costly punishment that facilitate cooperative behaviour.

Punishment, however, represent a second-order collective action problem because the means to solve a collective action problem itself poses a collective action problem since punishment is a public good open for free riding (see Smith, 2003). More to the point, while punishment may favour cooperation it is less evident why natural selection would favour such a trait (West et al., 2011). Nevertheless, experimental evidence indicate that, in the long run, both groups and individuals are better off when punishing non-cooperative behaviour since the cost of punishment becomes negligible and is also outweighed by the increased benefits that comes from cooperation (Gachter et al., 2008). Moreover, punishment may provide: (1) direct fitness advantage by seceding interactions with

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2 Following Smith (2003:402) cooperation can be defined as collective action for mutual benefit, where collective action can be defined as when two or more individuals have to interact to achieve a specific goal.
uncooperative individuals to the benefit of interactions with cooperative individuals; and (2) indirect fitness advantages as punished individuals may change behaviour in response to punishment and may thus be more likely to cooperate in the future (cf. West et al., 2011).

Kin relations may thus provide a powerful coordinating principle (Gintis et al., 2005; Griffin and West, 2002; Alvard, 2003; Smith, 2003; Hamilton, 1964) because groups organized on the basis of kinship are usually small where individuals have: (1) close and long-term contact; (2) the possibility to monitor the behaviour of others with the possibility to; (3) punish people who break the rules (Borgerhoff Mulder and Coppolillo, 2005, see below for arguments in relation to why reciprocity, kinship and punishment may not explain large scale cooperation). Kin relationship may thus be conducive for making it possible for herders to monitor and punish rule breakers and thus mitigate the inherent social dilemma in utilizing common pool resources.

1.3 Predictions

In sum, it could be argued that, ceteris paribus, herders’ strategies are formed by a combination of the household’s own state, such as herd size, and by the strategies adopted by neighbouring households. Consequently, this paper aims at investigating how slaughter strategies in the Saami reindeer husbandry in Norway are influenced by: (1) reindeer herder’s own wealth, where herd size is expected to be a positive predictor for slaughtering. (2) The actions of other herders, since negative density-dependence influence the reindeer husbandry (Næss, 2009; Næss et al., 2010; Tveraa et al., 2007; Bårdsen and Tveraa, 2012; Bårdsen et al., 2010) and the situation facing reindeer herders can thus be characterized as a
tragedy of the commons\textsuperscript{3} we expected that the number of animals slaughtered by
neighbouring herders to be a negative predictor for slaughtering. (3) The degree of kinship
within groups, if kinship works as a coordinating principle (as shown by Næss et al., 2010) we
expected kinship to be a positive predictor for slaughter. Finally, (4) the interaction between
the actions of other herders and kin relations, should be positively related to slaughter
because as kin relations increase, conflicts are reduced and thereby weakens the negative
effect of the amount of slaughter undertaken by other herders.

2.0 METHODS

2.1 Study area

Reindeer husbandry has been said to be the cornerstone of the Saami culture in northern
Fennoscandia (Bostedt, 2001). Reindeer husbandry is, however, historically relatively recent
(300-400 years old) and probably evolved from a hunting culture based on wild reindeer (cf.
Næss et al., 2010). Over the years, Saami reindeer husbandry has changed, most
significantly, from milk and meat production with smaller herds to meat production alone
with larger herds (Paine, 1994). Traditionally, reindeer pastoralism was based on households
that followed their herds year-round and the pastoral economy was primarily tied to
reindeer products (Vorren, 1978). Between 1960 and 1990 reindeer husbandry underwent
major technological, economic, and political changes leading to a motorized and market
oriented industry (Riseth, 2003).

\textsuperscript{3} According to McPeak (2005:188-9) the fact that the herd size of other herders exerts a negative influence on
the production of the target household herd captures the essence of the negative externality, i.e. the tragedy
of the commons posited for pastoral areas.
At present Saami reindeer husbandry operates at three different levels of social organization: (1) husbandry unit; (2) siida; and (3) district. The husbandry unit is the basic unit of the social organization, and is licensed by the government to manage a herd of reindeer within a delimited area (Ulvevadet and Klokov, 2004). The husbandry unit is similar to the household as defined by Dahl (1979:70), but as the herd can also contain reindeer belonging to family members of the husbandry unit’s manager, it resembles an extended family unit. The siida is a cooperative unit composed of one or more reindeer management families, and is part of the traditional reindeer husbandry system4 (cf. Næss et al., 2010). The siida is usually organized on the basis of kinship joined together in social and labor communities for keeping control of herds of reindeer through herding (cf. Næss et al., 2010).

Saami kinship system is extensive and includes terms for consanguinal and affinal relationships (Pehrson, 1964). Traditionally, Saami kinship system was bilateral, i.e. kinship defined through both the male and female lines (Gjessing, 1975:326). Sibling solidarity, however, could be extended to include cousins and other affinal relatives of the same generation (Paine 1964:256-257 in Bergman et al., 2008:101).

Saami reindeer husbandry districts are formal management units with responsibility to provide the Norwegian reindeer husbandry administration with information. The district is also responsible for ensuring that reindeer husbandry is managed in accordance with government regulations (Bull, 1997). As such the district might be better described as the lowest level of government management of the reindeer industry rather than a level of social organization (Ulvevadet, 2008) even though members of reindeer districts have to

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4 This level of social organization is formally recognized by the Norwegian government in the new Reindeer Management Act as what has previously been designated as husbandry unit will change to siida share (Ulvevadet, 2008; Anonymous, 2007a).
cooperate in, e.g., maintaining fences or fulfilling governmental quotas on the maximum number of reindeer per district (Næss et al., 2010; Næss et al., 2009).

