Vegetation development on newly embanked sandflats in the Grevelingen (The Netherlands) under different management practices*

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Abstract

In 1971 the Grevelingen estuary was embanked. In the newly created lake Grevelingen the tidal movements stopped and a few thousand ha of sandflats fell permanently dry. Ca 40% of the surface of those flats was immediately afterwards sown with rye and other grasses to prevent wind erosion. This fixation of a rather uniform environment resulted in a monotonous vegetation cover. Grazing with domestic animals is now applied as management practice to create more environmental variation and thereby a higher species diversity.

The present study gives the results of eleven years of comparing vegetation development under various management practices, including non-interference in the spontaneous and sown vegetation. Sequential vegetation mapping, repeated inventories of selected areas and studies in permanent plots are the main techniques used.

On the unsown shore zones interesting vegetation types are developing where species diversity is higher than in the sown areas. In the shore zones not only a faster succession occurred compared with the sown areas, but also a shifting of environmental gradients, e.g. in moisture and salinity conditions, encouraged vegetation changes. After 10 yr grazed areas had a higher number of species than ungrazed equivalent areas. The results also indicated that grazing slows down the establishment of (tall) woody species and shrub development.

Introduction

In 1964, a dam between the former islands of Goeree-Overflakkee and Schouwen-Duiveland, in the eastern part of the Grevelingen, was completed. Its construction was part of the Delta Project which was a consequence of the disastrous storm flood of 1953. Six years later the closing of the Brouwershavense Gat in the west stopped the tidal movements in the Grevelingen estuary, where previously a tidal amplitude of 2.3–3.0 m existed. After completion of the dam in 1971, in the newly created lake Grevelingen nearly 3 000 ha tidal flat, including the islands of Hompelvoet, Veermansplaat (both ca 300 ha) and Stampersplaat (100 ha) fell permanently dry (Fig. 1). In the Grevelingen a water level of 0.2 m -Dutch Ordnance Level is maintained. Using a 1978 built sluice in the Brouwersdam the salinity in the lake is regulated and as far as possible kept at the same level as that of the North Sea (>16.5‰ Cl).

* Nomenclature of angiosperms and syntaxa follows Heukels & van Ooststroom (1977) and Westhoff & den Held (1975), respectively.

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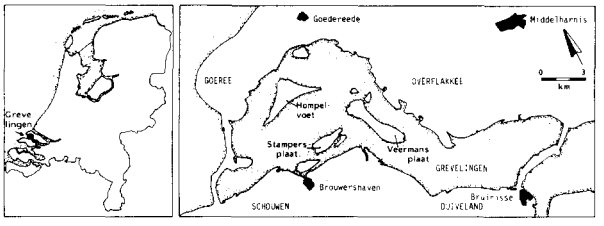

Fig. 1. Location of the study areas, the islands of Hompelvoet, Veermansplaat and Stampersplaat in the Grevelingen area (The Netherlands).

Initially, the newly created islands were bare, with the exception of the Hompelvoet island, where already before the closing of the dam some low dunes, a low salt marsh-area (5 ha) and sparsely vegetated mudflats existed. A vegetation of *Elytrigia junceiformis* and the following communities: *Halimionetum portulacoidis, Puccinellietum maritimae, Suaedetum maritimae, Salicornietum strictae, Spartinetum townsendii* and *Zosteretum noltii* could be observed.

To prevent wind erosion the elevated parts of the now permanently dry sandy areas were in 1971 and 1972 locally covered with a layer of straw, which was harrowed into the soil, and sown with a mixture of winter rye, summer barley (60–80%) and some other grasses, including *Poa pratensis* (8–12%), *Festuca rubra* (6–10%) and *Lolium perenne* (5–7%). The rye was harvested in 1972. Planting of twig screens accompanied the harrowing of the straw. Wind-blown sand ridges, up to 3 m high, were planted with *Ammophila arenaria* for fixation. Over a limited area of the Hompelvoet and Veermansplaat no measures were taken in order to provide a spontaneous development of blowouts to the phreatic level.

