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Goose damage to grassland and winter cereals by White-fronted and Bean geese (*Anser albifrons* and *A. fabalis*) in the Lower Rhine area, Germany

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The effect of different intensities of winter and early spring grazing by both White-fronted and Bean geese, *Anser albifrons* and *A.fabalis*, on the yields of agricultural grasslands (first grass cut) and autumn-sown wheat and barley (grain yield) was studied in the lower Rhine area of Germany.

In a first phase of the study paired plots of grazed and ungrazed portions of the same grassland or winter cereal fields provided information on loss of yield at harvest. On both crops the field observations indicated a loss of yield due to goose grazing at accumulated grazing intensities more than 3000 goose days/ha (gd/ha), but only in the more homogeneous cereal fields the results were statistically relevant.

To confirm the field observations in the second phase of the study, trials were conducted with captive geese held in movable cages on both grassland swards and cereal fields. Trials at various grazing intensities were carried out, and analysis at 3000 gd/ha grazing pressure corresponding to intensities measured in the field confirmed a loss of yield in both crops.

Yield losses in the study area (10–15 % on grassland, 8–14 % on cereals) at a grazing intensity of 3000 gd/ha are closely comparable to results from improved grasslands in the Netherlands and on wheat and barley crops in both England and Scotland, and comparable to values obtained on hayfields in Eastern Canada.
Further studies are necessary to calibrate trials with captive geese to the field situation with wild congeners, as captive birds are expected to require less feed per day.

Key words: White-fronted Goose (*Anser albifrons*), Bean Goose (*Anser fabalis*), grazing, grazing experiments, grasslands, winter cereals, goose damage.

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1. Introduction

In older literature there is no uniform picture about the effects of goose grazing on agricultural crops (see e.g. Mooij 1984). More recent studies on effects of winter grazing by geese have uniformly shown loss of yield in both improved grasslands (Bedard et al. 1986; Groot Bruinderink 1989; Patterson 1991, Percival & Houston 1992) and cereal crops (wheat: Summers 1990; wheat and barley: Patterson 1991, Patterson et al. 1989) under levels of grazing intensity commonly occurring over at least part of the wintering area.

The Lower Rhine valley is a traditional wintering site for arctic geese, mainly White-fronted (*Anser albifrons*) and Bean Geese (*Anser fabalis*). Since the beginning of the 1960s, as a winter peak of 1000–1500 Bean and less than 100 White-fronted Geese was counted, numbers increased considerably and reached a more or less stable number of 140000–180000 White-fronted and 5000–10000 Bean Geese annually since the end of the 1980s. Increasing goose usage of the Lower Rhine wintering area have been a cause of concern for the local authorities administering the goose damage scheme aimed at compensating farmers for crop losses (Mooij 1993, Fig. 1). Detailed information about species composition, phenology and winter ecology is published elsewhere (Mooij 1992 & 1993). Since winter 1975/76 no shooting of geese has been permitted in the study area. Present management aim is to spread the wintering geese as evenly as possible within the area by avoiding disturbance, to avoid big local concentrations and to minimize the areas where damage occurs. On a small scale scaring devices (scarecrows, flags) as well as the distribution of liquid manure are employed by the farmers to keep the geese from their land.

The aim of this study was to determine if and to what extent grazing by geese in winter results in actual yield loss to the farmer and if so, whether goose damage levels in the Lower Rhine study area are comparable with those recorded elsewhere. Two approaches have been taken, first by determining yields on grazed and ungrazed parts of sites visited by geese and second by undertaking grazing trials with captive birds.

2. Study area

The goose wintering site of the Lower Rhine area is situated between the coordinates 51.50 N, 5.52 E (Nijmegen, NL) and 51.30 N, 6.45 E (Duisburg, D) in the natural floodplains of the Rhine between Rhinekilometer 793 and 883. About 85 % of the area belongs to Germany (Federal state of North Rhine-Westphalia), 15 % to the Netherlands (Province of Gelderland). Land usage at the time of the study can be summarized as follows: about 70 % of the study area is used for agriculture, of which about 60 % as improved grassland and about 40 % as arable land, with winter grains, sugar beets and maize as main crops. Grassland in the study area are dominated by *Lolium perenne*, *Festuca ovina*, *Festuca rubra* and *Poa* spp. and belong to the association Lolio-Cynosuretum (Foerster 1983). The Lower Rhine area is one of the most productive agricultural areas of North Rhine-Westphalia.

3. Methods

3.1. Field estimation of goose damage

To assess grazing intensity, all geese in the study area (c. 25000 ha) were counted at least once a week, and goose flocks entered on detailed topographic maps (grid 50 x 50 m). Information on land use was also entered at this scale. These data were used to calculate the grazing intensity of each site, in goose days per hectare (gd/ha), of both White-fronted and Bean Geese, which often occur in mixed flocks. At 34 sites with known feeding density droppings were counted in 50 at random selected plots of 1 m^2 at each site (1700 plots) after the geese left the site for the roost to determine the relation between dropping density and grazing intensity as recorded by direct count of birds.

In the early years of the study (1979–1981) the method of paired plot comparison was employed at feeding sites where geese were prevented from using the entire field on account of obstacles (e.g. stables, tension lines) or proximity of roads. Around such obstacles a zone of 50 m or more and along roads a zone of 150 m or more was not used by geese (Keller 1991, Mooij 1982b). Both in the grazed and in the ungrazed part of such fields plots were selected at random. From these plots above-ground biomass of grass was ascertained by cutting plots of 1 m^2 with hand shears to ground level, on a date in May, timed to precede by a few days the harvest by the local farmer. The clipped material was oven-dried to constant mass at 90 °C.

During the winters 1977/78, 1978/79 and 1979/80 on three grassland feeding sites favoured by geese in the previous years exclosures were made by help of metal cages (24 cages of 2 x 1 m and 10 cages of 1 x 1 m) to compare grazed and and non-grazed parts of the sites.

After winter 1978/79, six grassland feeding sites and after winter 1980/81, nine grassland feeding sites were studied. At each site a number of plots was sampled, each of 1 m^2 and in equal numbers in both grazed and ungrazed conditions: in 1979 at two sites 18 plots, at two sites 10 and at two sites 8 plots, in 1982 at 3 sites 16 plots and at 6 sites 8 plots were sampled.

Similar procedures were followed in cereal fields (date of harvest July, again conforming to the farmer's dates). At these sites after the winters 1979/80 and 1980/81 at each site 20 plots and after winter 1983/84 40 plots of 1 m^2 were sampled. In 1985/86 the yield of 3745 m^2 grazed and 3431 m^2 non-grazed winter barley was harvested by the farmer in July and weighed separately.

In Winter 1982/83 sward height was determined 10 times between the beginning of November until the end of April by employing a movable disc of polystyrene (radius 10 cm, weight 10 g) mounted on a stick with a centimeter scale. By this method, used also by Groot Bruinderink (1987 & 1989) grazed and ungrazed portions of seven pastures were sampled (each time about 100 samples of 1 m^2 per site and category). The results were compiled in catagories of 1 cm. Besides from 5 grassland sites the composition of the sward (50 plots of 1 m^2 each) and the composition of the plant remnants in the goose droppings (200 droppings each) of these sites was analysed by the methods of Owen (1975) and Zettel (1974a & b): three sites 1979 and two in 1982.