2.2 Study design

Different reindeer summer pasture districts represent heterogeneous units that differ in both climate and herding strategies (e.g. Bårdsen and Tveraa, 2012). Previous studies have used differences in density as a basis of a paired-block design between neighbouring districts with low and high density. This quasi-experimental design, consisting of 10 pairs and 20 districts, have been adopted to separate the effects of reindeer density from other environmental factors (see Ims et al., 2007; Bråthen et al., 2007a; Bråthen et al., 2007b for details). While not estimating the effects of the design directly, the present study used the same districts to ensure that the analyses were based on a subsample of heterogeneous districts.

2.3 Study protocol

This study is based on two datasets: the first consist of governmental statistics compiled and published annually by the Norwegian reindeer husbandry administration (31 of March, see e.g. Anonymous, 2007b). This dataset contains data pertaining to husbandry unit numbers, herd size (total number of reindeer in the spring) and number of reindeer slaughtered. These data covers the period 1998-2007 with data from 20 reindeer husbandry summer districts. Data on husbandry unit numbers and herd size are based on counts made by herders that are regularly checked by the authorities (Anonymous, 2007b), while data in relation to slaughter are recorded by slaughterhouses approved by the government (Tveraa et al.,...

205 The second dataset consists of data pertaining to the genealogical relatedness between active reindeer herders within summer districts, i.e. herders that have a license to practice reindeer husbandry. Data pertaining to kinship denote the average coefficient of relatedness within a reindeer husbandry district (for details pertaining to this dataset and how it was collected see Næss et al., 2010:250 & Appendix B). As in our previous studies we made a selection of husbandry units with ≥70 reindeer (Næss and Bårdsen, 2010; Næss et al., 2010; Næss et al., 2009). The dataset contains the following variables:

212 $S_{off_t}$ (response).-- A (husbandry unit level) variable that either acts as a binary variable ($0 = \text{no slaughter} \ & \ 1 = \text{slaughter}$) or as a continuous variable denoting the total number of slaughtered offspring in each husbandry unit per year.

215 $S_{♂t}$ (response).-- Similar to $S_{off_t}$ except that this (husbandry unit level) variable denotes the number of slaughtered adult males.

217 $S_{♀t}$ (response).-- Similar to $S_{off_t}$ except that this (husbandry unit level) variable denotes the number of slaughtered adult females.

219 $N_t$.-- A continuous (husbandry unit level) variable denoting the total herd size at the beginning of the year.

221 $S_{around_t}$.-- A continuous (district level) variable denoting the number of slaughtered reindeer in the district (after subtracting the number of slaughtered animals in the husbandry unit itself). This variable measures the number of animals being slaughtered around each husbandry unit per year.

225 $r_{district}$. -- A continuous (district level) variable denoting the average coefficient of relatedness, where we used kinship information up to second cousins, within each district (see Næss et al., 2010 for details).

ID$_{district}$.-- This is a factor variable with each district acting as levels.
2.4 Statistical analyses

2.4.1 An overview of the statistical analyses

Selecting a slaughter strategy entails several decisions: (1) the choice to slaughter or not; and (2) if slaughtering, the herder has to choose: (i) how many animals to slaughter; and (ii) the type of animal to slaughter. Consequently, we divided our statistical analyses in three steps:

Step 1: evaluating the probability that a husbandry unit slaughtered or not.

Step 2: by using information solely from units that slaughtered at least one animal belonging to each category, we tried to identify slaughter strategies by identifying possible gradients along the three variables $S_{off_t}$, $S_\sigma_t$ and $S_{\varphi_t}$ (taking into account correlation between them).

Step 3: by using information from Step 2 we tried to identify important predictors affecting slaughter strategies.

In Step 1 & 3 we selected the fixed model structure based on a priori expectations as follows: $N_t + S_{around_t} + r_{district} + S_{around_t} \times r_{district}$. This structure was chosen due to the expectation that: (1) $N_t$ represents an important state variable as it is related to wealth; (2) $S_{around_t}$ represents the actions of other herders (see above); (3) $r_{district}$ represents an important coordinating principle (cf. Næss et al., 2010); and (4) $S_{around_t} \times r_{district}$ represents the interaction between the actions of other herders and kinship. In Step 1 both $S_{\sigma_t}$ and $S_{\varphi_t}$ contained too few zeroes in all years in order to model slaughtering.
probabilities, and this was due to the fact that most herders slaughters adult reindeer every year. $S_{off_t}$ contained too few zeros in most years, but when year was removed as a grouping variable the proportion of zeros became more satisfactory (Table 1). We thus chose to remove year as a fixed effect in all subsequent mixed models since we wanted to keep the fixed effects structure similar across analyses. We do not, however, view this as problematic as herd size and year are related to each other (see below for discussion).

The random effects in a mixed-effects model can conceptually be viewed as a way of controlling for additional sources of variation (or error) that cannot be estimated (Luke, 2004), were $ID_{unit}$, $ID_{district}$ and $ID_{unit}$ nested in $ID_{district}$ were included as potential random effects in all analyses. In order to select the most appropriate random structure we selected the most parsimonious model (i.e. the model with the lowest AIC value; results not shown) from a set of models in which the random structure varied [following the procedure described in Zuur et al. (2009)]. In the analyses of slaughter probability (Step 1) we fitted models using the Laplace approximation, whereas in the other analyses (Step 2-3) we fitted all models using a restricted maximum likelihood fitted model (REML) as we kept the fixed effects structure constant across models (Pinheiro and Bates, 2000). Statistical analyses and plotting of results were carried out in R (R Development Core Team, 2009). All tests were two-tailed and the null-hypothesis was rejected at an $\alpha$-level of 0.05, we used Wald statistics to test if estimated parameters were significantly different from zero.

