THE IMPACT OF TOURISM UPON SOME BREEDING WADER SPECIES ON THE ISLE OF VLIELAND IN THE NETHERLANDS' WADDEN SEA

GERLOF TH. DE ROOS

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With a summary in Dutch

Proefschrift
ter verkrijging van de graad
van doctor in de landbouwwetenschappen
op gezag van de rector-magnificus
dr. C. C. Oosterlee,
hoogleraar in de veeteeltwetenschap,
in het openbaar tė verdedigen
op woensdag 23 september 1981
des namiddags te vier uur in de aula
van de Landbouwhogeschool te Wageningen

H. VEENMAN & ZONEN B.V. - WAGENINGEN - 1981

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STELLINGEN

1.

Ten onrechte verwerpt DE VRIES de mogelijkheid dat zeepostelein (*Honckenya peploides*) op slikarm zand kan voorkomen.

VRIES, V. DE (1950). Vlieland, landschap en plantengroei. E. J. Brill, Leiden.

2.

Uit allerlei overwegingen verdient het aanbeveling bij de planning van wegen ernaar te streven dat bestaande houtopstanden zoveel mogelijk worden opgenomen in de aan te leggen wegbermen.

3.

De vaste correctiefactor f door BEUKEBOOM gebruikt om de werkelijke verdamping $E_a(t)$ in het Vlielandse duingebied, gedurende de tijdsduur t, te berekenen ($E_a(t) = fE_o(t)$) is niet nauwkeurig omdat deze per vegetatietype te sterk verschilt.

BEUKEBOOM, TH. J. (1976). The Hydrology of the Frisian Islands. Thesis. Vrije Universiteit, Amsterdam.

4.

Langlopende flora en fauna inventarisaties zijn onmisbaar bij het natuurbeheer. En wordt daarmee te weinig rekening gehouden. Het Ministerie van C.R.M. zou hiervoor, zelfs in tijden waarin het budget beperkt is, jaarlijks fondsen ter beschikking moeten stellen.

5.

De zeeden (*Pinus pinaster*) is een naaldhoutsoort die zich op Vlieland op natuurlijke wijze verjongt en meer aandacht verdient in het kader van herbebossingsplannen.

6.

De χ^2 toets, door SWENNEN en DE BRUYN gebruikt om verschillen in nestdichtheden van de scholekster (*Haematopus ostralegus*) aan te tonen, kan worden verfijnd door rekening te houden met landschap/vegetatie verschillen en door de toets eenzijdig uit te voeren.

SWENNEN, C. en C. L. M. DE BRUYN (1981). De dichtheid van broedterritoria van de scholekster (*Haematopus ostralegus*) op Vlieland. Limosa 53 (3), 85–90.
DE ROOS, G. TH. (1981). Dit proefschrift.

7.

In duingebieden met verhoogde wateronttrekking kan het dwergbiezenverbond (*Nanocyperion flavescentis*) zich alleen handhaven op kunstmatige (uitgegraven) groeiplaatsen. Het is verantwoord hiervoor speciale natuurtechnische beheersmaatregelen te nemen. Hieraan zou veel meer aandacht moeten worden besteed.

8.

Het instellen van natuurreservaten en afgesloten rustgebieden in het broedseizoen in duingebieden werkt het ontstaan van zilvermeeuw (*Larus argentatus*) kolonies in de hand en heeft daardoor een ongunstige invloed op de levensmogelijkheden van andere vogelsoorten, tenzij regulerende maatregelen worden getroffen.

9.

In periodiek droogvallende duinvalleien, gelegen in zilvermeeuw kolonies, wordt de natuurlijke successie via pioniergemeenschappen van het dwergbiezenverbond verstoord door de eutrophiërende- en daardoor pH verhogende invloed die van dergelijke kolonies uitgaat. Het beperkte voorkomen van dergelijke valleien met hun grote botanische waarde pleit voor het streven meeuwenkolonies uit deze milieus te weren.

10.

Informatieve borden die aangeven dat men een natuurreservaat betreedt zijn van meer belang voor de instandhouding en het beheer van deze reservaten dan menigeen zich realiseert. Het weglaten van dergelijke borden vergroot de risico's van schade en verstoring.

Proefschrift van GERLOF TH. DE ROOS
The impact of tourism upon some breeding wader species on the isle of Vlieland in the Netherlands' Wadden Sea

Wageningen, 23 september 1981.

Aan mijn ouders

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1. SCOPE OF THIS INVESTIGATION

1.1. Introduction and summary

1.1.1. *Introduction*

The Netherlands is small and densely populated, but is still one of the areas in western Europe which is very rich in waterfowl (*Anseriformes*, *Charadriiformes*), about 20 per cent of the total surface being water, marshland or wetland habitat and therefore for waterfowl research and conservation a very interesting area.

In autumn and spring hundreds of thousands- and probably more than a million duck of all kind of species, millions of waders, hundreds of thousands of geese and thousands of swans stay in the Netherlands for short or long periods. When winters are not severe, which is often the case due to the maritime climate (mean temperature in January 1 °C), large numbers of duck, geese and swans winter in Holland. The Netherlands is world-famous because of its characteristic meadow bird community. Within this community the Black tailed Godwit (*Limosa limosa*) represents 80 per cent of the W. European breeding bird population (120000 pairs), while the Lapwing (*Vanellus vanellus*) (some hundreds of thousands) and the Redshank (*Tringa totanus*) are also important species.

It is not surprising therefore that a great many ornithologists, sportsmen and biologists in the Netherlands are interested in waterfowl and their ways.

Industry, trade, agriculture and fisheries are among the most important sources of income. They and the increasing urbanisation affect in many ways the areas of importance for waterfowl. Incréased leisure, longer week-ends, and the greater mobility (cars, mopeds) of city dwellers have brought a great expansion of recreational activities in recent years. These activities may threaten certain bird species and their habitats.

