Wild boar rooting in a northern coniferous forest - minor silviculture impact.

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Abstract:

European wild boar (*Sus scrofa*) is expanding northwards beyond its preferred habitat of broadleaved forests. We studied wild boar habitat use in a northern coniferous forest, and noted whether their rooting damaged roots, thereby influencing timber quality and forest regeneration (*n* = 562 rootings). Overall, the animals selected older spruce (*Picea abies* L.) forest of higher soil fertility with sparse field vegetation for rooting. During winter, they rooted more in pine (*Pinus sylvestris* L.) forest on lower soil fertility, possibly because the lichen cover can easily be removed even on frozen ground. Average size and depth of rootings were 6 ± 0.6 m^2 and 10 ± 0.2 cm, respectively. Rooting occurred on <1% of the area, and caused negligible damage to roots of trees with commercial value. Because the wild boar mainly rooted in older forest, rootings will do little to improve germination of seeds by scarification of the top soil layer.

Keywords: *forest damage, forest regeneration, habitat*, *Sus scrofa*, *wildlife conflict*

Introduction

Over the last 50-70 years the European wild boar (*Sus scrofa*) has increased dramatically in numbers and expanded into the northern coniferous forests (Markov et al. 2005, Apollonio 2010). This has caused debate and concern in the newly colonized areas. One such area is the southeastern part of Norway. Here a population of wild boar has been present since about 2006 (currently holding 50-100 animals). Besides doubts as to whether the wild boar should be endorsed as a native species (Rosvold et al. 2010), the debate has been focused on how it will affect commercial forestry and agriculture in the region .

Although the wild boar's future in Norway is difficult to predict (Rosvold et al. 2010, this edge population is worth studying as it occupies an atypical habitat. The principal habitat of the European wild boar is broadleaved forests where energy-rich masts of oak (*Quercus* L. spp.) and beech (*Fagus* L. spp.) are the preferred food (Groot Bruinderink and Hazelbroek 1996). Another important part of the diet is underground items such as roots, bulbs, truffles (Elaphomyces Ness spp.) and soil invertebrates (Schley and Roper 2003, Lawrynowics et al. 2006). In many areas, the wild boar also uses agricultural land extensively, feeding on grain, potatoes and vegetables (Barrios-Garcia and Ballari 2012). The northern coniferous forests, because of cold climate, frozen ground and snowy winters, therefore appear to offer the wild boar only marginal habitats. However, these are assumptions only, as practically nothing is known about how wild boar utilizes and affects such forests.

In this study we looked at the foraging behaviour of wild boar residing in a coniferous forest of southeastern Norway. Our aim was three-fold: 1) to make an inventory of rooting in relation to vegetation type, soil fertility and forest age, 2) to determine if rooting caused damage to roots of trees with commercial value, and 3 to evaluate if rootings and scarification of the top soil layer occurred on clearcuts and thus were beneficial to seed germination.

Materials and methods

Study area

The study area Aremark is located in southeastern Norway (59º33´N, 11º22´E) along the border to Sweden (Fig 1). Most of the area is forested (78 %), while lakes and bogs cover 17% and 5%, respectively (Strand 1961). The forest belongs to the boreonemoral zone (Nordiska Ministerrådet 1984), with the main tree species being Norway spruce (*Picea abies* L.), dominating on slopes and in creek valleys with deep soil and sufficient moisture. Scots pine (*Pinus sylvestris* L.) grows predominantly at higher elevations in the eastern part of the area. While scattered deciduous trees are mixed with the conifers, less than 1 % of the forest consists of homogeneous deciduous forest. Mature forest is almost exclusively harvested by clearcutting. Rowan (*Sorbus aucuparia* L.), birch (*Betula pubescens* L., *Betula pendula* L.) and aspen (*Populus tremula* L.) along with various graminoids dominate on clearcuts in the first years after logging. Clearcuts are small compared to international practice, typically 1-3 ha. To the west the forests border agricultural land, where grain is the major crop.