2.4.2 Step 1: Predicting slaughtering probabilities

Generalized linear mixed effect models (using a logit link function and a binomial distribution), applied using the glmer function of the lme4 package (Bates and Maechler,
2009) were used in the analysis with a binary response variable (0 = ‘no slaughter’, 1 = ‘slaughter’, Bolker et al., 2009).

2.4.3 Step 2: Gradients in slaughtering strategies – amounts vs. offspring/male proportions

Principal component analysis (PCA) of the three response variables was applied using the `princomp` function (Everitt, 2004; Venables and Ripley, 2002). PCA is not a statistical test, but a heuristic procedure aiming at representing as much information in the data as possible using a reduced number of axes or abstract variables (Borcard, 2006; Everitt, 2004). PCA describes variation in a set of correlated variables by creating a new set of uncorrelated, or orthogonal variables, which is a linear combination of the original variables: these new uncorrelated variables are derived in a decreasing order of importance with respect to the amount of variation they contain relative to the original variables (Everitt, 2004). These abstract variables, called principal components (PC), will then be used to ease our interpretation of the structure in the original data. We applied PCA on a subset of the data containing only husbandry units who slaughtered at least one individual per slaughtering category, i.e. $S_{off} \geq 0$, $S_{♂} \geq 0$ and $S_{♀} \geq 0$. The PCA was performed on loge transformed values for the three variables and by using the correlation matrix. The first PC and possible also the second PC will, if they explain more than their proportion of the variance in the original variables (i.e. $>2/3$ of the total variance), be used as proxies for the three variables in further formal statistical testing of relationships (see below). We evaluated the results from the principal component analysis by plotting the scores from principal component 2 (PC2) as a function of principal component 1 (PC1) and by evaluating the loadings for the principal
components and the Pearson’s product moment correlations between the components and
the original variables.

2.4.4 Step 3: Predicting gradients in slaughtering strategies
Linear mixed-effect models (lme) applied using the nlme package (Pinheiro and Bates, 2000;
Pinheiro et al., 2006) were used in the analyses of the scores from the principal component
analyses.

3.0 RESULTS

3.1 Step 1: Predicting slaughtering probabilities
Husbandry units with larger herds had a higher slaughtering probability (the positive effect
of \( N_t \): Table 2) indicating that husbandry units with few animals were more reluctant to
slaughter compared to larger herds (but note the relative lack of variability in the response
indicating that most herders slaughtered at least one animal, see Table 1 for details).
Slaughtering also appeared to be correlated with what others were doing since the number
of slaughtered animals around each husbandry unit was a positive predictor of slaughtering
probability (the positive effect of \( S_{around_t} \): Table 2). Moreover, the average degree of
kinship within the district had a positive, although not statistically significant, effect on
slaughter probability (the positive effect of \( r_{district} \): Table 2). We also found a positive, but
not statistically significant, effect of the interaction between the number of slaughtered
animals around each husbandry and the average degree of kinship within the district (the
positive effect of $S_{around_t} \times r_{district}$: Table 2). In sum, a combination of individual state and interdependent factors affected whether reindeer owners slaughtered or not.

3.2 Step 2: Gradients in slaughtering strategies – amount vs. offspring/male proportions

PC1 and PC2 jointly explained 83.41% of the original variation (Table 3a), and as judged by the correlations between PC1, PC2 and the original data (Table 3b) and the loadings for the PCs (Table 3c) we identified two main gradients in the data (Figure 1): (1) an ‘amount gradient’ in which husbandry units with the most negative scores for PC1 on average slaughtered many animals in all categories (the loadings for $S_{off_t}, S_{\varnothing_t}$ and $S_{\varpi_t}$ were all negative, see Fig. A1.1); and (2) an ‘offspring-male gradient’ in which husbandry units with the most negative PC2 scores on average slaughtered few offspring and many males (the loadings for $S_{off_t}$ were highly positive whereas the loadings for $S_{\varnothing_t}$ and $S_{\varpi_t}$ were negative, see Fig. A1.2).

3.3 Step 3: Predicting gradients in slaughtering strategies

3.3.1 PC1: amount gradient

In the analysis of the scores from PC1, the effect of herd size was negative [$N_t$: -1.382 (Table 4a; Figure 2a)], which indicates that husbandry units with larger herds slaughtered more animals than smaller ones (as PC1 was negatively related to $S_{off_t}, S_{\varnothing_t}$ and $S_{\varpi_t}$). The amount of slaughter was also positively affected by what others were doing since the scores from PC1 was negatively correlated to the number of animals slaughtered by neighbouring husbandry units [$S_{around_t}$: -0.617 (Table 4a; Figure 2b)]. We also found a positive effect of
kinship as the scores from PC1 was negatively correlated with the average coefficient of relatedness in districts \( r_{\text{district}}: -6.224 \) (Table 4a; Figure 2c). In other words, husbandry units surrounded by more closely related kin slaughtered more animals compared to those being surrounded by more distantly related kin. Finally, we also found a positive (but not statistical significant) interaction between number of animals slaughtered by neighbouring husbandry units and average coefficient of relatedness since the interaction term had a negative effect on PC1 \( S_{\text{around}_t} \times r_{\text{district}}: -0.546 \) (Table 4a; Figure 2c).

