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Risk Factors Associated with Bruising in Red Deer at a Commercial Slaughter Plant

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ABSTRACT

Bruising of slaughter animals has both economic and welfare implications. In order to identify potential risk factors we surveyed bruising of red deer carcasses from a single Deer Slaughter Plant (DSP) over a three year period. Downgrading due to bruising did not vary between the three years surveyed [1991, n = 21 454, 6.5% downgraded (dg); 1992, n = 22 289, 7.9% dg; 1993, n = 22 262, 6.1% dg]. From an intensive examination of one year's kill (1991) we related the incidence of bruising to various preslaughter transport, seasonal and animal variables. Bruising varied significantly with time of year, hot carcass weight, distance transported, carrier company and carcass fatness. Bruising was related to duration of lairage for some periods of the year which varied with sex. The majority of bruising was on one or other hindquarter implying a consistent cause of the damage. Carcass quality and deer welfare can be best protected by careful driving, by only transporting animals in good condition and avoiding transporting males during the rut. Copyright © 1996 Elsevier Science Ltd

INTRODUCTION

Returns from the sale of venison contribute more than 50% of the income of the New Zealand deer industry. From 1991 to 1994 between 340 000 and 400 000 farmed deer were slaughtered annually [New Zealand Game Industry Board (NZGIB), unpublished data]. Several species of deer are raised for venison, but 95% of animals slaughtered are red deer, *Cervus elaphus* (NZGIB, unpublished data).

In New Zealand, deer are transported from farms to licensed deer slaughter premises (DSPs) for slaughter, inspection and processing. Selwyn & Hathaway (1990) surveyed three New Zealand DSPs and found that between 1.34% and 9.84% of carcasses were wounded or bruised, with trauma-related defects the most common reason for downgrading. In a second study, Selwyn & Hathaway (1992) reported an overall lower prevalence of trauma-related defects (1.54%) and indicated that sex had an effect on the type

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of defects, with stags showing a higher incidence of acute injuries, while chronic injuries were more common in hinds. Both farmers and processors incur costs from such damage to carcasses. The farmers are paid at a lower rate for downgraded carcasses, and the carcass weight is reduced by the trimming of bruised tissue. Trimming entails extra labour and cost for the processors and once trimmed, carcasses do not meet the requirements of the premium priced markets. Bruising also has implications for animal welfare. Injuries which result in bruising are presumably painful and potentially stressful, and so compromise the welfare of the deer.

There are three distinct stages of the journey to the slaughter plant when bruising might occur: on the farm, in transit, and at the slaughter plant. Research with other domestic species suggest that at each of these stages, factors which might cause bruising include: the physical environment (the construction and state of repair of handling facilities) (Grandin, 1993), the social environment (the size, density and composition of the group and the class of stock) (Warriss & Brown, 1985; Tarrant *et al.*, 1988), animal temperament and the amount of handling the animals have experienced in the past (Vowles, 1977; Fordyce *et al.*, 1985) and the behaviour of the handlers (Grandin, 1981).

In cattle, bruising has been shown to be directly related to the method of handling before slaughter and the design of the transport vehicle (Marshall, 1977). Quiet and careful handling is reported to reduce the risk of injury, bruising and stress during transit (Wythes, 1981). Cattle transported at relatively low and high densities have more bruising than those transported at medium densities (Eldridge & Winfield, 1988). Also, Meischke *et al.* (1974) and Shaw *et al.* (1976) reported that the presence of horns was a major cause of bruising in slaughter cattle.

McCausland & Millar (1982) measured the time of occurrence of bruises in slaughtered cattle at two abattoirs in Victoria, Australia. They found that at least 43% of all bruises occurred after the animals had arrived at the abattoir. Subsequently, Barnett *et al.* (1984) found that susceptibility to bruising was associated with the physiological state of the animal. Chronically stressed cows had significantly more bruised tissue than acutely stressed cows. Thus, stress at any stage of the handling process may increase bruising at subsequent stages of the transport/slaughter process.

