Key note address:

Management stress in reindeer

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Abstract: The general mechanism and biological effects of stress are dealt with. Investigations performed on semidomesticated reindeer concerning the stress response under different herding and management conditions are presented and discussed.

The findings indicate that:

Reindeer are susceptible to management stress and that their degree of tameness plays an important role in the development of stress lesions such as muscular and myocardial degeneration and abomasal haemorrhages, etc.

The animals are not favoured by rests between events of stress exposure as the effects produced tend to be cumulative.

Depletion of muscular glycogen stores, increased catabolism of muscular protein, muscular degeneration and increased blood-urea levels can not be excluded as a cause of an altered and bad taste of the meat, i.e. a bad meat quality.

Thus prolonged and repeated manual handling and transportation of live animals should be avoided. The use of helicopters or other motor vehicles must be correlated to the tameness of the animals and to environmental conditions.

Stress due to incorrect management methods may, by means of stress induced lesions, severly affect the productivity of reindeer.

Key words: stress lesions, meat quality

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Introduction

During many years of work with reindeer under different circumstances, I was taught by several very experienced herdsmen the importance of careful handling of the animals. When selecting for slaughter these herdsmen were experts in "reading the behaviour" of reindeer, picking out animals with abnormal breathing, movements, etc. I also learned the importance of careful handling and early slaughter of animals intended for consumption, in order to obtain the best meat quality. (Hanssen et al 1984). Obviously, the best meat is obtained from animals shot with a rifle when grazing or resting, i.e. totally undisturbed. It was also obvious that harsh and rough treatment under unsuitable conditions, such as gatherings during hot sunny summer days could be fatal, first of all for young animals and calves. In fact, the combined effects of heat, insect harassment and gatherings seem to be able to contribute to a considerable calf mortality (Rehbinder 1975). Today, the demands of rationalization are valid also for the reindeer industry. The "old methods" of intensive herding and relatively tame animals are not practiced any more but have been replaced by an extensive herding of semidomesticated or almost wild animals, and the use of modern equipment such as motorcycles, snow mobiles, lorries for transports, etc.

The objective of this report has been to compare some common knowledge of the effects of stress in animals with results obtained from four different investigations concerning management stress in reindeer.

What is stress and how does it affect the organism?

According to Selye (1956, 1974) stress is the nonspecific response of the body to any demand upon it. The exposure to different stressors is, as such, not harmful and not producing disease. Stress becomes harmful to the body when the normal level of resistance is exceeded by any stimulus or succession of stimuli of such magnitude as to tend to disrupt the homeostasis of the organism. Thus, a stage of exhaustion is initiated when the capacity to adapt to the sum of all nonspecific systemic reactions of the body, is exceeded, which ensue upon long-continued exposure to systematic stress. This has been known as the General Adaption Syndrome of Selye (loc cit) and points out that the body's adaptability is finite. Hence, when mechanisms of adjustment fail or become disproportionate or incoordinate, the stress may be considered an injury, resulting in disease, disability, or death.

Selye's concept of the non- specific stress response has later on been refuted. It is now widely accepted that there are unique but different endocrine responses to different physical, chemical, and psychological stress factors (Mason 1968, Dantzer and Mormide 1988, Griffin 1989). The effect of stress may be influenced by the severity of the stressor the time during which it is applied (acute vs chronic) or whether there is a possibility to escape the stressor or not or if it is applied repeatedly (escapable vs inescapable, Griffin 1989). Any external stimulus that challenges homeostasis can be viewed as a stressor and the changes in biological function which occur as attempts to maintain homeostasis consitute the stress response (Moberg 1985). Capture of wild animals, restraint and transport of wild or semidomesticated as well as domesticated animals may consitute considerable stress factors to which the animals can adapt with difficulties only or not at all. Failure of the animal to express the flight-fight response results in the expression of ange or rage, and if the stimulus persists, in frustration or helpless. (Griffin 1989).

In man and animals with a highly developed nervous system, emotional stimuli are in fact the most common and important stressors (Levi 1967, Seley 1974, Stephens 1980, Becker 1987).

Animals have a genetically determined behaviour which includes defense mechanisms and warning signals (Fabricius 1973). Animals do also have space requirements which are depending upon many factors such as living habits, size, species, strain, etc. The space requirements may be divided into zones or distances of different size (Fox 1974, Fig 1). When humans or animals regarded as a threat, enter into the different zones, the response elicited may vary from alertness, over anxiety and distress to fear, depending on how close the threat comes. Approach or intrusion within the flight distance will provoke anxiety and/or distress, and the animal will flee in order to try to keep or regain the flight distance. An intrusion into the personal or critical distance will make the animal frightened and it will, if proximity becomes intolerable, make all efforts to escape, and if necessary, it will attack and fight.

The size of the zones and the lenght of the

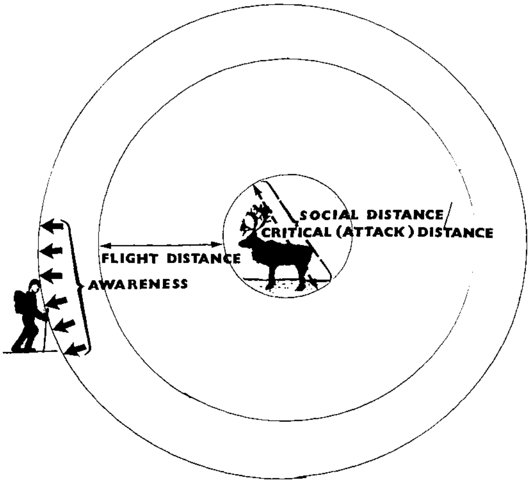

Fig.1. Animal's space zones. Approximate concentric zones in the spatial world of a reindeer are arbitrarily depicted (Adapted from MW FOX, Envir. Var.Anim. Exp., H. Magalhaes, ed., 1974).

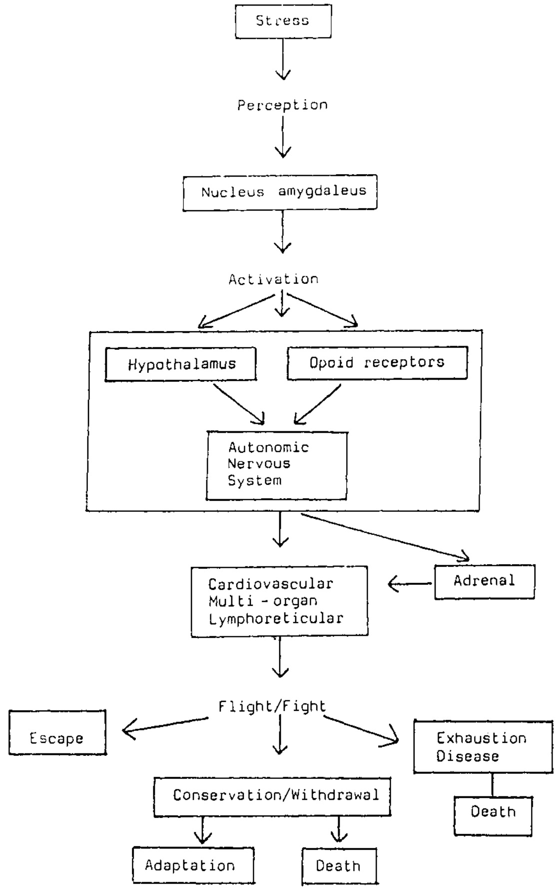

Fig. 2. Sympathetic adreno-medullary response to stress.

distances, however, are depending upon the tameness of the animal. Socialization of animals with man not only facilitates handling but also increases tolerance to proximity. Tame, socialized species do even seek human contact. Tameness also eliminates the flight response and defensive aggression so characteristic of wild non-socialized animals (Fox loc cit).

There are two major pathways for the effect of stressors on the individual; the sympathetic - adrenomedullary response to stress (Fig 2) and the hypothalmic-pituitary-adrenal response to stress (Fig 3).