Moreover many bird watchers want to have a permanent opportunity to observe birds in their prefered habitats and this also can give rise directly to conflict situations.

Therefore adequate nature management is necessary and requires research. Several institutes in the Netherlands are dealing with waterfowl research and much is done for the conservation of important breeding areas, roosting-sites and feeding-grounds in the wintering areas.

The Dutch part of the Wadden Sea is a very important area for migrating and wintering waders, gulls, duck and geese. On each of the Wadden islands, surrounded as they are by the North Sea and the Wadden Sea, different habitats have developed comparatively undisturbed in the course of the centuries. These include beaches, dunes, polders, saltmarshes and mudflats with all sorts of transitions, none of which are found in other coastal areas.

Though mammals are scarce, birds are exceedingly abundant on the islands, both in numbers and species. This is due to the 'islands' location between the North Sea and the Wadden Sea, the large and rich feeding areas and relative little disturbance on these islands.

In the migration season the large numbers of migratory, birds, congregating on the Wadden islands, include both 'land' birds (e.g. song-birds) and 'water' birds (duck species, geese, waders, gulls and terns) and many of these use the islands especially as a refuge during high tide.

The most important bird species nesting on the islands are gulls, terns, duck and waders.

The Wadden islands also attract many tourists. Eight to ten per cent of all summer holidays, spent in the Netherlands, are spent on the Dutch Wadden islands. For example about sixty thousand tourists visit the isle of Vlieland each year.

This study was carried out in order to collect relevant data for adequate management of certain breeding-bird populations.

The scope of this investigation has been summarized in subsection 1.1.2.

1.1.2. *Summary*

Birds are of importance to mankind. Various reasons are outlined in subsection 1.2.1. Man affects populations of wild birds directly, e.g. by killing and capturing (subsection 1.2) or indirectly, e.g. by destroying habitats, furnishing extra food via refuse or by other means (subsection 1.2.3).

Many bird populations and their characteristic habitats are threatened (subsections 1.2.2. and 1.2.3). Protection, e.g. by creating nature reserves which have to be managed effectively, is necessary to prevent depletion or even extinction of populations and, in the long run, of species. Research, focussed on management problems, is essential for adequate nature management.

Such investigations are intended to provide adequate guidelines and to collect relevant data necessary for better protection. They are also carried out to provide material in order to convince people that special preservation measures should be taken. Solid knowledge should be available of the effects and interactions of various factors affecting bird populations. Though the original motivation was to study the effects of tourism upon numbers of nest sites or territories, effects of the factors landscape/vegetation and altitude/hydrology are investigated in the same way (see the survey of literature in section 1.3).

The Wadden island Vlieland was chosen as the research area because it contains many different habitats, attracting large numbers of birds, in particular wader species (subsection 1.4.1), while it also attracts tens of thousands of tourists, who start to visit the island already by the beginning of the breeding season.

Therefore the study was carried out at Vlieland (subsection 1.4.3) where suitable study plots, especially in the dunes, could be selected for the investigations.

1.2. Man and birds

1.2.1. *Significance of birds to mankind*

Birds, more than mammals, reptiles, amphibians or fishes, seem capable of generating public interest and concern for conservation. Their plumage, behaviour and songs are conspicuous and attractive. They can often be seen on and near their nests, as well as caring for their young and gathering food. Their migration, although only partially understood, is a source of great fascination. Many species can easily be observed in gardens and parks, but many people are willing to travel considerable distances to observe interesting birds outside urban sites in natural areas such as forests and marshes in the countryside, at weekends or during holidays.

In a great many countries some species are of direct economic importance as a source of food, (e.g. waterfowl (*Anatidae*, *Charadriidae* etc.) and seabirds), or for their feathers, (e.g. down of the Common Eider (*Somateria mollissima*)) or as cage birds (so-called pets).

For this reason many bird species are 'game' species and many individuals are shot or caught each year. Hunting, catching and collecting became a real threat in too many cases, resulting in severe depletion of populations. During the last decades bird-preservationists, organizations of hunters and governmental agencies have become increasingly aware of these threats, and measures are taken to improve the situation. Due to these activities the situation has improved considerably in this period.

In western Europe and especially in the Netherlands the result has been that bird trapping and shooting are more strictly controlled now than ever before.

Birds have many more functions for mankind. They are considered to be useful allies of man in his struggle against insect pests. They are also valuable as indicator species for several kinds of environmental contaminants. Well known examples are the high content of organochlorine residues of pesticides in Sandwich Terns (*Sterna sandvicensis*) breeding on the isle of 'Griend' in the Netherlands' Wadden Sea (KOEMAN, et al., 1967) (in 1964 and 1965 numbers of breeding pairs dropped markedly as a result of this pollution)), or in Peregrine Falcons (*Falco peregrinus*) in England (PRESTT, 1977).

Furthermore a great deal of fundamental ecological and ethological research, as well as applied research, has been done and is still going on.

Birds also play an important part in biology teaching and in education. In these contexts, the need for conservation and wise management of bird populations is self-evident.

1.2.2. *Direct influence of man upon bird populations*

Every organism, plant or animal, including every bird is able to establish and maintain itself in a certain area if it finds there all the conditions necessary for its survival and reproduction. The most important condition for life is that of sufficient attainable food, but nesting-opportunities, roosting site availability and safety are almost equally important.

Bird populations may be threatened directly for instance by hunting, catching, use of pesticides (against avian target species), disturbance as a consequence of activities of tourists, etc. These influences exist nearly everywhere and some also play a part on Vlieland.