Very little is known of the extent of bruising in commercially slaughtered deer, and even less about the cause of this damage. In this study, we examined the slaughter records of all animals processed from 1991 to 1993 at one DSP in order to compare the incidence of bruising between years, seasons and sex. For a single year (1991) we then investigated the relationship between the incidence of downgrading due to bruising and a number of pre-slaughter handling variables in order to identify the major factors contributing to bruising.

METHOD

Data from all red deer slaughtered and processed at the DSP from 1991 to 1993 were collected from DSP records. Identities of transport operators and farmers were given numerical codings to preserve anonymity. The sex (stag or hind), GR (depth of tissue in millimetres over the 12th rib, 11 cm from the midline), hot carcass weight (HCW), and origin of each animal was recorded. We also obtained the following information.

Bruising

The carcasses were inspected for bruising and other damage by the meat inspector and trimmer/grader on the slaughter floor as part of the usual trimming and grading routine. Bruises were identified visually and classified as either major or minor. A bruise was classed as major if after trimming there was significant damage to major muscles of high

value primal cuts such as the hind leg and saddle, and resulted in the carcass being downgraded. Minor bruises were smaller in size or on areas other than high value primal cuts. These were removed either on the slaughter floor or in the boning room and did not result in downgrading; therefore, details of these bruises were not recorded on the slaughter forms. The trimmer/grader used his discretion in deciding if the damage was sufficient to downgrade the carcass. If a carcass was downgraded a record was made of the location of the bruise or bruises. The categories were as follows: 1 forequarter damaged; 2 forequarters damaged; middle (saddle) damaged; 1 hindquarter damaged; 2 hindquarters damaged; recent broken bones; more than one area bruised (e.g. hindquarter and saddle) and severe bruising. The side (left or right) on which the damage occurred was not recorded. Only carcasses with major bruising that resulted in downgrading of that carcass were considered to be 'bruised' in this study.

Transport variables

Fifteen registered transport companies transported deer from farms to the DSP. When the farmer transported his/her own animals this was recorded as "owner". When one farmer transported another farmer's deer this was recorded as "private". If it was not possible to identify the transporter this was recorded as "unknown". The distance (km) each animal travelled to the DSP was estimated from topographical maps of the routes taken from the farms to the DSP.

Lairage

All deer were held in lairage for less than 24 h to comply with industry regulations. Deer were classed as either slaughtered on the day of delivery, or slaughtered the following day.

Statistical analysis

The effect of sex, year and month differences on the mean proportion of animals downgraded (weighted for number killed daily) were tested using Residual Maximum Likelihood (REML) allowing for year interactions with sex, month and sex by month as random effects. REML produces a Likelihood Ratio (LR) which approximates the Chi-square distribution (Genstat, 5.3, Lowes Agricultural Trust, Rothamstead Experimental Station). For the 1991 data, the effect of sex, month and lairage (killed the same day or held overnight) differences on the mean proportion of animals downgraded were tested using a generalised linear regression incorporating a random day to day effect and assuming a binomial distribution on the actual observations (Genstat 5.3, Lowes Agricultural Trust, Rothamstead Experimental Station). Bruising percentages for carrier companies were calculated by averaging the percentage bruised for each consignment of deer in 1991. For 1991 bruising percentages for distance, GR, and HCW categories were calculated as a proportion of bruised animals in a particular category and compared using Chi-square.

RESULTS

1991 to 1993

The DSP processed 21 454 deer in 1991, 22 289 in 1992 and 22 262 in 1993. There was no significant difference in the number of animals slaughtered or the proportion downgraded

among the three years (Chi-square = 0.53, df = 2, ns; Table 1). The proportion of stags downgraded was higher than hinds in all three years (Wald test = 18.2, df = 1, $p < 0.001$; Fig. 1). However, there were significant interactions between sex and month across years (Wald test, sex by month interaction = 44.2, df = 11, $p < 0.001$; Fig. 1). This suggests that, although the sex difference was consistent between years, in any one month the difference might vary. A greater proportion of hinds were downgraded in November and January, whilst stags were more likely to be downgraded in all other months except December and February during which there was no sex difference.