Elevations are between 110 and 240 m.a.s.l. and the topography is broken by small creek valleys. Average temperature for the coldest month is -5.5ºC (January), but extremes may fall below -25ºC. Snow normally covers the ground from late December to late March. Greatest snow depth usually occurs in late February, averaging 36 cm (Norwegian Meteorological Institute 2011). During the year of the study snow depth averaged 45 cm in February and snow covered the ground from early December throughout March (Norwegian Meteorological Institute 2011).

Wild boar is artificially fed during fall and winter by hunters at eight sites bordering agricultural land at the western edge of the study area. The feed consists of vegetables, fruit and grain and likely provides a substantial part of energy requirement of the animals during these seasons. Hunting wild boar is allowed throughout the year.

Field work

Because we had no previous estimates of the wild boar home range, the study area was determined based on local reports and a preliminary search for rootings. After outlining the broad area of wild boar use, we divided the area into three parts: a northern, a middle and a southern part. Using 1:50 000 maps (WGS84) we randomly selected five 1-km^2 squares in each part for survey in the field. Within the squares, wild boar rootings were recorded continuously by the observer along 1-km long and 10-metre wide transects during July 2010. Nine such transects, parallel to one side of the square and 100 m apart, were surveyed on foot per square.. We randomly alternated the orientation of transects (north-south or east-west) between squares to avoid bias from major landscape features.

For each rooting we recorded its depth (cm) and the area of removed vegetation (m^2). We classified age of rootings following Welander (2000): 1) current summer, i.e. a fresh rooting where green plants had been destroyed and regrowth had not yet occurred, 2) last winter/spring, i.e. sprouts of new plant shoots and/or regeneration of moss are present, but no litter of leaves or needles in the rooting, 3) older rooting, i.e. a rooting covered with litter from leaves and needles.

The habitat around each rooting was categorized by 1) forest type (homogenous spruce forest; homogenous pine forest; mixed coniferous forest; homogenous deciduous forest), by 2) soil fertility (non-productive; poor; intermediate; high) (Statistics Norway 1993), by 3) forest age (I = logged within the last year; II = young forest < 20-30 years since logging, III = age approximately 25-45 years, IV = age approximately 45-75 years; V = mature forest 75-110 years) (Tomter 1999), and by 4) vegetation type (determined by dominant plants in the field layer, following Larsson 2000). The general occurrence of habitat types in the study area (the availability) was quantified by systematically recording the same forest characteristics (as around the rootings) in circular plots (r = 5 m) at every 200 m along the transects (five plots per transect, a total of 949).

Damage to spruce and pine caused by wild boar rooting was recorded as number of rootings where roots had been either cut or had bark peeled off. In order not to overlook covered wounds, rootings were carefully searched by hand.

Data analyses

We analyzed the wild boar habitat use on both a yearly and seasonal basis. For the yearly analysis we used all rootings recorded regardless of age. In the seasonal analysis we compared rootings from the last winter/spring and the current summer.

When analyzing which factors influenced the habitat choices, we used generalized linear models (GLIM) with link function (logit link) to account for binomial response data (rootings versus not rootings) (McCullagh and Nelder 1989). Explanatory variables were vegetation type, soil fertility and forest age. Originally we had 19 vegetation types in the field data, but prior to the analyses we grouped types with frequencies <5% (resulting in seven vegetation types). Interaction effects were included, but none were significant. We did not include season as an explanatory variable in order to maintain sufficient degrees of freedom. Rather we ran additional GLIMs with season as the binomial response variable, using only observations from sites with rootings (same explanatory variables). We used the Akaike's Information Criteria (AIC, Akaike 1974), as well as chi-tests on the deviance residuals, to compare parsimony of the various models. For the best model, we further used *z*-tests to identify which categories of the explanatory variables differed from each other. We used ordinary linear regression to test the relationship between depth and area of rootings. The effects of habitat parameters and season on depth and area of rootings were analyzed with ANOVA. Full models were overdispersed, so we had to analyze for single effects only.

