SHORT COMMUNICATION

Short communication articles are short scientific entities often dealing with methodological problems or with byproducts of larger research projects. The style should the same as in original articles.

Roe deer *Capreolus capreolus* feeding on yew *Taxus baccata* in relation to bilberry *Vaccinium myrtillus* density and snow depth

Atle Mysterud & Eivind Østbye

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The extent of roe deer *Capreolus capreolus* feeding on the highly toxic yew *Taxus baccata* during winter was quantified from 1989-1994 in areas with varying density of bilberry *Vaccinium myrtillus*. Yew was most heavily harvested by roe deer in areas with low densities of bilberry. In areas with high densities of bilberry shrub, roe deer started browsing on yew when snow depth increased and reduced access to the field layer. However, in areas with low densities of bilberry, roe deer browsed heavily on yew also when snow was absent. Our observations suggest that roe deer may be the main factor affecting yew survival in areas where other preferred feeding plants are not available.

Keywords: Roe deer, Capreolus capreolus, bilberry, browsing, management, snow depth, toxicity, yew

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In most parts of Fennoscandia roe deer *Capreolus capreolus* adapt to a changing habitat and shift from a concentrate-selector strategy in summer, i.e. low gut fill, high intake of easily digestible forage, and short retention time, to a bulk-limiting situation in winter, i.e. increased gut fill, relatively low intake of a diet rich in fibre, and a long retention time (Holand & Staaland 1992). Snow depths of more than 60 cm restrict roe deer from reaching the best quality forage, such as bilberry *Vaccinium myrtillus* stems (Cederlund et al. 1980). Throughout the winter, the roe deer is frequently forced to feed on low-quality forage of twigs and branches from deciduous and evergreen trees (Holand & Staaland 1992).

However, the described dynamic of feeding on the field layer as long as snow does not limit access, may not be applicable to areas with a poorly developed field layer.

We investigated how roe deer exploitation of yew *Taxus baccata*, which constitutes an important part of the winter diet of roe deer in our study area, varied with the density of and access to the field layer. We used bilberry, which is considered to be the most important winter food source of roe deer in Sweden (Cederlund et al. 1980) and Norway (Hagen 1958, Bjørnsen 1985) as representative of the field layer, and snow depth as an indicator of access to the field layer.

To our knowledge, no earlier study has found the highly toxic yew in the diet of roe deer, although some observations of roe deer feeding on yew exist in local literature in Norway (Hagen 1969, Saga 1981, Svalastog & Høiland 1991), Sweden (Ståhl 1988) and the Åland Archipelagoes (Hæggström 1990). Special interest is devoted to the heavy exploitation of yew by roe deer since part of the study area is proposed as a yew reserve by nature management authorities (Svalastog & Høiland 1991).

Material and methods

Study area

The study area is located in the Lier valley in southern Norway between 59°52'-59°58'N and 10°14'-10°20E. The area is situated within the boreonemoral region and is mostly forested (Abrahamsen et al. 1977). Vegetation varies and is dominated by Norway spruce *Picea abies* mixed with Scots pine *Pinus sylvestris* in the drier and poorer locations. Along the bottom of the valley, the soil is particularly fertile with predominance of deciduous forest interspersed with cultivated fields. Here the forest consists of species such as hoary alder *Alnus incana* and bird cherry *Prunus padus* mixed with elm *Ulmus glabra* and linden *Tilia cordata* at the richest locations. One of the highest densities of yew in Norway has been recorded at locations with soil profiles rich in calcium (Svalastog & Høiland 1991). The roe deer population in the cultivated area feeds on agricultural crops as well as wild plants (Kjøstvedt 1995). The winter density of roe deer in the Lier valley is approximately 3-5 deer/100 ha (Mysterud 1993).

Estimating feeding on yew

In addition to the three surveys undertaken each winter along transects (see below) for quantification of browsing, the areas were regularly checked for tracks on the snow to insure that no species other than roe deer were feeding on yew. Generally, this was not the case, but during the snow-rich winter of 1994 some moose *Alces alces* were feeding on yew in one part of the area. The moose bites, however, were easily identified by height and cut diameter, and consequently do not affect our results.

The seven transects each measured 250 x 20 m and densities of yew and bilberry varied within transects. The transects were at least 250 m apart, often more. Within the transects feeding on all individual yew plants was quantified by counting the number of cuts by roe deer per tree. Only fresh cuts were counted. Old cuts were surrounded by a line of dead brown tissue and were easily identified. We categorised feeding on individual trees arbitrarily into three classes: no feeding (0 cuts), moderate feeding (1-9 cuts) and severe feeding (>10 cuts). Cuts were counted in autumn (November-December), midwinter (January-February) and spring (April-May) during 1989-1994. Additionally, we measured the upper browse limit on each yew tree after a snow-poor winter (1992) and a snow-rich winter (1994). The lower browse limit was measured after a snow-rich winter (1994).