The sympathetic-adrenomedullary response is an immediate response to cognitive stimuli resulting in a direct flight or fight situation, caused by a stimulation of the autonomic nervous system.

The somatic response to the catecholamines released is characterized by increased cardiovascular function and metabolism, vasoconstriction and splenic contration (Axelrod and Reisine 1984).

The flight-fight system mediates the active response whereby the animal struggles to escape from an external danger. The conservation - withdrawal system comes into play when the active response is fruitless, and it serves to conserve energy and reduce contact with the environment (Engel 1967). The hypothalamic-pituitary-adrenal response is a slow response to stress. Failure of the sympathetic-adrenomendullary system to resolve stress leads to the activation of the hypothalmic- pituitary-adrenocortical response which is manifest behaviourally by the conservation-withdrawal reaction and displacement activities (Stephens 1980, Griffin 1989). The persistence of the hypothalamic-pituitary-adrenocortical activation will

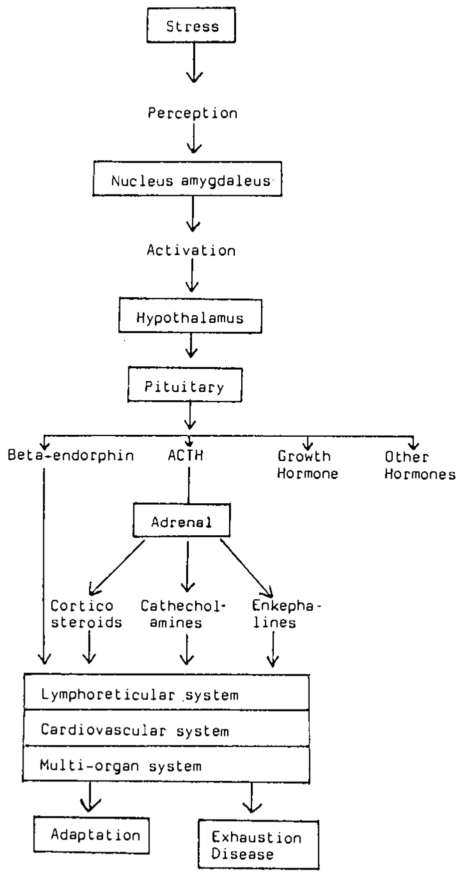

Fig. 3. Hypothalmic - pituitary - adrenal (HPA) response to stress.

produce prepathological or pathological changes (Kagan & Levi 1974) and may cause the death of the subject (V. Holst 1985).

To develop a stress response the animal must be able to identify the external stimuli which represents a threat to its homeostasis, and then when appropriate, make those adjustments in its biological balance which will provide the best biological defense against the threat. Perception of an external threat, whether a change in temperature, a social conflict or the experience of pain is thus of crucial importance, considering the fact that the first controlling component of an animal's response to an external event is the manner in which the animal perceives a stimulus (Moberg 1985). Experience of different factors and situations plays an important role in the response of the animal to a stressor.

When wild or semidomesticated animals are captured, restrained, and immobilized, this is a very definite intrusion into their personal distances and produces a severe emotional stress response. The animals may then behave differently. Some may fight desperately trying to escape, while others may exhibit different displacement activities. The latter animals may act as if they had surrendered, accepting the situation, while others may show other and more obvious kinds of abnormal behaviour, such as biting themselves, gasping, etc. Neverthenless, animals that seem to adapt to the situation may thus suffer from severe emotional stress. Immobilization is in fact a common and effective method to produce gastric stress ulcers, and there is a progressive increase in the incidence of lesions correlated to the duration of immobilization (Brodie 1963, Ader 1971). Servere, prolonged and repeated stress exposures may also produce muscle degeneration (Bartsch *et al.* 1977) and myocardinal degeneration (Jönsson & Johansson 1974) and a number of other important physiological changes (Harthoorn 1977). By amygdalectomy, Johansson et al (1982) demonstrated the importance of the amygdaloid part of the limbic and the sympathetic-adreno- medullary system. Hence, by preventing the animal's conception of fear, by amygdalectomy, the production of restraint-stress induced lesions was prevented. In laboratory animals it is found that even minor changes in the environment may affect several physiological parameters (Gärtner *et al.* 1980) but also that warning signals sound and smell, may produce a considerable state of emotional stress (Sadjak *et al.* 1983). Thus situations thought to be fearsome, i.e. intrusions wihtin defence distances, warning signals, restraint situations, transports, etc are all considerable stress factors.

It is obvious that rationalization and the changes in herding methods it produces are connected with several factors causing stress in reindeer. Therefore, the investigations carried out by us were initiated in order to study the influence of different factors such as handling, transports, herding conditions, tameness, ect, on the stress response of extensively herded, semidomesticated animals.

Own investigations

I. Influence of stress on some blood constituents in reindeer (Rangifer tarandus L) (Rebbinder & Edquist 1981).

Blood samples from 3 different groups of animals were compared. The first group consisted of 10 animals; 6 bulls (3-5 years), 2 females (2 and 4 years); and 2 calves (1 female and 1 male). They were killed, by means of a rifle-shot in the head, when resting or grazing. These animals were considered an undisturbed control group.

The second group consisted of 5 female reindeer (1-4 years and 1 calf) kept for experimental purposes in a corral. These animals were confined during feeding. After the initial sampling they were released into the corral and kept moving during a 2 hour period, whereafter they were recaptured with a lasso for final sampling.

The third group consisted of 10 animals selected at a slaughter event; 4 bulls (2-7 years), 3 females (3-7 years) and 3 calves (2 females and 1 male). The animals had been subjected to one day of gathering and herding into a large grazing corral where they rested during the night. The next day they were driven into a small (60 cm in diameter) selection corral where they were captured with a loop on a pole and put into a small pen from where they were taken out by hand and slaughtered.

The blood picutre of the shot, unstressed animals (Group I) appeared different from that of the groups subjected to different kinds of stress (Fig. 4). In the unstressed animals the blood leucocyte composition was found to be comparable to normal values ofidomestic ruminants (Schalm *et al.* 1975).

In the experimental animals (Group IIa captured and sampled and Group IIb recaptured with lasso and sampled after being kept

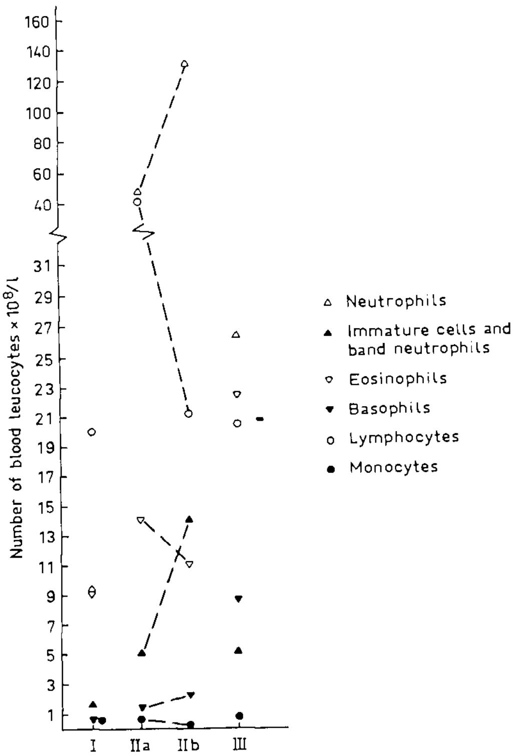

Fig. 4. Mean values of number of blood leucocytes in unstressed and stressed reindeer.
I = Unstressed animals: Group I
IIa = Experimental animals: Group IIa. Captured by hand and sampled animals.
IIb = Experimental animals: Group IIb. Animals recaptured by means of lasso and sampled after being persued, kept moving, during 2 hours.
III = Reindeer exposed to management stress. Group III. Samples obtained at slaughter event.