In Figs, 2 and 3 we have included Ivlev`s selectivity index (Ivlev 1961). The index may achive values ranging from -1 to +1, where negative values indicate avoidance and positive preference. Values between -0.3 and +0.3 are genrally considered to be not significantly different from 0 and represent nonselective use of the habitat (Lazzaro 1987).

All statistical analyses were run in R (Development Core Team 2010). In the reported test statistic $F_{m,n}$, m is the number of factors included and n is degrees of freedom, for example, $F_{8,323}$ means eight factors and 331 observations were part of the model. In the test statistic Z_n, n is the number of rooting observations (i.e. sites used by wild boar). All central measures are mean ± 1 SE.

Results

Based on the rooting inventory we estimate that the wild boar population used approximately 60 km^2 of forest on a year-round basis. Tracks in the snow showed that a wild boar could wander up to 7-8 km east from the feeding stations into the forest, before settling down for bedding or rooting. Overall we surveyed 189 km of transects, covering an area of 189 ha. Of the surveyed area less than 1 % had been rooted. We recorded a total of 562 rootings (and an additional three rootings, for which age could not be determined). Of these 114 were from the current summer (20%), 218 were from last winter/spring (39%) and 230 were older (41%).

Habitat selection on a yearly basis was best explained by vegetation type, soil fertility and forest age (Tab. 1). Bilberry (*Vaccinum myrtillus* L.) forests, where the dominating tree species is spruce, were used more than all the other vegetation types taken together (Fig. 2). There was a clear selection for the two subtypes not having field layer vegetation (Z_{310} = 2.0, P = 0.043, and Z_{58} = 4.9, $P \leq 0.001$, respectively) (Table 2). Older forest (class IV and V) were selected above young forest (Fig. 3a) (Z_{241} = 4.0, $P \leq 0.001$ and Z_{144} = 3.9, $P \leq 0.001$, respectively). The use of fresh clearcuts (class I) was negligible. Regarding soil fertility the most fertile class was the most selected (Z_{90} = 4.2, $P \leq 0.001$) (Fig. 3b). Older rootings occurred more frequently on soil of high fertility compared to newer rootings (24 % vs. 12 %) (Z_{562} = 2.3, $P \leq 0.001$). The other habitat characteristics did not differ with age of rootings. For a better overview we include a table of all model coefficients, which show that all variables are highly significant (Table 2).

The wild boar largely showed the same pattern of habitat selection during summer and winter, but in winter more rootings were found in the lichen (*Cladonia* L. spp.) and pine dominated forest (14 % vs. 9 % in summer) ($F_{7,323}$ = 2.5, P= 0.011) and on sites of lower soil fertility (32 % vs. 19 %) ($F_{4,328}$ = 3.8, P = 0.010). In accordance with increased selection for pine forest in winter, there was also a stronger selection for poor soil fertility compared to in summer (27% vs. 12 %) ($F_{3,325}$ = 6.0, $P \leq$ 0.001). Furthermore, the wild boar rooted less in the younger stages of production forest (class III) during winter (31% vs. 17%) ($F_{5,326}$ = 3.5, $P \leq 0.001$). The depth and area of rootings did not vary with season.

The average size of rootings was 6 ± 0.6 m^2 (varying between 100 cm^2 and 200 m^2). Less than 2% of the rootings exceeded 50 m^2, and three out of four rootings were <5 m^2. Depth of rootings averaged 10 ± 0.2 cm (varying between 3 and 25 cm). Every fourth rooting was more than 15 cm deep. There was no clear relationship between area and depth (R^2= 0.027, $P \leq 0.001$). Nevertheless, both area and depth increased with forest age (and $F_{4,558}$ = 4.1, P = 0.006 and $F_{5,556}$ = 5.9, $P \leq 0.001$, respectively). The depth also was less on sites with low soil fertility, where the animals had mostly removed only the lichen cover ($F_{4,557}$ = 4.1, P = 0.006).

Damage to roots of coniferous trees was negligible. Root damage was found in less than 0.5 % of all rootings (26 out of 562 rootings). Only finer roots occurred at rootings, and damages to larger roots were generally small, with less than 2 cm^2 peeled off bark (O. Haaverstad, pers. obs.).