Variation in yew browsing

A regression analysis was conducted to investigate how the extent of roe deer feeding on yew varied with density of bilberry, access to bilberry (snow depth) and yew density. The percentage of yew with more than 10 cuts in spring (1) was used as a dependent variable, and bilberry density (2), yew density (3) and snow depth (4) as independent variables. As we calculated yew feeding as a percentage of total number of yew trees within a transect, we transformed it (arcsin[sqrt{yew feeding/100}]).

1) We chose the category severe feeding (>10 cuts) in spring since accumulated severe browsing during winter represents the most important category to management of

Table 1. Data on roe deer feeding on yew (in %) in seven transects (1-7), mean upper and lower browse limits (in cm), yew density and bilberry coverage during 1989-1994 with average snow depth (in cm) in March in brackets. Only spring values of yew trees with more than 10 cuts are included in the data on yew feeding.

Transect line			1	2	3	4	5	6	7
Yew feeding (%)	1990	(3)	16.7	21.4	50.0	0	0	7.8	0
	1991	(72)	100	72.3	50.0	89.3	48.1	76.1	0
	1992	(1)	100	90.9	80.0	91.1	67.6	82.9	0
	1993	(32)	90.9	77.3	75.0	91.8	75.7	80.4	3.7
	1994	(100)	100	74.2	67.5	88.4	77.2	75.6	35.9
Upper browse limit	1992		102	75	80	81	86	111	34
Mean (cm)	1994		180	191	198	170	140	175	171
Lower browse limit Mean (cm)	1994		23	20	27	13	18	19	32
Yew density (plants/100 m)			4.0	7.2	5.6	22.4	72.7	83.9	26.9
Bilberry coverage	mean		4.2	8.9	0	0.3	0.1	4.4	12.3
(%)	median		0.3	1.8	0	0	0	0.8	2.5

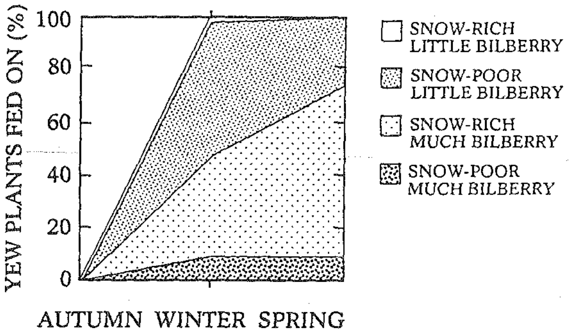

Figure 1. Total accumulated roe deer feeding (>1 cut) on yew plants from autumn to spring along representative transect lines, one with low and one with high density of bilberry. Differences in snow depth and densities of bilberry affected the degree of yew browsing.

yew. 2) Density of bilberry was quantified in the same transects as yew feeding. Every 10 m along the transect line we made a 2 x 2 m plot and estimated the coverage of bilberry in percent. In the test, we used the median of all the plots along that specific transect line. 3) Density of yew was calculated as the number of plants per 100 m of transect. 4) Snow measurements were obtained from a meteorological station situated 25 km away from the study area (DNMI 1869 Tryvasshøgda II). We used average monthly snow depth in March each year to indicate maximum lasting snow depth that winter.

Results

Main results are presented in Table 1. The regression model explained 33.6% of the variation in feeding on yew trees between years (F = 5.218, P = 0.005). There was significantly more feeding on yew at locations with low densities of bilberry (T = -3.222, P = 0.003) and feeding increased proportionate to snow depth (T = 2.083, P = 0.046). However, in areas with sparse occurrence of bilberry, feeding on yew was also common in snow-poor winters (Fig. 1). Browsing pressure from roe deer did not vary with yew density (T = -1.363, P = 0.183).

Discussion

There may possibly be unknown confounding variables correlated with the gradient in bilberry density, e.g. in the density of roe deer. But our observations of tracks and an ongoing radio-telemetry study suggest that the relationships discovered are not biased in a direction that could explain our results. There may have been changes in the density of roe deer in the area on the whole, but it is not likely that such changes had a significant impact on our results. We also assume that the degree of feeding within one transect is independent on the degree of feeding in other transects. An ongoing radio-telemetry study will probably reveal if the same roe deer feeds within different transects.

The method of categorising severe feeding as more than 10 cuts, does not show how many yew trees have lost close to 100% of their needles. This was a frequent observation, especially after severe winters, and may lower the strength of the statistical tests of between-year feeding variation.

Poisonous plants

The heavy browsing on yew trees by roe deer is remarkable since yew is a highly toxic plant (Lampe 1991). Yew (including the Japanese yew *Taxus cuspidata*) has been reported lethal to a wide variety of birds and other animals including pheasants *Phasianus colchicus* (Jordan 1964), horses *Equus caballus* and cattle *Bos taurus* (Knowles 1949, Orr 1952, Lowe et al. 1970, Alden et al. 1977, Persson et al. 1988), sheep *Ovies aries* (Orr 1952), fallow deer *Dama dama* (Dietz et al. 1994) and humans *Homo sapiens* (Czerwek & Fischer 1960, Schulte 1975). In all cases death occurred suddenly within few hours after ingestion without precursive symptoms. It is interesting that related species like moose and roe deer can deal with yew while fallow deer cannot. The roe deer also eats other poisonous plants like wood anemone *Anemone nemorosa*, bitter sweet *Solanum dulcamara*, bracken *Pteridium aquilinum*, herb paris *Paris quadrifolia*, John's wort *Hypericum maculatum* and species of the buttercup family *Ranunculus* spp. (Selås et al. 1991). A species like wood anemone is completely dominant in the diet during spring (Cederlund et al. 1980, Selås et al. 1991). Consequently, roe deer must be able to deal with relatively large quantities of different toxic substances. Toxins can be handled by roe deer either through 1) metabolising enzymes in the liver, 2) increasing its tolerance for toxins in the cells or 3) biodegradation by the rumen flora (J. Stenersen pers. comm.). How roe deer handle taxol, one of the toxic taxine alkaloids in yew (Lampe 1991), is being investigated (J. Stenersen pers. comm.).

