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Vegetation characteristics of a brackish marsh on Gotland and foraging choices of migrating and brood rearing geese

Alexandra J. van der Graaf[1,2,*], Julia Stahl[1,3], Roos M. Veeneklaas[2] & Jan P. Bakker[2]

[1)] *Animal Ecology Group, Centre for Ecological and Evolutionary Studies, University of Groningen, P.O. Box 14, 9750 AA Haren, The Netherlands*
[2)] *Community and Conservation Ecology Group, Centre for Ecological and Evolutionary Studies, University of Groningen, P.O. Box 14, 9750 AA Haren, The Netherlands (*corresponding author's e-mail: a.j.van.der.graaf@rug.nl)*
[3)] *Landscape Ecology Group, University of Oldenburg, D-26111 Oldenburg, Germany*

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Arctic breeding barnacle geese use brackish marshes along the coastline of the Baltic Sea intensively in spring, during short stopovers on their migration to breeding sites in northern Russia. We mapped the vegetation of one important spring staging and brood rearing site on the Swedish island of Gotland and investigated the habitat use of barnacle geese. The geese mainly use plant communities with a high cover of edible species and a low canopy height. These vegetation characteristics are best maintained through livestock grazing and the maintenance of current grazing practices will be responsible for future site use by small herbivores.

Key words: barnacle geese, *Branta leucopsis*, brood rearing, foraging choices, habitat description, spring staging, salt marsh

Introduction

Barnacle geese (*Branta leucopsis*) are herbivorous migratory birds, foraging almost exclusively on salt marshes and coastal grasslands. In spring the geese migrate from their winter and spring staging sites in the Wadden Sea in western Europe to breeding sites that traditionally are situated on the arctic islands of Novaya Zemlya and Vaygach (Ganter *et al*. 1999). The birds do not cover this distance all at once, but migrate in several distinct steps, and refuel and rest at each stopover site. The first stop of the barnacle geese on their spring migration to arctic Russian breeding sites is in the Baltic Sea. Traditionally a large proportion of the Russian barnacle geese used the island of Gotland as a stopover site during migration. They utilise narrow strips of coastal grasslands along the shore of southwest Gotland for a few weeks at the end of April and early May before continuing their journey. Since the 1980s some geese have remained on

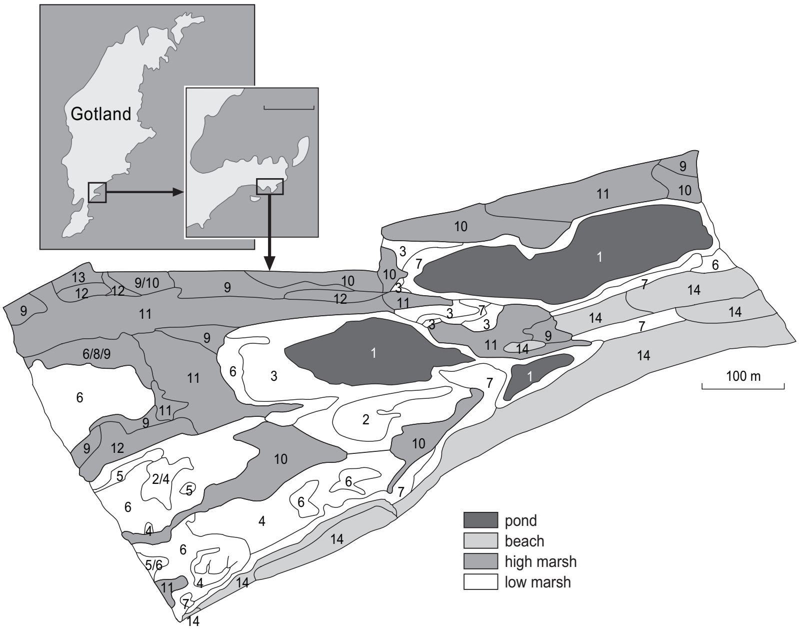

Fig. 1. Location of Grötlingbo-udd and of our study area on Grötlingbo-udd and the vegetation map of our study area. *See* Table 1 for a description of the 14 plant communities.

small islands along the coast of Gotland during the summer period and started to breed there (Larsson *et al*. 1988). At present about 10% of the total flyway population of barnacle geese breeds in the Baltic, the majority near Gotland (Ganter *et al*. 1999). Geese that breed on the small islands along the coast return with their goslings to the mainland of Gotland soon after hatch. Throughout the summer the geese remain on the brackish marshes, which at this time are also grazed by cattle and sheep.

