EVALUATION OF WELFARE INDICATORS FOR THE SOCIAL ENVIRONMENT IN CATTLE HERDS

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Abstract *Animal Welfare 2000, **9:*** 297-316

The social environment is very important for the welfare of animals in loose housing dairy production systems. This article reviews recent literature on the effect of animal density (AD) and regrouping (RG) on the welfare of cattle and describes the development of feasible indicators for the social environment. Special emphasis is given to the methodological problems that arise when AD and RG are used as welfare indicators in a welfare assessment at the herd level. Various factors affecting estimates of AD were considered, including the size of the animals, correction for very high AD values, pen shape and how best to aggregate the results at herd level and over time. The examination of RG is centred around the effect of early social experience of the animals, the stability of social relationships, and the effect of pen changes.

A range of parameters is suggested for the evaluation of AD and RG as possible welfare indicators. These are based on observational data from 10 Danish dairy herds and related to clinical records from the herd farms. It is concluded that mean AD is not feasible as a welfare indicator at the herd level but the 25th percentile of AD corrected for the liveweight of the animals should be used instead. The two most promising parameters for evaluation of RG are the frequency of combined pen and group changes for a sample of the herd, and the probability of a certain duration of inter-animal relationships. Results from clinical observations correlated with neither AD nor RG.

Keywords: *animal density, animal welfare, pen changes, regrouping, space*

Introduction

It is generally agreed that operational management plays a major role in animal welfare and that the effects of management and production systems on animal welfare interact in a complex manner (eg Clark *et al* [1997]; Duncan & Fraser [1997]). The complex effect of a farm-specific combination of production factors calls for the development of methods for welfare assessment at the farm level (Johannesson *et al* 1997). In loose housing production systems for dairy cattle, the animals are highly affected by their social environment

(Wierenga 1990; Ingvartsen & Andersen 1993; Fisher *et al* 1997; Hasegawa *et al* 1997; Mogensen *et al* 1997b).

Several indicators can be used to describe the social environment in a group of animals. Animal density (AD) and regrouping (RG) have been shown to influence animal welfare in growing dairy cattle (eg Ingvartsen & Andersen [1993]; Hindhede *et al* [1996]) and can thus be considered as promising candidates for the assessment of social environment in loose-housed animals. AD is usually defined as the number of animals per unit floor area (even though the proper measurement would be area animal^{-1}), while RG is used here to cover any changes in the inter-animal relationships over time. The term 'pen changes' normally refers to inter-pen transport of individual animals, but also includes events such as the division of one pen into two or more, and the joining of two or more pens into one (Ekkel *et al* 1996). All three indicators have mainly been used in experimental circumstances (Hasegawa *et al* 1997) and not on farms. Therefore, it is important to develop methods for applying AD, RG and pen changes, and for describing the measures as welfare indicators, in a welfare assessment at the herd/farm level. Other important parameters such as space at the feeding trough, group size, pen type and dominance relationships in the groups will not be discussed.

The main objectives of this paper are to refine existing methods for on-farm evaluation of AD and RG in dairy cattle herds with special emphasis on group-housed young stock, and to assess AD, RG and pen changes within and across farms.

Monitoring animal density in group-housed young stock

AD or stocking density is related to terms such as 'social space' and 'crowding' (used to describe high levels of AD; Hurnik *et al* [1995]).

In a literature review, Ingvartsen and Andersen (1993) concluded that a high AD negatively affects production parameters such as dry matter intake, daily weight gain and feed conversion ratio, and increases the risk of tail-tip lesions in young bulls. Subsequent experiments on heifers have documented that a high versus low AD results in a decreased growth rate, feed conversion ratio and lying time (Hindhede *et al* 1996; Fisher *et al* 1997; Mogensen *et al* 1997a,b). High AD has additionally been associated with increased mounting behaviour (Tarrant *et al* 1988; Fisher *et al* 1997) and head-resting behaviour (Fisher *et al* 1997), abnormal lying down behaviour (Müller *et al* 1985), increased agonistic behaviour (Nielsen *et al* 1997), reduced play behaviour (Jensen *et al* 1998) and various physiological stress responses (Ladewig *et al* 1985; Tarrant *et al* 1988; Fisher *et al* 1997).

Space requirements are frequently included in standards for animal care (eg Agriculture Canada [1991]; Anonymous [1995]; Bartussek [1999]). In the following sections, the application and interpretation of AD as an indicator of the welfare of cattle will be discussed.

Size and activity of the animals

Growing animals need increased space as their liveweight increases (Morrison & Prokop 1982). The AD for a group of animals should, therefore, only be presented as m^2 animal^{-1} if the animals are of similar size. When dealing with a group of animals with large individual variations in size, the problem arises of how to express the situation as a whole. In Codes of Practice, this problem is typically solved by dividing the animals into distinctive groups by age or weight (eg Agriculture Canada [1991]; Anonymous [1995]). Using age has the obvious advantage that most farmers are familiar with the age of their animals, but the disadvantage that size and growth rate varies between different breeds and even between animals within a breed.

Using the liveweight of the animals gives a more uniform scale, and some researchers have presented animal density as kg liveweight m^{-2} (Tarrant *et al* 1988) or m^2 400kg^{-1} liveweight (Bartussek 1999). Others have argued that liveweight might not be the best measurement for the size of the animals, and the height of the animals at the wither (Bogner 1982) and body surface area (Hurnik & Lewis 1991a,b) have been suggested as more descriptive criteria. Using body surface area gives young animals relatively more space kg^{-1} liveweight when compared with older and heavier animals, and as young animals are generally more active than older animals (Kerr & Wood-Gush 1987) this bias can be seen as a positive one. Following the same line of argument, bulls should be provided with more space than steers and heifers, as bulls usually show relatively more active behaviour and a need for a greater social distance (Hinch *et al* 1982; Tennessen *et al* 1985; Tarrant 1989).