1991

In 1991 6.5% of the carcasses processed at the DSP were downgraded because of bruising or recent injury.

Duration of lairage

Fifty percent of animals were slaughtered on the day of arrival at the plant, the remainder were held overnight and slaughtered the next day. Averaged over the year, the level of bruising in animals held overnight (6.8%) was not significantly different from that of deer slaughtered on the day of arrival (6.1%) ($\chi^2 = 4.255$; df = 1, ns). However there were significant interactions between sex and lairage (LR = 6.46, df = 1, $p < 0.01$), and also between sex and month (LR = 21.27, df = 11, $p < 0.05$) when lairage was included in the generalised linear regression. A greater proportion of females were downgraded after being held overnight in lairage than those killed on the day of arrival in January, February, September and December and for males from July to October. In March and May females were less likely to be downgraded after overnight lairage. Hinds held overnight were more likely to be downgraded than stags during January and December but less likely from March to October (Fig. 2).

Distance transported

The distance deer were transported from the farm to the DSP ranged from 24 to 434 km. The median distance travelled was 72 km. The percentage of animals downgraded as a function of distance travelled increased from a low of about 6% at short distances (< 100 km) to 11.3% amongst deer transported over 200 km (Fig. 3). Bruising levels were significantly different between distance categories ($\chi^2 = 36.9$; df = 4, $p < 0.001$).

TABLE 1

The Number and Sex of Deer Killed and the Number Downgraded at a Single DSP for the Years 1991, 1992 and 1993

Year	*Sex*	*Number killed*	*Number downgraded*	*% Downgraded*
1991	Stags	11 512	852	7.4
	Hinds	9937	557	5.6
	Total	21 449	1409	6.6
1992	Stags	8386	913	10.9
	Hinds	13 903	841	6.1
	Total	22 289	1754	7.9
1993	Stags	12 249	922	7.5
	Hinds	10 013	438	4.4
	Total	22 262	1360	6.1