Some examples of direct effects on Vlieland. The Kentish Plover (*Charadrius alexandrinus*) is still diminishing in numbers and now only occurs as breeding-bird on military training-grounds, where only a few tourists come. Since the end of 1950 the Little Tern (*Sterna albifrons*) disappeared from a much frequented beach area on Vlieland, probably in consequence of the increased activities of tourists (SPAANS and SWENNEN, 1968). A new colony became established on the nearby sand-bank the 'Richel' where only a few tourists try to land. It is worth pointing out that the last Little Terns on Vlieland bred on military training-grounds (DE ROOS, in press).

The conditions of life for some interesting breeding-birds also deteriorated as a result of egg-collecting, bird watching, photography and filming of nests etc. This applies to the Hen-Harrier (*Circus cyaneus*) and the Short-eared Owl (*Asio flammeus*).

Note that even picnicing amongst or near colonies of Common Tern (*Sterna hirundo*) has been observed on the Wadden island Schiermonnikoog.

1.2.3 *Indirect influence of man upon bird populations*

Bird species are threatened in their existence in a great number of areas by loss of habitats, use of pesticides against non-avian target specties, etc. Loss of habitat may occur through re-allotment, drainage, urbanisation, mining activities, the development of facilities for tourists (e.g. parking areas, camping-sites), etc.

Indirect effects on Vlieland. In the recent past, several facilities for tourists (bungalow-developments, camping-sites, hotels, a swimming-pool, a football ground, marinas, golf-links, more roads and paths, picnic sites, etc.) have been created on this island with an area of about 3258 ha. Some breeding bird populations (e.g. Curlew) have certainly declined as a result of these developments, although precise information on the extent of this decline is lacking.

A few species, however, such as the Collared Turtle Dove (*Streptopelia decaocto*), Starling (*Sturnus vulgaris*), Carrion-Crow (*Corvus corone*) and the Magpie (*Pica pica*) have increased in number. Species like House Martin (*Delichon urbica*), Swallow (*Hirundo rustica*) and the White Wagtail (*Motacilla alba*) have increased in number because they have benefitted from the new nesting opportunities afforded by more buildings.

The construction of dikes of drift-sand by the Board of Works ('Rijkswaterstaat') has created new habitats on the 'Vliehors' for Yellow Wagtail (*Motacilla flava*), Common Gull (*Larus canus*) and Common Eider (*Somateria mollissima*). New nest sites have arisen for Wren (*Troglodytes troglodytes*), Blackbird (*Turdus merula*), Pheasant (*Phasianus colchicus*), etc. by the development of more undergrowth and the branches of *Pinus nigra*, left in the Forestry Service plantations after thinning.

1.2.4. *Protection of wild birds*

For a great many people, helping to prevent the decline or even the extinction of bird-populations, has a direct emotional appeal. This ethical side plays a large part in all activities related to bird-protection. However, efficient protection and conservation is only possible if we know a good deal about the ecology of any particular species to be preserved. This includes details of its breeding, migration, moulting and wintering areas.

In the Netherlands attention was first paid to these problems many years ago. According to historical information about the Hague Forest in Holland, as far back as the 16th century measures for bird-protection existed. This is evident from a proclamation of April 2nd 1529, forbidding anyone from robbing the nests of any bird, small or large, or removing eggs or young. If children were convicted then their parents were made to pay the fine. This is probably one of the first forms of bird-protection in Europe.

In the beginning of the twentieth century, the struglle for bird-protection was directed particularly against the direct killing of birds (for instance in order to obtain their plumage or over shooting for domestic consumption), as well as against egg-robbing by collectors, which was fashionable for many years.

The first legal measures against persecution of birds in the Netherlands date back to 1880 (TOLSMA, 1936). In 1899 the Netherlands' Society for the Protection of Birds (developed from the Alliance for the Fight against Bird-persecution) was founded, while in 1901 the Ornithological Society (the present Netherlands' Ornithological Union (N.O.U.)) was established.

In 1912 the first Bird Protection Act (amended in 1936 and improved in 1954) was passed. By this, legal protection was given in principle to all wild birds in the country, with the exception of those species, mentioned in the Game Act of 1954. This Game Act acknowledged the hunting and agricultural interests as well as those of the protection of nature.

As early as about 1920 the need for an international approach to bird preservation has been recognized, particularly in the USA, the Netherlands, the United Kingdom and Switzerland. The I.C.B.P. (International Council for Bird-Preservation) was already founded in 1922 and proposed the text of a new bird preservation treaty during a European Conference in 1937. This formed the basis of the international treaty for the protection of birds in 1950, known as the Convention of Paris of 1950. For the first time it was acknowledged internationally that birds are of value in their own right and therefore merit preservation.

More recently the internationally organized protection of birds against illegal killing, catching and egg collecting has been followed by regulations which also afford protection of bird habitats. In many cases this has been done by the I.C.B.P. itself and especially for waterfowl by the International Waterfowl Research Bureau (I.W.R.B.) (a daughter of the I.C.B.P. and founded in 1948). Especially for waterfowl the I.W.R.B. has been the main force behind the Convention on wet lands of international importance, signed in Ramsar in Iran in 1971. In addition to the I.C.B.P. and the I.W.R.B., the 'Conseil International de la Chasse' (C.I.C.) and last but not least, the International Union for Conservation of Nature and natural resources (I.U.C.N.) have been leading organizations in the establishment of conventions for better protection of species and their habitats.

In addition to the non-governmental organizations the international governmental organizations such as the F.A.O. (Food and Agriculture Organization), UNESCO (United Nations Educational, Scientific and Cultural Organization) and UNEP (United Nations Environmental Program), the Council of Europe and the European Economic Communities have paid special attention to species and habitat conservation since the sixties. For instance in September 1979 the Convention on the conservation of European wildlife and natural habitats of the Council of Europe was signed in Bern and in April 1979 the Bird Directive of the E.E.C. was instituted in Brussels. Apart from the protection of species, this directive also deals with habitat preservation, in particular.