Distribution of the measurements and animal welfare

Ingvartsen and Andersen (1993) concluded that bulls of 250–500 kg liveweight show diminishing positive responses in feed intake, growth rate and feed conversion rate, in response to a change in AD from 1.5 to 4.7 m^2 $animal^{-1}$. Some observations of the grazing behaviour of bulls and steers show that if space is abundant they will keep an AD of 300–400 m^2 $animal^{-1}$ (Hinch *et al* 1982) and dairy cows kept with two cubicles cow^{-1} make use of all the space with which they are provided (Wierenga *et al* 1985). Therefore, cattle might have a preference for considerably more space than 4.7 m^2 $animal^{-1}$, even though this would not affect food intake, growth rate or feed conversion rate.

The effect of pen shape

Several authors have pointed out that 'space' for an animal is not the same as 'area'. Cattle seem to prefer to make use of the perimeter of enclosures, rather than the central area (Stricklin *et al* 1979; Hinch *et al* 1982). Therefore, pen shapes maximizing the perimeter:area ratio might be preferable, taking into account other restraints on pen design. Also, the ratio between the number of animals and the number of pen corners might influence the individual space, measured as locomotor ability and the ability to retain a preferred social distance, as showed by simulation models (Zhou & Stricklin 1992; Stricklin *et al* 1995). Measurements such as pen perimeter, the number of corners or the diagonal distance of the pen could be important indicators in a welfare assessment.

Aggregation of AD measurements for welfare assessment

When AD for animals is summarized over a period (eg 1 year) important information on individual experiences is lost. First, AD may vary over time within the sample period. The weight-corrected AD would, for example, typically be higher late in a housing period than at its beginning as the calves and young stock gain weight during this time. Second, there may be differences in the average AD between individuals, despite being kept in the same housing system for the same period. Finally, individuals in the same group at the same time may experience a given AD differently because of factors such as dominance rank (Hasegawa *et al* 1997; Mogensen *et al* 1997a). Most methods of welfare assessment imply that greater suffering by a few animals can be outweighed by lesser suffering of the majority of the group. The same applies to the various experiences of individual animals over time; a very low degree of welfare during some periods can be compensated for by the animals experiencing a high degree of welfare during other periods.

Monitoring regrouping of young stock

Relationship between RG and animal welfare

The effect of RG on dairy cattle welfare has typically been estimated by mixing two groups of animals (eg Hasegawa *et al* [1997]), by introducing a small number of animals into an existing group (eg Krohn & Konggaard [1980]), or by observing the mixing of animals at abattoirs (Kenny & Tarrant 1987). In the succeeding days or weeks, data are collected on animal behaviour, production and, sometimes, on physiological stress responses (Brakel & Leis 1976; Friend *et al* 1977; Bouissou & Andrieu 1978; Krohn & Konggaard 1980; Martin 1981; Kondo *et al* 1984; Tennessen *et al* 1985; Kenny & Tarrant 1987; Kondo & Hurnik 1990; Mench *et al* 1990; Hasegawa *et al* 1997).

However, all these situations differ from the farm situation in that they involve only a single mixing and do not usually consider the experience of the animals prior to mixing. Young stock on a farm might be regrouped repeatedly at least in some periods, and they might be familiar with some of the 'guests'. Therefore, there is a need for a dynamic evaluation of the rate of RG at the farm level; an approach where the experiences of individual animals can be assessed. No reports on measurements of the rate/magnitude of RG at the farm level were found in the literature.

Most research on the regrouping of cattle deals with dairy cows. These results can, however, also be useful in determining the welfare impact for young stock. The effects reported in the literature are very variable, ranging from no effect at all to a prolonged one lasting more than 2 weeks. Table 1 summarizes the most important findings in the literature. Part of the explanation for the different results could be factors such as the prior social contact of the cows, previous milk yield, animal density and housing design.

Pen changes

It has been suggested that familiarity with the pen may give existing animals advantages over animals transported into the pen (Stricklin *et al* 1980) and much research supports this, although not always explicitly (Brackel & Leis 1976; Sowerby & Polan 1978; Krohn & Konggaard 1980; Stricklin *et al* 1980; Hasegawa *et al* 1997). The same phenomenon has been observed in pigs (Tan & Shackleton 1990). However, in most of these experiments various confounding variables complicate the interpretations. The 'guest group' is often smaller than the 'resident group' and in some instances the feed composition differs between the two environments. Only the results of Hasegawa *et al* (1997) are suitable for analysing the effect of pen familiarity. They found that while mixing had no effect on the resident animals, the transferred cows showed reduced milk yields and various behavioural responses.

Social bonds between the animals

When evaluating the effect of regrouping cattle, one important factor to consider is the prior social contact the animals have had with one another. Once constructed, social bonds between animals seem to be stable and long lasting and have been referred to as 'friendships' (Reinhardt & Reinhardt 1981).

Bouissou and Andrieu (1978) found that dairy heifers grouped at the ages of 6 and 12 months, and then regrouped 10 months later, showed less aggressive behaviour towards their former group members than towards members of other groups. The difference disappeared within 6 months. When comparing these results with a previous study, they found that

Table 1 Summary of experiments on the effect of regrouping on production, behaviour and physiology of cattle.

Method	Drop in milk yield	Behaviour	Physiology	Comment	Authors
4 cows moved into a group of 20 (repeated 5 times)	3% on day 1 for the transferred cows	Agonistic encounters were 3 times higher on day 1 than day 28 and were slightly elevated in weeks 1, 2 & 3		Low average milk yield	Brackel and Leis 1976
Exchange of 14 heifers between two groups of 23 & 28	Not significant in week 1; 4.7% in week 2 for transferred cows	Prolonged duration of standing; increased frequency of short lying bouts	Increased level of serum cortisol response to ACTH injection in dominant heifers on day 14	Agonistic behaviour was not recorded	Hasegawa *et al* 1997
Shift of 2–14% of milking cows from one group to another in 7 herds (6371 cow observations)	On average 2.28% from 2–3 days before to 2 days after mixing, with shifted cows showing 3 times more decline than non-shifted				Sowerby and Polan 1978
10 cows moved into each of 3 groups of 10		Alien cows received significantly more agonistic acts in the first month	Plasma cortisol levels increased until day 84 in most of the cows	Beef cows	Mench *et al* 1990
32 bulls and steers in groups of 8 were regrouped so that each animal was penned with 6 strangers and 1 acquaintance		High levels of agonistic behaviour on day 1, returning to baseline in 5–10 days			Tennessen *et al* 1985
a) 3 cows moved into a group of 12–14 (repeated 22 times) *b) 15 cows moved to a group of 100–110 (repeated 2 times)*	No effect on first lactation cows but 5–6 % reduction for older cows on day 1, and permanent reduction of 2–3 %	No change for older cows. First lactation cows showed reduction in total eating and lying time the first day On day 8 no difference was found			Krohn and Konggaard 1980
2 groups of 6 individually reared 5-month-old calves were formed		Aggressive behaviour stabilized within 7 days			Kondo *et al* 1984