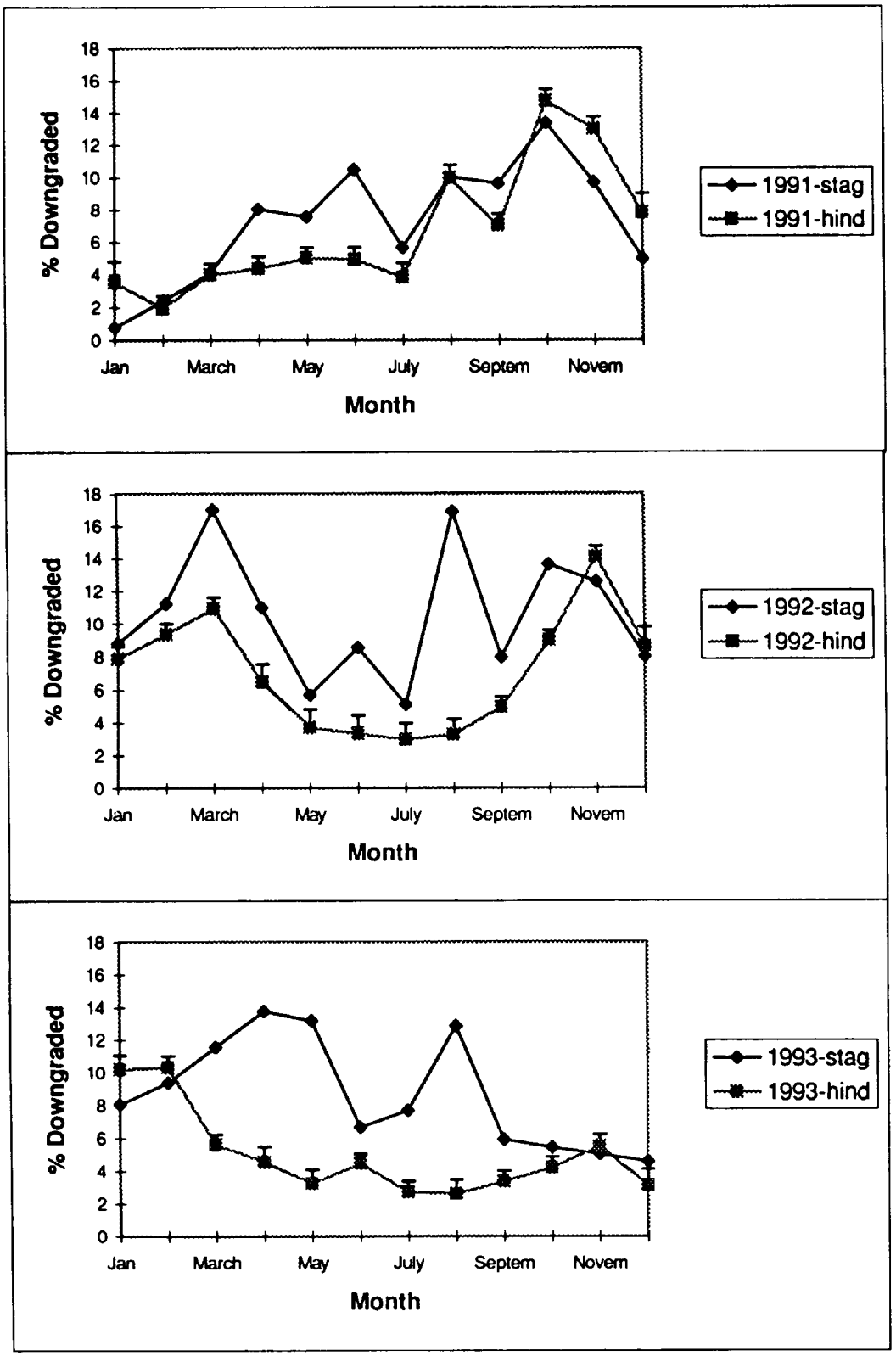

Fig. 1. Weighted mean (±s.e.m.) percentages of carcasses downgraded because of bruising, for stags and hinds according to month of slaughter during (top) 1991, (middle) 1992 and (bottom) 1993 at one New Zealand DSP.