Bilberry versus yew

Cederlund et al. (1980) found that browse constituted 80% of the diet of roe deer in severe winters when snow depth exceeded 60 cm, but only 5-20% in winters when snow depths were less than 60 cm. Our results suggest that the proportion of browse in the winter diet of roe deer may also vary locally with the development of the field layer. Radio-tracking has shown that areas with maximum and minimum densities of bilberry in our study area are occupied by different roe deer (A. Mysterud unpubl. data). In areas with poorly developed field layers, roe deer are forced to feed rather heavily on browse species even in mild winters either because the field layer has already been heavily harvested or is insufficient to provide the deer with the necessary energy required for survival. In areas with sparse bilberry occurrence, roe deer started browsing on yew early in the winter. This was in contrast to the situation in areas with high densities of bilberry, where yew was only browsed on, to any extent, in snow-rich winters. When the snow melted, roe deer seemed to switch back to bilberry indicated by a higher lower browse limit in this area (See Table 1). However, statistical tests on differences in lower browse limit were not conducted due to low sample sizes.

Even though bilberry is preferred to yew when available, the heavy use of yew may be ascribed to the exceptionally high digestibility measured *in vitro* (70.6-76.8%) (H. Staaland unpubl. data, Kjøstvedt 1995). This is actually much higher than for bilberry (36-59.1%) as well as most other browse species (Cederlund & Nyström 1981, Holand 1993, Kjøstvedt 1995). The higher digestibility is probably owing to the lower content of lignin, cellulose and hemicellulose and the higher content of protein in yew than in bilberry (Kjøstvedt 1995). Yew also has quite a large quantity of food per plant which is easy to harvest (Kjøstvedt 1995). Thus, the situation of roe deer being able to survive winters in areas with poorly developed field layers, may depend on the browse species present.

Consequences for management of yew

Over time, yew plants which have survived browsing seem to develop two main morphological forms. One form is the 'hourglass' where roe deer completely remove the needles in the middle part of the plant, with the upper limit being how far they could reach and the lower limit where snow limited access (Fig. 2). The other morphological form is the 'brush', in which twigs are growing so close that they seem to form some kind of mechanical herbivore defence. However, after the severe winter of 1994, even the 'brush'-shaped plants seem to have problems with survival. The high densities of roe deer experienced in Scandinavia today are of a new date (e.g. Cederlund et al. 1980, Holand & Staaland 1992). The yew trees shaped like 'hourglasses' seem to be older plants (tree-like) that reached safe heights before the roe deer population attained the present high densities, whereas the 'brush'-shaped plants were younger plants that probably never will reach such heights in the present situation.

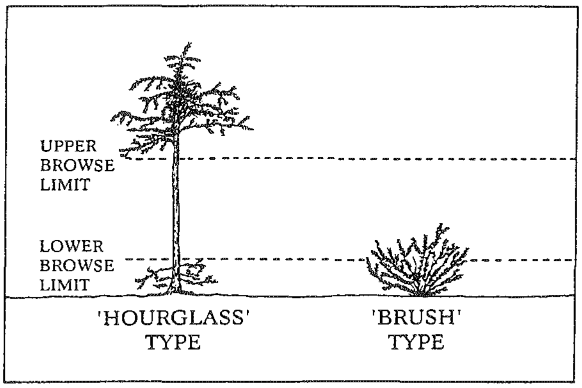

Figure 2. Yew plants browsed over time seem to develop varieties over two different morphological growth forms, i.e. the 'hourglass' and the 'brush' (see text).

There is also a high occurrence of totally destroyed yew plants in our study area, probably caused by roe deer browsing. The occurrence of yew on the Åland Archipelagoes (between Sweden and Finland) has declined drastically since roe deer were introduced (Hæggström 1990). Ståhl (1988) suggested that roe deer are the main factor in limiting the distribution of yew northwards. Svalastog & Høiland's (1991) and our observations suggest that roe deer are the main constraint to yew recruitment also in southern areas of Scandinavia. Thus, the yew reserves planned in southern Norway (Svalastog & Høiland 1991) will probably be unsuccessful in the long term if action is not taken to prevent roe deer from overbrowsing the yew. This may either be done by offering roe deer supplementary food, or by fencing in yew for as long as it takes the plant to grow out of reach of the roe deer. The height required for this varies considerably with snow depth and may be more than 2 m.

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