heifers kept together from birth showed even less intra-group aggression; this effect lasted longer than 6 months and the heifers were more tolerant of former group members, even in a competitive food situation. Similarly, other researchers have noted selective social behaviour, and suggested that it might be due to animals being raised together (Hasegawa personal communication 1998). Non-related animals have been observed forming bonds of close inter-animal distance at grazing (Stricklin 1983; Kerr & Wood-Gush 1987) often lasting for many years (Reinhardt & Reinhardt 1981) and dominance relationships between dairy cows tend to remain stable for many years, once they have been formed (Wierenga 1990).

Application of RG measurements in welfare assessments

In conclusion, although many experiments show negative effects of mixing strange animals, or even animals with some prior social experience, very few researchers have tried to evaluate the importance of various confounding factors. Thus, little is known about the importance of prior social contact between the animals, pen familiarity or the effect of the number of animals mixed. Therefore, measurements of RG at the farm level should primarily be concerned with the frequency of changes in group composition, and only to a lesser extent with the magnitude of changes or pen changes.

Evaluation of the suggested indicators using observational data

A welfare assessment system was developed for dairy and pig farms as part of the *Development of an Ethical Account for Livestock Production* project (see Sandøe *et al* [1997] for details). For 18 months, the recording protocol included calves and young stock as well as cows. Technicians visited herds on 10 dairy farms and collected information on various parameters, at intervals of approximately 14 days (Johannesson *et al* 1997). Information on farm, date, pen number and animal identification were gathered in a database, allowing AD and RG to be evaluated at intervals of approximately 2 weeks.

Additional measurements on the animals were also evaluated as welfare indicators in the study. A veterinarian visited the farms every 3–4 months (altogether six times) and recorded the following clinical symptoms: body condition, respiratory diseases, skin lesions, arthritis, leg disorders, mange, diarrhoea (Bådsgård & Enevoldsen 1997; Bådsgård *et al* 1997). As a preliminary analysis did not show any effect of observation days, the data for the 6 observation days were pooled. The symptoms were originally rated by their severity, but in the current analysis the ratings have been reduced to dichotomous variables (no symptoms vs some symptoms). The farm data were used to calculate and compare different measurements used for evaluating the different measurements of AD and RG. Pens where the average age of the animals was less than 90 days were omitted from the analysis, as those calves were often housed with mother cows or in individual crates. Calculations of the frequency of regrouping are based only on those animals that were recorded more than 9 times, but for pen changes the minimum was set to 12 records. Table 2 summarizes some important aspects from the data recording on the 10 farms. Large differences in the ratio between young stock and milking cows are due to the fact that some of the farms fed bulls for meat production while others only raised heifers for recruiting to the dairy herd.

The liveweight (LW) of young stock was estimated from their age using the following linear relationship:

$$LW = AGE*0.650 + 42$$

where LW is measured in kg and age in days. Maximum weight was set to 600kg which is

Table 2 General aspects of the records from the 10 herds included in the current study 1996–97.

Herd[1]	No milking cows	Average yield (kg ECM[2])	Total no pens	No pens with fully slatted floors	No young stock[3]	No observations
D1	129	7248	6	0	121	1856
D2	37	6356	10	0	34	715
D3	84	8127	7	0	94	1591
M1	64	5847	11	0	64	793
M2	83	8342	18	0	84	1218
M3	64	7325	5	0	58	913
S1	74	6892	35	20	84	1242
S2	71	8622	28	21	115	2303
S3	90	8126	22	14	148	2630
S4	70	7976	14	7	87	1400

[1] D = deep-straw systems; M = mixed systems; S = fully slatted floor systems.
[2] ECM = energy corrected milk.
[3] The total number of young stock per farm on 1 January 1997.

close to the average weight for the dairy cows under consideration (Anonymous 1995). When correcting for the weight of the animals, an average weight of 375kg was used for presenting area animal^{-1} (AD_{375}).

Body surface area (BSA) was derived from the weight using the following correlation:

$$BSA = 0.12*LW^{0.6}$$

where BSA is the body surface area in m^2 and LW is measured in kg (Esmay 1978). AD corrected for BSA (AD_{BSA}) was then calculated as the total BSA of all the animals in a pen divided by the area of the pen, and presented as a percentage.

When AD_{375} was transformed to reflect the impact on the feed conversion ratio the following relationship, calculated by Ingvartsen and Andersen (1993) was used:

$$Y = (-0.83*AD_{375} + 0.092*AD_{375}^2 + 7.31)/0.0544$$

In the following analyses, the farms were divided into three categories by housing system: D = deep-straw pens; S = pens with fully slatted floors; and M = mixed systems.

Animal density

Corrections for the size of animals

When the AD of different-sized animals is compared, it must be corrected for their size. Figure 1 compares ADs derived from two methods for correcting AD for the size of growing animals with the uncorrected ADs.

The real figures for mean, standard deviation between the averages of individual animals and the standard deviation between single observations of the same animal are shown in Table 3. The standard deviation of the lifetime average for individual animals ($AD_{375}SD_{ani}$) is much higher than the standard deviation for single observations for the same animal ($AD_{375}SD_{obs}$). This indicates a systematic difference in AD between individual animals.