moving, during 2 hours) there was seen a marked increase of segmented neutrophils, band neutrophils, and immature cells. The changes were still more pronounced at the second sampling with an obvious decrease in the number of lymphocytes and eosinophils. In the group of slaughter animals (Group III) the same values were found as for the experimental animals except for very high values of eosinophils, reflecting a heavy burden of endo- and ectoparasites. Of the noncellular constituents,

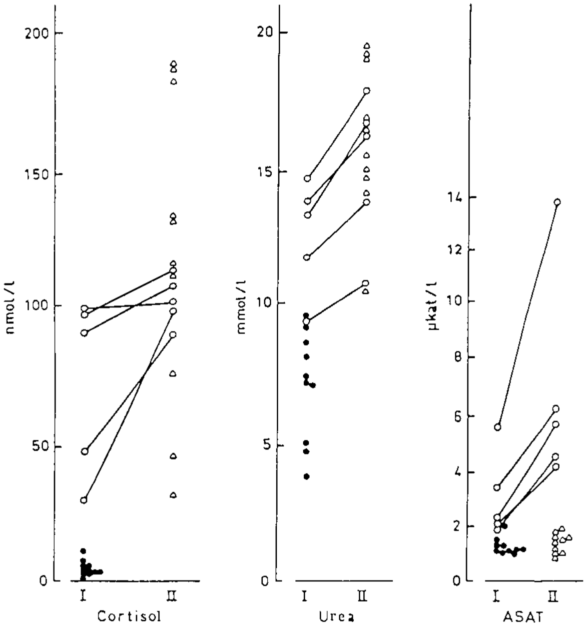

Fig.5. Cortisol, urea and ASAT values in stressed and unstressed reindeer.

marked differences were noticed between unstressed an stressed animals in the levels of cortisol and urea. In addition, a pronounced increase between samplings was found in Group II concerning ASAT, (Fig. 5). All animals in the study were exposed to a low level of physical stress. The major stress event was mental stress, obviously due to the manual handling as such.

II. Skeletal muscle characteristics of reindeer (Rangifer tarandus L.) (Essén-Gustavsson & Rehbinder 1985).

Fiber type composition, fibre areas, capillaries, enzyme activities, and intramuscular substrates were analysed in skeletal muscle samples (triceps, gluteus, semitendinousus, and longissimus dorsi). Two eleven-month-old reindeer, one male and one female, were used in the study. The animals were killed by means of a rifle-shot in the brain when resting or ruminating. These animals also served as controls for a similar investigation on animals exposed to stress. Muscle samples were obtained within 10 min. of death. The samples were immediately frozen in liquid nitrogen. The muscles were analysed for fibre composition, fibre areas, capillaries, enzyme activities (citrate synthase, CS), 3-OH-acylCoA dehydrogenase (HAD), lactate dehydrogenase (LDH), triose phosphate dehydrogenase (TPHD), glycogen, and triglyceride levels.

The muscles contained 10-20% Type I fibres (slow twitch fibres). The percentage of Type IIB fibres (40-60%) was higher than the percentage of Type IIA fibres (20-40%). All fibre types revealed medium or dark staining intensity for oxidative capacity. Glycolytic capacity was greatest in Type IIB fibres. All fibres stained for glycogen, while Type I and IIA fibres stained for lipids.

The mean number of capillaries in contact with fibres of each type, relative to fibre type, were high in all muscle types. The metabolic profile of reindeer muscle indicates that energy to a great extent is produced via oxidative pathways, and that both carbohydrates and lipids are important for energy production.

III. The influence of stress on substrate utilization in skeletal muscle fibres of reindeer (Rangifer tarandus L) (Essén-Gustavsson & Rehbinder 1984).

The same animals as in Investigation I were used and the same investigations as in Investigation II were performed. The animals of Investigation II served as controls. It was found that even moderate stress in connection with handling, sampling, and herding caused a very pronounced depletion of glycogen in mainly II A and II B fibres (Table 1) as compared to the control animals. Type II B fibres are fast-fatiguable and largely involved in maximal efforts (Burke *et al.* 1973), providing high speed and thus part of flight behaviour. Also, intramuscular triglyceride levels decreased, but mainly so in type I fibres. Muscle lactate levels increased in all animals. Reindeer muscles appear to have a great capacity to oxidize both car-

Table 1. Glycogen in the semitendinosus of stressed and unstressed reindeer. A = initial samplings. B = final sampling. Controls were killed by means of a rifleshot in the head.

Groups	Animal No	Glycogen /μmol/g A	B
Experimental animals	Calf	174	164
	759	217	155
	758	256	187
	52	120	32
	994	17	15
Controls	106	523	
	184	464	

bohydrates and lipids.

The experimental animals, as compared to the controls, showed increased cortisol, ASAT, und urea-values (Table 2).

IV: A field study of management stress in reindeer (Rangifer tarandus L), (Rehbinder, Edquist, Lundström & Villafané 1982).

The objectives of the investigation were to perform a field study of the pathological and haematological responses in different reindeer herds subjected to different management methods.

The investigated herds were:

A. ÖSTRA KIKKIJAURE (22. Aug.): Ten animals were killed, resting or grazing in the forest, by means of a rifle-shot in the head. These animals were considered as unstressed controls and served as such also in the previous investigation A.

B. ROMPERHEDEN (22. Jan.): About 1800 animals were herded into a large grazing corral of about 1,5 km^2. The animals were gathered by men on snowmobiles and on skis. The following day the herd was driven into an ordinary corral. (Romperheden, Fig. 6:1), using the same method. The herd was very calm. Parts of the herd where driven into a selection corral were those to be slaughtered were picked out and lassoed, dragged out of the corral and stunned. The remaining animals were let out into a smaller grazing corral.

C. ROMPERHEDEN (23. Jan.): The same herd as for B had been kept overnight in a small (0,25 km^2) grazing corral. In the morning the animals were driven by herdsmen in skis and by snowmobile back into the ordinary corral. This time the animals were rather reluctant to enter the corral. The average drive distance of less than 1 km took about 40 min. Most of the snow was trampled into a dry slush and did not hinder the movements of the animals. Selection for slaughter was done in the same way as on the previous day (see B).

Table 2. Cortisol, ASAT and urea levels in the blood of stressed and unstressed reindeer. A = initial sampling. B = final sampling. Controls were killed by means of a rifleshot in the head.

Groups	Animal no	Cortisol nmol/l		Asat μkat/l		Urea μ/nmol/l	
		A	B	A	B	A	B
Experimental animals	Calf	90	106	2,3	5,7	13,4	16,8
	759	30	97	1,9	4,5	9,3	10,7
	758	48	89	2,1	4,2	11,7	13,9
	52	99	100	3,4	6,2	13,9	16,3
	994	97	112	5,6	13,8	14,8	17,9
Controls	106	15	—	1,9	—	5,2	—
	184	2	—	1,2	—	5,1	—

Plate 1. Animals of herd B inside the corral. The animals are seized with panic. The picture is taken 1 hour after the animals entered the corral, but they are still running senselessly. Photo C. Rehbinder.

D. BRÄNDVALLEN (31. Jan.): Around 3000 animals of a mountain herd were grazing in the forest not far from the corral. They had been gathered 3-4 days earlier by snowmobile borne herdsmen. On Jan. 31, about 1200 of these animals were driven into a corral by means of a helicopter and, at the end of the drive, by snowmobiles. The average herding distances was approximately 3-4 km. During the drive the animals were obviously seized with a panicky fear of the helicopter, but were prevented from escaping or stampede by a thick snow cover. The drive took nearly 2,5 hours. Inside the corral the animals continued to run and most of them never calmed down (Plate 1, Fig. 6:2). Six animals were found dead or dying. After about 1 hour in the corral, parts of the herd were driven into a small selection corral, 15 m in diameter, where the animals were captured by hand (Plate 2). Those picked out for slaughter were put into a rectangular pen (Fig. 6:2) from which they were taken by hand for slaughter, or driven into lorries for transport to a slaughter-place (Brändåsen), 71 km away.