The rather uniform original situation was fixed by the sowing which resulted in an equally uniform sparse vegetation. Grazing with domestic stock at low stocking rates is since 1972 applied over large areas to create variation in environmental conditions, resulting in biological diversity and thereby a more attractive and, from a conservation point of view, more valuable landscape. The present paper gives the results of eleven years of comparative research on vegetation development on the islands Hompelvoet, Veermansplaat and Stampersplaat, with special emphasis on the impact of the various management practices.

For earlier descriptions of the major abiotic and biotic changes in the Grevelingen area, the reader is referred to Feitsma & Deelman (1973), Deelman (1975), Beijersbergen & During (1980), and Beijersbergen & van den Berg (1980).

Materials and methods

Monitoring of the vegetation changes was carried out at three scale levels; sequential vegetation mapping, repeated inventories of selected areas and permanent plot research.

Vegetation mapping was done on the basis of interpretations of black and white prints of false-colour vertical aerial photographs at scale 1:5 000, supplemented with extensive ground truth. For the inventories of selected areas an adapted version of the scale of Tansley (1965) was used. The symbols *o, r* and *vr,* were interpreted as the presence of 10–20, 1–5 and 1 specimens of a species, respectively. Permanent-plot sizes ranged from 2 × 4 to 4 × 5 m. These were laid out at places in and outside areas fenced for grazing and along a transect at increasing distances from livestock concentration points such as a drinking site. Retrieval in the field was ensured by placing wooden poles at fixed predetermined distances of the corners to prevent impact from bird droppings, livestock trampling, etc. The records of the permanent plots were made with a cover-abundance scale (Doing Kraft, 1954; Beeftink *et al.,* 1971). Intervals of 5% were used. Sociability was noted according to Braun-Blanquet (1964).

Results

The overall vegetation development

Dramatic vegetation changes occurred after closing of the Grevelingen estuary. The once virtually bare and now permanently emerged sandflats soon showed a vegetation cover. The total number of phanerogamic species increased from about ten to a few hundred. Most species were anemochores and established in the first few years. The number of new species decreased in later years (Fig. 2).

The species to establish first were those responding to the increased availability of nutrients, such as *Cakile maritima* and *Salsola kali* on sand ridges

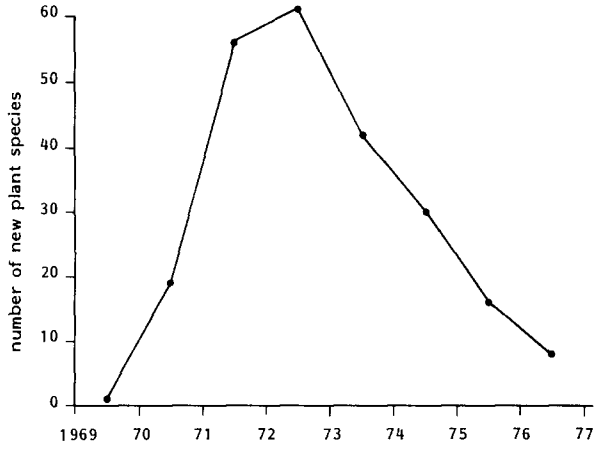

Fig. 2. Annual numbers of new plant species on the island of Hompelvoet after embankment in 1971.

and overblown materials deposited at the high-water line. Dispersed clumps of *Spartina anglica,* already found on the mudflats under tidal conditions, became nuclei for small dunes by catching the wind-blown sand. *Chenopodium album, C. ficifolium, Atriplex hastata* and the anemochores *Senecio vulgaris, S. sylvaticus, Taraxacum* sect. *Vulgaria, Sonchus oleraceus, S. arvensis, Erigeron canadensis, Epilobium hirsutum, E. parviflorum* and *Chamaenerion angustifolium* invaded the changed environment. Vegetation types with *Suaeda maritima* and with *Puccinellia maritima* as dominants developed to luxurious stands. The dry mudflats were covered with halophytic vegetation types composed of *Salicornia europaea, Suaeda maritima, Spergularia marina, S. media, Puccinellia maritima, P. distans, P. capillaris* and *Aster tripolium.* At places where the flats are still influenced by the saline water (e.g. by occasional flooding with stormy weather) such vegetation types stay and even extend. At locations where the salt was leached out, a fast succession took place. Figure 3 shows for permanent plot H5 the increase and subsequent decrease of a number of species. Similar processes and species sequences have been reported from embanked areas in the Zuiderzee, the Lauwerszee in the north of the Netherlands and from other areas in the SW Netherlands (Feekes, 1936; Feekes & Bakker, 1954; Beeftink *et al.,* 1971; Joenje & During, 1977; Koutstaal & Sipman, 1977; Joenje, 1978; van Noordwijk-Puijk *et al.,* 1979; Westhoff & Sykora, 1979).