For 2 out of the 10 herds, the correction for liveweight and BSA meant that their relative rank was markedly changed. This outcome means that if AD is to be evaluated for the calves and young stock at a dairy farm as a whole, the results should be corrected for either weight or BSA. There was no major difference between the order of the farms depending on which

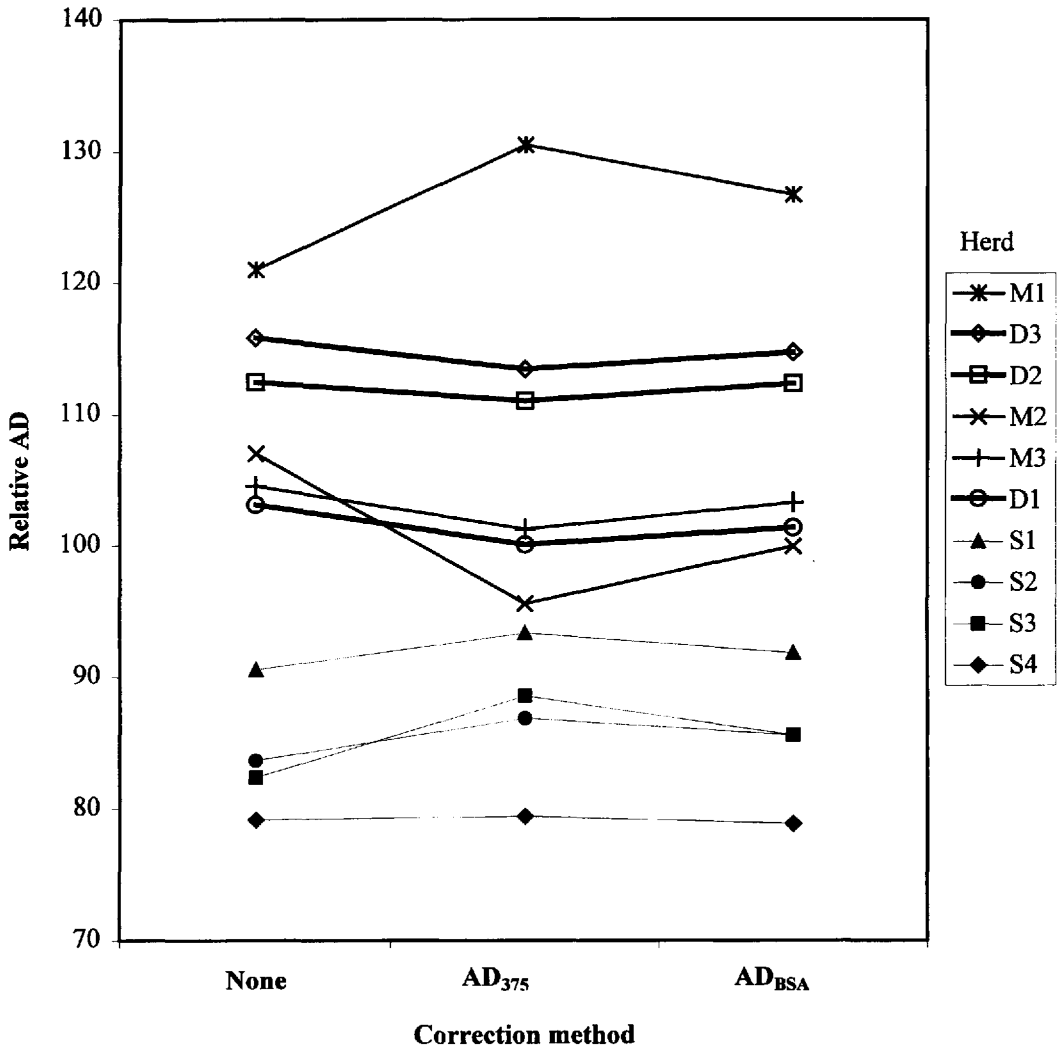


Figure 1 **Effect of methods for correcting AD for the size of the animals on the ranking of results from 10 dairy herds. All measurements are presented on the same scale with a mean of 100 and standard deviation of 15 units. (D – deep-straw pens; S – pens with fully slatted floors; M – mixed systems; AD_{375} – AD corrected for liveweight; AD_{BSA} – AD corrected for body surface area.)**

of the two corrections was used. The former has the apparent advantage that the outcome is presented in familiar units (m^2 adult $animal^{-1}$) while the latter is a relatively new idea which requires some explanation. Using AD_{BSA} gives smaller (more active) animals more space (Hurnik & Lewis 1991b) and is also favoured by its universality as the same criteria can be used for a range of farm animals (Hurnik & Lewis 1991a,b). These authors have recommended that a value of 50 per cent should be considered as the minimum area required for cattle (and pigs) and all the farms in the present study meet this criterion.

Table 3 **The means of different indicators of AD at herd level, and standard deviations between (AD_{375} SD_{ani}) and within ($AD_{375}SD_{obs}$) animals for the weight-corrected means. (AD – uncorrected animal density [m^2 $animal^{-1}$]; AD_{375} – corrected AD standardized for a mean liveweight of 375kg; AD_{BSA} – AD corrected for body surface area; $AD_{375}Y$ – AD corrected according to effect of feed conversion ratio; $AD_{375}log$ – AD corrected for liveweight by a log transformation before calculation of the means; $AD_{375}25th$ pctl – 25th percentile of AD. For other abbreviations see text or Table 2.)**

Herd	AD	AD_{375}	AD_{375} SD_{ani}	AD_{375} SD_{obs}	AD_{BSA} (%)[1]	AD_{375} Y	AD_{375} log	AD_{375} 25th pctl
D1	3.6	4.7	4.6	1.8	99	98	4.3	3.4
D2	4.3	5.8	7.1	2.2	122	99	5.3	4.4
D3	4.6	6.1	5.9	2.2	127	100	5.6	4.5
M1	5.0	8.0	12.8	2.7	152	100	6.8	5.4
M2	3.9	4.3	5.2	1.3	96	98	3.9	3.1
M3	3.7	4.8	3.1	1.0	103	100	4.7	3.9
S1	2.7	4.1	10.1	2.3	79	94	3.1	2.0
S2	2.1	3.4	4.8	1.0	66	95	3.0	2.5
S3	2.0	3.5	6.9	1.1	66	94	3.0	1.5
S4	1.8	2.7	3.4	1.0	52	92	2.4	1.6

[1] An AD_{BSA} of 100 per cent means that the area $animal^{-1}$ is the same as the total BSA.