Several persons stood around and inside the selection corral. Most of the animals inside the selection corral and pen were seized with fear and panic and showed abnormal behaviour such as hyperactivity, attempts to escape by jumping the fences, aggressiveness, but also lethargy.

Plate 2. Reindeer dragged out of the corral after being selected for slaughter. A typical example of restraint stress added to other stress events. Photo C. Rehbinder.

About 4 hours after the start of the drive the first slaughters took place. No other than animals slaughtered at the corral were examined.

E. BRÄNDVALLEN-BRÄNDÅSEN (1. Feb.): Out of the same main herd (D) around 1800 animals were driven by helicopter and snowmobiles to the corral. This means that a mixture of animals that had and had not been in the corral the day before was driven for selection. The drive by helicopter lasted around 2,5 hours. The animals showed similar signs of panic as in the day before. Animals for slaughter were selected in the same way, but only animals transported by lorries to the slaughterplace at Brändåsen were examined. The transport distance was 71 km and took, on an average, 1,5 hours. The unloading took about 30 min. The animals were let out into a small corral (Fig. 6:3). From there they were taken out by hand for slaughter.

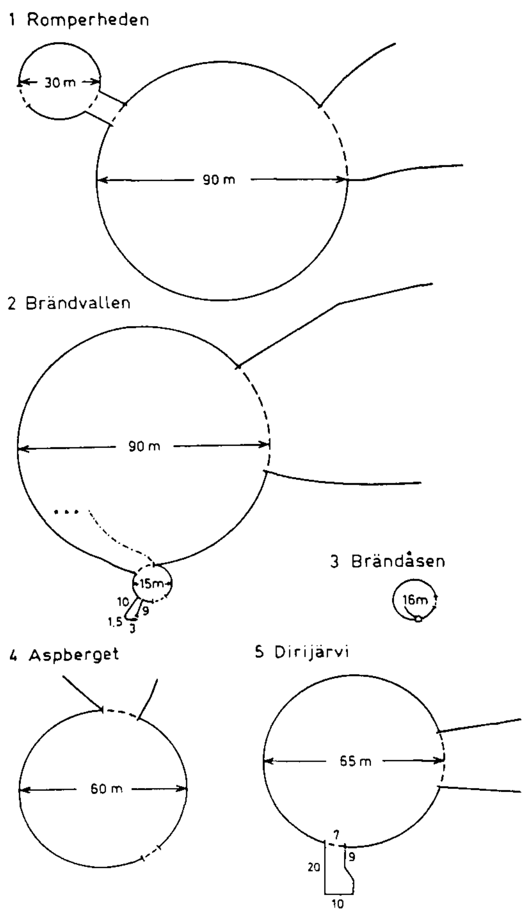

Fig. 6. The construction and shape of the corrals used for the different herds investigated.

F. BRÄNDÅSEN (2. Febr.): The reindeer examined were the last to be brought in by lorry around midnight the day before. These animals had been allowed to rest during the night in the small corral at the slaughterplace (Fig. 6:3) and reindeer had been exposed to handling for more than 24 hours including the overnight stay in the corral.

G. MAUSJAURE (2. July): A herd of around 400 animals was driven into a corral for calf marking. Blood samples were drawn from 10 herded by herdsmen on foot.

H. ÅNGSÅ (19. Sept.): A small herd of around 300 animals was scattered in the forest. An attempt to herd them into a corral had failed in the morning. Instead, a few bulls were killed by a rifle-shot in the neck after the animals had been cautiously driven out of the forest by slowly walking herdsmen.

I. ASPBERGET (19. Sept.): Around 300 animals were herded into a small corral (Fig. 6:4) during a period of around 4 hours. Slaughtering started at once. The animals were lassoed, taken out of the corral, and slaughtered.

J.DIRIJÄRVI (20. Sept.): A herd of about 300 animals had been herded into a large grazing corral on September 18. The following day an additional 400 animals were driven into the same grazing corral. On September 20 the animals were driven into the ordinary corral (Fig. 6:5). The handling was calm. The animals were lassoed and put into a pen from which they were taken out by hand or by lasso, dragged out and killed. Numerous spectators, herdsmen, ect, stood around the slaughterplace and pen, and also inside the corral and the pen.

At slaughter, macroscopical inspection of carcasses and viscera was undertaken. From randomly chosen animals, blood samples were taken and material for histopathological examination was taken from M.semitendinosus, M.longissimus dorsi, myocardium, liver, kidney and abomasum. The gross examination of slaughtered animals revealed a major patho-

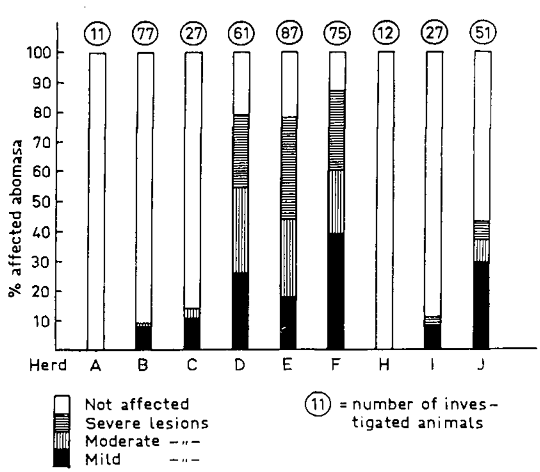

Fig. 7. Distribution of abomasal lesions

logical finding to be haemorrhages in the abomasa (Plate 3). These lesions were classified as mild, moderate, or severe according to their appearance in size and number (Fig. 7). Haemorrhages were found in the abomasa of animals from all herds except A and H. They were fewest in herds B, C, and I, while herd J had more than these, but fewer than herds D, E, and F. It should be noted that haemorrhages were present in the material even as early as only within 4 hours of handling and herding (Plate 3).

Microscopically, most of the lesions consisted of a local mucosal haemorrhage, oedema, and constriction of submucosal vessels. These changes varied from minor mucosal haemorrhages to severe haemorrhages, coagulative necrosis and submucosal haemorrhages (Plate 4). Ulcers penetrating to the submucosa were not found. A marked inflammatory reaction with infiltration mainly of neutrophils was present in cases of more pronounced mucosal lesions.

Lesions in the skeletal muscles and myocardium were not observed at the gross examination. The histopathological examination of muscular

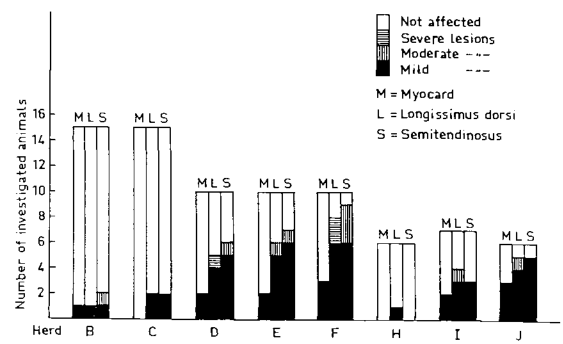

Fig. 8. Distribution of degenerative muscular lesions

Plate 3. Abomasum with several mucosal haemorrhages. The animal was slaughtered 4 hours after the beginning of a helicopter drive. Photo C. Rehbinder.