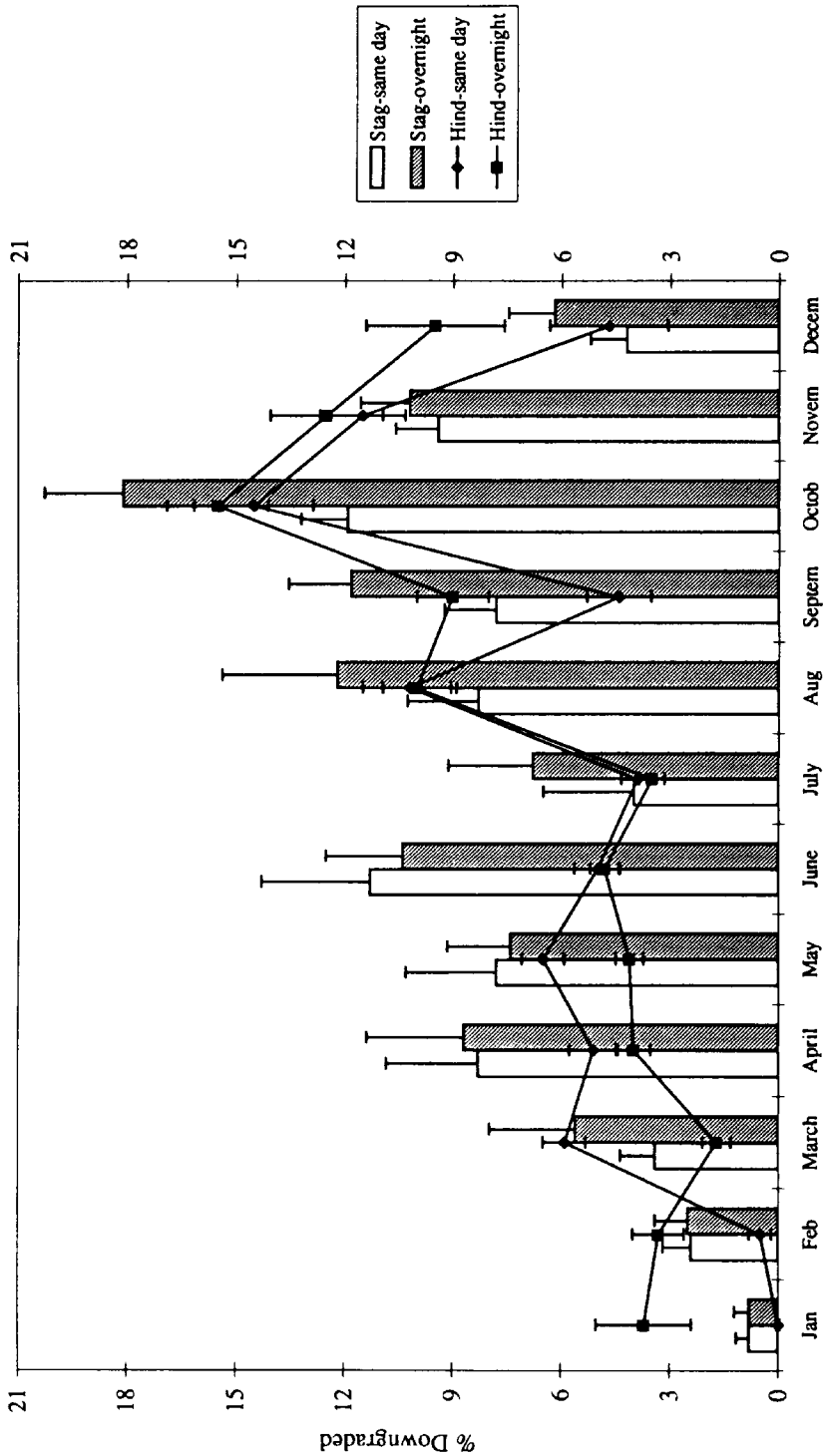

Fig. 2. The proportion of stags and hinds downgraded by month in 1991, comparing those killed the day of arrival at the DSP with those held overnight in lairage.

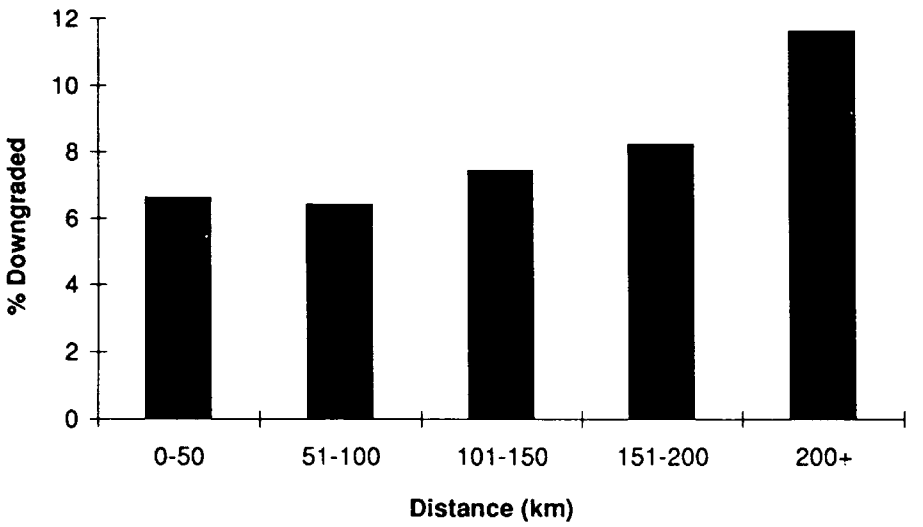

Fig. 3. The percentage of carcasses downgraded in 1991 because of bruising, according to five distance transported categories.