During spring migration, the birds have to balance their energy expenditure and food intake, in order to build up sufficient energy reserves to be able to migrate to their breeding areas and breed successfully. Plant forage availability and quality at staging sites play a crucial role for these small herbivores, as the amount of body reserves accumulated by individuals prior to migration directly affects breeding success (Prop & Black 1998). At the breeding sites, food availability and quality influence gosling growth rates, which determine final adult body size and post-fledging survival (Loonen *et al*. 1997, 1998, Van der Jeugd & Larsson 1998). Food availability and quality along the flyway, thus, shape fitness and life history parameters for the geese.

In this study we describe the salt-marsh vegetation at one of the main staging sites on the Swedish island of Gotland and map the habitat use of the geese in this area. The aim of our study is to gain better insight into the foraging decisions of barnacle geese in these critical stages of their life cycle. We hope that our research will facilitate and support management decisions for brackish coastal grasslands in the Baltic region.

Material and methods

Study site

The peninsula Grötlingbo-udd (57°07´N, 18°27´E) on the east coast, near the southern tip of the Baltic island of Gotland (Sweden), is a stopover site for large numbers of migrating barnacle geese in April and May, as well as a foraging site for families and non- or failed-breeders of the Gotland breeding population of barnacle geese from the end of May onwards (Van der Graaf *et al*. 2006). The brackish marsh stretches from the east point of the peninsula along the southern shore for about 1 km (Fig. 1). The east point of the peninsula is protected as a nature reserve, whereas the southern part is private property of local farmers. Directly adjacent to the marsh, we find open pine forest and juniper (*Juniperus communis*) shrubland. At some parts, the meadows stretch inland and halophytes disappear from the vegetation. The entire marsh and adjacent meadows are moderately grazed by cattle from early June onwards. Besides its function as a foraging site for barnacle geese, the salt marsh is a breeding site for many species of waders.

Our study site is an area of ±14.5 ha in the southern part of the peninsula; the area is enclosed by a stone wall which forms a natural border for the geese which rarely forage inland, though vegetation is similar to that of the high marsh. This can probably be explained by an increase of the perceived predation risk in an area where small shrubs and other obstacles reduce early predator detection and block the escape to safe water bodies in case of an attack. Goslings and moulting adults cannot fly and need open water at walking distance. In the study area, juniper shrubs (*Juniperus communis*) started to encroach the patches of meadow at a higher elevation, but farmers have been preventing further spread by regular burning and removal. The cutting of shrubs is part of an EU LIFE program — which has been in action since 1990 — promoting the open landscape along the Gotland coastline.

Field measurements

On 14 June 2005, plant communities within the southern salt marsh were defined (Table 1). Communities were defined in the field, based on dominant or typical species or combinations of species. After the compilation of Table 1 we compared our results with those in the present literature on other Baltic brackish marshes. Each community was described in three plots of 1 m × 1 m. The plots were randomly placed within each community. Species presence in the plots was noted and percentage cover of each species was visually estimated. Subsequently, the vegetation communities in the study area were mapped using GPS techniques (Fig. 1). Each patch was assigned to a specific community or was defined as a mosaic of multiple communities.

Within each patch assigned to a specific community, we conducted measurements on grazing pressure by geese, canopy height and the cover of edible species. We measured the cumulative spring grazing pressure (April to early June) within each patch by counting goose droppings in five plots of 2 m × 2 m in mid-June 2005. Dropping numbers give an accurate indication of the use of an area by geese, since geese defecate regularly, approximately every five minutes (Prop & Vulink 1992). Droppings of resting birds, recognisable as resting piles, were not included. We counted only droppings from the same season and therefore dropping numbers reflected the use of the area in that year. Since some droppings might have disappeared within the season due to tidal or wind action, the number of droppings counted represents a net number. Canopy height was measured to the nearest 0.5 cm using a calibrated sward stick with a styrofoam disc (20 cm diameter, 24 g), this was done ten times per patch. Cover of individual species was estimated visually, once in every patch. Edible species were defined as the species preferred in the diet. The percentage of species in the diet is based on epidermal plant fragment analyses (following Van der Wal *et al.* 2000). For this we collected five samples of five droppings on 11 occasions between 7 May and 11 June 2004. Each sample was dried, ground and homogenised and subsequently dissolved in water, then a small subsample was taken and within this subsample 100 epidermal fragments at regular intervals were determined under the microscope (400× magnification). For each date the five samples were averaged. The diet included *Festuca rubra* (43% of diet), *Juncus gerardi* (15%), *Poa* sp. (12%), *Triglochin maritima* (11%), *Plantago maritima* (6%) and *Agrostis* spp. (3%).