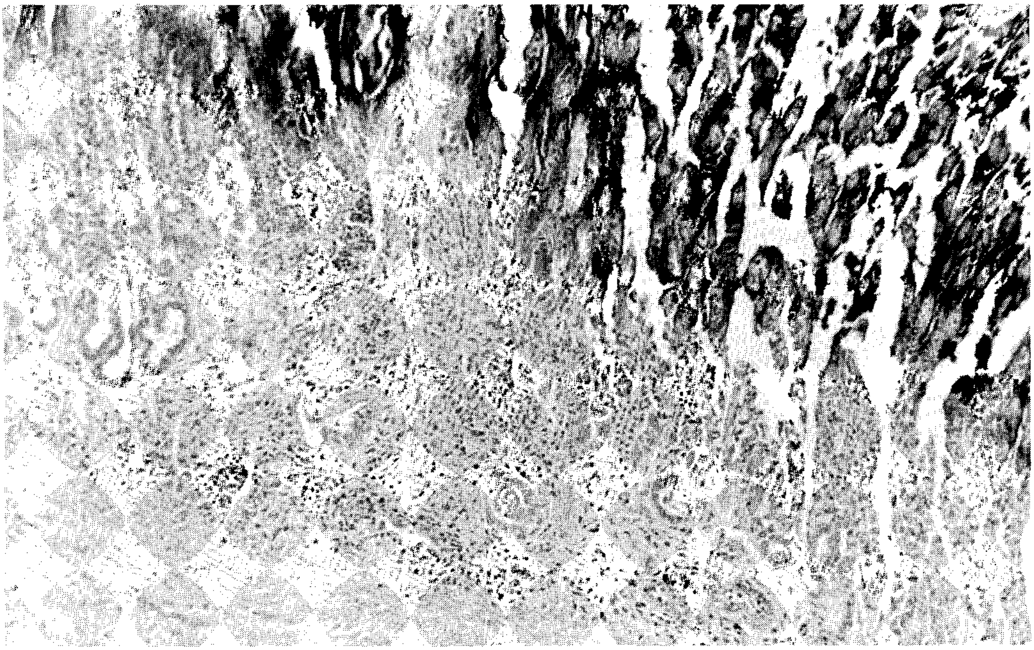

Plate 4. Extensive mucosal haemorrhage. Note coagulative necrosis and infiltration of neutrophils HE x 130. Photo C. Rehbinder.

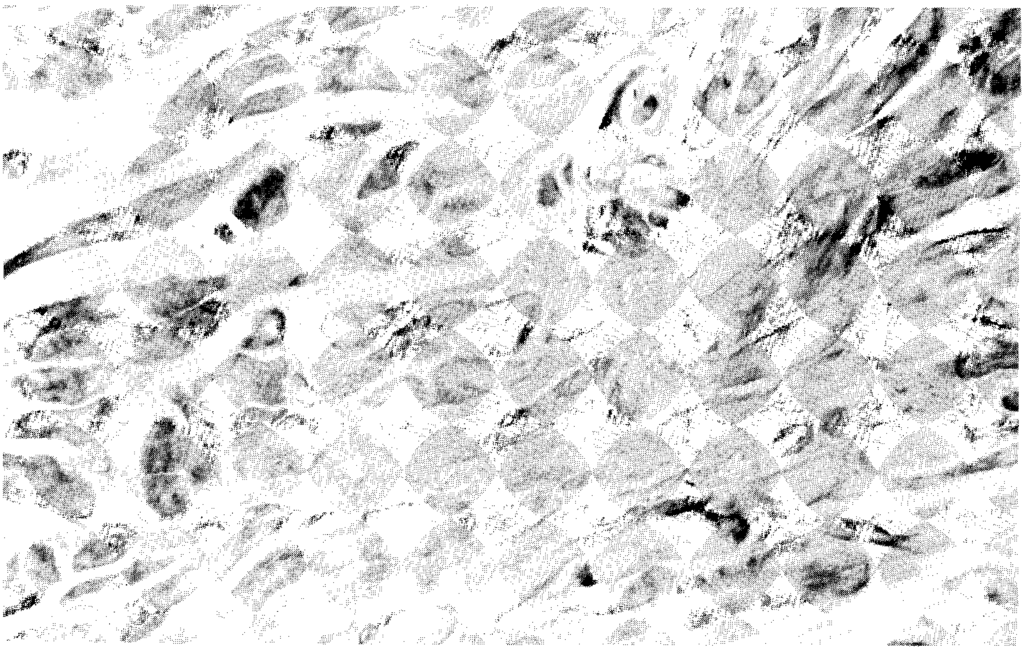

Plate 5. Skeletal muscle (semitendinosus). Note the almost complete destruction of the normal configuration by fragmentation, necrosis, fibrosis and histiocytic reaction. Histiocytes HE x 270. Photo C. Rehbinder.

tissues, revealed degenerative lesions in both skeletal muscles and myocardia. These changes ranged from loss of striation and fragmentation, to hyalinization and necrosis, and the extent of the lesions varied from minor focal lesions to larger areas of necrosis (Plate 5).

Degenerative muscular lesions were not found in herd A. Herds B, C, and H were considerable less affected than herds D, E, F, I, and J (Fig. 8).

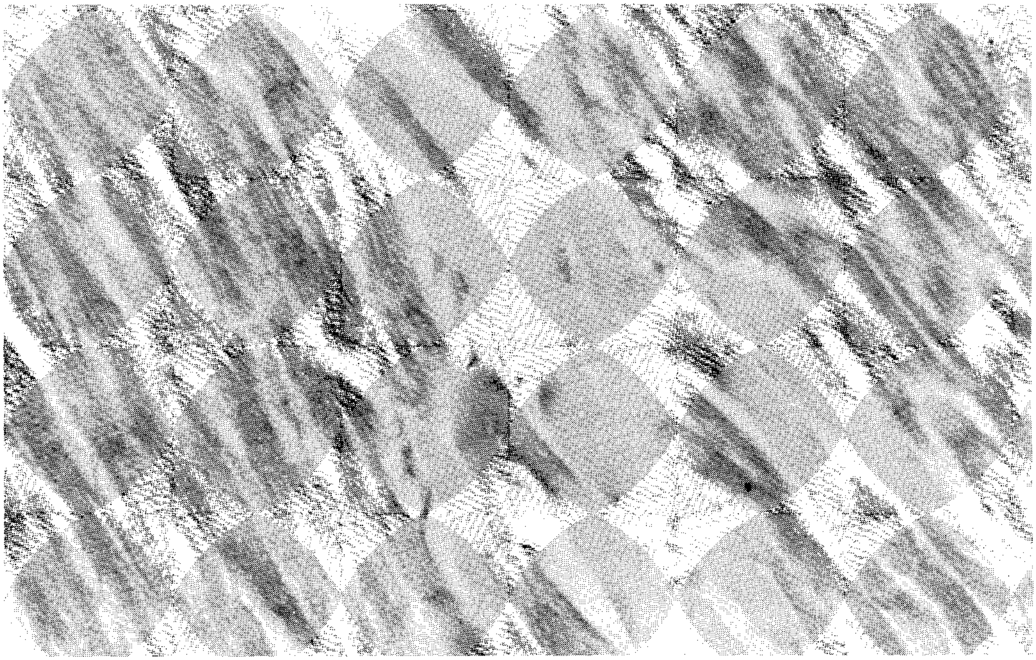

Plate 6. Myocardium. Note loss of striation, swelling and hyalinization of affected muscle cells. PTAH. x 440. Photo C. Rehbinder.

The differential counts of leucocytes revealed marked differences between the control group and handled animals. The most striking effects of handling stress was an increase in immature and mature neutrophils and a decrease in lymphocytes correlated to the degree of stress to which the animals had been exposed. Prolonged exposure to stress produced a considerable decrease in the number of eosinophils. In addition, in herd I, paired blood samples were taken at 3-5 min intervalls between samples. These animals were lassoed (1:st sample) in the corral and dragged out for slaughter (2:nd sampled). Changes in the blood picture appeared fast. (Fig. 9).