In conclusion, progress has been made in the field of bird preservation in a great many countries, and not only on a national level; non-governmental and governmental international organizations paved the way for international understanding and co-operation which has been shown by the above-mentioned developments (CURRY LINDAHL, 1979; MATTHEWS, 1979; MÖRZER BRUYNS, 1979b).

1.3. HABITAT AND BIRDS (LITERATURE REVIEW)

1.3.1. *Landscape/vegetation and birds*

In this chapter literature relevant to the investigation on Vlieland will be discussed in relation to three major factors: (1) landscape/vegetation, (2) altitude (topography)/hydrology (water-table) and (3) tourism.

Birds actively select habitats in which they live and reproduce. Food-abundance, nesting-opportunities, roosting site availability and safety are important factors in the selection. These factors are related to the observable factors landscape/vegetation, altitude/hydrology and tourism. The first observable factor, in particular the structure of the vegetation, is probably the most important one.

Nearly all ornithologists studying bird habitats made observations on the preference of bird species for special habitats, characterized by a special vegetation type (for instance VOOUS, 1960; 1971). Only few investigators go further in detail.

In the Netherlands the publications of TINBERGEN (1947) and OVER (1957) indicate this. They found that the structure of the vegetation is critical in determining the composition of the breeding-bird community and its density in woods. Similar results have been found for woodlands in France (BLONDEL, 1973) and earlier in Finland (PALMGREN, 1941).

In his study in Holland on the Lapwing (*Vanellus vanellus*) and the Black-tailed Godwit (*Limosa limosa*), KLOMP (1954) pointed out a clear relationship between gait and vegetation structure, this leading to distinct habitat selection.

Even plant communities can be important for the distribution of a number of bird species. BEECHER (1941) was one of the first authors to describe how the distribution of a number of breeding-bird species in Canada is closely bound up with that of plant communities. He also drew the attention to the importance of gradients of transition areas. From his investigations it had already become evident since 1941 that a number of species prefer to breed along the edges of plant communities.

TINBERGEN (1947) recognized the importance of the floristic composition in this connection, but was of the opinion that the structure of the vegetation is more important. A correlation sometimes exists between the occurrence of certain plant species or combinations of species and the distribution of bird species. (TINBERGEN, 1947; 1967).

In Holland, further studies of the vegetation of breeding biotopes have been made by KLUYVER et al. (1940) on the Wren (*Troglodytes troglodytes*), By DE RUITER (1941) on the Redstart (*Phoenicurus phoenicurus*), by KLUYVER (1951) on the Great Tit (*Parus major*) and by KLUYVER (1955) on the Great Reedwarbler (*Acrocephalus arundinaceus*). A few years ago MÖRZER BRUYNS (1979a) summarized the field studies in the Netherlands. It is clear that distinct relationships exist between breeding-bird populations and vegetation. The investigation of these relationships at Vlieland was restricted to the wader species: Oystercatcher, Curlew, Redshank and Kentish Plover. Some data (literature) about these species are given now.

Oystercatcher. GLUTZ VON BLOTZHEIM et al. (1975) mentions that this species breeds in large numbers along the North Sea coast preferring the *Cakiletalia* plant-communities of the tidal marks, the *Elymo-Agropyretum* and *Elymo-Ammophiletum* of the beach and primary dunes and the tidal-flat meadows (low-growing *Puccinellietum* and *Armerietum*). The species rarely breeds in grey dunes ('Graudünen').

In Holland Oystercatchers are breeding birds of dunes, beaches, meadows and arable land (VOOUS, 1960). They are regular and common breeders in the tidal marshes (*Amerion maritimae* and *Puccinellion maritimae*) along the coast (VAN DIJK, 1980). DE ROOS (1981) mentions breeding of Oystercatchers in the *Agropyretum boreo-atlanticum* and *Cakiletum maritimae* on the sand bank the 'Richel' near Vlieland. Studies of inland breeding Oystercatchers in Scotland (HEPPLESTON, 1971) and Holland (HULSCHER, 1972) showed that the birds prefer nesting in cultivated land and that grass fields were avoided as a nesting substrate.

Curlew. GLUTZ VON BLOTZHEIM et al. (1977) stated that in coastal areas, the Curlew prefers grey dunes ('Graudünen') with *Corynephorus canescens*, *Koeleria glauca*, *Salix repens*, solitary shrubs of *Hippophäe rhamnoides*, mosses and lichens or, at lower altitude, brown dunes ('Braundünen') with *Calluna vulgaris* and *Empetrum nigrum*, so that the plant species themselves may be important in the selection of the breeding-ground. This is in agreement with VON FRISCH (1956, 1965), who studied the Curlew in Germany. The situation in the Netherlands is similar (BRAAKSMA, 1960; VOOUS, 1960).

Redshank. GLUTZ VON BLOTZHEIM et al. (1977) stated that the Redshank prefers a nest site in vegetation consisting for the greater part of grasses and similar plants, whilst the height of the vegetation must be such that the nest site is invisible from above, yet not so dense that the breeding adults field of view is restricted. (GROSSKOPF (1959, 1963) mentions that Redshanks, among other species in Germany, breed in the vicinity of the coast in the *Corynephoretum* of the grey dunes ('Graudünen') and also in the *Agropyretum juncei*-dunes if these are in the neighbourhood of tidal zones with an adequate food supply available. In Holland, Redshank nest sites commonly occur in meadows, alongside dikes and ditches and in heaths (VOOUS, 1960; TEIXEIRA, 1979). They are regular and common breeders in the tidal marshes (*Armerion maritimae*) along the coast (VAN DIJK, 1980).