Correction for high values of AD

As expected, large variations were found in the observed ADs: some observations were very high, exceeding $50m^2$ $animal^{-1}$. However, a diminishing positive effect of increased space allowance seems likely (Ingvartsen & Andersen 1993; Mogensen *et al* 1997a; Nielsen *et al* 1997) and, thus, it would be preferable to focus on situations with low values of AD. In Figure 2 and Table 3 three methods of correction for extremely high values of AD are shown and compared with AD only corrected for animal weight. The three methods are:

i) Transformation of AD_{375}, using formulae given by Ingvartsen and Andersen (1993; shown as 'Y' in Figure 2). This reduced the variation in the data and resulted in grouping of farms (and observations within a farm) close to the value of 100 and thus the distribution of observations became biased.
ii) A log transformation, which did not radically alter the results based on records from these 10 farms.
iii) Taking the 25th percentile of AD, which appeared to be a useful correction, maintaining the variation between farms and stressing the circumstances of the worst-placed animals.

Regrouping

Pen changes

The number of pen changes was calculated for animals that were in the system for at least 6 consecutive months. The average number of pen changes $year^{-1}$ along with 25th and 75th percentiles are shown in Figure 3. The highest mean value was 12.3 pen changes $year^{-1}$ while the lowest was 4.2.

The values in Figure 3 do not include instances where the animals were moved back into a pen in which they had previously stayed. The high rate at some of the farms is notable taking into account how little is known about how pen changes influence the welfare of the animals. The fact that there was no obvious correlation between housing system and the rate of pen changes indicates that the difference was due to different management strategies.

Changes in group composition

There are several ways to calculate the degree of group changes in a herd. Obviously, individual pens cannot be used as references as they are not static units; sometimes pens are joined or one pen may be split in two or replaced by a different type.

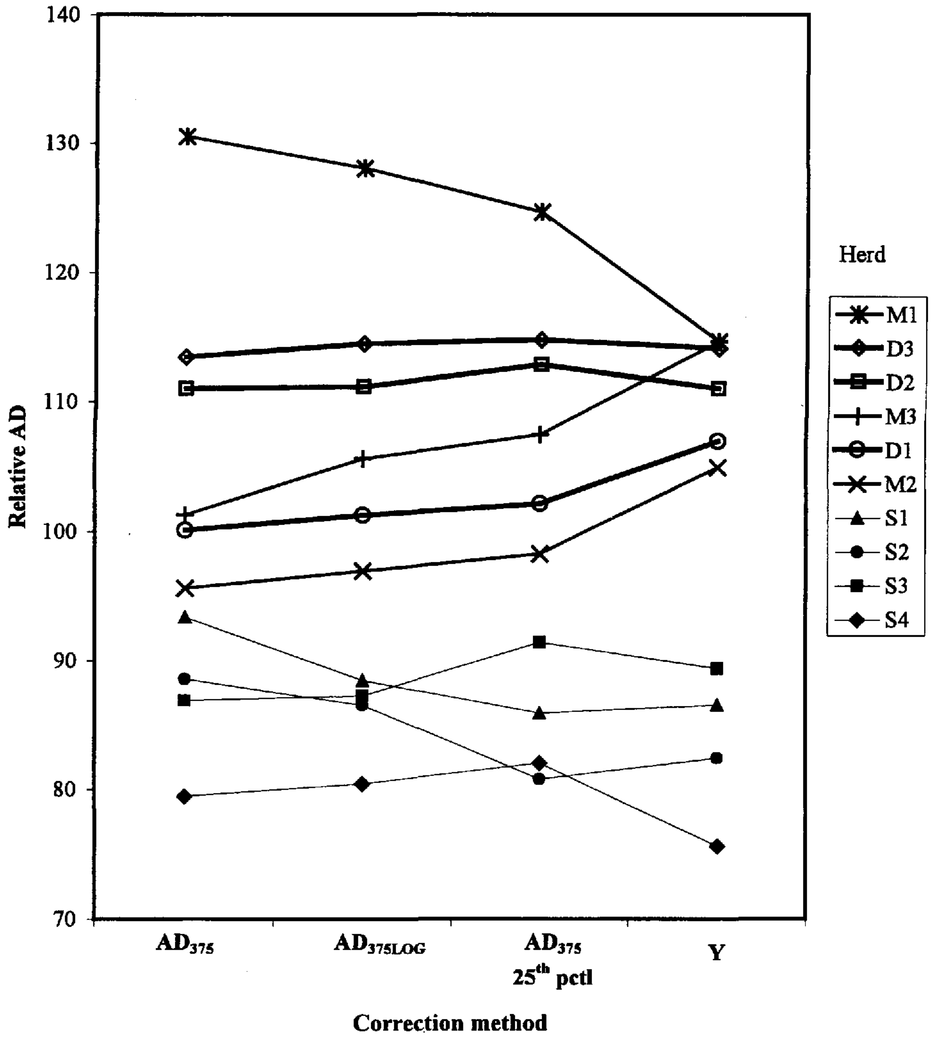


Figure 2 **Effect of methods for correcting very high observations of AD_{375} on ranking of results from 10 dairy herds. All measurements are presented on the same scale with a mean of 100 and standard deviation of 15 units. (AD_{375} – corrected AD standardized for a mean liveweight of 375kg; AD_{375}log – AD corrected for liveweight by a log transformation before calculation of the means; AD_{375}25th pctl – 25th percentile of AD; Y – AD_{375} corrected according to effect of feed conversion ratio. For other abbreviations see Figure 1.)**

We chose two main approaches. First, to select a group of representative animals and analyse their experiences over the whole 18 months of recording. Four indicators for the stability of the group were calculated:

i) The frequency of any change in group composition from one observation to another.
ii) The frequency of any change in group composition from one observation to any of the three following observations.
iii) The mean percentage of new animals in the group compared to the last observation.
iv) The frequency of combined group and pen changes.