The corticosteroid levels were found to be considerably lower in animals shot (herds A and H) than in handled animals (Fig. 10). The shot animals of herd H, however, showed a wider range. The lowest cortisol levels in handled animals were found in herds B and C, and the highest in herds F and J. The very quick response in the corticosteroid levels of the animals from herd I between initial sampling (I_1)

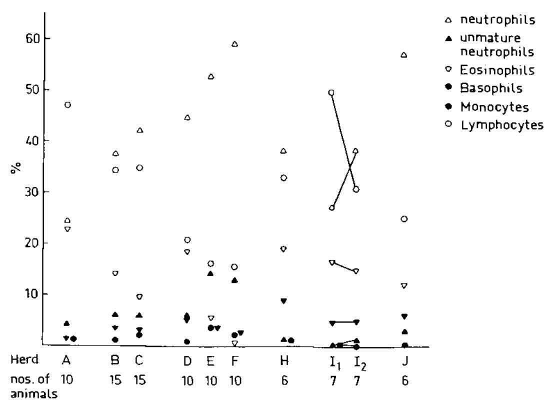

Fig. 9. Differential counts of leucocytes

and sampling at slaughter (I_2) was remarkable.

Urea levels were found to be lower in herds B, D, H, and I than in animals shot in August (herd A), while animals kept overnight in grazing or resting corrals (herds C, F, and J) revealed significantly higher values than animals from all the other herds (Fig. 11).

Significantly increased ASAT values were found only in herd F; but individual animals with high levels were found also in herds B, C,

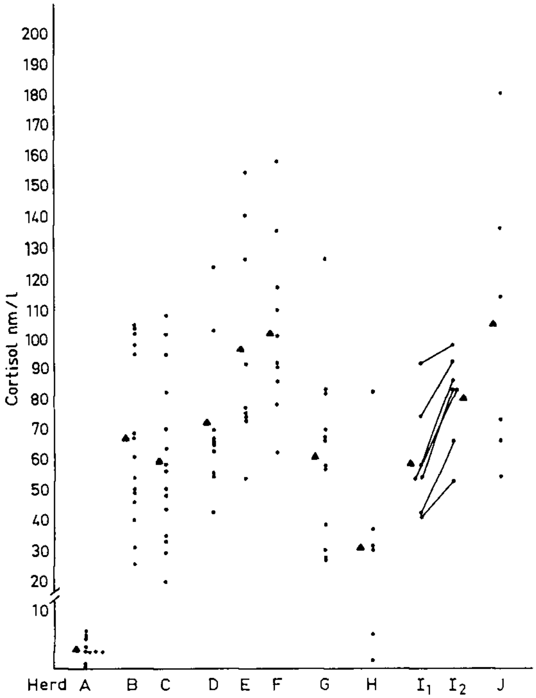

Fig. 10. Peripheral blood plasma levels of cortisol

and E. A tendency toward comparatively higher levels of ASAT was found in herd E (Fig. 12).

General discussion

Modern methods of reindeer herding differ considerably from the traditional old herding methods. The latter involved a rather intimate relationship beween the herdsmen and their reindeer, which contributed to the creation of comparatively domesticated animals. Furthermore, the animals were kept in relatively small herds in those days. Present herding methods imply larger herds of less domesticated animals. The traditional methods, which involved daily contact with the animals by herdsmen on foot or by skiis, have given way to territorial surveillance and round-ups of large herds, often with the aid of snowmobiles and sometimes even helicopters. In addition, transport of reindeer by lorry for different purposes is a common practice.

Thus, numerous stress factors are involved in the management of reindeer, inherent in the

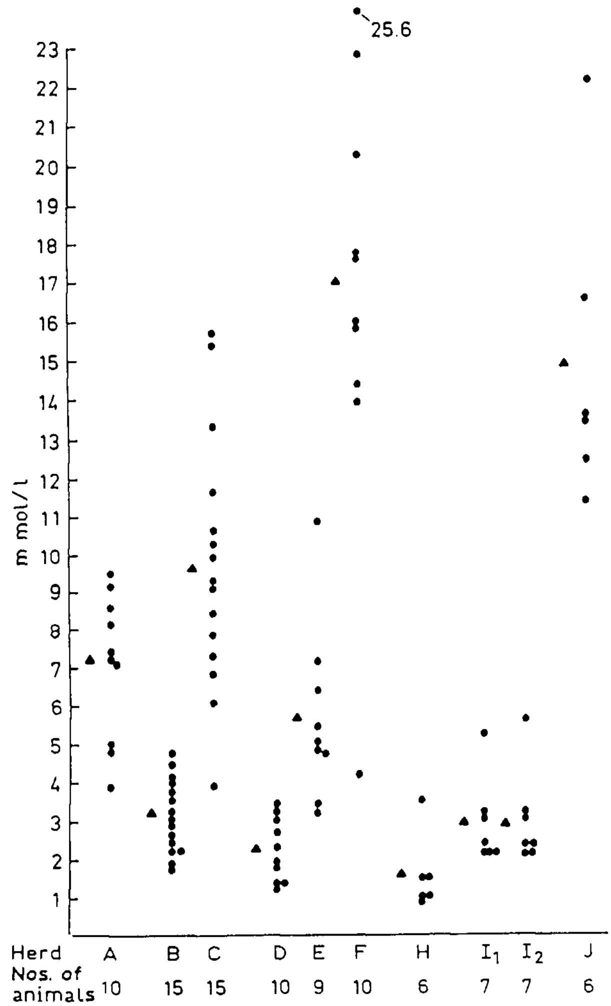

Fig. 11. Periferal blood plasma levels of urea

methods of gathering and herding them, other conditions under which they are herded, the extent of manual handling and contact with people, transportation, etc. All these factors imply intrusion into the flight and critical distances. (Fox 1974). *Hence, in the reindeer, the degree of its tameness should be considered an important factor.*

The field study of management stress largely confirmed the results of earlier investigations. The animals investigated, except those of herd A, had all been subjected to varying levels of stress. The animals of herd A which were shot while resting or grazing were considered un-

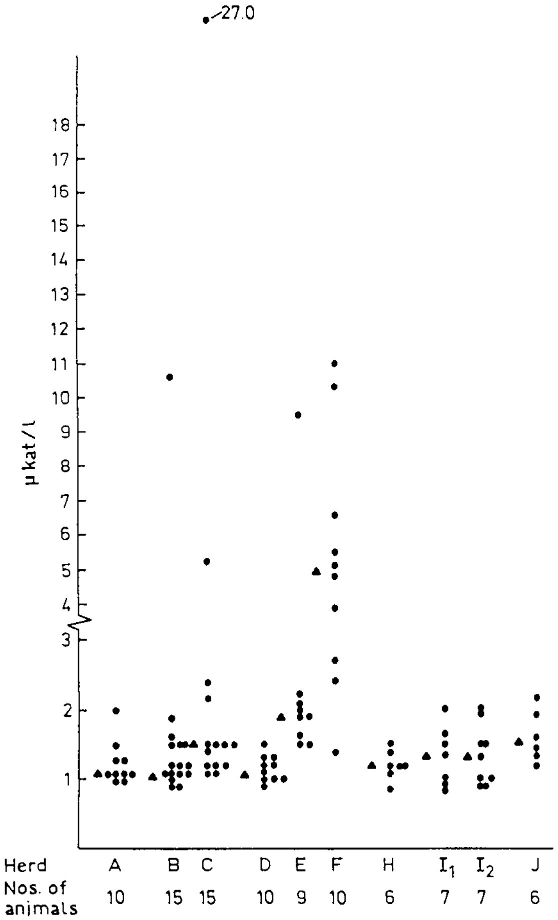

Fig. 12. Periferal blood plasma levels of ASAT

stressed. The animals of herd H were also shot, though some of them apparently did not die immediately when shot in their necks, but were only paralysed, as shown by the presence of blinking reflexes. This fact may explain the wide individual differences in the blood parameters encountered in theses animals.

Herds B, C, and I were subjected to a comparatively mild herding stress and a breif handling stress. Herd J was exposed to a moderate degree of herding stress but a pronounced handling stress.