Kentish Plover. According to GLUTZ VON BLOTZHEIM et al. (1975) the Kentish Plovers may nest directly in the coastal area among tidal litter on non-vegetated beaches. This is in agreement with the investigations of RITTINGHAUS (1956, 1961) in Germany and of WALTERS (1954, 1960) in the Netherlands. The Ringed Plover replaces it in better vegetated areas.

More detailed information concerning the occurrence in the Wadden area of the four species mentioned has been published in VAN ORDEN (1963), TANIS (1963), SPAANS and SWENNEN (1968), MOSER (1973), VALK (1976) and DIJKSEN (1977).

1.3.2. *Altitude/hydrology and birds*

Various authors attach importance to the influence of the unevenness, i.e. the variation in elevation in the terrain, on the different life-activities of certain bird species. Because of these differences in altitude above the groundwater table, differences in the proportions of dry, humid and wet areas also arise. This factor plays an important part in dune habitats and therefore a short summary of the influence of the unevenness in these habitats is described briefly.

Unevenness leads to increased diversity and also may determine if, e.g., a breeding Curlew or Oystercatcher has a good view of a path or road used by tourists (SWENNEN and DE BRUYN, 1981). Under favourable conditions more breeding pairs of a certain species may occur in uneven terrain as compared with a level area (e.g. more rabbit holes in hilly than in flat terrain may give more potential breeding-places for Shelduck (*Tadorna tadorna*) and Wheatear (*Oenanthe oenanthe*). The importance of unevenness also applies to meadow-birds. For example the Black-tailed Godwit looks for higher and drier places within the damp environment to nest (KLOMP, 1954; MULDER, 1972).

Certain meadow-bird species prefer breeding grounds with relatively high water tables and are very sensitive to drainage or reclamation of their habitats Meadow areas, with a complete or nearly complete combination of meadow-bird species are becoming increasingly scarce in the Netherlands, particularly as a result of systematic agricultural improvement by drainage schemes. Inside the total grassland area, species such as Ruff (*Philomachus pugnax*) and Common snipe (*Gallinago gallinago*) are most selective in the choice of their habitat in this respect and for that reason most affected by drainage (EYGENRAAM, 1969; BEINTEMA, 1975).

GLUTZ VON BLOTZHEIM (1977) also mentions that the Redshank prefers occasionally flooded feeding areas in the vicinity of the nest site. However in the vicinity of the tidal zone, where food is available, the Redshank will nest in drier areas.

The Curlew prefers heath land with both wet and dry areas and frequently nests in the vicinity of water (VOOUS, 1960; GLUTZ VON BLOTZHEIM et al., 1977). It prefers wet peat-moors with *Erica tetralix*, *Calluna vulgaris*, etc. but nests occasionally in dry areas with solitary bushes and clumps of trees.

At present swampy grasslands in the Netherlands are protected and, if possible, bought systematically as bird-sanctuaries with the aim of preserving representative populations of those species which are most sensitive to drainage. This is also done for damp to wet dune-valleys.

For that reason the water management in such areas is of utmost importance for the local preservation of breeding-bird species, which prefer those habitats. Damp, swampy and wet areas in the dune areas are very valuable, not only for birds, but also because of their floristical composition, vegetation and geomorphology (BAKKER et al., 1979).

1.3.3. *Tourism and birds*

The absolute number of tourists visiting breeding areas during critical periods in the reproductive season (from the establishment of territories to the fledging of the young, probably has a significant influence on the breeding succes in species such as Curlew and Lapwing (*Vanellus vanellus*) etc. This was evident in the National Park 'De Hoge Veluwe' in Holland for the Black-tailed Godwit during days with peaks in the number of visitors (GENDEBIEN and MÖRZER BRUYNS, 1970). Other investigators, such as SPEIGHT (1973), state that the frequency of intrusion is more critical than total numbers of people involved.

Now some information (literature), concerning the effects of tourism upon birds of dunes and beaches, water- and marsh-birds and birds of prey is given.

(1) Disturbance of breeding-birds in dunes and beaches is mentioned by TANIS (1963), CANTERS (1975), VALK (1976), DIJKSEN (1977) for the Dutch Wadden islands Terschelling, Ameland and Texel, respectively.

SWENNEN and DE BRUYN (1980) studied the distribution of breeding territories of the (European) Oystercatcher on the eastern half of the isle of Vlieland in 1977. They found that in a strip of 75 m width on both sides of metalled roads and cycle paths, densities were relatively low, viz. 1.8 pairs/10 ha as compared to 8.8 pairs/10 ha in the next strip of the same width. Near forestry plantations, open to the public, the density was relatively low too. They state that the last-mentioned, lower density is probably caused by human activities as such differences were absent around woods where the public had no access. The density of Oystercatcher territories was also relatively low in areas with Herring Gull colonies.

SUMMERS and COOPER (1977) mention for South-Africa that on the mainland coast, Black Oystercatchers (*Haematopus moquini*) are readily disturbed by visitors because of their habit of breeding on sandy beaches during the summer tourist season. Remote beaches are threatened by the recent proliferation of off-road vehicles. There are a number of apparently suitable habitats which now contain few or no Black Oystercatchers, probably due to human presence on beaches.

BRAAKSMA (1960), RODERKERK (1961), DE GOOYER (1975) and VAN DER ZANDE (1980) mention that the Curlew has disappeared as a breeding-bird species from disturbed dunes and heathlands in the mainland of the Netherlands.

CANTERS (1973) concludes for the isle of Ameland in Holland that the Ringed Plover (*Charadrius hiaticula*) is threatened by activities of tourists. The same was observed for this species in England and Ireland (NORMAN, 1967; OWENS, 1973; PRATER, 1973; WILKINSON, 1973).