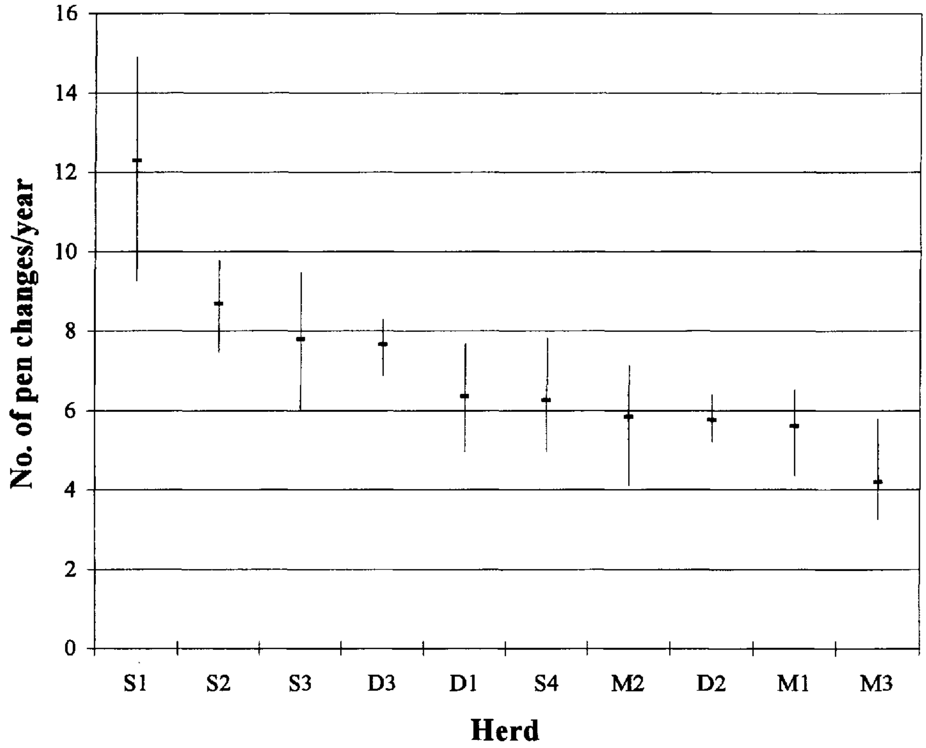


Figure 3 **Means, 25th and 75th percentiles for number of pen changes animal^{-1} year^{-1} in 10 dairy herds. (See Table 2 for abbreviations.)**

Indicators i) and ii) did not diverge significantly from each other, ie once two animals were moved apart they rarely met again within three observations (1.5 months). Consequently, only the first of the two indicators was used in the subsequent analysis. Figure 4 shows the results for indicators i), iii) and iv).

The average frequency of group changes ranged from 25 to 57 per cent of animal observations for the 10 herds. A frequency of 25 per cent meant that the animals, on average, experienced changes in group composition every fourth observation, ie every second month. It should be noted again that no distinction was made between various degrees of mixing, ie whether the group was identical except for one animal or completely different.

The magnitude or the degree of mixing is assumed to have an additional influence on the welfare of the animals, especially in larger groups. Figure 4 shows the average percentage of 'new' animals in the group, given that some change did occur. The degree of change varied from 43 to 72 per cent of the animals in any particular group. It would be logical to assume a negative correlation between the frequency and degree but such a relationship was absent in this sample.

The combination of changes in the composition of the group and pen changes occured in approximately 10 per cent of the observations in most of the farm herds. There were, however, two farms in which values exceeded 25 per cent. In herd S1 the animals changed pens almost as frequently as they changed pen mates. The combination of pen and group

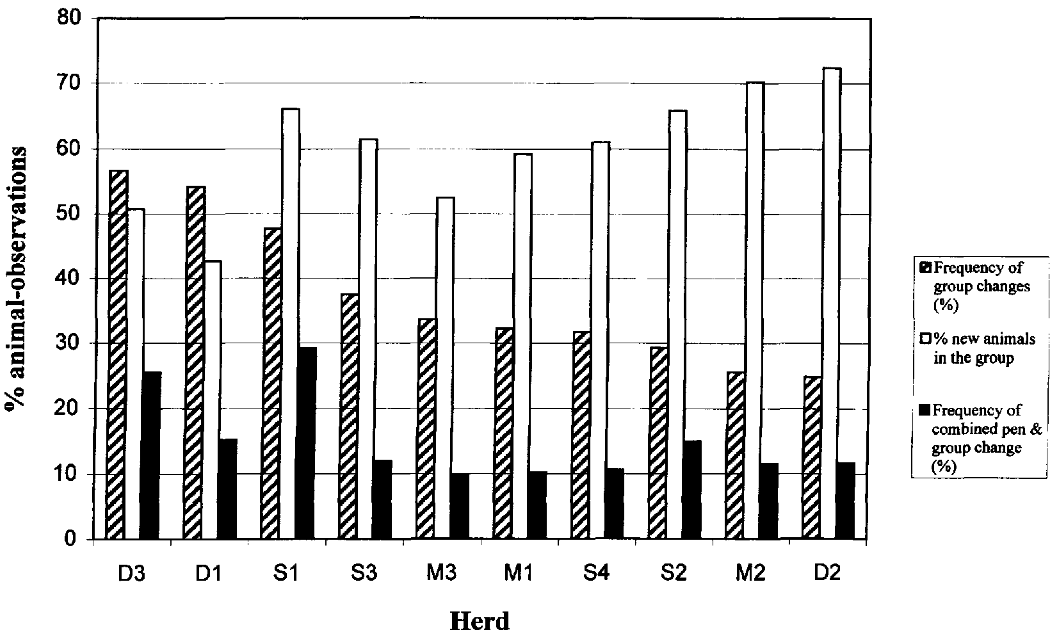


Figure 4 **Magnitude of group changes, frequency of group changes, and frequency of combined group and pen changes for 10 dairy herds. (See Figure 1 for abbreviations.)**

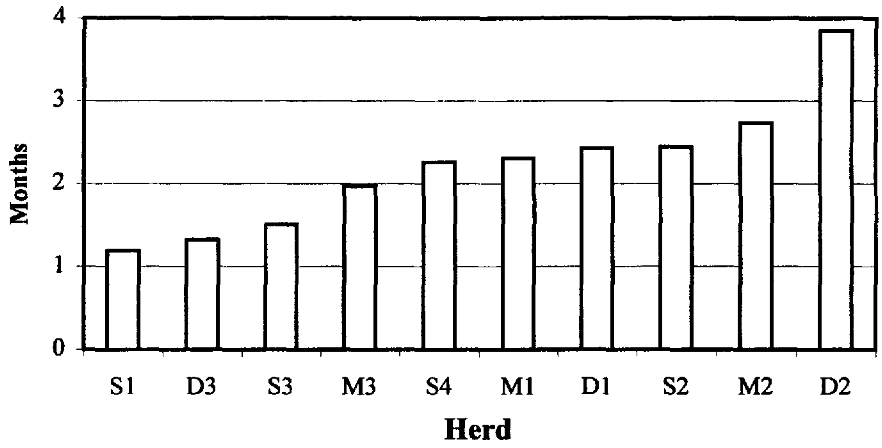
changes probably had a considerable impact on the welfare of the animals and we suggest that this measure would be the most interesting with regard to animal welfare issues.