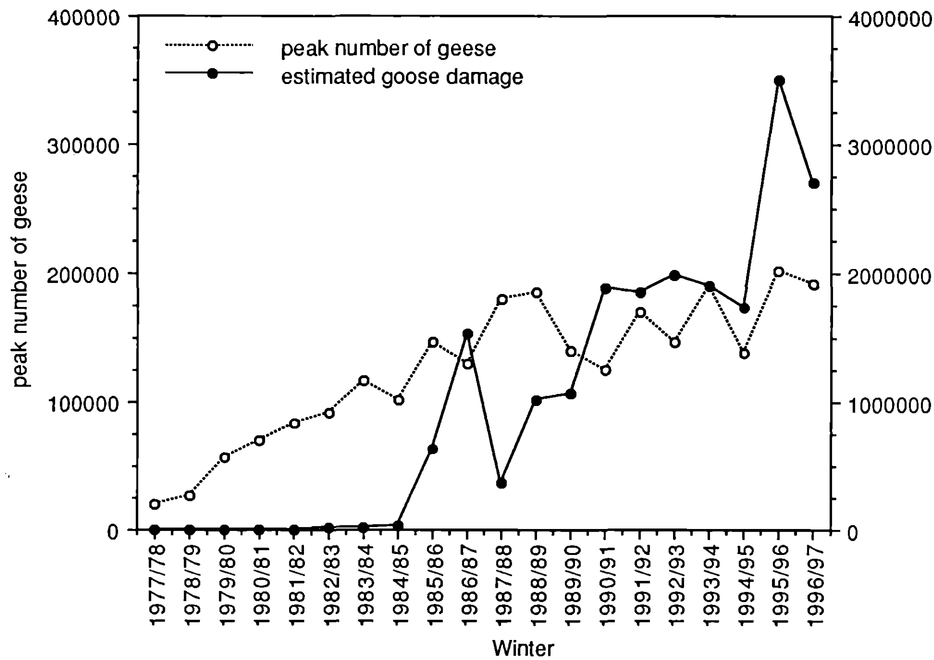

Fig. 1: Goose peak numbers and estimated goose damage at the Lower Rhine area between 1977/78 and 1995/96 (Source: Arbeitsgemeinschaft Wildgänse 1996 & 1998, Gemmeke 1998, Mooij 1995 & ZWFD unpubl.).

Abb. 1: Gänsemaxima und Entschädigungen für Gänseschäden am Unteren Niederrhein zwischen 1977/78 und 1995/96 (Quelle: Arbeitsgemeinschaft Wildgänse 1996 & 1998, Gemmeke 1998, Mooij 1995 & ZWFD unveröffentl.).

3.2. Grazing trial experiments

Because in the field experiments there were a number of important factors not controllable by the investigator (e.g. differences in soil, water regime, vegetation and agricultural treatment) it was felt necessary to conduct a series of grazing trials carried out with captive geese under controlled conditions confined to movable cages mounted on wheels. These wire mesh cages (floor area 5 x 5 meters, 1 meter high) could be displaced over a field. By varying the number of occupants or the duration of grazing at a site the desired grazing intensity could be achieved.

In six consecutive winter seasons (1982/83–1987/88) these trials were conducted on improved grassland managed at the grassland research station of the „Landesanstalt für Ökologie, Landschaftsentwicklung und Forstplanung Nordrhein-Westfalen (formerly „LÖLF NW", now „LÖBF NW")" to conform with local farming practice (fertilizer input amounted to 60 kg N/ha, applied between April and July annually). The experimental fields were selected on uniformity of abiotic conditions and vegetation and got uniform agricultural treatment. Each field was covered with a 5 x 5 meter grid and the plots for different grazing levels were selected at random. To reduce bias due to so-called cage effects (e.g. more favourable growing conditions for the vegetation caused by microclimatic changes in the cages) the cages were only moved on the plots during grazing-hours.

In the first three seasons grazing intensities of 0, 500, 1500 and 3000 gd/ha were established and grazing implemented in the period December through February, corresponding to the period of usage by the wild geese. In the final three seasons a grazing intensity of 6000 gd/ha was implemented in a limited number of trials, and the 500 gd/ha level omitted, because this grazing level is about the mean grazing intensity in the area and did not cause significant differences in yield. In a supplementary series the grassland plots were irrigated by a pipe network during the grazing trials to simulate puddling conditions.

The effect of goose grazing on the dry matter yield in the subsequent growing season was determined by comparison of harvest results from grazed and ungrazed treatments. The plots were harvested by means of a mechanical mower equipped with yield collector, which covered each plot in two swaths. Material for each plot was pooled, subsequently dried to constant mass at 90 °C and yield mass measured. The time of harvest (mid-May) was selected to coincide with the first cut of the local farmers, the period when according to the farmers impact of goose grazing was deletrious.

In the winters of 1986/87 and 87/88 these grazing trials with movable cages were extended to winter cereals as well. Autumn-sown barley and wheat were grazed by semi-tame White-fronted and Bean Geese (two pairs each) with feeding intensities of 750, 1500, 3000 and 6000 gd/ha. On cereals, harvest was accomplished by means of a mechanical mower equipped with yield collector, the grains subsequently dried to constant mass at 90 °C and grain mass measured. The cereal plots were harvested in July at the time the grains were ripe for harvest.

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4. Results

4.1. Goose usage in relation to land use

At the Lower Rhine wintering site both goose species utilized the grassland preferentially; although grassland acounted for 58.1 % of agricultural land use of the region wintering geese spent about 87% of all goose days on grasslands: *Anser albifrons* 96 % and *A. fabalis* 82 % of their feeding time (the remainder being devoted to arable land (see Mooij 1984 & 1993). Grasslands used in this study were dominated by *Lolium perenne* (35%), *Festuca ovina* and *Festuca rubra* (33%) and *Poa* spp. (10%, all percentages refer to the frequency of the species in the 250 samples of 5 grassland sites favoured by feeding geese where vegetation was sampled quantitatively). *Alopecurus* spp., *Phleum pratense*, *Dactylis glomerata*, *Bromus mollis*, and *Cynosurus cristatus* and the herbs *Taraxacum officinale*, *Urtica dioica*, *Ranunculus* spp., *Trifolium* spp., *Rumex* spp., *Polygonum* spp. and *Plantago* spp. were also found in the sward. This species composition is considered typical for the whole study area, where grasslands are usually classified as belonging to the association Lolio-Cynosuretum (Foerster 1983 & pers. comm.). From analysis of 1000 droppings of these feeding sites according to the methods described by Owen (1975) and Zettel (1974a & b) it was found that the diet of the geese contained *Festuca*, *Lolium* and *Poa* in approximately the same proportion as they occurred in the sward. These species groups accounting for slightly more than two-thirds of the epidermal fragments identified in the microscopic analysis (Fig. 2). The herbs *Taraxacum* and *Trifolium* were also identified in the droppings.

Arable land is visited briefly at the beginning of winter when remnants of harvest, e.g. sugar beets and maize, are still available (3 % of all goosedays) and during periods of cold weather (especially with snow) when winter cereals are utilized (10 % of all goosedays). The intensity of utilisation of arable land by geese in the study area is correlated with the average winter temperature ($R^2 = 0.40$; Fig. 3). Further information on use of the site can be found in Ernst & Mooij 1988, Mooij 1984, 1991, 1992 & 1993.

4.2. Field estimation of goose damage

The exclosures by help of metal cages used in the winters of 1977/78, 1978/79 and 1979/80 did not produce useful data, because hardly any geese used these sites in the winters the cages were situated there.