The last-mentioned authors concluded that the same applies to the Little Tern (*Sterna albifrons*), a colonial breeder. SPAANS and SWENNEN (1968) mention that the Little Tern colony at the eastern point of Vlieland probably disappeared as a result of increased tourism. Similar examples with regard to the Little Tern are mentioned for other Dutch Wadden islands such as Terschelling and Texel by TANIS (1963) and DIJKSEN (1977), respectively.

Note that in the wardened nature-reserves of these and other Wadden islands an increase in the density of certain breeding-bird species, such as Common Eider and Herring Gull, was observed.

(2) Water-and marsh-birds also appear to be sensitive to frequent disturbances but publications with exact information are scanty. Open water species like e.g. the Great crested Grebe (*Podiceps cristatus*) in the Netherlands, turn out to be particularly sensitive to motorboats and waterskiing (LEYS, 1966; DE ZEEUW, 1968; LEYS et al., 1971; VAN DEN BERG, 1974; DE ZEEUW, 1976).

The same phenomenon is mentioned by REICHHOLF (1974) along the 'Inn' in southern Germany. He also describes how the prohibition of motorboats in the Bight of the 'Heitzing Eglsee' resulted in a doubling or tripling of the number of Mallard females with offspring.

In Canada, Canada-Geese (*Branta canadensis*) desert their nests when disturbed by tourists before or during the breeding season (HANSON, 1971).

HANSEN et al. (1971) noted a significant difference in the mortality of young Trumpeter-swans (*Olor buccinator*) in Alaska in areas with different recreation-pressures. The mortality was highest in the areas with highest recreation-pressure.

In the Netherlands it has been observed that breeding Little Bitterns (*Ixobrychus minutus*) are very sensitive to boats and visitors in the vicinity of their nest sites. (BRAAKSMA, 1968; DE ZEEUW, 1968, 1976). Purple Herons (*Ardea purpurea*) also turned out to be sensitive to increasing recreation pressure in their breeding-grounds (pers. comm. A. TIMMERMAN, 1970). Moreover, some populations disappeared from areas with increased disturbance by tourists.

(3) Tourism is also a disturbing factor of importance for large birds of prey. This is especially the case if they themselves become a tourist attraction and insufficient precautions are taken to prevent disturbance (BIJLEVELD, 1974). WAARDENBURG (1974) investigated the effect of tourism upon the distribution of nests of the Buzzard (*Buteo buteo*) and this species showed a significant pre-

ference for nest sites outside the disturbed zone (about 75 m from a road or a path).

Sanctuaries affect the density and distribution of species of birds of prey. For example in the Netherlands the number of breeding-pairs of Goshawks (*Accipiter gentilis*) was about 20 or even more in an area of 10000 ha at the 'Kroondomein Het Loo' near Apeldoorn. In 1979, nearly all nests were located in bird sanctuaries, while only 5 pairs were nesting in the National Park 'De Hoge Veluwe' (6000ha) in the same year. Note that 'De Hoge Veluwe' has more visitors and less sanctuaries. SARIS (1976) also mentions the concentration of different breeding-bird of prey species located in sanctuaries of 'De Duivelsberg' in the Netherlands.

Increased predation due to disturbance. Different authors state that clutches are lost indirectly as a result of predation following disturbance by man.

In the Netherlands wardens, game-keepers and many field ornithologists are acquainted with the phenomenon that Carrion-Crows and Magpies often systematically follow birdwatchers and people involved in research (for instance mapping of bird nests), and take the eggs of these species on their route. Other examples in the Netherlands are the predation on chicks of the Common Eider and the Shelduck by the Herring Gull (*Larus argentatus*) at Vlieland (HOOGERHEIDE, 1946; DE ROOS, 1972). Clutches of these and other species like Redshank are also predated by Carrion-Crows and Magpies.

Similar date have been published in other countries. On the isle of Skokholm in Wales, the predation of eggs and chicks of the European Oystercatcher by Lesser Black-backed Gulls (*Larus fuscus graellsii*) is the main factor influencing egg and chick loss and is related to disturbance by visitors (HARRIS, 1962).

NEWTON (1970) found that only 17 per cent of the clutches of Tufted Duck (*Aythya fuligula*) and Mallards in Scotland were predated by Jackdaws (*Corvus monedula*) in a secluded and undisturbed area, whereas 41 per cent were predated in an area, which was regularly visited by investigators.

1.4. HABITAT AND BIRDS (FIELD INVESTIGATIONS ON VLIELAND)

1.4.1. *The isle of Vlieland as a suitable research area*

For a number of reasons Vlieland is suitable for investigations dealing with the impact of tourism upon bird-life. Owing to the large diversity in habitats, which is determined for the greater part by a wide variety of environmental gradients, the island is utilised by a large number of breeding, migrating, moulting and wintering bird-species (particularly 'waders') during a large part of the year.

As a result of its restricted size and isolated situation, it was possible to draw up a complete inventory of the total breeding-bird populations of the four investigated species. In addition there is a wide variety of tourist activities whose effects can be studied.

Finally, the author has an intimate knowledge of this area, stretching back over several years and has already investigated the effects of tourism upon breeding and migrating waders and duck species in the bird-sanctuary 'De Kroonspolders' at Vlieland (DE ROOS, 1972).

For these reasons Vlieland has been chosen as a research area.

1.4.2. *Physical geography of Vlieland*

Vlieland is the smallest and most western Frisian island. It has a north-eastern orientation with a bend to the east in the north-eastern part. The area above low-water-mark, including the 'Vliehors', comprises 3560 ha. The length of the island is 18.5 km and the width varies from .9–3 km (see fig. 1).