The second approach we adopted for evaluating RG was to use the duration of inter-animal relationships as a measure of the stability of the groups. Starting when grazing animals were housed (1 November), all existing pairs of inter-animal relationships were mapped. These pairs were followed until they broke up. Then, the average length of the relationships was calculated for each farm. This parameter is prone to bias if the duration of the housing period varies between the farms. Therefore, the proportion of animal pairs terminated within 3 months was calculated. It can be argued that the housing period would not, in any case, be shorter than 3 months, given that it started close to 1 November.

Figures 5a and 5b show the average length of the relationships and the proportion of animal pairs that failed to last 3 months. Obviously, the general trend is the same, but there are some important differences between some of the farms. The reason is the different distribution patterns for the observations on individual farms. Herds S2 and S4, for example, have similar means for the length of inter-animal relationships. However, a plot of the distribution of the length of the relationships for the two farms shows two distinctive shapes (Figures 6 a and 6b).

Only 29 per cent of the relationships at farm S4 lasted longer than 3 months, while the corresponding figure for farm S2 was 42 per cent. Whether or not this finding should be interpreted as representing different regrouping strategies at the farms is unclear.

a)



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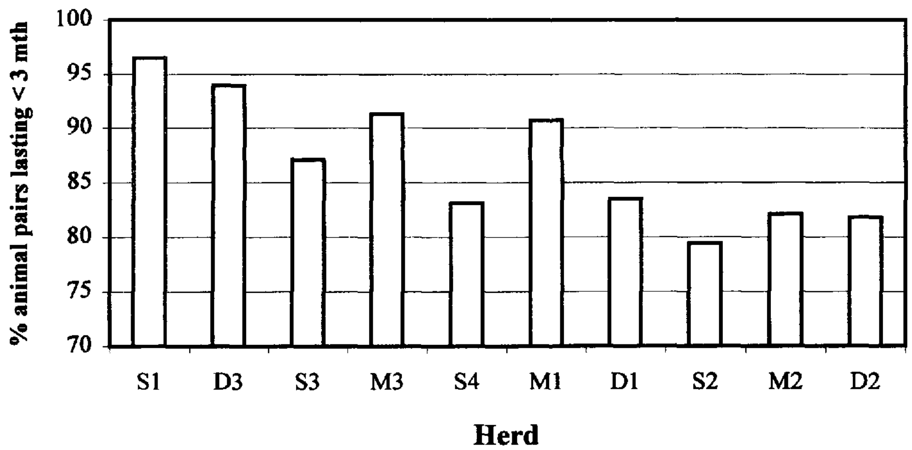

Figure 5 **Comparison of the ranking or the results for 10 dairy herds using: (a) the average length of inter-animal relationships; (b) the probability of relationships ending within six observations from 1 November. (See Figure 1 for abbreviations.)**

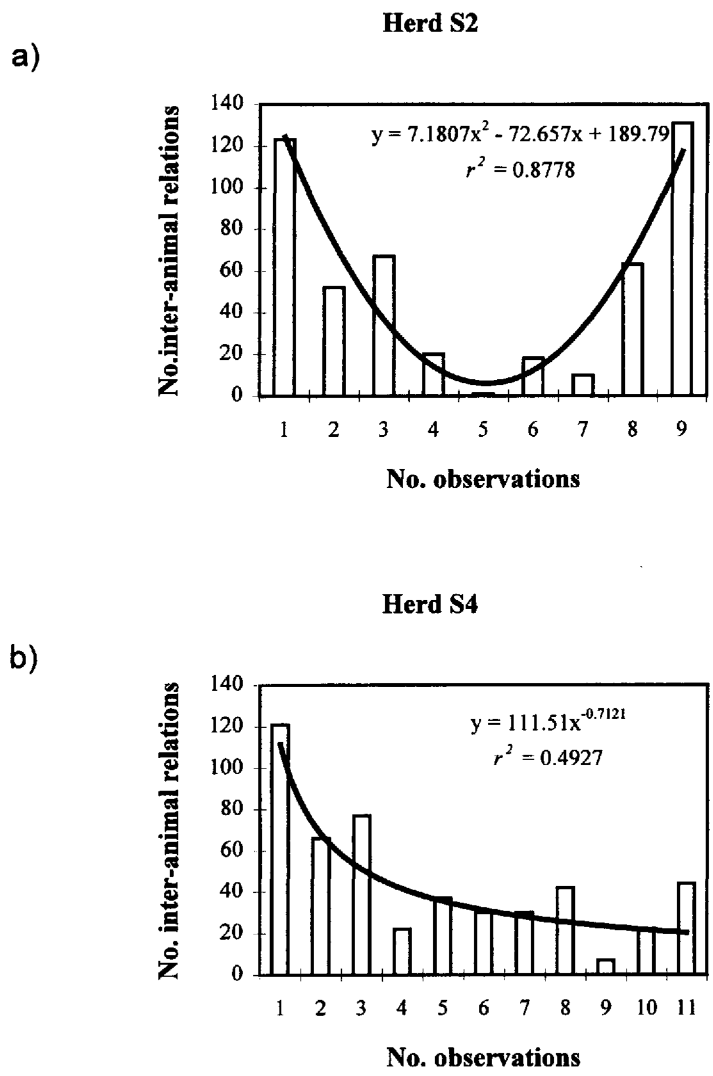

Figure 6 **Distribution graphs for the length of inter-animal relationships for two herds: (a) S2; (b) S4.**

Clinical findings

Table 4 shows the results from the clinical observations of the animals. Although 'skin lesions' should cover all types of skin lesion on the body, by far the most common location proved to be the neck region of the animals. This kind of skin lesion is usually caused by incorrectly designed feeding bars. Compared to the number of animals 'at risk', the number of observed symptoms was very low and a traditional correlation analysis performed with measurements of AD and RG was not informative. Instead, the total number of clinical signs (except 'skin lesions') per 100 animal observations was plotted against the 25th percentile of AD_{375} and RG respectively (Figures 7a and 7b). The figures indicate that there was no relationship between AD and clinical symptoms.