The pattern of small squares as a consequence of the sowing technique is still visible after 11 yr and in this matrix the species composition of the spontaneous vegetation is as yet rather uniform. Gradually, some species established *(Crepis capillaris, Hypochaeris radicata, Leontodon autumnalis* and *L. taraxacoides)* that showed up as conspicuous dominants in summertime. Even here, however, certain rare plant communities develop as outlined below. Apart from the sown *Festuca,* the shrub species *Hippophae rhamnoides,* becomes locally dominant.

On the unsown shore zones relatively species-rich communities develop, enhanced by the gradient in abiotic environmental conditions. Some communities belong the *Nanocyperion flavescentis* alliance, others to the *Caricion davallianae* or the *Saginion maritimae* alliance.

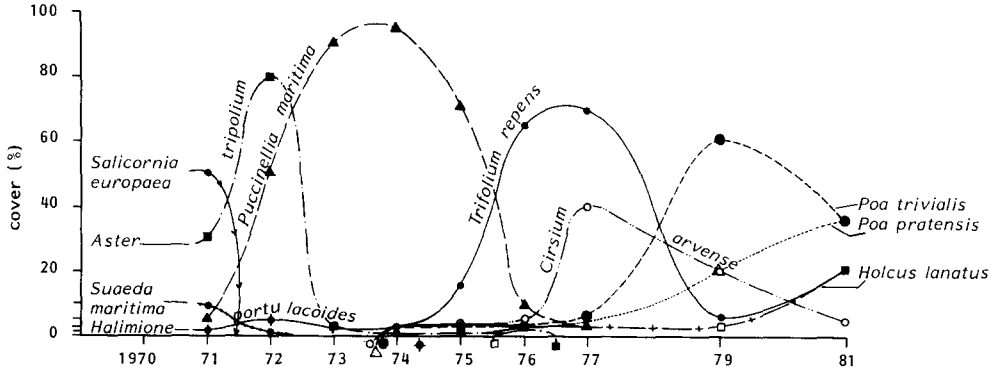

Fig. 3. Example of vegetation development in a grazed permanent plot on the former salt marsh of the island of Hompelvoet after embankment in 1971. Only species with a cover exceeding 5% are mentioned.

Soil tillage

A small area in the central part of the Hompelvoet and the Veermansplaat (together about 30 ha) was not sown. Here an attempt was made to create, by allowing the sand to be blown away, a lowered soil surface, thus making suitable conditions for vegetation types related to wet or moist soil conditions. Soon after wind erosion had started, however, the remaining shells formed a type of pavement, prohibiting further sand blowing. To promote continued lowering of the soil surface, the shells were crushed (Hompelvoet) or ploughed under (Veermansplaat), or locally mechanically removed and stacked.