Statistical analyses

For all analyses, values were averaged per vegetation type. We used a simple regression to test the effects of the cover of edible species and canopy height on goose grazing pressure. A Pearson correlation was used to describe the relationship between canopy height and cover of edible species. Furthermore, in an attempt to disentangle the effects of cover of edible species and canopy height, we applied a univariate ANOVA with goose grazing pressure as dependent variable and cover of edible species and

Table 1. Plant communities on the marsh of Grötlingbo-udd as recorded in June 2005. Mean cover percentage of three relevés (1 m^2) is shown, 1 indicates a species is present. Characteristic species of the plant community are indicated with boldface. Footnote shows species that are present with low cover (< 1%) in only one or two communities. For the low marsh the communities as described in the literature are given (Tyler 1969, Wallentinus 1973): A = *Agrostis* association, J = *Juncetosum gerardi* sub-association, F = *Festucetosum rubrae* sub-association, FC = *Festuco-Caricetosum nigrae* sub-association.

	Pond	Low marsh							High marsh					Beach
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
(Sub)Association according to literature	–	A	A	J	J	F	F	FC	–	–	–	–	–	–
Plant community	*Ranunculus baudotii/Rumex crispus*	*Agrostis stolonifera/pioneers*	*Agrostis stolonifera/Potentilla anserina*	*Juncus gerardi*	*Juncus gerardi/Serephidium maritimum*	*Festuca rubra/Plantago maritima*	*Festuca rubra/dicots*	*Festcuca rubra/Carex nigra*	*Carex flacca/Sesleria albicans*	*Festuca ovina/Juniperus communis*	*Festuca ovina/Lotus corniculatus*	*Festuca ovina/Anthyllus vulneraria*	*Festuca ovina/Hieracium pilosella*	*Honkenya peploides/Potentilla reptans*
Total cover (%)	22	3	18	97	90	95	94	70	73	97	65	77	63	42
Ranunculus baudotii	**3**													
Rumex crispus	**11**		1				1		1	1	1			3
Salicornia europeaea		**2**			1	1								
Spergularia salina		**2**	2		1	1								
Glaux maritima	1	1	1	1										
Puccinellia distans	1	1	1		1									
Potentilla anserina	1		**13**	8		4	7	20	1					1
Juncus gerardi		2	1	**83**	15	4	1	1		1				
Agrostis stolonifera	3	2	3	3	1	1		1	1	1	1			
Serephidium maritimum					**50**		1		1					
Plantago maritima		1			**15**	**14**	4	1						
Festuca rubra			1			**55**	**20**	**6**	1	10	1	1		
Bellis perennis						1	**10**	1	1	1	1	1		
Plantago lanceolata						**14**	1	1	14	17	17	4		
Potentilla reptans							**18**	1	1	1		2	1	**11**
Odontites vernus				1	1	4	1		1					
Atriplex prostrata				1	1	1	1		1					
Carex nigra								**33**	1					
Carex flacca								1	**15**	2				
Sesleria albicans									**40**					
Festuca ovina									7	**32**	**25**	**27**	**27**	
Luzula campestris							1		1	**13**	1		1	
Juniperus communis									**7**					
Lotus corniculatus						1	1	1	2	1	**10**	1	1	
Filipendula vulgaris										1		**7**		
Anthyllis vulneraria							1		1		1	**5**		
Galium verum									2	1	1	1	1	
Galium boreale										1		1	**7**	
Hieracium pilosella									1			1	**12**	
Honkenya peploides													**25**	
Urtica dioica							2							2

continued

Table 1. Continued.