### 3.3.2 PC2: offspring-male gradient

In the analysis of the scores from PC2, the effect of herd size was positive \( N_t: 0.104 \) (Table 4b; Figure 3a), indicating that husbandry units with larger herds slaughtered on average more offspring and fewer males than husbandry units with smaller herds (PC2 was positively correlated with \( S_{\text{off}_t} \) and negatively correlated with \( S_{\text{♂}_t} \)). The number of animals slaughtered by neighbouring husbandry units affected the offspring-male proportion positively \( S_{\text{around}_t}: 0.333 \) (Table 4b; Figure 3b). We also found a positive effect of kinship on PC2, even though this effect was only near to reach statistical significance \( r_{\text{district}}: 5.316 \) (Table 4a; Figure 3c). The same was also the case with the interaction between number of animals slaughtered around each husbandry unit and average coefficient of relatedness in the district \( S_{\text{around}_t} \times r_{\text{district}}: 0.401 \) (Table 4a; Figure 2c), but this effect was not statistically significant.
4.0 DISCUSSION

The main finding in this study was that Saami reindeer herders’ slaughter strategies are shaped by a combination of the herder’s own state and the actions undertaken by neighbouring herders. First, when assessing the probability of slaughtering, both wealth and the amount of slaughter undertaken by neighbouring herders had a positive effect on the probability of slaughtering. Moreover, we found a weak positive, i.e. only nearly significant, effect of kinship on the probability of slaughtering. We also identified two main gradients in the data in the PCA, which show that husbandry units who chose to slaughter were faced at least two strategic choices: (1) the amount of reindeer to slaughter; and (2) the type of animal to slaughter. Second, the amount of reindeer slaughtered increased with increasing values for herd size, the amount slaughtered by neighbouring herders and kinship. Third, we found that husbandry units with larger herds slaughtered more offspring and fewer males than husbandry units with smaller herds. Moreover, when the number of animals slaughtered by neighbouring units increased individual husbandry units slaughtered more offspring and fewer males.

4.1 State dependent strategies

The amount of slaughter was positively correlated with own herd size, indicating that wealthy husbandry units slaughtered more than poor ones (see also Grandin, 1983). Moreover, we also found that wealth was a positive predictor for the type of reindeer slaughtered as wealthier units slaughtered more calves and fewer males. This was expected as calves typically represent the majority of slaughtering within the Norwegian reindeer husbandry (at least in recent years, see Anonymous, 2008a). Nevertheless, this result can be
interpreted with reference to pastoral risk management. In general, it has been found that herd accumulation maximizes long term household survival and is therefore an effective risk reducing strategy (e.g. Templer et al., 1993; McPeak, 2005; Mace, 1993; cf. Næss and Bårdsen, 2010; Næss et al., 2011). Mace (1993) found, for example, that wealthy herders maintain large herds by controlling breeding rates: by reducing the number of offspring per year the longevity of females is increased. The underlying rationale is linked to the cost of reproduction (see above for details) and a herder can reduce this cost by controlling breeding rates (Mace, 1993) or by slaughtering calves (this study). Just as poor Gabbara households cannot control breeding rates since they have no choice but to increase their herds to maximize long-term household survival, poor husbandry units have to maximize herd size by restricting calf slaughter since those with the larger herds have the highest probability of staying in the pastoral game (Næss and Bårdsen, 2010).

4.2 Interdependent strategies

The results from this study indicate that slaughtering strategies is not only influenced by the husbandry units’ own state but also by the amount of slaughter undertaken by neighbouring herders. Consequently, our results support the game theoretical expectation that strategies are interdependent (see above) Nevertheless, previous studies have indicated the presence of a tragedy of the commons in the reindeer husbandry since density dependence has been shown to influence the reindeer husbandry negatively (Næss, 2009; Næss et al., 2010; Tveraa et al., 2007; Bårdsen and Tveraa, 2012; Bårdsen et al., 2010). Consequently, if the cost of overexploitation by adding additional reindeer is shared by all (negative density
dependence) but the benefit (increased long term viability and access to common pastures) from increasing herd size is individually accrued, it could be argued that when other husbandry units slaughter, the best response is to restrict own slaughter and thereby exploit the cooperative effort of others. In contrast, the positive association between the amount of slaughtering undertaken by individual husbandry units and the amount of slaughter by neighbouring units indicate that slaughtering in the reindeer husbandry is not characterized as a tragedy of the commons situation. This interpretation is valid because in a Prisoners’ Dilemma the best strategy is to always restrict slaughtering regardless of what others are doing. For reindeer herders, however, the appropriate question may not be whether to slaughter or not (as most units slaughter at least a few animals) but rather how much to slaughter. This decision may entail balancing the need for income from slaughter with the risk beneficial aspects of accumulating herd size. As such the situation facing reindeer herders is neither characterised as a Prisoners’ Dilemma where it is always better to exploit the cooperative efforts of others nor by the same mutualistic aspect as cooperative labour input among pastoralists (Næss et al., 2010) or cooperative hunting (Alvard and Nolin, 2002; Smith, 1997) where individuals are always better off cooperating. Rather decisions in relation to slaughtering may entail a level of risk aversion where reindeer herders are more concerned with not doing worse (slaughtering more than neighbours and be outcompeted e.g. by losing access to grazing) than being the best (slaughtering less than neighbours and thus outcompete neighbours e.g. by gaining access to more grazing). If this is the case, the best strategy may be to monitor how much others are slaughtering and synchronise slaughter accordingly. This should give rise to a synchronous pattern in slaughtering, which can be revealed by looking at temporal trends in the amount of slaughter undertaken by neighbouring husbandry units (Fig. 4).
4.3 Kinship and cooperation – indirect and direct benefits

While kin selection is a powerful force promoting cooperation and helping behaviour, one could question the universality of genetic kinship as an organizing principle for social cooperation among humans (Bock, 2009). Alvard (2003), for example, found that among whale hunters in Lamalera, Indonesia, lineage membership rather than genetic kinship determined hunting group formation (see also Allen-Arave et al., 2008). In contrast, when reanalysing the Chagnon’s famous analysis of the axe fight among the Yanomamöös living in the rainforests of southern Venezuela, Alvard (2009) found, in support of Chagnon and Bugos’s (1979, cited in Alvard, 2009) original conclusion, that genetic relatedness rather than lineage identity was a primary organizing principle for individuals’ choosing sides in the fight (for other studies documenting the importance of kinship see e.g. Borgerhoff Mulder, 2007; Crognier et al., 2002; Sear and Mace, 2008; Tymicki, 2004). Alvard (2009) concludes that for problems that require small groups (which seems to characterise summer districts in the reindeer husbandry, cf. Næss et al., 2010:253-4), genetic kinship is sufficient (for the problem of large-scale cooperation see e.g. Paciotti and Hadley, 2004; Alvard, 2009).