The sward height of the grazed and ungrazed parts of seven pastures that were measured showed great differences after the geese left the wintering site in mid-March (Fig. 4), the sward

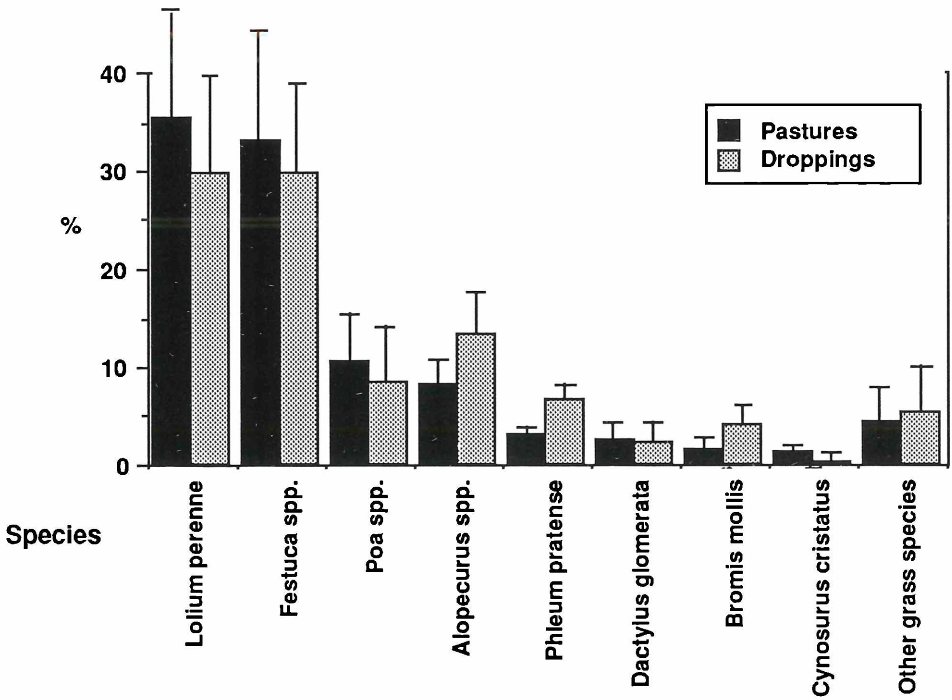

Fig. 2: Composition of the sward on five pastures (total plot size: 250 m²) at the Lower Rhine goose wintering site and of goose dropping samples (n = 1000) of these pastures.

Abb. 2: Zusammensetzung der Grasnarbe von fünf Grünlandflächen (Gesamtgröße Probefläche: 250 m²) im Gänsewintergebiet am Unteren Niederrhein sowie von den Gänsekotstangen (n = 1000) von diesen Flächen.

height of the ungrazed area ranged between 2–24 cm (n = 769; mean = 8.8 cm, SE = 3.7) and of the grazed parts 2–13 cm (n = 818; mean = 4.9 cm, SE = 2.3). This difference was statistically significant (Wilcoxon-test; $p < 0.05$). 60% of the samples on grazed pasture measured 2-5 cm. At time the mean sward height of the grazed area reached a level of 2-4 cm this area usually was left by the geese until the sward had more or less recovered, which usually was the case after 4-6 weeks (Mooij, unpubl.). By the end of April most of the difference in sward height between the grazed and ungrazed parts of the investigated pastures was gone. The sward of the grazed parts (n = 364, mean = 15.9 cm, SE = 3.4) was still somewhat lower than that of the ungrazed (n = 336, mean = 16.8 cm, SE = 4.5), but this difference was statistically not significant (Wilcoxon-test). The investigated plots showed a tendency to a more homogeneous grass sward at the grazed plots.

The most reliable data on goose days accumulated during the winter season were obtained from the systematic counts, and results for the sites where the farmers expected goose damage are collected in Table 1 (pastures) and 2 (cereal crops). These data only show significant differences between the grazed and ungrazed plots on grassland with grazing intensities higher than 2000–3000 gd/ha (significance of the differences tested with Wilcoxon-test). In seven out of 15 cases the difference between grazed and ungrazed plots was statistically significant: in five cases yield loss of 6–20 % and in two cases a 20–25 % higher yield was found on the grazed plots. On cereals yield loss of c. 18.5 % was confirmed statistically in the case of the rather homogeneous wheat field sampled in 1983/84 (grazing intensity 3500 gd/ha) and of c. 13 % for the barley field sampled in

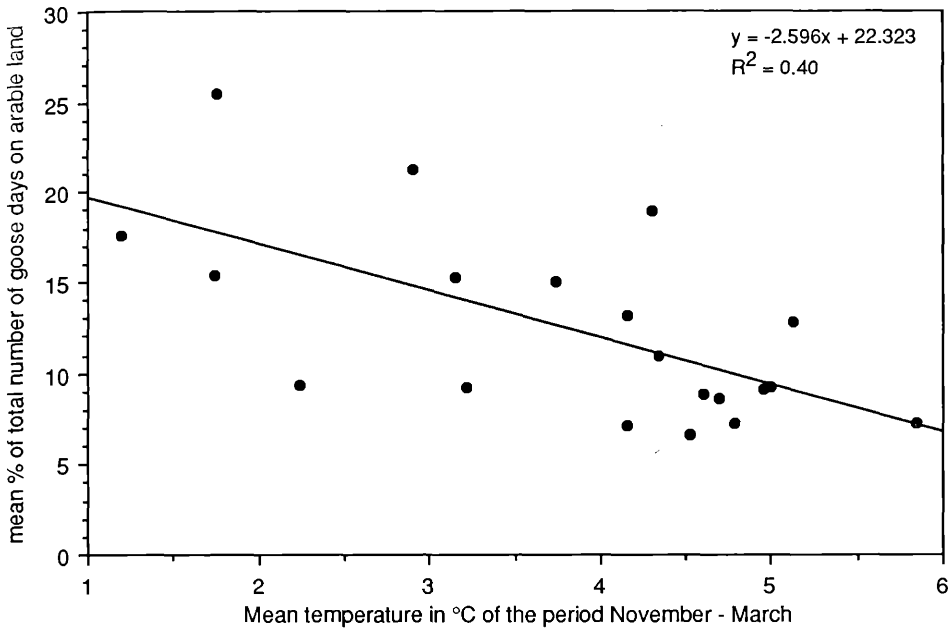

Fig. 3: Relation ($R^2 = 0.40$) between the average temperature during the period November-March (in °C) and the utilisation of arable land by the geese wintering at the Lower Rhine area between winter 1977/78 and 1996/97 (in % of all goose days).

Abb. 3: Zusammenhang ($R^2 = 0.40$) zwischen den durchschnittlichen Temperaturen in der Periode November-März (in °C) und der Nutzung von Ackerflächen durch überwinternde Gänse am Unteren Niederrhein zwischen Winter 1977/78 und 1996/97 (in % aller Gänseweidetage).

1979/80 (grazing intensity 2400 gd/ha). No effect of goose grazing could be established at grazing intensities below 2000 gd/ha. In 1986 a chance observation provides a field check concerning goose impact on barley. A 6.5 hectare barley field was bisected by a high-voltage power line inhibiting goose visitation on half of the area. The utilized half accumulated 2630 gd/ha (as determined from the weekly census). Yield of the ungrazed portion was 8150 kg (dry matter)/ha compared to 7100 kg/ha on the grazed portion, a reduction of 13%. Unfortunately because this result was obtained from total harvest by combine (weighing one run on each portion) without subsamples it is not possible to substantiate this difference statistically.