	Pond	Low marsh							High marsh					Beach
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cirsium arvense							1				1			4
Achillea millefolium							1			1		1	1	
Agrostris capillaris										1	1	1	1	
Allium vineale										1	1	1	1	
Bromus hordeaceus						1		1		1	1	1		
Centaurium littorale						1	1	1		1				
Cerastium fontanum					1			1	1	1	1	1		
Cirsium vulgare							1	1		1	1	1		1
Elytrigia repens							1	1				1	1	1
Erophila verna										1	1	1		
Linum catharticum									1	1	1	1		
Myosotis ramosissima						1			1	1	1	1		
Phleum phleoides											1	1	1	
Poa pratensis							1	1	1		1		1	
Ranunculus bulbosus						1		1	1	1	1			
Sagina procumbens					1	1	1							
Saxifraga granulata									1	1	1			
Stellaria gramminea						1			1	1				
Taraxacum spp.									1		1	1	1	
Trifolium dubium							1		1	1	1		1	
Trifolium micranthum						1	1	1	1	1	1	1		
Trifolium pratense								1	1	1	1	1	1	
Trifolium repens						1	1	1			1		1	
Veronica arvensis							1			1	1	1	1	
Veronica chamaedrys						1			1	1	1	1		
Vicia lathyroides											1	1	1	

Agrostis canina (12), *Alisma plantago-aquatica* (1,3), *Anthoxanthum odorantum* (12,13), *Arabis hirsuta* (10,12), *Arenaria serpyllifolia* (12), *Asperula tinctoria* (12), *Avenula pratensis* (12,13), *Avenula pubescens* (10), *Bupleurum tenuissimum* (6,9), *Carex distans* (8), *Carex hirta* (13), *Carex panicea* (9), *Carex spicata* (9,10), *Chenopodium album* (10), *Cochlearia danica* (5,6), *Cynosurus cristatus* (8), *Eleocharis palustris* (1), *Galium palustre* (9,13), *Geranium molle* (12), *Geum urbanum* (10), *Leontodon autumnalis* (8,10), *Lolium perenne* (7,11), *Medicago lupulina* (12), *Myosurus minimus* (6), *Plantago major* (7), *Prunella vulgaris* (8), *Ranunculus scleratus* (3,8), *Rhinanthus angustifolius* (9), *Rosa canina* (12), *Rumex acetosella* (13), *Orchis* spp. (12), *Polygonum aviculare* (7,14), *Potentilla argentea* (11,12), *Potentilla tabernaemontani* (12,13), *Ranunculus circinatus* (1,2), *Rumex acetosa* (7,10), *Salsola kali* (14), *Saxifraga tridactylites* (10,11), *Sedum acre* (7), *Senecio vulgaris* (14), *Thymus pulegioides* (13), *Trifolium arvense* (13), *Trifolium campestre* (10,13), *Tripleurospermum maritimum* (7), *Valerianella* spp. (10), *Valerianella locusta* (12), *Veronica serpyllifolia* (11), *Vicia hirsuta* (13).

canopy height as covariates. Analyses were done in SPSS 11.5.0 for Windows.

Results

The low salt marsh of Grötlingbo-udd falls within the *Juncetum gerardi* association, as described by Tyler (1969). He divided this association into three sub-associations: *Juncetosum gerardi*, *Festucetosum rubrae* and *Festuco-Caricetosum nigrae*. A second association was distinguished by Wallentinus (1973); the *Agrostis* association. Within each of these four (sub-)associations, except the *Festuco-Caricetosum nigrae* sub-association, we distinguished two variants, based on the presence of characteristic species (Table 1). What we call high marsh actually has few halophytes and is therefore not considered salt marsh in the literature. We chose to incorporate these types in our description, since the geese feed in the entire area.