The southwestern tip of the island, called 'the Vliehors', consists of an extensive coastal sand-plain with actively formed low primary dunes, vegetated by *Elytrigia juncea*, *Cakile maritima* and *Honkenya peploides* (see fig. 1). At the beginning of this century, the Board of Works ('Rijkswaterstaat') reclaimed a part of the 'Vliehors' on the Wadden Sea side by means of dikes of drift-sand and obtained an agricultural polder area for dairy-cattle (DE VRIES, 1961). This failed because the adjacent dune area was too narrow and thus the freshwater supply, seeping from the adjacent dunes into the polder area, was too small to enable a good growth of grasses. The development of biological interesting brackish to salt polders ('Kroonspolders') with dikes of driftsand was the result (DE ROOS, 1981). These polders are very important for wintering, roosting and feeding waders and duck and also for many breeding-bird species (e.g. duck). For a review of the historical geography of the western tip of Vlieland see DE VRIES (1946) and for the geomorphology see BRIELSMAN (1972).

East of 'De Kroonspolders' there is a small salt-marsh area ('Posthuis' salt-marsh), which is an important high-tide roost for migrating waders.

The north-eastern part of the island consists of a dune area with high dunes (maximum height of 45 m (above Amsterdam ordnance datum, comparable with A.M.S.L. (above mean sea level), further indicated as: +NAP).

About 300 ha of the dune-area is covered with *Pinus nigra* var. *austriaca* woodland.

Along the North Sea coast, dune formation is artificially promoted by means of screens of reeds or branches or both. The outer dunes are protected by means of a number of basalt piers, constructed during the second half of the 19th century. These are important feeding-grounds for Turnstone (*Arenaria interpres*) and Purple Sandpiper (*Calidris maritima*) (DE ROOS, 1981).

Vlieland has a little over 1000 inhabitants. The most important source of employment is tourism. The village of 'Oost-Vlieland' is situated in the north-eastern part of the island (see fig. 1).

1.4.3. *Selection of the study-plots*

Different habitats such as dry dunes, damp to wet dune slacks, beaches and shell-banks were investigated.

The study-plots were selected on such a way that gradients in path and road densities (tourism zones) could be distinguished. The selected study-plots were:

(1) Experimental study-plots 1 and 2.

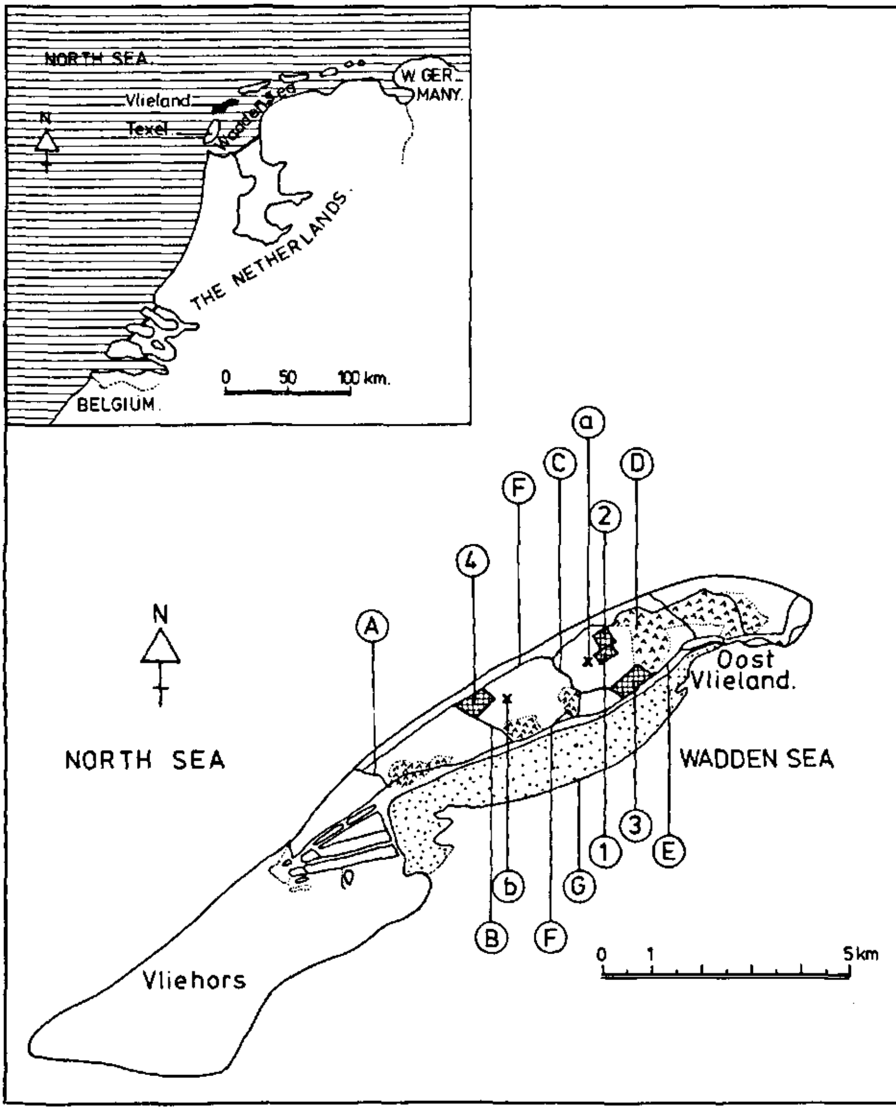

FIG. 1. Situation of the isle of Vlieland and its study-plots
1 = Study-plot 1
2 = Study-plot 2
3 = Study-plot 3
4 = Study-plot 4
Study-plot 5 = Area between the 'Pad van 30' and 'Schelpepad Oost'
Study-plot 6 = Area between the 'Pad van 20' and the 'Pad van 30'
A = 'Pad van 6'
B = 'Pad van 20'
C = 'Pad van 30'
D = 'Schelpepad Oost'
E = 'Postweg'
F = 'Lange Paal'
G = Low tide line
a = Counting site for tourists ('Kooisplek')
b = Counting site for tourists ('Nieuwe Kooi')