The inventory data of the blowouts of the Hompelvoet and the Veermansplaat reflect on the one hand differences in abiotic conditions of the sandflats as a whole, and on the other hand differences brought about by repeated crushing vs annual ploughing of the shell cover. Moisture content of the Veermansplaat is higher and sand blowing out continued longer: together resulting in lower relatively moist areas. In Table 1 a survey of the vegetation succession is presented for this area. More species characteristic of the *Nanocyperion flavescentis* vegetation types occurred here than in the Hompelvoet blowout. Critical species, with a rather narrow ecological amplitude, e.g. some of the *Caricion davallianae,* which do occur in the sown and grazed area of the Veermansplaat, are lacking. Apart from *Salsola kali and Corispermum leptopterum,* ruderal species as a reaction to the repeated ploughing were found in abundance, including *Polygonum lapathifolium, P. aviculare, Chenopodium rubrum, C. album, Sonchus asper, Poa annua, Matricaria maritima* subsp. *inodora, Erigeron canadensis* and *Cirsium arvense.* The grasses applied in the sowing elsewhere and the planted *Ammophila* also stand out very pronounced in the blowouts. *Euphrasia stricta* subsp. *stricta* is only and abundantly found in the Hompelvoet blowout. *Calamagrostis epigejos* is more common on the Veermansplaat.

From a conservation point of view, the most interesting vegetation types of the blowouts, were best developed at sites where no soil tillage was applied.

Sowing

About 40% of the area of the permanently dry island flats was harrowed with (wheat) straw and sown with cereals and other grasses, as outlined in the introduction. *Triticum aestivum* and *Secale cereale* had disappeared by 1973 and 1974 and *Lolium perenne* was of no importance after 1974/76. *Festuca rubra* and *Poa pratensis* on the contrary still determine the aspect of the vegetation over large parts of the islands (Table 1).

On the unsown shore zone vegetation types with a higher number of species develop compared with those in the comparable sown areas (Fig. 4). This can be attributed partially to the environmental gradients occurring in the shore zones (dry–wet, fresh–saline), and partially to a retarded development in the sown areas. Here, species diversity reached only after about ten years the same level as in the unsown areas, and not even in all plots. Figure 5 provides the evidence for the retarded establishment of more species under sown conditions. In reading the figure the 4 or 5 introduced species occurring in the first years as a direct effect of the sowing should be kept in mind. Figure 5 shows a temporary decrease in number of species for both treatments.

Comparison of the inventories of the sown (29 ha) and unsown (4 ha) areas on the Stampers-

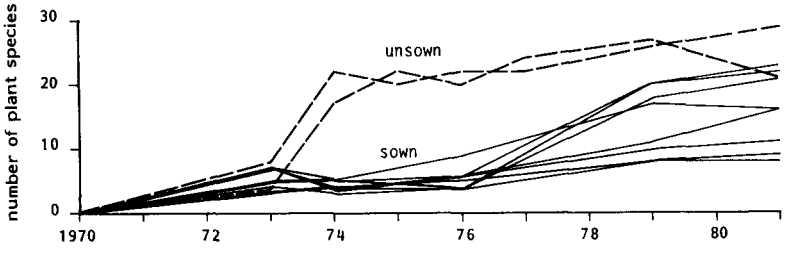

Fig. 4. Number of plant species in sown and unsown permanent plots (of 8 m^2 each) on the island of Hompelvoet.

Table 1. Vegetation development in a blowout (ploughed) on the island of Veermansplaat. Symbols according to Tansley (1965).

Date	1972 Aug.	1973 Sept.	1974 Aug.	1975 July	1976 Sept.	1977 Sept.	1980 Aug.	1982 Sept.
Cumulated number of plant species	11	47	61	74	77	77	97	108
Number of plant species	11	45	48	61	47	44	66	65
*Secale cereale**		a**						
Polygonum lapathifolium		a						
Polygonum aviculare		a						
Chenopodium rubrum		va						
Senecio vulgaris		va						
Chenopodium album		va						
Salsola kali		a		a				
Sonchus asper		a		a				
*Lolium perenne**	d			a	va			
Poa annua		va		va	va			
*Ammophila arenaria**		va		va	va			
Cakile maritima		a		a		va		
Epilobium tetragonum				a				
Poa trivialis				a				
Corispermum leptopterum				d	cd	va		
Aster tripolium				a	va	va		
Sonchus oleraceus					a			
*Poa pratensis**		a		cd	va	d	va	cd
Matricaria maritima				a		a	a	
Epilobium parviflorum						a		
Epilobium obscurum						a		
*Festuca rubra**				va	va	va	cd	va
Plantago major						a	a	
Centaurium pulchellum						a	a	
Gnaphalium luteo-album					va		va	cd
Erigeron canadensis					a		a	a
Juncus bufonius							va	
Blackstonia perfoliata							a	cd
Agrostis stolonifera							a	va
Sonchus arvensis							a	va
Cirsium arvense							a	a
Phragmites australis								cd
Centaurium littorale								cd
Calamagrostis epigejos								va
Erigeron acer								va
Sagina nodosa								va
Hypochaeris radicata								a

* Subspontaneous.