We summarised data on the total surface area of each plant community, goose grazing

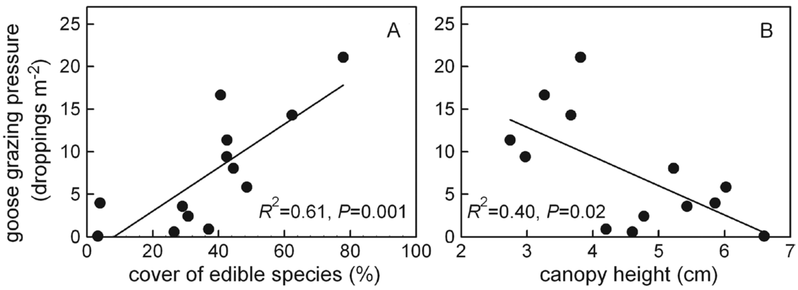

Fig. 2. Relation between (**A**) average cumulative goose grazing pressure from April–June 2005 (droppings m^{-2}) in 13 communities and the cover of forage species and (**B**) canopy height in this community, as found on the salt marsh of Grötlingbo-udd, mid-June 2005. Plant community 8 was not found in sufficiently large patches to make measurements. *See* Table 1 for descriptions of the plant communities.

pressure, canopy height and the cover of edible species in Table 2. Patches in which a mosaic of multiple communities occurred were discarded. Goose grazing pressure was highest in communities of the low salt marsh, containing the species *Festuca rubra*, *Juncus gerardi* and *Plantago maritima*. A regression analysis showed that grazing pressure in each plant community is largely explained by the average cover of edible species (Fig. 2A), as well as by average canopy height (Fig. 2B). A regression model incorporating both parameters revealed that the cover of edible species is most important in determining the foraging choices of geese (univariate ANOVA: $R^2 = 0.66$; canopy height $F_{1,10} = 1.401$, $P = 0.264$; cover of edible species $F_{1,10} = 7.574$, $P = 0.020$). Canopy height and cover of edible species were negatively related ($R^2 = 0.34$, $P = 0.04$, $n = 13$).

Discussion

Foraging choices of barnacle geese

In line with previous studies on other sites, this study shows that barnacle geese at Grötlingbo-udd selected foraging patches with the highest cover of edible species and with low canopy height. Similar results were obtained in a study

Table 2. Total surface area of each plant community (ha), cumulative goose grazing pressure April–June 2005 (droppings m^{-2}, 5 times per patch), canopy height (cm, 10 times per patch) and cover of edible species (%, once per patch) of all plant communities on Grötlingbo-udd described in Table 1. Plant community 8 was not found in sufficiently large patches to make measurements. Patches with a mosaic of multiple communities were not included. N is the number of patches of each plant community in which the measurements were done.

	Plant community	Surface area (ha)	Grazing pressure (droppings m^{-2})	Canopy height (cm)	Edible species (cover %)	*N*
1	Pond	2.05	0.07	6.6	3.3	3
2	*Agrostis stolonifera/*pioneers	0.23	0.9	4.2	37.0	1
3	*Agrostis stolonifera/Potentilla anserina*	0.41	11.4	2.7	42.6	7
4	*Juncus gerardi*	1.22	14.3	3.7	62.3	3
5	*Juncus gerardi/Serephidium maritima*	0.04	9.4	3.0	42.5	2
6	*Festuca rubra/Plantago maritima*	1.83	21.1	3.8	77.9	8
7	*Festuca rubra/*dicots	0.71	16.6	3.3	40.6	8
9	*Carex flacca/Sesleria albicans*	0.60	3.6	5.4	29.0	7
10	*Festuca ovina/Juniperus communis*	1.83	5.8	6.0	48.6	7
11	*Festuca ovina/Lotus corniculatus*	2.59	8.0	5.2	44.5	8
12	*Festuca ovina/Anthyllus vulneraria*	0.15	2.4	4.8	30.7	4
13	*Festuca ovina/Hieracium pilosella*	0.06	0.5	4.6	26.5	2
14	*Honkenya peploides/Potentilla reptans*	2.68	4.0	5.9	4.0	9

earlier in the same year at a spring-staging site in the Dutch Wadden Sea (Van der Graaf 2006). Here, the diet consists of the same species. The same relationship between grazing pressure and canopy height was also found for a Russian breeding site of barnacle geese, where *Puccinellia phryganodes* and *Carex subspathacea* are the main diet components (Van der Graaf *et al*. 2002). As discussed there, either the geese may prefer low canopy heights or the low canopy height might be a result of the high grazing pressure; and it is impossible to disentangle these two processes in this descriptive approach.