Discussion

The wild boar in Aremark selected only a few out of several available forest types for rooting. Consequently, the potential silviculture damage is likely to be concentrated. The only other report of wild boar use of northern coniferous forests is Markov et al. (2004), discussing the spread of wild boar into the taiga zone of North Western Russia during the last 40-60 years. Like for our study, they conclude that the wild boar at the northern limit of its range uses a relatively narrow range of habitats.

Markov et al. (2004) also stated that wild boar of the northern coniferous forest depends on anthropogenic food, particularly in winter. Furthermore, the study quotes Russian reports of wild boar in these forests foraging at the periphery of high bogs and in swamped lowlands. It is difficult to make direct comparisons between the two study areas (Norway vs. Russia), but bogs and swamped forest are indeed available in Aremark as well. It is likely that the Norwegian wild boar population will utilize more marginal habitats if the animal density is allowed to increase.

The wild boar selectivity for forest types with sparse field layer in our study is noteworthy. In areas where coniferous forest occurs together with broadleaved forest, the wild boar generally selects the latter (Singer et al. 1981; Dardaillon 1986; Welander 2000; Fonseca 2008), or occasionally uses the forest types in accordance with their availability (Meriggi and Sacchi 2001). One exception is a study by Thurfjell et al. (2009) in southern Sweden, where wild boar selected planted spruce stands over broadleaves during all seasons except in summer. Possibly abundant artificial foods made ample cover a more important deciding factor.

There were few rootings on recently logged clearcuts in our study. Consequently, our hypothesize that the scarification effect of wild boar rooting may be positive for forest regeneration, by improving seed germination, was not supported. Also Meriggi and Sacchi (2001), using a transect method similar to ours, reported that large clearings in the forest were avoided. It should be noted, however, that in our study area clearcuts have abundant field layer vegetation and the wild boar may have used these sites to feed on above ground plants (we only recorded rootings). In southern regions the use of open areas like agricultural and alpine grasslands by wild boars is well documented (Bueno et al. 2009; Barrios-Garcia and Ballari 2012).

Wild boar damage to tree roots is a concern among foresters. They worry that removal of bark and wounding of roots will serve as entrance for rot-causing fungus. However, no studies of wild boar rootings, including this one, have reported root damages to be a problem. In some areas the direct foraging effect of wild boar can possibly be more harmful to forestry, because the animals eat seedlings and saplings of broadleaves (Lipscomb 1989; Groot Bruinderink and Hazebroek 1996; Barrios-Garcia and Ballari 2012). Whether this applies to coniferous seedlings is not known.

Focardi et al. (2000) considered two types of wild boar rootings: those restricted to the upper humus layer (animals searching for acorns and similar foods) and those below the humus (animals searching for roots, invertebrates or other below ground edibles). The wild boar in our study area typically both removed the humus and continued to root deeper down. Presumably, lack of field vegetation in closed spruce forest made rooting and digging easier and may explain the preference for this forest type (but less field vegetation also means fewer underground roots to search for). The use of lichen dominated pine forests in winter may be explained by lichens being easily removed even when the ground is frozen. Possibly the animals find invertebrates within and just below the lichen cover. We made no systematic investigation of the wild boar diet in Aremark. Superficial investigation of faces and of the rootings in spruce forest revealed remains of truffles (*Elaphomyces* spp.). Very little is known of the availability of truffles in northern coniferous forests, and consequently, about their potential as food for wild boar.

In conclusion the wild boar in our study area appear to choose forest sites providing easy conditions for rooting, either closed spruce forest with no field vegetation (summer) or pine lichen forest (winter). As little digging occurred in soil infiltrated by larger roots they caused little damage to standing forest.

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Table 1. Model selection (GLIM) for explaining wild boar use of sites for rootings, Norway 2010..