Earlier studies (Mooij 1984) indicated a damage threshold of 2000–3000 gd/ha for grasslands, and at a somewhat lower level for winter grain crops.

Results for grazing impacts on grass yields (Table 1) are unsatisfactory given the variability of the sward and the very limited sampling regime. The data show lower as well as increased yields at grazed plots as well as a tendency to a more homogeneous grass sward at the grazed plots, but significant differences in yield were only found above a grazing intensity level of about 2000 gd/ha. A part of the yield differences could be the result of influences other than goose grazing, because the condition of the plots before goose feeding was not investigated (see Mooij 1984).

The results of these field experiments indicate that yield loss on grassland and cereals can happen in case of goose grazing intensities higher than 2000 gd/ha without indicating the grazing intensity expected to transgress the damage threshold or a connection between grazing intensity and yield loss level. As such these experiments form the starting point for the detailed experimental work.

Winter	Plot no.	Feeding intensity in gd/ha	Yield in kg dry matter/ha: grazed area (g) mean yield (kg)	S.E.	no. of plots	ungrazed area (ug) mean yield (kg)	S.E.	no. of plots	relative yield (g/ug) in %	significance (Wilcoxon)
1978/79	1	1292	4504	482	9	4239	494	9	106.3	n.s
	2	1950	3925	516	9	4928	520	9	79.6	< 0.005
	3	2608	3645	710	5	4740	546	5	76.9	< 0.005
	4	2968	4070	657	4	4730	418	4	86.0	n.s
	5	3004	4275	384	4	5160	304	4	82.8	< 0.025
	6	3016	4850	508	5	3850	497	5	126.0	< 0.025
	mean	2473	4212	712	36	4608	702	36	91.4	n.s
1981/82	1	1066	3563	332	8	3155	370	8	112.9	n.s
	2	1382	3940	448	8	4783	413	8	82.4	n.s
	3	2332	2419	398	8	2714	359	8	89.1	< 0.025
	4	2654	4240	364	4	6020	532	4	70.4	n.s.
	5	2700	2405	80	4	2565	310	4	93.8	< 0.005
	6	2964	2435	276	4	2865	269	4	85.0	n.s.
	7	3011	3845	553	4	3245	498	4	118.5	< 0.005
	8	3110	3640	455	4	3545	544	4	102.7	n.s.
	9	3120	3280	347	4	3065	196	4	107.0	n.s.
	mean	2482	3307	820	48	3551	1207	48	93.1	n.s.
mean		2478	3669	892	84	3974	1154	84	92.3	n.s.

Table 1: Results of the yield (in kg dry matter/ha) comparison between grazed and ungrazed parts of grasslands at the goose wintering site at the Lower Rhine (significance of the differences tested with Wilcoxon-test).

Tab. 1: Ergebnisse der Erntevergleiche (in kg Trockenmasse/ha) auf von Gänsen beweideten und unbeweideten Teilen von Grünlandflächen im Gänsewintergebiet am Unteren Niederrhein (Signifikanz-Test nach Wilcoxon).

Winter	Feeding intensity in gd/ha	Yield in kg dry matter/ha: grazed area (g) mean yield (kg)	S.E.	no. of plots	ungrazed area (ug) mean yield (kg)	S.E.	no. of plots	relative yield (g/ug) in %	significance of difference (Wilcoxon)
WINTERBARLEY									
1979/80	2366	6279	336	10	7096	265	10	88.5	< 0.05
1980/81	1676	6998	209	10	6911	264	10	101.3	n.s.
1985/86	2630	7100	-	1	8150	-	1	87.1	-
mean	2224	6792	-	-	7386	-	-	92.0	n.s.
WINTERWHEAT									
1983/84	3520	4902	237	20	6020	280	20	81.4	< 0.005

Table 2: Results of grain yield (in kg dry matter/ha) comparison on grazed and ungrazed parts of fields with winter cereals at the goose wintering site at the Lower Rhine (significance of the differences tested with Wilcoxon-test).

Tab. 2: Ergebnisse der Erntevergleiche auf Getreide (in kg Trockenmasse/ha) auf von Gänsen beweideten und unbeweideten Teilen von Getreideflächen (Wintergerste und Winterweizen) im Gänsewintergebiet am Unteren Niederrhein (Signifikanz-Test nach Wilcoxon).

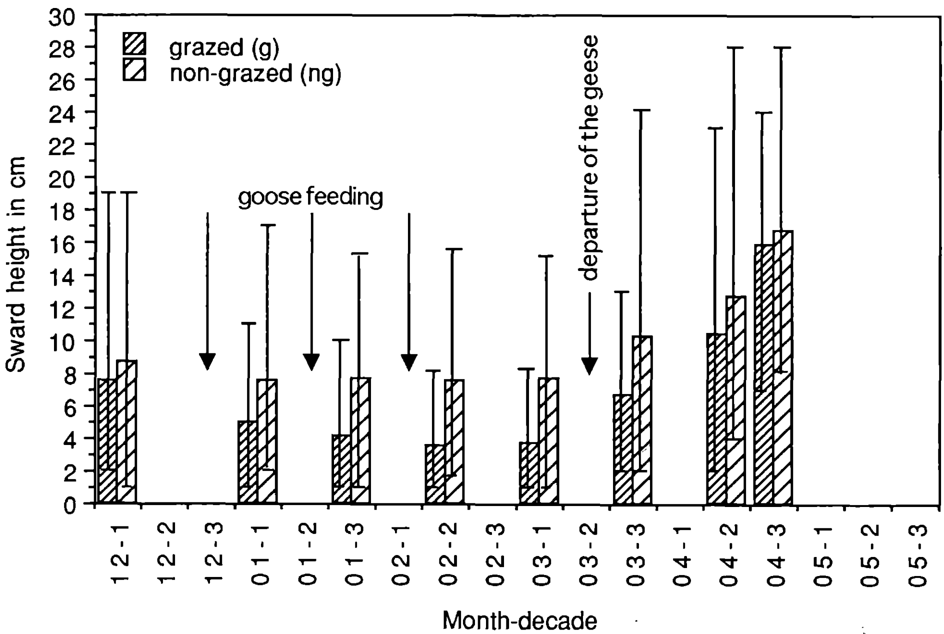

Fig. 4: Sward height (with range) on grazed (1600 gd/ha) and ungrazed parts of 7 pastures grazed by geese at the goose wintering site at the Lower Rhine between December and April.

Abb. 4: Höhe der Grasnarbe (mit Streuung) auf von Gänsen beweideten (1600 Gänseweidetage/ha) und unbeweideten Teilen von 7 Grünlandflächen im Gänsewintergebiet am Unteren Niederrhein zwischen Dezember und April.

4.3. Experimental demonstration of grazing impact

In the cage experiments on grassland yield reduction without irrigation at grazing intensities of 500 and 1500 gd/ha was statistically not significant for the first cut and total yield, whereas the plots at a grazing intensity of 3000 gd/ha showed statistically significant yield reductions in both cases (Wilcoxon-test, $p < 0.005$) and at 6000 gd/ha produced a significant yield reduction in the first cut (Wilcoxon-test, $p < 0.025$). The results of these grazing experiments (winter 1982/83–1987/88) are summarized in Table 3.