** The addition *l* and the symbols *vr, r, o* and *f*, and so a great number of species, have been omitted.

plaat showed an approximately equal total number of species. In the unsown area, however, the introduced grasses also occurred in large numbers. From aerial photographs a pattern of establishment could be recognized governed by the predominantly southwestern winds. In other words, the vegetation development in the unsown areas has been heavily influenced by the sowing of the adjacent area.

Grazing

In 1973 seasonal grazing with ponies and sheep, at stocking rates of 0.1 and 1.0 animals per ha, respectively, was started in separate fenced areas on the Hompelvoet. Data from permanent plots laid out inside and outside the fences showed as yet no distinct differences in species composition and

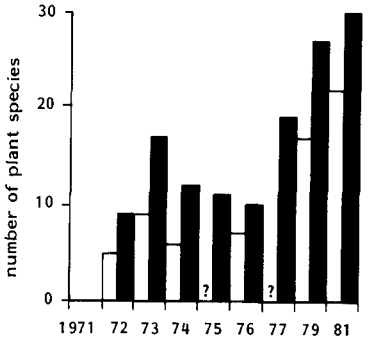

Fig. 5. Annually observed species numbers in adjacent sown (white) and unsown (black) permanent plots (8 m^2) on the island of Stampersplaat.

diversity in the vegetation. The species *Plantago coronopus* and *Cerastium semidecandrum* were only found in plots under pony grazing. This may be due to processes of soil compaction and the creation of small patches of bare soil (Bakker, 1984). Apart from species of the *Nanocyperion flavescentis* (already mentioned before for the Veermansplaat) also *Gnaphalium luteo-album* was found in the relatively drier, grazed areas of the Hompelvoet. Species of the *Caricion davallianae* communities were lacking, but those of *Saginion maritimae* vegetation types were present, contrary to what was found in the permanent plots of the Veermansplaat.

Repeated inventories of grazed (12 ha) and ungrazed (32 ha) areas of the Hompelvoet showed so far a parallel development of the vegetation. Differences are the greater abundance of *Poa pratensis* and *Trifolium pratense* in the ungrazed area, and more *Leontodon taraxacoides, Cerastium diffusum, Plantago major, P. coronopus and Gnaphalium luteo-album* in the area under pony grazing. Some ten fungus species only found on pony dung have been observed in the grazed area, including the rare species *Poronia punctata.* In addition, the terrestrial occurrence here of some usually epiphytic lichens should be mentioned, such as *Usnea* cf. *subfloridana, Parmelia caperata, P. sulcata* and *Hypogymnia physodes.* Also various *Cladonia* spp. developed. In the ungrazed area only *H. physodes* and one *Cladonia* species were found. Koutstaal & Sipman (1977) described a similar situation for the Veerse Meer area, embanked in 1961.

In 1972, before harvesting of the rye, part of the Veermansplaat was put under cattle grazing. It started with seasonal grazing with 0.4 animal per ha. In 1975 this was changed to a year-round grazing at a stocking rate of 0.1 animal per ha. In 1973 a number of permanent plots were laid out along a transect at distances varying from 150–1450 m from the drinking place to study the effect of a supposed grazing pressure gradient on the vegetation. Later on, the drinking site was replaced. This allowed the recording of the impact of grazing along the gradient in whole directions. Figure 6 gives the vegetation in the permanent plots as recorded in 1973 and (after replacing the drinking site in 1973) in 1981. The results show an increasing number of plant species under increasing grazing pressure (supposed to coincide with the distance from the drinking place) including more species of the rare *Nanocyperion* and *Caricion davallianae* communities. Prior to the reversal of the situation, an opposite gradient in vegetation composition oc-