The effects of management stress were reflected in the blood samples by an increase in both immature and mature neutrophils and a decrease in lymphocytes, and these changes were positively correlated to the degree of stress to which the animals had been exposed. Prolonged exposure produced a remarkable decrease in the number of eosinophils (Fig 9).

The results correspond well with the investigation on blood constituents (Investigation I, Fig 4). Considerable variations are found within and between reports on differential counts of blood leucocytes in reindeer and caribou (*e.g.* Yagimoff & Mitzkewitsch 1931, Gibbs 1960, McEvan 1968, McEvan & Whitehead 1969, Dieterich 1970, Drescher-Kaden & Hoppe 1973, Timisjärvi *et al.* 1976, Nieminen 1980). Apparently, stress has an influence on several blood parameters which may explain the differences found in literature. It must be considered almost impossible to obtain normal values for blood constituents of reindeer as many of these will reflect the state of stress in the individual animal, which results from the capture and handling necessary for sampling.

In the experimental investigation (investigation I) there were small variations among the unstressed animals (Group I), yielding a higher number of lymphocytes than that of neutrophils. In the stressed animals the relation between lymphocytes and neutrophils was that of neutrophilia. In the experimental animals (Group II) a decrease in the number of lymphocytes and eosinophils with a simultaneous increase in segmented, band, and immature neutrophils is evident (Fig 4). This interchanged distribution is well known from other animals in connection with different kinds of stress (Winqvist 1954, Dvorak 1968, Gartner *et al.* 1969, Hartman *et al.* 1973, Jacobsen *et al.* 1978).

The cortisol levels found in the unstressed animals (Group I) were markedly low as compared to the levels found in the experimental animals at the initial sampling, (Fig. 5), indicating that the hypothalmic-pituitary- adrenal system of the latter animals rapidly responded to handling (Fig 3).

The generally high cortisol values and the wide range found in them thus reflect the individual response to herding and handling.

Apparently, the manual handling of reindeer provokes a rapid stress response as judged from the elevated cortisol levels.

The elevated urea levels in the stressed animals may be explained by an increased catabolism of protein from cellular depots, probably muscle tissue. It is known that cortisol exerts such a catabolic effect (Wilkinson 1980), and that skeletal muscle in several species such as the rat (Dahlberg *et al.* 1980) and the pig (Snochowski et al. 1981) contains specific glucocorticoid receptors mediating the hormone action. The finding of elevated cortisol levels in the stressed animals further supports this assumption.

The animals of Groups I and III showed the same magnitude of ASAT activity as reported by Bjarghov *et al.* (1976) and by Nieminen (1980). The experimental animals showed a higher activity at both sampling occasions with a pronounced increase between the two sampling events.

Elevations of ASAT activities have been reported in connection with muscular disorders and capture myopathies (Cardinet III & Stephens-Orvis 1980). The higher activity in the experimental animals probably indicates that these animals were physically less well adapted to running exercise as they were kept in a corral and artificially fed, which should have limited their need for physical movement. The skeletal musculature in these animals is therefore probably more vulnerable to physical exercise and handling, resulting in leakage of ASAT from muscle cells to the general circulation (Table 2).

The differences established, in certain blood parameters between unstressed animals and animals subjected to stress, i.e. the change of the white blood cell composition and the elevation of cortisol and urea values in the stressed animals indicate that reindeer are markedly stress susceptible. This is underlined by the striking changes in these values in the experimental animals and in the handled animals of the field study. The lower lymphocyte and higher eosinophil counts found in older animals might be attributable to a more pronounced parasitic infestation in these animals (*Elaphostrongylus rangiferi*, *Setaria tundra* and *Onchocerca tarsicola*, Rehbinder et al., 1979).

Abomasal haemorrhages (Fig. 7, Plate 3) are also characteristic of stress in many different species (Brodie *et al.*, 1963; Iversen *et al.*, 1972; Johansson *et al.*, 1973; Krisst & Freimark, 1973), and gastric ulcers due to acute and prologned stress have been observed in cervidae (Anon., 1981; Presidente, 1978).

The muscular and myocardial lesions (Fig. 8) and the heamatological values in animals subjected to prolonged herding and handling are all charateristic of physical exertion and acute mental stress (Jönsson and Johansson 1974; Bartsch *et al.*, 1977).

The results of the studies of the blood constituents are presented in Figs. 9-12. When analysing pathological changes and haematological variation in relation to treatment (stress), sex, and age it is obvious that stress significantly influences most parameters studied. Consequently, even the degree of stress applied is more or less directly reflected in pathological lesions and in changes in blood constituents. Thus the distribution of abomasal and muscular lesions and the changes in blood constituents must be considered to reflect a general response correlated to the stress to which the animals had been exposed. The higher urea levels in younger animals could be due to the comparatively more vigorous physical exertion of these animals.

The herding stress applied to herds B, C, and I in the field study was comparatively mild, and the handling stress was low. Even herd H had been subjected to a very low degree of herding stress. The handling stress applied was also of short duration. Consequently, the lowest rates of pathological lesions and the least pronounced haematological changes were found in these herds.

Herd G, from which only cortisol values

were obtained, was exposed to a moderate herding and handling stress. The cortisol values are comparable to those of herds B, C, and I, indicating herd similarities under stress exposure. If there is any difference in the adrenocortical function between seasons as stated by Yousefi et al (1971), such differences are most probably masked by stress induced changes.

When repeated handling is applied as in the case of the seven animals of herd I, this is reflected in a significant increase in immature and segmented neutrophils and a decrease in monocytes and lymphocytes (Fig. 9), accompanied also by a marked increase in cortisol levels (Fig. 10). These changes apparently were attributable to the short period of restraint stress. Prolonged and repeated handling - but moderate herding stress - was applied to herd J and was reflected in a marked increase in pathological lesions and alterations in the blood constituents studied. *Thus prolonged and repeated manual handling as such appears to be the most important factor producing stress lesions.* Consequently, in reindeer, mental stress, sheer fear as reported in pigs (Johansson *et al.*, 1982) and seen in restrained (Ader, 1971; Franzmann *et al.*, 1975) or trapped animals (Iversen *et al.*, 1972; Jacobson *et al.*, 1978) appeares to be the most significant factor in the development of stress induced lesions.

The use of helicopter or snowmobiles when herding animals (herds D, E, and F) can cause severe mental stress owing to the animals' attempts to escape (from these vehicles). Overstraining when trying to escape is bound to contribute to the kind of pathological lesions found. It has been reported earlier that low-flying aircraft provokes a strong escape on panic response (Calef *et al.*, 1976; Miller & Gunn, 1979). When this effect is used in herding the animals, the response may be severe mental and exertional stress, especially when escape attempts are hindered by snow, and when deep snow also prevents early escape.

Capture myopathies in wild ungulates usually develop within 4 hours (Harthoorn 1977; Bartsch *et al.*, 1977), but capture stress and capture myopathy may be inflicted in a matter of a few minutes (Harthoorn, 1977).

Fowler (1977) stated that non-specific responses involving the hypothalamic-pituitary-adrenocortical axis are cumulative. Thus, repeated stress, viz. handling and/or herding, may result in more pronounced and advanced stress induced lesions. *The increase in abomasal and muscular lesions and the marked changes in the blood constituents seen in the herds subjected to prolonged or repeated handling or herding are strongly indicative of such a cumulative response in the semi-domestic reindeer.*

Whether the muscular degeneration observed by others as well as myself can be related to an increased catabolism exerted by cortisol remains to be elucidated. The remarkable depletion of glycogen and lipids in many of the fibres may be a major factor involved in the development of reindeer skeletal muscle degeneration in connection with exertion and mental stress. Apparently, repeated and prolonged stress may result in elevated urea and ASAT values (Figs. 11, 12), the latter probably due to a progressive muscular degeneration. Both urea and, ASAT values were correlated to the distance of the drive and the time spent in the corral. These findings are consistent with the values found here for herds B, C, and D, E, F, and for herd J. The comparatively high urea values in the unstressed control animals (herd A), sampled in August were probably related to a higher protein intake (Bjarghov *et al.*, 1976).