Analysis of variance on the paired data set (controls versus grazed) revealed no significant interaction with year, and the total data set demonstrate a significant reduction in grass yield at first cut (mid-May) at grazing intensities of 3000 gd/ha and higher. The average yield reduction for the 35 trials at a grazing intensity of 3000 gd/ha was 10% and for the 18 trials at a grazing intensity of 6000 gd/ha was 28 % of the control yield.

The grazing experiments on irrigated grassland showed hardly any statistically significant results (Table 3), but there is a clear tendency that the yield of the first cut on the irrigated plots was generally lower than on the non-rrigated plots, independent from the grazing activities of the geese (m = 5 %). The same was true for the total yield, allthough on a lower level. Therefore it cannot be stated that goose feeding on irrigated plots caused an additional deletrious effect under the conditions of the experiment (Table 4). Yield loss clearly was due to irrigation and not to puddling by geese.

Results of the yield comparsion between grazed and ungrazed grasland plots										
	without irrigation					with irrigation				
feeding intensity	no. of plots	mean gras yield (kg dry matter/ha)	S.E.	difference in %	significance (Wilcoxon)	no. of plots	mean gras yield (kg dry matter/ha)	S.E.	difference in %	significance (Wilcoxon)
First cut in May										
0 gd/ha	35	2940	714	-	-	15	2794	662	-	-
500 gd/ha	17	3166	602	107,7	n.s.	9	3017	463	108,0	n.s.
1500 gd/ha	35	2870	791	97,6	n.s.	15	2778	704	99,4	n.s.
3000 gd/ha	35	2626	720	89,3	< 0.005	15	2424	726	86,8	n.s.
6000 gd/ha	18	2113	779	71,9	< 0.025	6	2000	627	71,6	n.s.
Second cut in June										
0 gd/ha	35	2666	504	-	-	15	2641	461	-	-
500 gd/ha	17	3159	305	118,5	n.s.	9	2899	414	109,8	n.s.
1500 gd/ha	35	2792	416	104,7	< 0.050	15	2563	400	97,0	n.s.
3000 gd/ha	35	2763	449	103,6	< 0.010	15	2743	496	103,9	< 0.050
6000 gd/ha	18	2339	244	87,7	n.s.	6	2372	245	89,8	< 0.005
Third cut in July										
0 gd/ha	35	2703	991	-	-	15	2809	906	-	-
500 gd/ha	17	3007	981	111,2	< 0.050	9	3179	751	113,2	n.s.
1500 gd/ha	35	2641	955	97,7	n.s.	15	2848	815	101,4	n.s.
3000 gd/ha	35	2632	1005	97,4	n.s.	15	2708	780	96,4	n.s.
6000 gd/ha	18	2374	1003	87,8	n.s.	6	2255	832	80,3	n.s.
All three cuts (total yield)										
0 gd/ha	35	8309	1313	-	-	15	8244	1161	-	-
500 gd/ha	17	9332	821	112,3	n.s.	9	9095	333	110,3	n.s.
1500 gd/ha	35	8303	1102	99,9	n.s.	15	8189	1159	99,3	n.s.
3000 gd/ha	35	8021	1234	96,5	< 0.005	15	7875	942	95,5	n.s.
6000 gd/ha	18	6826	452	82,2	n.s.	6	6627	619	80,4	n.s.

Table 3: Yield results of the grazing experiment with captive geese on grassland with feeding intensities of 0, 500, 1500, 3000 and 6000 goose days/ha with and without irrigation (significance of the differences tested with Wilcoxon-test).

Tab. 3: Ernteergebnisse der Beweidungsexperimente mit Gänsen in Käfigen auf Grünland nach einer Beweidungsintensität von 0, 500, 1500, 3000 und 6000 Gänseweidetagen/ha mit und ohne Bewässerung (Signifikanz-Test nach Wilcoxon).

In the cage experiments on cereal yield reduction closely comparable results were obtained for both wheat (14 % yield reduction) and barley (8 % yield reduction) concerning losses at a grazing intensity of 3000 goosedays/ha and more than 30 % at a grazing intensity of 6000 goose days/ha. In all cases a statistically acceptable result was obtained despite the small sample size (n = 6–12) no doubt due to the greater homogeneity of the crop compared to the grassland (Table 5).

Besides confirming yield losses at a grazing intensity of 3000 gd/ha, the data from the captive trials can be employed to provide a dose-response relationship. For the grassland series, in all years 0, 1500, and 3000 gd/ha treatments were run (six replicates in each season). Subjecting these data (108 samples in all) to an ANOVA analysis confirms that there is a significant effect of goose grazing on yield at first cut ($F = 16.09$, $p < 0.001$, $df = 2$, $R^2 = 0.89$, no significant interaction between year and grazing pressure).

This analysis was repeated for the last three seasons only, when the series 0, 1500, 3000 and 6000 goosedays/ha were undertaken (six replicates each year, total 72 plots) and again an ANOVA analysis substantiates the impact of goose grazing on yield ($F = 14.13$, $p < 0.001$, $df = 3$, $R^2 = 0.90$) (Fig. 5).

No significant influence of grazing on dry matter yield of grassland was established during the second and third cuts both with and without irrigation. There seems to be a partial compensation of

Results of the yield comparsion between irrigated and non-irrigated grasland plots								
feeding intensity	without irrigation yield (kg d.m./ha)	SE	no.plots	with irrigation yield (kg d.m./ha)	SE	no.plots	%	significance (Wilcoxon)
First cut in May								
0 gd/ha	2940	714	35	2795	662	15	95,1	n.s.
500 gd/ha	3166	602	17	3017	463	9	95,3	< 0.089
1500 gd/ha	2870	791	35	2778	704	15	96,8	n.s.
3000 gd/ha	2626	720	35	2424	726	15	92,3	n.s
6000 gd/ha	2113	779	18	2000	627	6	94,7	n.s.
mean	2743	781	140	2603	703	60	94,9	
All three cuts (total yield)								
0 gd/ha	8309	1313	35	8244	1229	15	99,2	n.s.
500 gd/ha	9332	821	17	9095	333	9	97,5	n.s.
1500 gd/ha	8303	1102	35	8189	1159	15	98,6	n.s.
3000 gd/ha	8021	1234	35	7875	942	15	98,2	n.s.
6000 gd/ha	6826	452	18	6627	619	6	97,1	n.s.
mean	8158	1289	140	8006	1150	60	98,1	

Table 4: Comparison of yield results of the grazing experiment with captive geese on grassland with and without irrigation and feeding intensities of 0, 500, 1500, 3000 and 6000 goose days/ha (significance of the differences tested with Wilcoxon-test).

Tab. 4: Vergleich der Ernteergebnisse der Beweidungsexperimente mit Gänsen in Käfigen auf Grünland mit und ohne Bewässerung bei einer Beweidungsintensität von 0, 500, 1500, 3000 und 6000 Gänseweidetagen/ha (Signifikanz-Test nach Wilcoxon).