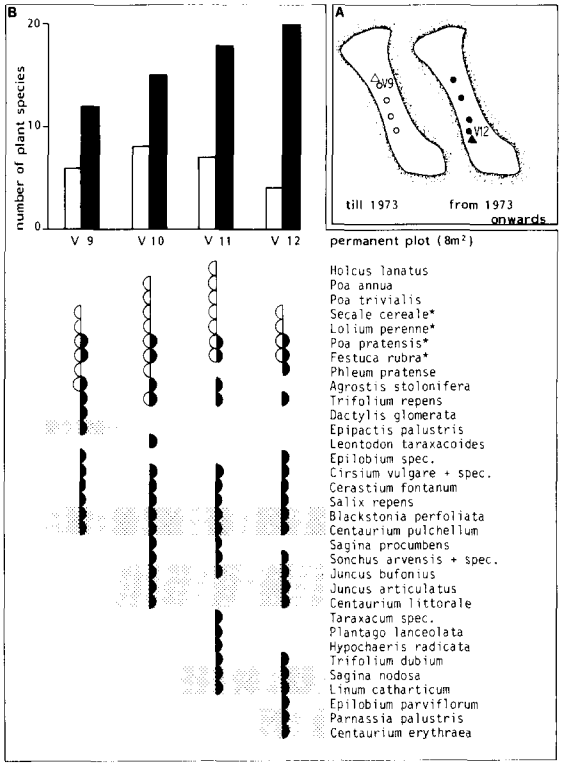

Fig. 6. Changes in species numbers due to replacing of the drinking site: △ 1973; ▲ 1981 (A), resulting in a reversed grazing pattern: white 1973; black 1981 (B). Sown species are indicated with an asterisk.

curred. Permanent plot V12 had then the lowest number of species. In 1981 in and nearby this plot the species *Blackstonia perfoliata* subsp. *serotina, Centaurium pulchellum, C. littorale, C. erythraea, Juncus bufonius* subsp. *bufonius, J. articulatus, Sagina nodosa, Linum catharticum, Parnassia palustris, Epipactis palustris* and *Carex serotina* subsp. *pulchella* were observed. *Equisetum variegatum* covered relatively large areas. The position of the very rare species *Dianthus armeria* in relation to grazing pressure is not yet clear.

Pony grazing at the Hompelvoet seems to slow down the process of establishment of woody species, such as *Hippophae*. The *Salix* species *S. repens, S. viminalis, S. cinerea* and *S. caprea* had so far only been found in the ungrazed areas. Cattle grazing on the Veermansplaat has clearly slowed down *Hippophae* expansion as illustrated by a comparison of developments inside and outside the fence.

When sheep grazing ceased on the Stampersplaat (due to heavy attack of liver fluke through the host *Lymnaea truncatula*), the vegetation with the relatively rare *Equisetum hyemale, Orchis praetermissa, Parnassia palustris, Linum catharticum* and *Epipactis palustris,* was invaded by a woody canopy, consisting of *Hippophae rhamnoides, Salix repens, S. caprea, S. cinerea, S. alba, S. triandra, Populus canescens, P. tremula* and *Betula pendula.*

Discussion and conclusions

After being permanently emerged the areas under discussion endured some wind erosion, resulting in blowing away of the sandy topsoil. Harrowing of straw and sowing of Gramineae seem to have been unnecessary practices because spontaneous vegetation development would soon have fixed the bare soil. Local sowing of rye can be justified. After disappearance of this species, *Festuca* would not have been so dominant as it presently still is. Twig screens caught the blowing sand and created abiotic environmental differentiation. The large-scale sowing prevented such developments. Sowing therefore will hamper spontaneous vegetation development and will result in a lower species diversity of the vegetation. These negative effects were partially neutralized by sand drifts as found on the Veermansplaat. Such drifts slowed down the run-off of rainwater and created conditions which allow the development of vegetation types of moist dune slacks.