Model	Vegetation type	Soil fertility	Forest age	AIC	Residual deviance	df[a]	*P*-value[a]
1	x	x	x	1426.0	1394.0		-
2	x	x		1456.6	1432.6	-4	≤ 0.001
3	x		x	1443.3	1417.3	-3	≤ 0.001
4		x	x	1803.7	1787.7	-8	≤ 0.001

Note: n = 562 rootings.

[a] *chi*-tests on the residual deviances, testing the negative effect on model fit of excluding each factor from the full model.

Table 2. Coefficients of factors included in the best model (GLIM, see Table 1) explaining wild boar use of sites for rootings, Norway 2010.

Factor	**Estimate**	**SE**	**z**	***P*-value**
Intercept	-2.77	0.543	-5.10	≤ 0.001***
SoilFertility2	0.57	0.340	1.69	0.091
SoilFertility3	1.35	0.403	3.34	≤ 0.001***
SoilFertility4	1.89	0.448	4.21	≤ 0.001***
AgeClass2	1.26	0.525	2.40	0.016*
AgeClass3	1.26	0.500	2.86	0.004**
AgeClass4	1.43	0.491	4.05	≤ 0.001***
AgeClass5	2.00	0.502	3.89	≤ 0.001***
VegType2a	-1.88	0.317	-5.95	≤ 0.001***
VegType2b	0.70	0.348	2.02	0.043*
VegType3a	-1.68	0.370	-4.54	≤ 0.001***
VegType3b	2.19	0.449	4.88	≤ 0.001***
VegType4	-1.24	0.431	-2.87	0.004**
VegType5	-1.66	0.406	-4.09	≤ 0.001***

Note: n = 562 rootings. Estimates are relative to the first class of each factor. Factor classes are explained in Figures 2 and 3.

Figure 1. Study area, southeastern Norway.

Figure 2. Wild boar use of vegetation types as indicated by rootings (n = 562) in relation to availability (n = 941), Norway 2010. Classification of vegetation types follows Larsson (2000). Numbers above bars are Ivlev's index of selectivity (values above +0.3 and below –0.3 are considered significant).

Figure 3. Wild boar use, as indicated by rootings, of sites with varying (a) forest age and (b) soil fertility (n = 558 and 562, respectively) in relation to availability (n = 926 and 936, respectively), Norway 2010. I = logged within the last year; II = 20–30 years since logging, III = 25–45 years, IV = 45–75 years; V = 75–110 years. Numbers above bars are Ivlev's index of selectivity (values above +0.3 and below –0.3 are considered significant).