Table 4 Results of clinical observations on the animals. Total incidences of symptoms found in six visits. (For abbreviations see Table 2.)

Herd	No animal observations	Body condition	Skin lesions	Arthritis	Leg disorders	Mange	Respiratory symptoms	Diarrhoea
D1	730	3	47	0	0	0	0	0
D2	200	0	0	0	0	0	0	0
D3	560	3	0	0	0	0	0	0
M1	380	8	1	0	1	0	4	4
M2	500	5	6	0	1	1	1	0
M3	350	3	7	0	0	0	5	0
S1	440	1	0	1	2	8	0	0
S2	690	2	0	0	0	1	7	0
S3	890	0	0	0	0	0	5	0
S4	520	0	27	0	0	0	0	0

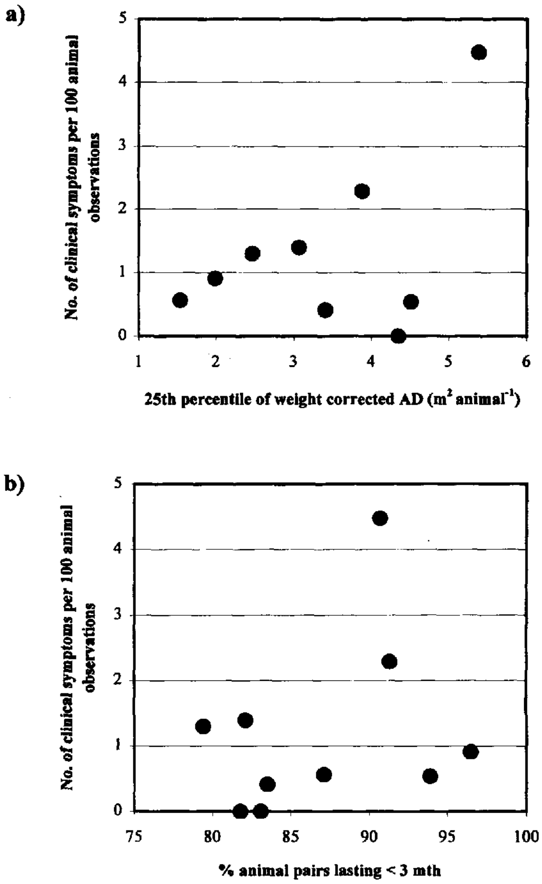

Figure 7 Relationship between clinical symptoms (total incidences of body condition, arthritis, leg disorders, mange, respiratory symptoms and diarrhoea per 100 animal observations) for the 10 herds in the study and: (a) AD_{375}25th percentile; (b) RG.

Discussion

This study demonstrates that both AD and RG should be used cautiously as welfare indicators for growing cattle because numerous confounding factors complicate interpretation of the results. The observational analysis showed that correction of AD for both liveweight of the animals and very high values of AD (abundant space) is preferable if the results are to be used in relation to animal welfare assessment. It is also important to keep in mind that the negative impact of crowding on animals is context-dependent, varying according to the time of day, and the activities in which the animals are engaged. Baxter (1985) suggested that certain forms of aggressive behaviour in pigs required a large amount of space – and if the pigs were not able to perform these behaviours it would result in a less stable social hierarchy and more general aggression in the group. Hinch *et al* (1982) found that grazing bulls and steers keep greater inter-animal distances during some parts of the day than others. In addition, how animals experience their situation is almost certainly influenced by a range of other factors such as the shape and interior of their pens as well as the social structure of the group.

The large within-farm variation for the average AD of individual animals compared to the variation over time for a certain animal (see Table 3) has some ethical implications. We typically use the annual average for the farm to represent the well-being of the herd. In so doing, we implicitly assume that the negative experience of one animal can be outweighed by the positive experience of another. This problem is well known and widely discussed among philosophers (see, for example, Rawls [1971]; Prafit [1984]). Using the 25th (or similar) percentile of AD ensures that the interests of the worst-placed animals are not dismissed even though other animals in the herd might fare far better. Variations within the chosen percentile would, of course, still be disregarded; a fact that should be kept in mind when the results are interpreted.

It is not possible on the available evidence to conclude whether the frequency or the degree of RG is the most important parameter, when the effects of RG on animal welfare are to be considered. There are results suggesting that prior social contact of the mixed animals does ease the mixing (Bouissou & Andrieu 1978) but other observations indicate that this relationship might not be that simple (Sowerby & Polan 1978; Kroff 1996; Hasegawa personal communication 1998).

The observational data indicated that inclusion of prior social contact does not appreciably affect the ranking of the farms. Consequently, we suggest that this factor is not suitable for assessing animal welfare at farm level. The most attractive indicator for RG seems to be the probability of a certain duration of inter-animal relationships, measured from the first day of housing (or any comparable date). This measure combines to a certain degree the frequency and magnitude of regrouping, but is easier to calculate, and requires less explanation than the other indicators. However, further observational data are needed to determine which of the mentioned parameters would be preferable as welfare indicators.

No correlation was found between the clinical observations and AD or RG. This implies that clinical records of this kind are a valuable addition to observations of AD and RG, and should be viewed as essential for any farm-level welfare assessment. Furthermore, these results emphasize their importance for the development of a suitable animal-based parameter supporting general measurements of AD and RG.

Animal welfare implications

Having tested the different measures of AD and RG on data from herds on 10 farms, we suggest an appropriate application of these parameters. The implications for animal welfare are improved assessment of the social environment at farm level, specifically as regards the regrouping of animals. AD and RG are among the few parameters capable of describing the social environment of young stock dairy cattle and it is, therefore, very important that they are used effectively and correctly.

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