Results of the yield comparsion between grazed and ungrazed cereal plots					
feeding intensity	no. of plots	mean grain yield (kg dry matter/ha)	S.E.	difference in %	significance (Wilcoxon)
Winterbarley					
0 gd/ha	9	5701	873	–	–
750 gd/ha	6	6741	316	118,2	n.s.
1500 gd/ha	12	5659	880	99,3	n.s.
3000 gd/ha	12	5217	743	91,5	n.s.(p = 0.113)
6000 gd/ha	12	3814	1563	66,9	< 0.001
Winterwheat					
0 gd/ha	12	6655	943	–	–
750 gd/ha	9	6209	377	93,3	< 0.025
1500 gd/ha	12	6172	1005	92,7	< 0.080
3000 gd/ha	12	5716	899	85,9	< 0.001
6000 gd/ha	6	4593	990	69,0	< 0.005

Table 5: Yield results of the grazing experiment with captive geese on winter cereals (winterbarley and winterwheat) with feeding intensities of 0, 750, 1500, 3000 and 6000 goose days/ha (significance of the differences tested with Wilcoxon-test).

Tab. 5: Ernteergebnisse der Beweidungsexperimente mit Gänsen in Käfigen auf Getreide (Wintergerste und Winterweizen) bei Beweidungsintensitäten von 0, 750, 1500, 3000 und 6000 Gänseweidetagen/ha (Signifikanz-Test nach Wilcoxon).

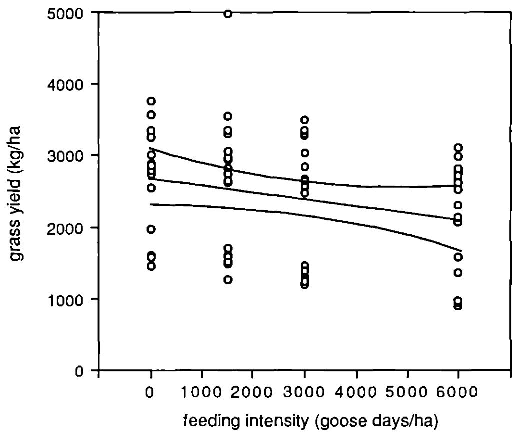

Fig. 5: Yields results of the grazing experiment with captive geese on grassland in relation to different feeding intensities (with 95% confidence intervals).

Abb. 5: Ernteergebnisse der Beweidungsexperimente mit Gänsen in Käfigen auf Grünland in Relation zu den verschiedenen Beweidungsintensitäten (mit 95% Vertrauensbereich).

the early spring yield loss in the period between the first and the third cut that compensates about half of early spring losses (Table 3).

The most comprehensive data for the cereal trials are collected in Fig. 6. For wheat, the 1986/87 data (four levels of grazing intensity in addition to controls, nine replicates) an ANOVA confirms a significant effect of grazing on yield ($F = 9.57$, $p < 0.001$, $df = 4$, $R^2 = 0.55$).

For barley, the 1987/88 data involve four levels of grazing as in the wheat trial, in addition to the controls (6 replicates) and the ANOVA confirms the significant effect of grazing on grain yield ($F = 9.79$, $p < 0.001$, $df = 4$, $R^2 = 0.64$).

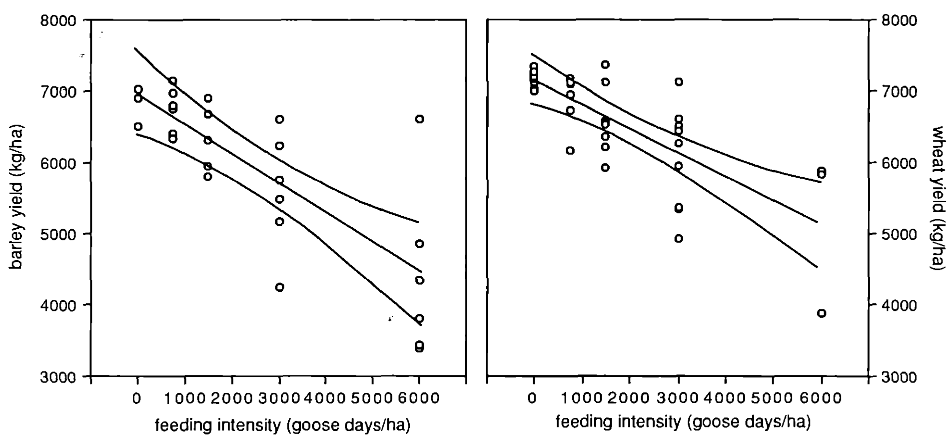

Fig. 6: Yield results of the grazing experiment with captive geese on cereals (winterbarley and winterwheat) in relation to different feeding intensities (with 95% confidence intervals).

Abb. 6: Ernteergebnisse der Beweidungsexperimente mit Gänsen in Käfigen auf Getreide (Wintergerste und Winterweizen) in Relation zu den verschiedenen Beweidungsintensitäten (mit 95% Vertrauensbereich).

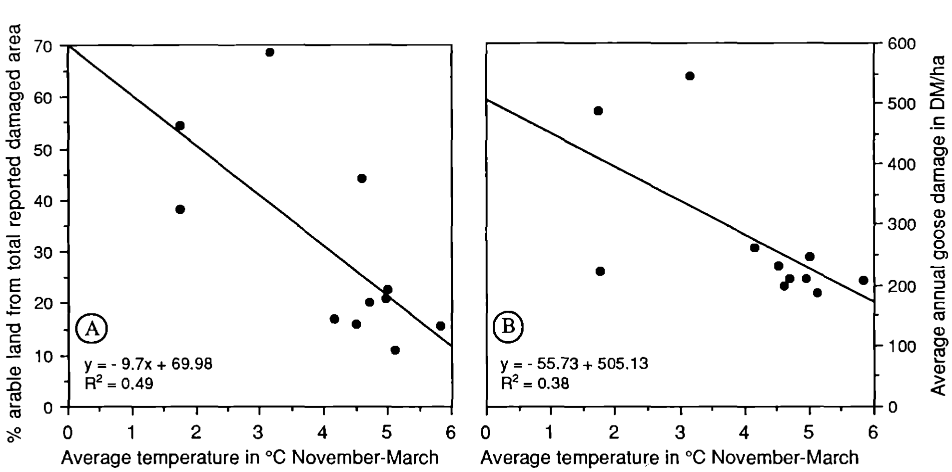

Fig. 7: Relation between the average winter temperature (Ø November-March) in °C and the portion of arable land from the annual reported damage area (A) in % as well as the annual compensation paid for goose damage (B) in DM/ha.

Abb. 7: Zusammenhang zwischen der mittleren Wintertemperatur (Ø November-März) in °C und dem Ackeranteil an den im jeweiligen Jahr gemeldeten Schadflächen (A) in % sowie der Höhe der im jeweiligen Jahr pro Hektar gezahlten mittleren Entschädigungssumme (B) in DM.

No correlation was found between temperature during winter and spring and yield loss, but a relation was found between the average winter temperature (November-March) at one hand and the rate of goosedays spend on arable land (Fig. 3; $R^2 = 0.40$), the portion of goose damage reported on arable land (Fig. 7; $R^2 = 0.49$) and the average amount of compensation paid per hectare (Fig. 7; $R^2 = 0.38$) on the other hand.

4.4. Dropping counts

According to the results of the dropping counts at sites with a known feeding density there seems to be a relation between the number of droppings/m^2 and the feeding density (Fig. 8; $R^2 = 0.91$). A feeding density of 3000 gd/ha seems to equate with about 30 droppings/m^2.

5. Discussion

The years of study can be considered average according to the long-term weather data of the area. These were gathered by the weather station of the LÖLF NW in Kleve-Kellen for all winters. Severe frost damage to the experimental plots that might have masked effects of goose grazing (cf. Groot Bruinderink 1987 & 1989) did not occur.