No kidney lesions such as described by Harthoorn (1977) and Bartsch *et al.* (1977) were recorded. However, the animals were killed within 24 hours after provocation of herding and/or handling stress, and chronic lesions are not likely to appear in such a short time.

The fact that manual handling elicits a marked stress response in reindeer also stresses the importance of correct selection methods and consequently of a suitable construction of the corral system. When the various corral system used are compared, B and C (Romperheden Fig. 6) represent a construction which is the most likely to reduce handling stress exposure of the animals. In fact, the animals allowed back to the herd are rarely captured and in most cases are not handled manually.

Consequently, *the use of a selection corral and pens in which manual handling is enforced should be avoided.*

Transportation is found to cause severe stress in domesticated animals (Dvorak, 1975; Simensen *et al.* 1980; Mitchell *et al.* 1988), and most likely provokes an even more severe stress response in semidomesticated animals. In connection with the transportation of reindeer, traumatic lesions are commonly found (Andersen, 1978) and were observed even in the transported animals of herds E and F in the present study. A trauma will *act* as a stress factor, but as it is often the result of aggression shown by other animals in transport crates it may be considered a *result* of stress behaviour as well.

Repeated or prolonged handling must be regarded as unfavourable for the semidomesticated reindeer, as is the case with wild ungulates (Harthoorn, 1977). Consequently, *the degree of tameness is of importance.* Harthoorn (1981) reported of considerably reduced death rates due to capture myopathies when wild ungulates were trained (*i.e.* partly tamed) to accept the presence of humans before being crated and transported. It is apparent from the field study that stress is not alleviated in animals allowed to stand overnight in an ordinary or grazing corral. It is also obvious that stress can affect the health of all animals exposed to it and not only the meat quality of those slaughtered.

A severe stress response with gastric lesions will affect the digestive tract and its utilization of fodder. A considerably lower weight gain in reindeer calves subjected to intensive herding, as compared with wild reindeer calves, was reported by Reimers (1972). Handling stress was considered the major factor underlying the differences in growth. Similarly, a significant negative correlation between cortisol levels and growht rate was observed in cattle (Purchas et al., 1980). Moreover, stress has a detrimental effect on the immune system (Gisler & Schenkel-Hullinger 1971, Simensen *et al.*, 1980, Kelly 1980, Riley 1985, Griffin 1989) and therefore animals suffering from stress may have an increased susceptibility to infectious diseases. Ulcerative and necrotizing lesions of the nose and upper alimentary tract caused by a herpes virus infection in connection with transportation and handling stress has been reported. It was suggested that lesions caused by herpes virus may be the background to outbreaks of necrobacillosis of the alimentary tract in reindeer reported earlier (Rockborn *et al.* 1989).

In wild ungulates, death due to capture myopathy has been reported to occur as late as 30 days after capture. The possibility that severely stressed reindeer may succumb even later after being released from the corral, cannot be excluded.

A marked depletion of glycogen and lipids in many muscle fibres may be a factor involved in the development of skeletal muscle degeneration in connection with mental stress and exertion. There seems to be a correlation between high ASAT-values and substrate depleed muscle fibres as seen in investigation III (Table 1). A connection therefore seems to exist between high intramuscular substrate stores and the ability of a muscle to tolerate stress. A further connection may be that of "stress taste" and meat quality, as the quantity of (number of animals yielding) low quality meat increases during autumn-winter, when energy deposits are depleted (Petäjä *et al.* 1982).

Summary

It is evident that herding and handling stress is an important factor (to be considered) in reindeer management. Therefore herding must be undertaken as carefully as possible, especially when motor vehicles are used.

To obtain a good meat quality, animals should be selected almost directely from the herd and subjected to a minimum of handling, i.e. slaughter should take place with as little delay as possible. *Transportation of live animals and the confining of animals in corrals overnight or in pens or crates while awaiting slaughter should be avoided.* (Stephens 1980).

The relative lack of tameness, as different from that of the reindeer herded according to "old days' herding methods", and the intrusion into the animals' critical distance, i.e. manual handling producing mental stress is a factor which seems to have a great impact on the animals' stress susceptibility.

As mental stress, sheer fear, thus appears to be the most significant kind of stress affecting reindeer it has to be taken into consideration in the planning of herding and other kinds of activities, and especially so when new methods are to be introduced in reindeer herding.

It appears that the idea of letting the animals rest for periods during and/or between stress-events is wrong. If lesions are produced, a "restitutio ad integrum" always requires a very long time, many days or several weeks, depending upon the severity of the lesions produced. The restoration of the hormonal balance ofi the rat adrenal after a major stress event takes 8 days (Schalling *et al.* 1988). Careful measures applied without delay are necessary to avoid cumulative effects upon the organ systems. *This fact again underlines the importance of avoiding prolonged and repeated manual handling.* When motor vehicles such as motorcycles, snowmobiles, and helicopters are used the importance of not producing stess and fear by unexpectedly intruding into the animals' flight distance or critical distance has to be borne in mind. *The use of vehicles or any other means of transport must be correlated to the tameness of the animals.* In order to obtain a good meat quality, animals should be selected for slaughter with as little intrusion as possible, into their critical distance i.e they should be manually handled and restrained as short time as possible. The herd as a whole must be keept calm.

It is reasonable to assume that animals, if let out severly stressed after slaughter, or other kinds of gatherings, have a hard time to face restoring their physical fitness. Their digestion and food conversion rate might be hampered by gastric lesions, their search for food by muscular lesions and their blood circulation and oxygen consumption by myocardial lesions. In addition, they have to restore their energy supplies and adversely affected immune systems. All these effects are causes of production losses even if the reindeer do not actually die.

To avoid the pitfalls of faulty equipment and herding methods we should take advantage of the expert knowledge of experienced old herdsmen in reading and interpreting the behaviour of reindeer.

It is evident form the results obtained that:

1. Reindeer are very susceptible to management and restraint stress.
2. Their degree of tameness is very important for their susceptibility to different kinds of stress.
3. Reindeer subjected to stress may develop abomasal, muscular, and myocardial lesions and changes in blood constituents. There is reason to conclude that repetition of stress events tend to increase such responses in a cumulative manner.

3:1. Therefore, prolonged an repeated manual handling should be avoided.

3:2. Letting animals rest in between events of stress exposure has no beneficial effects if it means an increase in the total amount of stress to which the animals are exposed.

3:3. The use of selection corrals and pens in which manual handling is enforced should be avoided.

3:4. Preferably, animals intended for slaughter should be captured and killed as fast as possible (without any delay).

4. It can not be excluded that the depletion of muscular stores of glycogen, increased catabolism of muscular protein, muscular degeneration, and increased blood-urea levels may be stress produced effects resulting in altered and bad taste of the meat - i.e. in a bad meat quality.
5. Transportation of live animals and keeping animals over night on corrals, pens or crates while awaiting slaughter should be avoided.
6. The use of helicopters, or other motor vehicles for transports, must be correlated to the tameness and condition of the animals and to environmental conditions, such as snow cover, temperature, insect harassment, etc. The less tame the animals are, the weaker their bodily conditions is, the more unfavourable the environmental circumstances are, the more careful management methods are required and the more the use of motor vehicles should be restricted.
7. It is obvious that animals, though not selected for slaughter but exposed to a severe and prolonged stress situation, when let out grazing, will need a considerable time to reach a "restitutio ad integrum". I.e., will take considerable time before stress induced lesions have healed. These animals may suffer from circulatory disturbances and muscle pains preventing them from normal grazing. The may also suffer exhaustion and, due to gastric lesions, be incapable of properly digesting their feed. In addition, their immune system can be negatively affected paving the way for outbreaks of parasitic and/or infectious diseases.

Stress due to incorrect management methods may thus severly affect the productivity ofi reindeer.

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