Many other studies in spring staging sites in the Wadden Sea have also shown a relationship between canopy height and goose grazing pressure, usually concluding that geese prefer short vegetation (Van de Koppel *et al*. 1996, Vickery *et al*. 1997, Van der Wal *et al*. 1998, Hassall *et al*. 2001, Van der Graaf *et al*. 2002, Bos *et al*. 2005). Our measurement on grazing pressure is a cumulative measure for the entire spring period, but it is likely that some species are preferred only within a certain time frame. Additionally, we acknowledge that we probably underestimated grazing pressure on the pond community, since droppings that fall on wet soil disintegrate quickly. We noticed that the geese preferred foraging along the edge of the pond in wet areas that continuously emerged due to the retreating water line of the pond in the course of early summer.

Conservation issues

Although the marsh of Grötlingbo-udd covers a rather small area (50 ha), it serves as an important stepping stone for many barnacle geese during migration. The vegetation is similar to many other Baltic brackish marshes (Tyler 1969, Wallentinus 1973, Dijkema 1990, Dupré & Diekmann 2001, Jutila 2001); however its location near breeding islands gives it a special status. Since the early 1990s, the adjacent islands are used as breeding sites; in recent years these islands have harboured approximately 1500 breeding pairs of barnacle geese each year (K. Larsson & H. van der Jeugd unpubl. data). The majority of these birds come to the mainland of Gotland soon after hatch or after a failed breeding attempt. They stay in the coastal meadows during moult and chick rearing and leave these areas only in autumn. As emphasised before by Dijkema (1990), grazing by livestock is of key importance for the maintenance of marshes (Bakker *et al*. 2003). In the absence of large herbivores, halophytes will disappear and reed (*Phragmites australis*) beds (on the lower parts of the marsh) or *Juniperus* shrubs (on the higher parts) will become more abundant and finally take over in the absence of preventive measures. In Estonia, many coastal marshes have already become overgrown due to the cessation of grazing on the coastal meadows (Ehrlich *et al*. 2002). Several studies on Baltic coastal marshes have demonstrated that species richness is higher in grazed than in abandoned marshes (Dupré & Diekmann 2001, Jutila 2001), with the exception of heavily grazed marshes (Dupré & Diekmann 2001). Cessation of livestock grazing will lead to a lower cover of edible species for the geese and a higher canopy height (Andresen *et al*. 1990, Aerts *et al*. 1996, Olff *et al*. 1997, Jutila 1999, Stock & Hofeditz 2002, Van der Graaf *et al*. 2002, Bakker *et al*. 2003). Concurrently, the carrying capacity of the marsh for grazing geese will decrease (Fig. 2). Many studies show a decrease in goose numbers after the abandonment of grazing (Aerts *et al*. 1996), or where a relatively low number of geese are present in permanently or temporarily ungrazed areas as compared to nearby livestock-grazed areas (Van der Graaf *et al*. 2002, Bos *et al*. 2005).

Finally, cessation of livestock grazing will not only result in a decreased diversity and a major loss of feeding habitat for barnacle geese, but also other species, in particular breeding waders, might suffer from the habitat changes. Waders have been shown to prefer moist habitats with short vegetation (Vickery *et al*. 1997). Many wader populations in Europe have been declining in recent years (Beintema *et al*. 1997, Heath *et al*. 2000, Wilson *et al*. 2005). Coastal meadows in southern Sweden traditionally harbour a large breeding population of several wader species. Breeding densities in coastal meadows of Gotland and Öland range between 10–440 pairs km^{-2} (Johansson *et al*. 2002, as cited in Ottvall *et al*. 2005), the most common breeding waders on these meadows are redshank (*Tringa totanus*), oystercatcher (*Haematopus ostralegus*), lapwing (*Vanellus vanellus*) and ringed plover (*Charadrius hiaticula*). For all these species, whose population trends are declining overall, a positive relation was found between breeding density and grazing intensity (Ottvall & Smith 2004). In the Netherlands, breeding numbers of several species of waders declined rapidly after cessation of grazing, whereas the decline was retarded in grazed areas (Vulink *et al.* 2001). Though not yet an issue in this area, managers should be keen to ensure continuing grazing by livestock on Baltic marshes in order to maintain diversity and protect the foraging and breeding habitat of geese and waders.

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