Low-density cattle grazing so far led to the, from a conservation point of view, most desired vegetation development. Other fauna elements accentuated the differentiation brought about by the large grazers. Grazing seemed to slow down or in some situations even prevent the establishment and extension of a woody shrub layer.

Soil tillage hardly resulted in a positive effect on vegetation development. Movement of the soil implies a major disturbance and may even lead to the establishment of undesired ruderal vegetation types. Measures including topsoil disturbance as carried out in a later stage in the blowouts, have not provided any signifcantly better conditions for a desired vegetation development.

Planting of *Ammophila* for the fixation of drifting sand around the blowouts resulted on the Hompelvoet into a local dominance of the species and should have been deleted.

Ploughing, harrowing, sowing and planting have created patterns in soil and vegetation that will remain visible for many years to come as witnesses of unnecessary and therefore undesirable anthropogenic influences.

The vegetation of the new lands in the Grevelingen seems now, eleven years after closing of the estuary and after many changes in management practices, best benefitted by a stable, consistent management. For the outlined, promising developments such an approach seems to provide the best chances for the establishment in due time of even more valuable vegetation types worth preserving for conservation purposes.

References

Bakker, J. P., 1984. The impact of grazing on salt-marsh communities, populations and soil conditions. In: W. G. Beeftink, J. Rozema & A. H. L. Huiskes (eds.), Ecology of Coastal Vegetation. Junk, The Hague.

Beeftink, W. G., Daane, M. C. & Munck, W. de, 1971. Tien jaar botanisch-oecologische verkenningen langs het Veerse Meer. Natuur en Landschap 25: 50–65.

Beijersbergen, J. & During, H. J., 1980. Mossen op de Hompelvoet in de Grevelingen, ZW-Nederland. Lindbergia 6: 147–153.

Beijersbergen, J. & Berg, A. van den, 1980. De Grevelingen; de vogels van een afgedamde zeearm. Kerckebosch, Zeist.

Braun-Blanquet, J., 1964. Pflanzensoziologie, Grundzüge der Vegetationskunde, 3rd ed. Springer, Wien.

Deelman, C., 1975. De ontzilting van de drooggevallen zandgronden in het Grevelingenbekken t/m voorjaar 1973. Cultuurtechnisch Tijdschrift 14: 185–198.

Doing Kraft, H., 1954. L'analyse des carrés permanents. Acta Bot. Neerl. 3: 421–424.

Feekes, W., 1936. De ontwikkeling van de natuurlijke vegetatie in de Wieringermeerpolder, de eerste groote droogmakerij van de Zuiderzee. Thesis, Wageningen.

Feekes, W. & Bakker, D., 1954. De ontwikkeling van de natuurlijke vegetatie in de Noordoostpolder. Van Zee tot Land 6: 1–92.

Feitsma, K. S. & Deelman, C., 1973. Het optreden van verstuivingen op de drooggevallen zandgronden in het Grevelingenbekken. Cultuurtechnisch Tijdschrift 13: 16–27.

Heukels, H. & Ooststroom, S. J. van, 1977. Flora van Nederland, 19th ed. Wolters-Noordhoff, Groningen.

Joenje, W., 1978. Plant colonization and succession on embanked sandflats. Thesis, Groningen.

Joenje, W. & During, H. J., 1977. Colonisation of a desalinating Wadden-polder by bryophytes. Vegetatio 35: 177–185.

Koutstaal, B. P. & Sipman, H. J. M., 1977. De korstmossen van de Middelplaten. Levende Natuur 80: 248–260.

Noordwijk-Puijk, K. van, Beeftink, W. G. & Hogeweg, P., 1979. Vegetation development on salt-marsh flats after disappearance of the tidal factor. Vegetatio 39: 1–13.

Tansley, A. G., 1965. The British Islands and their Vegetation, 4th ed. University Press, Cambridge.

Westhoff, V. & Held, A. J. den, 1975. Plantengemeenschappen in Nederland, Thieme, Zutphen.

Westhoff, V. & Sykora, K. V., 1979. A study of the influence of desalination on the Juncetum gerardii. Acta Bot. Neerl. 28: 505–512.

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