5.1. Level of goose damage

In this study in the Lower Rhine area, yield loss in barley of 8 % and in wheat of 14 % was found at a a grazing intensity of 3000 gd/ha. Recently grazing trials with captive geese have been undertaken in the northern Netherlands following virtually the same protocol employed in this study. There White-fronted Geese confined to autumn-sown wheat at a grazing intensity of 3000 goosedays/ha caused a loss in grain yield of 17 % (28 trials over three winter seasons, corrected for sea-

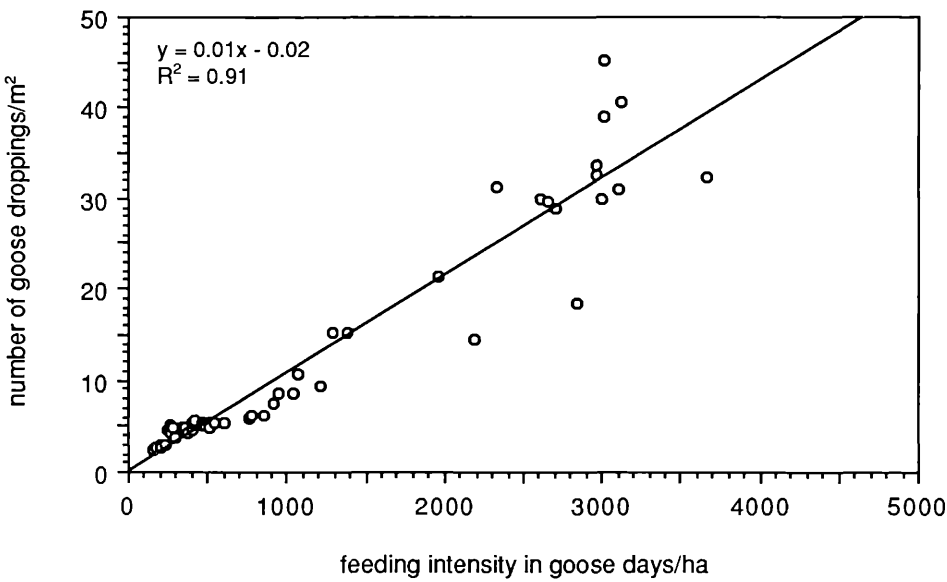

Fig. 8: Relation between feeding intensity (gd/ha) and the number of droppings per m² at the goose feeding sites of the Lower Rhine.

Abb. 8: Zusammenhang zwischen der Beweidungsintensität (in Gänseweidetagen/ha) und der Zahl der Kotstangen pro m² im Gänsewintergebiet am Unteren Niederrhein.

sonal effects by analysis of covariance). A similar decrement in yield was established for grass grown for seed (12 % loss in seed yield, 30 trials spread over three seasons, TEUNISSEN 1996). These values are closely similar to those obtained in the Lower Rhine study.

The main difficulty in extrapolating from these captive trials to the field situation lies in equating the grazing day of a semi-tame experimental subject with its wild counterpart. Detailed observations on tame Brent, *Branta bernicla*, compared with wild individuals by DRENT et al. (1978/79), suggested that tame birds consume 2/3 of the intake typical for unrestrained individuals. It may thus be assumed that the damage threshold confirmed by captive grazing at 3000 gd/ha is in reality a high value, and that grazing by free ranging geese at levels somewhat below this may already cause measurable loss of yield.

In praxis it mostly will be difficult to relate goose damage reported by a farmer to the actual grazing intensity, based on the actual grazing time and the number of geese that used the site, to estimate the expected level of goose damage. Several investigators (e.g. BEDARD et al. 1986, GROOT BRUINDERINK 1987 & 1989, PATTERSON et al. 1989, PERCIVAL & HOUSTON 1992, SUMMERS 1990) have reported yield losses in relation to the mean grazing intensity concerned, often expressed in terms of the mean density of goose droppings per square meter accumulated at the respective site. These values can in turn be converted to goosedays if the number of droppings deposited on the foraging sites during one feeding day can be determined.

By observing the average number of droppings produced per hour (10.7, n = 64) and the mean time spent at the feeding sites in the study area (10.5 hours) the feeding day of the White-fronted Goose was calculated to equate with 112 droppings per day at the feeding site (MOOIJ 1992). OWEN (1972) obtained a closely similar value for this species (120 droppings/day), and constants for other

Crop	droppings/m²	rel. yield loss	goose species	Author
Grass	15-45	8-9 %	*A. albifrons, A. fabalis*	This studdy, field
Grass	8	14 %	*Anser caerulescens*	GEDARD, NADEAU & GAUTHIER 1986
Grass	11.3-23.6	6-19 %	*A. albifrons, A.fabalis, A. brach.*	GROOT BRUINDERINK 1987 & 1989
Grass	10	19 %	*Branta bernicla*	PERCIVAL &HOUSTON 1992
Barley	14.1	8 %	*A. albifrons, A. fabalis*	This study, field
Barley	4.5	7 %	*A. anser, A.brachyrhynchus*	PATTERSON, ABDUL JALIL & EAST 1989
Wheat	22.1	19 %	*A. albifrons, A. fabalis*	This study, field
Wheat	5.4	15 %	*A. anser, A.brachyrhynchus*	PATTERSON, ABDUL JALIL & EAST 1989
Wheat	3.4-21.8	6-10 %	*Branta bernicla*	SUMMERS 1990

Table 6: Field observations relating crop damage to goose grazing (in droppings/m²).

Tab. 6: Freilanddaten zum Zusammenhang zwischen Gänseschaden und Beweidungsintensität gemessen an der Zahl der Kotstangen pro m².

species are in the same range: 112 droppings/day in Brent Geese, *Branta bernicla*, (EBBINGE & BOUDEWIJN 1984) and 135 droppings/day in the Barnacle Goose, *Branta leucopsis* (EBBINGE et al. 1975). The hourly rate of production of droppings has been reported for Pink-footed Geese, *Anser brachyrhynchus*, as 11.2 (PATTERSON et al. 1989), again close to the findings on the White-fronted Geese of the Lower Rhine area (10.7) so in this group of species dropping counts will be closely comparable.

Table 6 assembles data found in literature relating yield loss to goose grazing at sites intensively used, reflected in counts of dropping densities. It will be noted that in general the loss of yield in both pasture and cereal crops falls within the range 6–20% of the controls. This must not necessarily mean that throughout the entire study area this figure applies, but clearly more or less exhaustive attempts to ascertain the impact of goose grazing in the unrestrained situation, regardless of the species concerned, show that winter grazing can be associated with yield losses when densities of goose droppings exceed about 5 droppings/m² (cereals) or 10 droppings/m² (grasslands). Differences between the different studies can be the result of differences between abiotoc factors (e.g. climatic factors, soil quality, humidity), agriculture (e.g. farming technics, sward composition in grasslands) or goose species (e.g. food selection, feeding method, autumn, winter or late spring grazing). In the studies compared, yield losses were found on an average level of about 10 droppings/m² (cereals) or 15 droppings/m² (grasslands). These densities of droppings equate to approximately 500–1000 gd/ha (cereals) and 1000-1500 gd/ha (grasslands) which can be regarded as empirically determined thresholds of yield loss. These field values are considerably lower than the levels at which farmers in the study area tended to register complaints.