The results from this study suggest that that kinship is an important measure of cooperation in the Saami reindeer husbandry since the amount of reindeer slaughtered was positively correlated with the degree of relatedness between husbandry units within districts (see also Næss et al., 2010). Nevertheless, the lack of evidence for any interaction between kinship and the amount of slaughter undertaken by neighbouring herders indicate that while kinship may be an important coordinating principle in general, it may be important to synchronise slaughter regardless of kin relations. In other words, it could be argued that...
individuals may cooperate because it is in their own direct self-interest and not necessarily because of the benefits indirectly acquired through kin relations (Griffin and West, 2002:20; Alvard, 2003; Allen-Arave et al., 2008). Coordinated slaughter can thus be interpreted as being based on gaining direct benefits from cooperation, where the benefits can be expressed as both income from the reindeer slaughtered and a reduced probability of losing access to grazing areas, e.g. winter pastures, by not slaughtering more than others (Næss et al., 2010:254-5). This is substantiated when looking at the relative importance of the different predictors: while slaughter undertaken by neighbouring herders accounted for 13% of the variation in the amount of slaughtering undertaken by individual husbandry units alone, kinship alone explained no variation (models refitted not accounting for the grouping structure, see Table A1.1 for details). Nevertheless, the results from this study indicate that kinship plays a part in shaping slaughter strategies since husbandry units with larger herds in districts where neighbouring husbandry units slaughtered more animals and with more close related kin slaughtered more animals compared to those with smaller herds surrounded by husbandry units slaughtering fewer animals and with more distantly related kin (see Fig. 2a & b).

4.4 Confounding and limitations

All observational studies have potential problems in relation to confounding, which may lead to spurious relationships between the included predictors and the response and to biased estimation of effects (Cohen et al., 2003). Problems related to confounders were, however, reduced as we had a priori expectations to all predictors included in the analyses (Anderson, 2008; Burnham and Anderson, 2002). Nevertheless, there are several important known
factors not included in our models that can potentially influence slaughtering. First, variation in climate may affect slaughtering as survival is particularly constrained during harsh winters (Tveraa et al., 2003); and husbandry units experiencing negative winter conditions may be less reluctant to slaughter. While this needs to be further investigated, reindeer populations in Finnmark seems not to be severely limited by negative winter conditions since overall reindeer abundance in Finnmark (and nationally) has increased from ~2001 and onwards (e.g. Næss et al., 2011:Fig. 1; Næss and Bårdsen, 2010; Bårdsen et al., 2010). As such the inability to account for possible negative effects of winter climate should not affect our conclusions.

Second, temporal trends in the number of animals slaughtered can confound our analyses. While we have not included year as a covariate in our analyses, by including herd size we did, however, partially control for such temporal trends due to the positive association between herd size and year, which is apparent at the national level (Næss et al., 2011) as well as for many districts (Bårdsen et al., 2010; Tveraa et al., 2007) and husbandry units in Finnmark (Næss and Bårdsen, 2010).

Third, both mortality and reproduction are important potential confounders as they may influence slaughter strategies. We suspect that we also partially controlled for this effect through the inclusion of herd size in the analyses since both the number of individuals born and dying during a year are related to herd size.5

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5 Herd size was positively correlated with both number of calves (marked) [mean correlation estimated per unit: 0.682 (95% CI, 0.635, 0.728, n = 206) and reported loss to predation [mean correlation estimated per unit: 0.454 (95% CI, 0.406, 0.501, n = 206)]. Note: data pertaining to number of calves and reported loss is from a different dataset covering the period 2000-2008.
Fourth, variation in vegetation quantity and quality may have important consequences for slaughtering since good pasture conditions may lead to an increased calf production (Bårdsen and Tveraa, 2012). While we have not explicitly controlled for this source of variation we control for some measure of between district variations by including districts as a random effect in our analyses (cf. Næss et al., 2009).

Fifth, we have not taken into account important economic measures that may substantially influence slaughter in the reindeer husbandry. For example, several economic subsidies aim at stimulating production: operating subsidies; production premiums; subsidies for slaughtering calves; slaughter during autumn; and general subsidies for stimulating overall production (Ulvevadet and Hausner, 2011). The underlying rationale for this is connected to the explicit management goal to develop a sustainable reindeer husbandry by reducing the number of reindeer in Finnmark (Ulvevadet, 2008). One tool used to achieve this goal is the aforementioned subsidies (Anonymous, 2007c:6; 2008a:56).

Furthermore, from 1997 to 2007 producer prices for reindeer meat has been steadily increasing (net price per kg meat paid by slaughterhouses increased from 41.85 NOK in 1997 to 64.51 NOK in 2007 in Finnmark, see Anonymous, 2001; 2004b; 2008b). From an economical point of view it is to be expected that when the price of a product raises suppliers offers more of the product for sale (i.e. the “law of supply”, see Frank, 2006), indicating that as prices for reindeer meat increases reindeer herders should be willing to slaughter and sell more reindeer. Nevertheless, in spite of both economical subsidies and the overall temporal trend in meat prices, the number of reindeer has still increased (see above). In other words, economical factors assumed to influence slaughter positively are apparently not enough to decrease the number of reindeer in the region. Results from this

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6 100 NOK = $17.9 per 28.02.12.
study indicate that one reason for this may be that slaughter strategies are not selected solely on the basis of monetary considerations.