Carrier company

One carrier (company 3) transported 54.7% of the deer processed at the DSP (Table 2). Seven companies transported less than 150 animals from fewer than five farms and were excluded from the analysis. The incidence of bruising varied from 3.8% to 14.2% amongst the remaining 8 transport companies, owners and private farmers carrying deer ($\chi^2 = 83.7$; df = 10, $p < 0.001$). On average carriers transported deer of similar size (HCW) and condition (GR) except for carrier 1 who transported deer that were on average heavier and fatter than those carried by the other operators. The deer delivered by owners and private operators were in smaller consignments than those by the commercial operators.

The variation in bruising levels for carrier companies appeared to be unrelated to the mean distance they travelled to deliver the animals to the DSP. Carriers 1, 2, 7 and private farmers travelled similar mean distances of 74, 78, 78 and 78 km, respectively, and had corresponding bruising levels of 14.2%, 4.6%, 4.7% and 7.3%.

TABLE 2

The Number of Animals and Consignments Carried by Various Transporters to the DSP, Together with HCW and GR, Distance Transported and the Percentage of Animals Downgraded due to Bruising per Consignment (Mean ± s.e.m.)

Carrier	*Number of consignments*	*Number of animals*	*Consignment size*	*% Bruised*	*HCW (kg)*	*GR (mm)*	*Distance (km)*
1	16	349	22 (3.5)	14.2 (3.8)	62.8 (3.7)	5 (0.7)	74 (2.6)
2	10	234	23 (3.3)	4.6 (1.6)	52.8 (1.9)	4 (0.7)	78 (0.0)
3	576	11 738	20 (0.6)	5.9 (0.4)	51.7 (0.4)	4 (0.1)	62 (1.9)
4	23	493	21 (3.7)	9.2 (2.7)	53.0 (2.2)	3 (0.4)	27 (1.9)
5	8	212	27 (6.5)	4.7 (1.9)	53.9 (3.0)	3 (0.6)	78 (0.0)
6	25	540	22 (3.0)	3.8 (1.7)	52.5 (1.7)	4 (0.5)	50 (4.5)
7	27	676	25 (3.0)	5.8 (1.5)	53.5 (3.1)	4 (0.5)	46 (4.6)
8	10	680	68 (2.0)	8.3 (2.5)	54.4 (1.2)	2 (0.2)	24 (0.0)
Owner	316	3707	12 (0.5)	7.4 (0.9)	53.2 (0.7)	4 (0.2)	55 (2.5)
Private	59	581	10 (1.1)	7.3 (1.3)	51.9 (1.3)	3 (0.5)	78 (8.1)
Unknown	79	1830	23 (2.0)	8.0 (1.5)	50.6 (1.0)	3 (0.2)	98 (12.1)

Site of carcass damage

For both stags and hinds the most common cause of downgrading was for damage that was restricted to one hindquarter (Table 3). The distribution of bruising over the remaining sites appeared similar for males and females except that damage to the middle region of the carcass was higher for hinds.

HCW

The mean HCW of stags slaughtered in 1991 was 58.6 ± 0.09 kg, and 45.3 ± 0.07 kg for hinds. HCW was divided into 9 weight categories. The level of bruising differed between carcass weight categories ($\chi^2 = 41.5$; df = 8, $p < 0.001$; Table 4). The highest levels were recorded for carcasses lighter than 30 kg and the lowest levels for those heavier than 90 kg.