The main gap in the data so far is a systematic investigation of the significance of the temporal grazing pattern as distinct from the accumulated pressure without regard to timing. Furthermore, of the studies cited only one dealt with late spring grazing, and the impact of Snow Geese, *Anser caerulescens*, on the St Lawrence estuary (BEDARD et al. 1986) cannot be taken as representative for conditions elsewhere. For the Lower Rhine area and the Netherlands, where the goose damage problem on grasslands was investigated both with the same species and the same grazing period, the goose damage can be expected when densities of goose droppings exceed about 20 droppings/m² which equates about 2000 gd/ha. For cereals these values seem to be 15 droppings/m² and about 1500 gd/ha.

5.2. Costs of goose damage

The yield reduction on grasslands after goose grazing with a feeding intensity of 3000 gd/ha was about 260 kg dry matter/ha, i.e. 3% of the yield up to July. Good quality hay, that could compensate this loss of animal feed, would cost about 20–25 DM/100 kg (11.5–14 US$/100 kg), which would mean total damage costs of 52–65 DM/ha (30–37 US$/ha). The yield reduction after goose grazing on grassland with a feeding intensity of 3000 gd/ha was about 300 kg dry matter/ha, i.e. 10 % of the yield at the first cut in May, which should be compensated by grass silage or concentrated feed, which will cost 8–10 DM/100 kg (4.5–6 US$/100 kg) for silage or 10–13 DM/100 kg (6–7.5 US$/100 kg) for concentrated feed, i.e. 25–40 DM/ha (14–23 US$/ha). This means that the goose damage found on grassland ranges between DM 25,— and DM 65,— per hectare (14–37 US$/ha).

On winter cereals yield reduction with a feeding intensity of 3000 gd/ha is about 500–1000 kg dry matter grain-yield/ha (12–20%). With wintergrain prices between 22–25 DM/100 kg (12.5–14 US$/100 kg) for barley and 20–25 DM/100 kg (11.5–14 US$/100 kg) for wheat a goose damage case on cereals ranges between DM 100,— and DM 250,— per hectare (57–143 US$/ha).

These figures are based on average prices of fodder and grain at the level of January 1998. Changes in these prices will change the financial level of goose damage.

During the 1980s average prices were 15–20 DM/100kg for hay (8.5–11.5 US$/100kg), c. 15 DM/100 kg for grass silage (8.5 US$/100 kg) and 35–45 DM/100 kg for wintergrains (20–26 US$/100 kg). Based on this price level the costs of goose damage during the 1980s can be calculated on 50–60 DM/ha for grasslands (28,5–34 US$/ha) and on 175–450 DM/ha for cereals (100–257 US$/ha).

The average annual compensation rates paid per hectare for goose damage by the North Rhine-Westphalian government between 1986 and 1993 were about 170 DM/ha on grassland (97 US$/ha) and about 542 DM/ha on arable land (310 US$/ha) and reached a comparable level (although about 10 % higher) as the mean compensation paid in the Netherlands between 1977 and 1989: grassland: 175,– Hfl./ha (89 US$/ha), arable land: 553,– Hfl./ha (282 US$/ha), according to data of the Dutch Ministry of Agriculture, Naturemanagement and Fishery (MINISTERIE VOOR LANDBOUW, NATUURMANAGEMENT EN VISSERIJ 1990 and OOSTENBRUGGE et al. 1991). For Germany GEMMEKE (1998) estimated that during the 1990s annually 20000–60000 ha arable land and 10000–15000 ha grassland were damaged by waterfowl with an estimated loss of approximatily 50 million DM (28.5 million US$). As this damage was estimated mainly by the farmers themselves the experts of the federal ministries believe that damage is overestimated by at least 30 %. Based on the compensation rates paid in North Rhine-Westphalia and the Netherlands, which were estimated by official appraisers, the total amount of waterfowl damage could not have surmounted 13–35 million DM (7.5–20 million US$), which is about half of the official estimate. The estimated damage level for all Germany (GEMMEKE 1998) even seems to be overestimated at least four times compared to the results of this study.

Based on the calculations of the actual damage level in the experiments the average annual compensation rates paid per hectare for goose damage in North Rhine-Westphalia and the Netherlands seem rather high. Because of the fact that captive birds are expected to require less food per day as their wild congeners it may be assumed that actual yield loss in the field situation will be higher as found in this study.

Because of the relation found between the average winter temperature (November–March) at one hand and the rate of goosedays spent on arable land (Fig. 3), the portion of goose damage reported on arable land (Fig. 7) and the average amount of compensation paid per hectare (Fig. 7) on the other hand, it can be stated that for the goose wintering site at the Lower Rhine there seems to be a connection between winter temperatures and the level of goose damage claims. Here cold winters forced the geese to increased feeding on arable land. Most crops are more susceptible to goose damage than grasslands. Therefore in cold winters not only the proportion of arable land reported to be damaged increased but also the average amount of compensation paid per hectare, i.e. cold winters cause higher goose damage claims than mild winters. This conclusion is supported by the fact that in the severe winter of 1995/96 extremly high goose damage estimates were reported from most federal states of Germany, especially on arable land (GEMMEKE 1998).

6. Zusammenfassung

In der Periode 1978–1988 wurden am Unteren Niederrhein Untersuchungen zu den Auswirkungen der Winter- und Frühjahrsbeweidung durch Bläß- und Saatgänse (*Anser albifrons* und *A.fabalis*) auf die Ernteerträge von Grünland- und Wintergetreideflächen (Gerste und Weizen) durchgeführt. In einer ersten Phase gaben die Ernteergebnisse von benachbarten Probeflächen in beweideten und nicht-beweideten Teilen der Versuchsflächen Auskunft über Art und Ausmaß der Beweidungsfolgen für die Ernte (erste Schnittnutzung bei Grünland und Körnerertrag bei Getreide). Bei diesen Freilandversuchen zeigten sich, sowohl auf Grünland als auch auf Getreideflächen, Ertragseinbußen als Folge der Beweidung durch Gänse ab einer kumulierten Beweidungsintensität von 3000 Gänseweidetagen/ha. Die Ertragsunterschiede waren jedoch nur bei den mehr oder weniger homogenen Getreideflächen statistisch signifikant.

Zum Zwecke der Überprüfung der Freiland-Ergebnisse, wurden in einer zweiten Phase der Untersuchung Beweidungsversuche mit halbzahmen Gänsen in mobilen Käfigen auf standarisierten Grünland- und Getreideflächen durchgeführt. Es wurden verschiedene Beweidungsintensitäten simuliert (0, 500, 1500, 3000 und 6000 Gänseweidetage/ha). Die Ergebnisse des Beweidungsexperiments bei einer Beweidungsintensität von 3000 Gänseweidetagen/ha bestätigten, sowohl auf Grünland als auch auf Getreide, die Ergebnisse der Freilandversuche. Die gefundenen Ernteverringerungen bei einer Beweidungsintensität von 3000 Gänseweidetagen/ha (10–15% auf Grünland, 8–14% auf Getreide) sind gut mit den Ergebnissen ähnlicher Untersuchungen aus den Niederlanden (Grünland) und Groß-Britannien (Getreide) vergleichbar. Ähnliche Ergebnisse wurden auch auf Wiesen im Osten Kanadas ermittelt.

Da wildlebende Gänse wahrscheinlich einen höheren täglichen Energiebedarf haben als ihre gefangenen Artgenossen, müssen weitere Untersuchungen durchgeführt werden, um festzustellen ob und in wie weit eine Beweidung mit gefangenen Gänsen mit einer Beweidung durch Wildgänse zu vergleichen ist.

7. References

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