This is not the first study were we have experienced problems related to confounding (see e.g. Næss and Bårdsen, 2010; Næss et al., 2011). Even though the most likely confounders (based on experience) have varied between studies, the solution has been the same. While including more, if not all, relevant predictors in a statistical model is the preferred solution as this leads to reduced bias (Berry and Feldman, 1985), in reality this lead to collinearity problems (cf. Næss et al., 2011: Appendix II in relation to the reindeer husbandry; and Zuur et al., 2010 for general considerations). We thus chose to include the set of predictors we have a priori expectations to (from a theoretical point of view, as recommended by e.g. Licht, 1995).

5.0 CONCLUDING REMARKS AND MANAGEMENT IMPLICATIONS

In sum, this study found that pastoral slaughter strategies are both state dependent and interdependent since both amount and type of animal slaughtered was influenced by the husbandry units’ own wealth and what other husbandry units were doing and kin relations within districts. In light of the results from this paper and the governmental goal of reducing the number of reindeer by stimulating slaughter, one could question the one-sided governmental focus on targeting individual husbandry units through production subsidies. As we have shown that what others do is an important factor in explaining slaughter, it could

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7 To be eligible to receive the different subsidies reindeer herders have to fulfil two demands: (1) they need to slaughter a quota of reindeer meat, which in 2007 was set to the value of 50 000 NOK; and (2) the husbandry units should possess no more than 600 reindeer in the spring (Anonymous, 2008a:56).
be argued that the government should also focus on strengthening the already existing institutional framework represented by summer districts. In terms of subsidies it could be argued that districts as a whole should achieve some productivity measures before individual units are eligible for receiving subsidies. Such an approach would take into account and strengthen the coordinating principles already present in districts. Since subsidies are based on individual husbandry unit’s willingness to slaughter, a husbandry unit is not dependent on other units slaughtering for receiving subsidies. The present subsidy system may thus not properly account for how decisions in relation to slaughter are made.

If subsidies are, on the other hand, conditional on some district level quota\(^8\) one should be able to reduce the effect of a few herders restricting slaughter: if a majority of herders within a district depend on or are interested in receiving subsidies they will have an incentive to encourage all herders to contribute to attaining the goal set for the district. The failure of others to follow the rules will, in contrast to the current scenario, have negative effects on individual possibility for receiving economic subsidies. The results from this study may be taken to indicate that slaughter strategies are shaped by processes at different hierarchical levels, and subsidies targeting only one level, i.e. the husbandry level, may be argued to be doomed from the outset. In other words, subsidies cannot be aimed at reinforcing behaviour at only the level of individual actors but also have to take into account that individuals behave strategic in relation to other people.

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\(^8\) Note, however, that from 1999-2003 there was a possibility for districts to submit a joint slaughter plan where the districts had to fulfil the slaughter demand before individual husbandry units could receive subsidies. This approach was based on voluntarily participation (Anonymous, 2002:§10) and no statistics exists as to how many actually participated, although by the end of 1999 no districts had submitted a joint slaughter plan in West-Finnmark (Anonymous, 2004a:57).
6.0 ACKNOWLEDGMENT

The present study was financed by the Directorate for Nature Management, Norway; the Fram Centre, Norway; and the Research Council of Norway (the FRIMUF program). We thank the Norwegian Reindeer Administration for providing the data, and people employed at the Reindeer Administration’s office in Kautokeino and Karasjok for providing us with additional information. We would also like to thank Ellen Margrete Oskal for help with data collection.

7.0 REFERENCES


Amsterdam, Elsevier.


Table 1. The number of husbandry units that slaughtered (1) and the number who did not slaughter (0) separated by year and animal type (offspring, males and females). Numbers in bold text indicate where the proportion of non-slaughter (0) relative to the total (i.e. level 0 + 1 for each slaughter type) was <0.15.

<table>
<thead>
<tr>
<th>Year</th>
<th>( S_{\text{off}} )</th>
<th>( S_{\text{♂}} )</th>
<th>( S_{\text{♀}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1998</td>
<td>31</td>
<td>184</td>
<td>2</td>
</tr>
<tr>
<td>1999</td>
<td>28</td>
<td>192</td>
<td>4</td>
</tr>
<tr>
<td>2000</td>
<td>75</td>
<td>137</td>
<td>7</td>
</tr>
<tr>
<td>2001</td>
<td>44</td>
<td>161</td>
<td>12</td>
</tr>
<tr>
<td>2002</td>
<td>25</td>
<td>196</td>
<td>1</td>
</tr>
<tr>
<td>2003</td>
<td>23</td>
<td>199</td>
<td>4</td>
</tr>
<tr>
<td>2004</td>
<td>9</td>
<td>216</td>
<td>0</td>
</tr>
<tr>
<td>2005</td>
<td>10</td>
<td>208</td>
<td>1</td>
</tr>
<tr>
<td>2006</td>
<td>1</td>
<td>207</td>
<td>0</td>
</tr>
<tr>
<td>2007</td>
<td>5</td>
<td>207</td>
<td>1</td>
</tr>
<tr>
<td>( \Sigma \text{(year)} )</td>
<td>251</td>
<td>1907</td>
<td>( \text{32} )</td>
</tr>
</tbody>
</table>
Table 2. Generalized linear mixed-effect models (\textit{glmer}) relating offspring slaughter probability as a binary variable (i.e. a mixed GLM with binomial family and a logit link) to the total spring herd size for the husbandry units ($N_t$), the number of reindeer slaughtered by neighbouring herders ($S_{\text{around}_t}$; this variable was created by subtracting the total number of slaughtered animals in the district number from the number of reindeer slaughtered by the husbandry unit itself), the average coefficient of relatedness ($r_{\text{district}}$) and the interaction between the number of reindeer slaughtered by neighbouring herders and the average coefficient of relatedness ($S_{\text{around}_t} \times r_{\text{district}}$). All covariates were centred (see Aiken and West, 1991:35 for rationale).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (SE)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Slaughter probability ($S_{\text{off}_t}$): binary</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fixed effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>3.481 (0.386)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>$N_t$ \textsuperscript{a}</td>
<td>1.124 (0.161)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>$S_{\text{around}_t}$ \textsuperscript{a}</td>
<td>1.324 (0.131)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>$r_{\text{district}}$</td>
<td>14.328 (7.471)</td>
<td>0.055</td>
</tr>
<tr>
<td>$S_{\text{around}<em>t} \times r</em>{\text{district}}$</td>
<td>0.961 (2.668)</td>
<td>0.719</td>
</tr>
<tr>
<td><strong>Random effects\textsuperscript{b}</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Among $ID_{\text{district}}$ standard deviation (SD)</td>
<td>1.490</td>
<td>n_{\text{obs.}} = 260</td>
</tr>
<tr>
<td>Among $ID_{\text{unit}}$ nested in $ID_{\text{district}}$ SD</td>
<td>0.914</td>
<td>n_{\text{obs.}} = 20 \ n_{\text{ind.}} = 2158</td>
</tr>
</tbody>
</table>