GR

The GR of the deer ranged from 1 mm to 43 mm. Over the 12 months average GR in stags ranged from a mean of 1.7 mm in July to 5.5 mm in December. The mean GR for hinds ranged from 2.7 mm in July to 7.3 mm in January. Animals were divided into eight groups according to GR. There were seven categories (2 mm/category) up to and including a GR of 14 mm and a final category for carcasses with a GR of 15 mm or over. Animals with a lower GR were more likely to be downgraded due to bruising. ($\chi^2 = 153.5$; df = 7, $p < 0.001$; Fig. 4).

TABLE 3
Percentage of Stags and Hinds in each Downgrade Category in 1991

Downgrade category[a]	*Stags*	*Hinds*
1 Forequarter	7.1	4.0
2 Forequarters	0.4	0.2
1 Hindquarter	70.5	70.6
2 Hindquarters	7.5	8.1
Middle (saddle)	3.6	10.7
> 1 Carcass location	1.4	0.3
Severe bruising	1.5	0.3
Recent broken bones	0.2	0.3
Condemned	0.5	0.5

[a]Excludes non-injury related categories.

TABLE 4
Percentage of Carcasses Downgraded in 1991 According to HCW Category

HCW (kg)	*N*	*% Bruised*
0.0–29.9	102	19.6
30.0–39.9	2267	7.2
40.0–49.9	6513	6.2
50.0–59.9	8288	6.4
60.0–69.9	2990	6.9
70.0–79.9	831	5.3
80.0–89.9	245	4.9
90.0–99.9	103	1.9
100.0	60	1.7

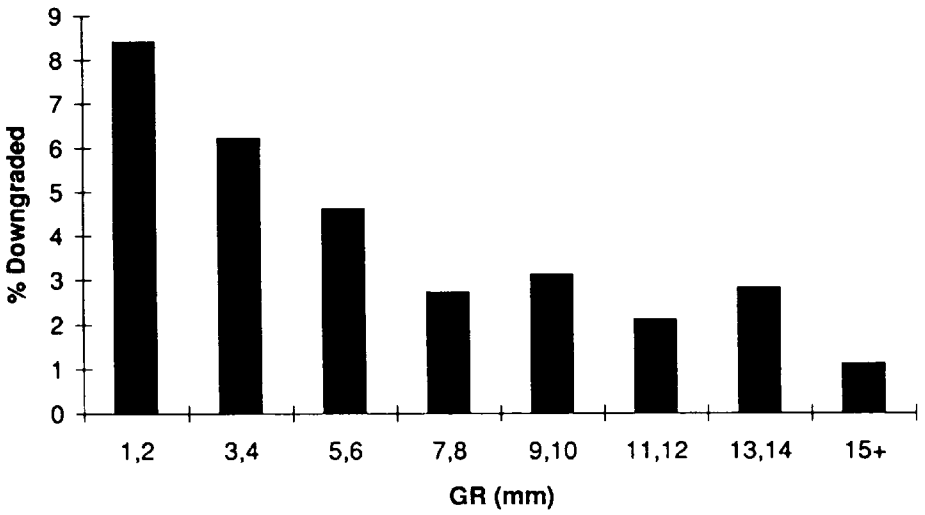

Fig. 4. The percentage of carcasses downgraded in 1991 because of bruising, according to eight GR categories.

DISCUSSION

The yearly bruising rates recorded in this study (6.5%, 7.9% and 6.1% for 1991, 1992 and 1993, respectively) were lower than the 9.8% reported by Selwyn & Hathaway (1990) at one DSP, and considerably higher than the 1.3% and 2.8% recorded at two other DSPs. These differences may be due in part to the different criteria used to downgrade a bruised carcass at different DSPs, thus making it difficult and potentially misleading to compare slaughter plants. Critical to any comparison is the variation found between different periods through the year. Selwyn & Hathaway (1990) surveyed downgrading over a relatively short period, October 1988 to January 1989. If we had calculated downgrading for a similar period in two different years, for example 1992 and 1993, the proportion downgraded would have been 10.9% in 1992 and 5.8% in 1993. If our study was limited to these periods, we might have erroneously interpreted this as a decrease in downgrading occurring in the latter year. The findings of the present study suggest that even conclusions drawn from a 12-month survey may be potentially misleading. For instance, in 1991 downgrading peaked in October for both hinds and stags. Yet when all three years were examined, this seasonal effect disappeared. In contrast, some seasonal effects, for example increased downgrading of stags during the rut, appear to be robust. We would caution against drawing conclusions about downgrading effects from surveys of limited duration.