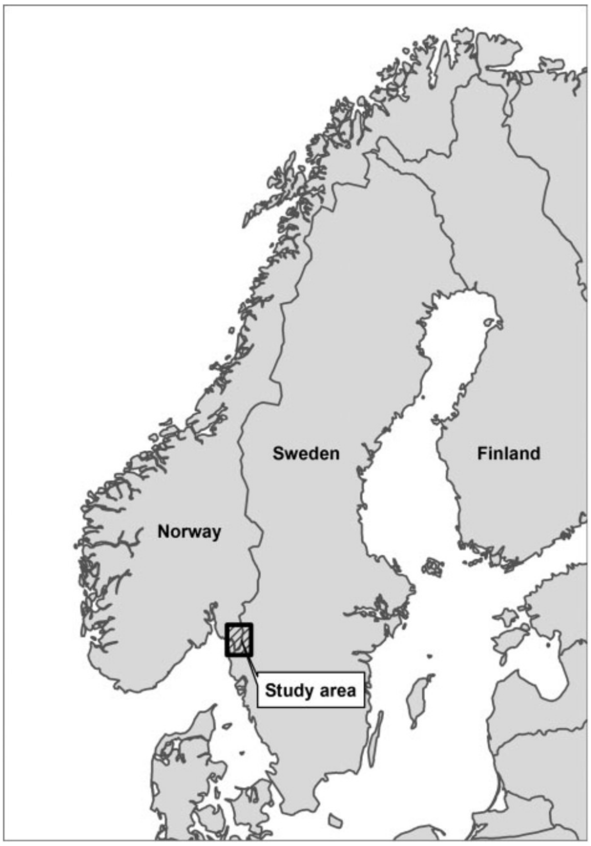

Fig. 1

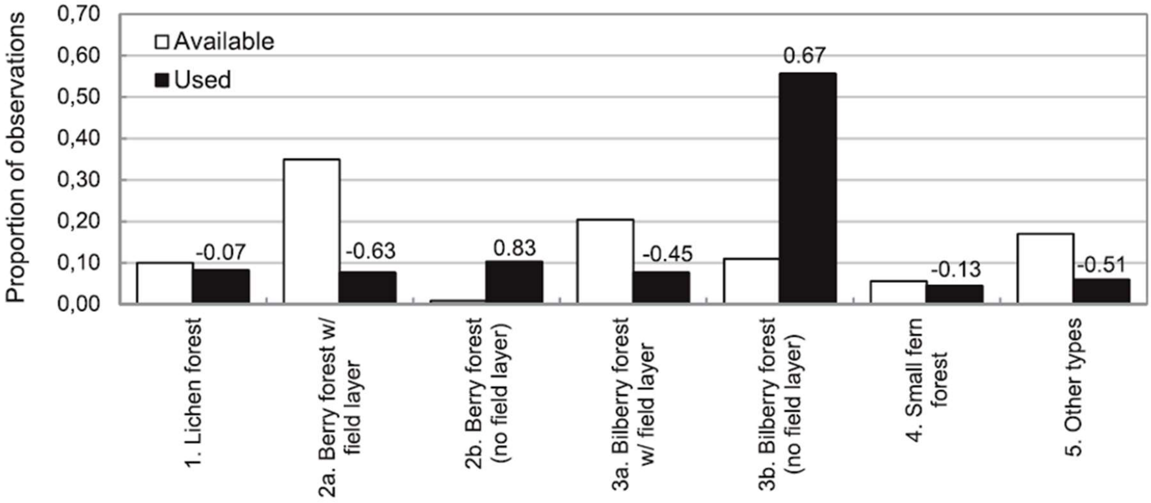
Proportion of observations
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,00
Available
Used
-0.07
-0.63
0.83
-0.45
0.67
-0.13
-0.51
1. Lichen forest
2a. Berry forest w/ field layer
2b. Berry forest (no field layer)
3a. Bilberry forest w/ field layer
3b. Bilberry forest (no field layer)
4. Small fern forest
5. Other types

Fig. 2

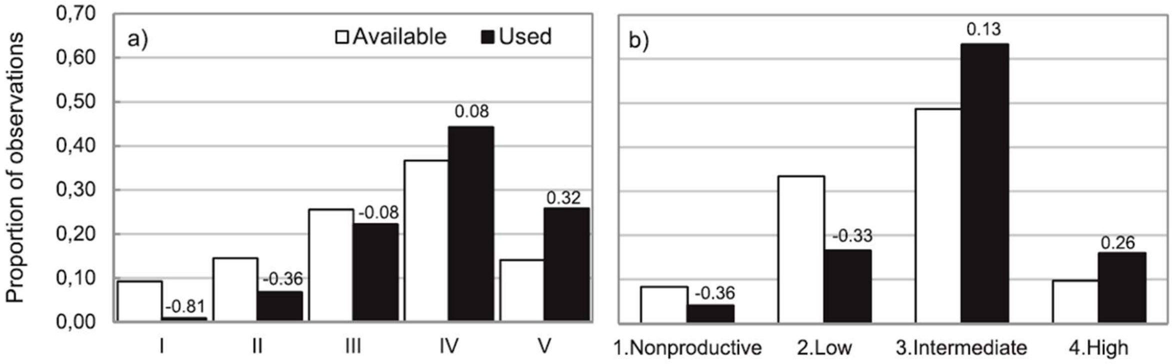
a)
Available
Used
Proportion of observations
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,00
-0.81
-0.36
-0.08
0.08
0.32
I
II
III
IV
V
b)
-0.36
-0.33
0.13
0.26
1.Nonproductive
2.Low
3.Intermediate
4.High

Fig. 3