\textsuperscript{a}This variable was transformed using the natural logarithm.

\textsuperscript{b}Random effects involves only the constant term (i.e. random intercepts).
Table 3. Results from the principal component analysis on slaughtering data.

<table>
<thead>
<tr>
<th>Values</th>
<th>PC1</th>
<th>PC2</th>
<th>PC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Importance of the components</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard deviation</td>
<td>1.271</td>
<td>0.942</td>
<td>0.706</td>
</tr>
<tr>
<td>Proportion of variance</td>
<td>0.539</td>
<td>0.300</td>
<td>0.166</td>
</tr>
<tr>
<td>Cumulative proportion</td>
<td>0.539</td>
<td>0.834</td>
<td>1.000</td>
</tr>
<tr>
<td>(b) Correlation with original variables (with 95% CI in parenthesis)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$S_{off_t}$</td>
<td>-0.538 (-0.570,-0.505)</td>
<td>0.830 (0.815,0.843)</td>
<td>0.149 (0.104,0.193)</td>
</tr>
<tr>
<td>$S_{s_t}$</td>
<td>-0.845 (-0.858,-0.832)</td>
<td>-0.136 (-0.180,-0.091)</td>
<td>-0.517 (-0.550,-0.483)</td>
</tr>
<tr>
<td>$S_{d_{st}}$</td>
<td>-0.782 (-0.799,-0.764)</td>
<td>-0.424 (-0.460,-0.386)</td>
<td>0.456 (0.420,0.492)</td>
</tr>
<tr>
<td>(c) Loadings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$S_{off_t}$</td>
<td>-0.423</td>
<td>0.881</td>
<td>0.211</td>
</tr>
<tr>
<td>$S_{s_t}$</td>
<td>-0.665</td>
<td>-0.144</td>
<td>-0.733</td>
</tr>
<tr>
<td>$S_{d_{st}}$</td>
<td>-0.615</td>
<td>-0.450</td>
<td>0.647</td>
</tr>
</tbody>
</table>
Table 4. Estimates from linear mixed-effect models (lme) relating gradients in (a) amount of slaughter (PC1) and (b) offspring-male proportions (PC2) to the total spring herd size for the husbandry units ($N_t$), the number of reindeer slaughtered by neighbouring herders ($S_{around_{t}}$; this variable was created by subtracting the total number of slaughtered animals in the district number from the number of reindeer slaughtered by the husbandry unit itself), the average coefficient of relatedness ($r_{district}$) and the interaction between the number of reindeer slaughtered by neighbouring herders and the average coefficient of relatedness ($S_{around_{t}} \times r_{district}$). All covariates were centred (see Aiken and West, 1991:35 for rationale).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (95% CI)</th>
<th>df</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>(a) PC1: ‘amount gradient’</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed effects</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>-0.143 (-0.391, 0.105)</td>
<td>1605</td>
<td>0.259</td>
</tr>
<tr>
<td>$N_t$</td>
<td>-1.382 (-1.462,-1.302)</td>
<td>1605</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>$S_{around_{t}}$</td>
<td>-0.617 (-0.685,-0.548)</td>
<td>1605</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>$r_{district}$</td>
<td>-6.224 (-11.145,-1.303)</td>
<td>18</td>
<td>0.016</td>
</tr>
<tr>
<td>$S_{around_{t}} \times r_{district}$</td>
<td>-0.546 (-2.002,0.909)</td>
<td>1605</td>
<td>0.462</td>
</tr>
<tr>
<td>Random effects</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Among $ID_{district}$ standard deviation (SD)</td>
<td>0.518 (0.347, 0.775)</td>
<td></td>
<td>$n_{Obs.} = 20$</td>
</tr>
<tr>
<td>Among $ID_{unit}$ nested in $ID_{district}$ SD</td>
<td>0.299 (0.244, 0.366)</td>
<td></td>
<td>$n_{Obs.} = 255$</td>
</tr>
<tr>
<td>Within group standard error (residuals)</td>
<td>0.740 (0.714, 0.766)</td>
<td></td>
<td>$n_{Ind.} = 1863$</td>
</tr>
<tr>
<td><em>(b) PC2: ‘offspring-male gradient’</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed effects</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>0.167 (-0.132, 0.466)</td>
<td>1605</td>
<td>0.275</td>
</tr>
<tr>
<td>$N_t$</td>
<td>0.104 (0.016,0.192)</td>
<td>1605</td>
<td>0.021</td>
</tr>
<tr>
<td>$S_{around_{t}}$</td>
<td>0.333 (0.264,0.402)</td>
<td>1605</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>$r_{district}$</td>
<td>5.316 (-0.538,11.169)</td>
<td>18</td>
<td>0.073</td>
</tr>
<tr>
<td>$S_{around_{t}} \times r_{district}$</td>
<td>0.401 (-1.062, 1.864)</td>
<td>1605</td>
<td>0.591</td>
</tr>
<tr>
<td>Random effects</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Among $ID_{district}$ standard deviation (SD) 0.629 (0.434, 0.911) $n_{Obs.} = 20$
Among $ID_{unit}$ nested in $ID_{district}$ SD 0.413 (0.359, 0.474) $n_{Obs.} = 255$
Within group standard error (residuals) 0.716 (0.691, 0.741) $n_{Ind.} = 1863$