The significant variation in bruising rates between months may be due to the changes in body composition, behaviour and stock selling patterns over seasons. Deer, particularly stags, undergo immense physiological, physical and behavioural changes throughout the year (Alexander, 1988). During the breeding season stags drastically reduce their food intake and consequently fat levels decline whilst simultaneously their behaviour becomes more aggressive and unpredictable (Lincoln *et al.*, 1970; Drew, 1985). For these reasons the number of stags slaughtered decreased from March to June. On average in 1991, 1992 and 1993 only $18.2 \pm 2.4\%$ of all stags processed were slaughtered in March, April, May or June, whereas $49.1 \pm 1.5\%$ of all hinds were processed over the same period. Those stags that were slaughtered at this time had higher levels of bruising than hinds slaughtered in the same months indicating that behaviour during the rut and subsequent weight

loss may have lead to increased bruising. This finding supports the decision of many farmers not to slaughter stags during this period.

The higher rate of bruising for leaner animals is consistent with that reported for sheep by Knowles *et al.* (1994) and implies that fat cover may protect against bruising. This raises a problem as fat animals are commercially undesirable because they are less marketable and farmers receive a lower payout. However very lean deer appear to be more susceptible to bruising and this results in lower returns because of downgrading of the carcass.

There are numerous environmental factors that could effect bruising levels and the welfare of deer during the process of moving from the paddock to the slaughter box. Differences in bruising rates for cattle have been attributed to many factors including vehicle design (Marshall, 1977), stocking density (Eldridge & Winfield, 1988; Tarrant *et al.*, 1988) and the mixing of different sexes (Yeh *et al.*, 1978; Wythes *et al.*, 1985). These factors may have contributed to the variable bruising rates between carrier companies seen in this study along with driving techniques and road conditions (Kenny & Tarrant, 1987; Jago *et al.*, 1993).

The increase in bruising with distance transported may have been due to animals becoming fatigued on long journeys. As a result their ability to respond to vehicle movements may have been reduced, making them more susceptible to loss of footing and injury, particularly bruising as has been suggested with cattle (Leach, 1982). Increased bruising with increase in duration of journey has been reported for cattle in several studies (Marshall, 1977; Yeh *et al.*, 1978; Wythes *et al.*, 1981).

Once at the slaughter plant animals are subjected to a novel environment with foreign odours, animals, noise and stock handlers. The design of races and holding pens and the skills of the stock person can affect the ease with which animals can be handled (Grandin, 1980; Blackshaw *et al.*, 1987; Matthews, 1993) and levels of bruising and stress (Grandin, 1981). Governmental regulations require that deer be slaughtered within 24 h of arrival at the DSP. The time spent in lairage depends on the time of arrival at the DSP and the number of animals already in holding pens when new stock arrive. Although the differences were not large, at certain times of the year overnight lairage did result in a slightly higher proportion of animals being downgraded. This varied between hinds and stags, and surprisingly, for a few months hinds held overnight appeared to be at a lower risk of bruising. This suggests that some of the differences in bruising may relate to factors not identifiable in this survey such as temperament. Although the differences in duration of lairage were statistically significant, they were numerically small and therefore may not be of major economic importance. However, they are still of concern with respect to the welfare of the animals.

This study has identified several factors which are associated with an increased risk of bruising. This work suggests that carcass quality and welfare may be enhanced by careful driving, transporting only well-conditioned animals, and avoiding transporting males during the rut.

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