This variable was transformed using the natural logarithm.

Random effects involves only the constant term (i.e. random intercepts).
Fig. 1. A biplot showing PC2 scores as a function of PC1 scores labeled where the coordinates of the triangle for each variable show the Pearson’s product moment correlations between the PCs and the original variables (red axis on the top indicated the correlation coefficient between PC1 and the original variables whereas red axis on the left indicated the same for PC2).
Fig. 2. A visualization of the model presented in Table 4a showing how the scores for PC1 (amount of slaughter) are predicted as a function of:

(a) herd size for the husbandry units ($N_t$), (b) the combined effect of number of reindeer slaughtered by neighboring herders ($S_{around_t}$) and the average coefficient of relatedness ($r_{district}$) and the interaction between them. Please note that the model was refitted without centering any
variables and shows the relationships for a specific predictor keeping the other predictors at their average values. Note that even though the relationship is negative, all predictors had a positive effect on the amount of slaughter because PC1 was negatively related to $S_{off_t}$, $S_{t}$, and $S_{g_t}$ (see Fig. A1.1. for visualization of the relationship between the original variables and PC1). A smoothed density representation of the data (a kernel density estimate) using the ‘smoothScatter’ function in the library ‘geneplotter’ (Gentleman and Biocore, 2011) was also added to give a better visualization of the predictors.
Fig. 3. A visualization of the model presented in Table 4b showing how the scores for PC2 ((offspring-male gradient)) are predicted as a function of: (a) herd size for the husbandry units ($N_t$), (b) the combined effect of number of reindeer slaughtered by neighboring herders ($S_{around_t}$) and
the average coefficient of relatedness ($r_{\text{district}}$) and the interaction between them (see Fig. A1.2. for visualization of the relationship between the original variables and PC2). Legend below Fig. 2 for technical details.
Fig. 4. Showing (a) the temporal trend in average number of reindeer slaughtered by neighboring husbandry units (bars represent the 25 and 75 percentiles) from 1998-2007 and (b) the predicted effect of the average number of reindeer slaughtered by neighboring husbandry units on PC1 (y-axis) and number of slaughtered offspring (z-axis; based on the relationship shown in Fig. A1.1). Note: highlighted line indicates the range in the average values presented in (a).
Fig. A1.1. Number of slaughtered (S) offspring (a), females (b) and males (c) as a function of principal component (PC) 1 for all husbandry units that slaughtered at least one animal belonging to each category. The lines show the predicted relationships between the number of slaughtered animals as a function of PC 1 in a regular linear model (LM) specified as follows: response = α + β₁ × PC 1 (α and β₁ represents the intercept and the slope for PC 1).
Fig. A1.2. Number of slaughtered (S) offspring (a), females (b) and males (c) as a function of principal component (PC) 2 for all husbandry units that slaughtered at least one animal belonging to each category. The lines shows the predicted relationships between the number of slaughtered animals as a function of PC 2 in a regular linear model (LM) specified as follows: response = α + β_1 × PC 2 (α and β_1 represents the intercept and the slope for PC 2).
Table A1.1. Test statistics and adjusted R$^2$ values from fitting regular (a) univariate linear regression and (b) multiple regression analyses relating amount of slaughter (PC1) to the total herd size for the husbandry units ($N_t$), the number of reindeer slaughtered by neighbouring herders ($S_{around_t}$), the average coefficient of relatedness ($r_{district}$) and the interaction between them ($S_{around_t} \times r_{district}$). While not accounting for grouping structure in the data (see main text), the table gives some indication as to the relative importance of the different predictors.

<table>
<thead>
<tr>
<th>Model parameter</th>
<th>R$^2$ (adjusted)</th>
<th>(F-statistics)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Univariate analyses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$N_t^a$</td>
<td>0.501</td>
<td>(F = 1868, df = 1,1861)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>$S_{around_t}^a$</td>
<td>0.131</td>
<td>(F = 281, df = 1,1861)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>$r_{district}$</td>
<td>-0.001</td>
<td>(F = 0.04, df = 1,1861)</td>
<td>0.845</td>
</tr>
<tr>
<td>(b) Multiple regression analyses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$N_t + S_{around_t}$</td>
<td>0.554</td>
<td>(F = 1157, df = 2,1860)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>$N_t + r_{district}$</td>
<td>0.500</td>
<td>(F = 934, df = 2,1860)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>$N_t + S_{around_t} + r_{district}$</td>
<td>0.562</td>
<td>(F = 799, df = 3,1859)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>$N_t + S_{around_t} + r_{district} + S_{around_t} \times r_{district}$</td>
<td>0.567</td>
<td>(F = 610, df = 4,1858)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

$^a$This variable was transformed using the natural logarithm.

Note: All covariates were centred (see Aiken and West, 1991:35 for rationale).