Tidal mudflats

Woods

(2) Non-experimental study-plots 3, 4, 5 and 6 with unlimited access to tourists. In addition, accessible beach areas and an inaccessible (military) sand-plain ('the Vliehors') were selected. For species with a low nesting density (e.g. Redshank) or large territory size (e.g. Curlew) larger study-areas were required. For that reason, study-plots 5 (250.6 ha) and 6 (219.3 ha) were selected for the Curlew and the Redshank. For the Oystercatcher study-plots 1 (10 ha), 2 (10 ha), 3 (25.9 ha) and 4 (14.2 ha) were chosen.

The location of the study-plots can be found in fig. 1. Most of the accomodation for tourists is situated on the eastern part of the island near the village of 'Oost-Vlieland'. More detailed information about this can be found in section 2.4.

2. FIELD DATA COLLECTION

2.1. Introduction and summary

On the basis of the literature review outlined in section 1.3, data were collected with regard to (1) landscape/vegetation, (2) altitude/hydrology, (3) tourism and (4) breeding-birds.

In section 2.2 variations of landscape/vegetation are discussed. In order to characterize landscape- and vegetation types, relevant for this study, methods are described. The landscape map of Doing for Vlieland was used to obtain the landscape units recognized in the study-plots 5 and 6, while the vegetation in the study-plots 1, 2, 3 and 4 has been mapped and characterized according to the standard Braun-Blanquet relevé method.

The factor altitude/hydrology was mainly studied by means of available altitude maps (scale 1:2000), delineated by the Board of Works ('Rijkswaterstaat') in 1968 (section 2.3). However, with respect to altitude class 1 (< 5 m) special hydrological data are presented.

The factor tourism is characterized by tourism zones. Though tourist counts were made, the three tourism zones, distinguished in this study, were based on aerial photograph interpretation instead of on these counts (section 2.4).

Using different survey methods, breeding-bird maps were prepared per study-plot, per year and per breeding-bird species. They give the precise distribution of nest sites or territory centres. Numerical data in various tables has been obtained from these maps (section 2.5).

2.2. Landscape/vegetation

2.2.1. *Relations between landscape and vegetation*

Different dune landscapes develop by succession, degradation and human influences as is described by several authors (van Dieren, 1934; Westhoff, 1947). Sand may accumulate above tidal litter if the wind direction is not too variable. Where there is sufficient stability and nutrition, *Elytrigia juncea* may establish itself in elevated situations in the tidal litter zone and then acts as a sand collector.

The primary *Ammophila* dune-landscape (A) develops if a primary dune is no longer flooded by the sea. It is exposed to high wind-velocities and much drifting sand. It has a changing, but relatively high, lime-content and a low humus-content of the soil. *Ammophila arenaria* establishes itself as soon as a fresh-water supply is available in the dunes, and eventually stabilises the dunes by its higher ramified, deep growing rootsystem and its sand accreting properties. The outer dunes thus consist of a single row of *Ammophila arenaria*-dunes.

The landward side landscapes develop from the *Ammophila arenaria*-

landscape following a succession, which is characterized by a decreasing lime-content of the soil and decreasing wind velocities.

Hippophaë rhamnoides is able to establish itself in relatively, lime rich soil and in a more sheltered environment behind the foredune ridge. The *Hippophaë*-landscape (H) on Vlieland occurs only in a narrow zone along the outer dunes. If the dune-sand decalcifies rapidly this species is present only for one generation, because germination is poor in lime-deficient substrates (DE VRIES, 1961). If however sand accretion continues the *Hippophaë*-landscape (H) may be maintained for a long time, which is usually the case on landward side of the foredune ridge. *Hippophaë* disappears if the nutrient and humus content of the soil increases and the lime content decreases.

If the lime content remains relatively high either because of sand accretion or other factors (e.g. the presence of colonies of Herring-Gull, as in the 'Oude Kooi' and the 'Meeuweduinen' at Vlieland) a *Koeleria* landscape is formed, although this was not observed in the study-plots.

In the remaining areas the *Hippophaë*-landscape is directly succeeded by the *Corynephorus*-landscape (C) and consists of lime-deficient dune pastures.

The major landscape of central Vlieland have been described by DOING and are listed in detail in subsection 2.2.3. He distinguishes the following major landscape units: A, H, C, P and E. The A, H and C landscapes have been mentioned before. The landscape of the temporarily wet and humid dune slacks with *Oxycoccus macrocarpos* and *Salic arenaria* (E-landscape) and the landscape of the humid to dry valleys with *Empetrum nigrum* (P-landscape) occur between the above-mentioned landscape types at lower altitudes where the increased humidity suppresses the characteristics of the other landscape types. However large differences in zonation may develop where coastal accretion varies locally (e.g. at the 'Lange Paal' at Vlieland, where rapid accretion is occurring), where coastal erosion occurs (e.g. on the eastern tip of Vlieland), where the older parts of the island differ in age (e.g. on the eastern half of the island) and where radical influences (e.g. intensive trampling on the eastern part of the island) occur.

2.2.2. *Methods for landscape/vegetation data collection*

Because of the large areas of the study-plots 5 (250.6 ha) and 6 (219.3 ha) the landscape units of DOING (1974) have been used as a starting-point. The landscape map of Vlieland (scale 1:10000), made by VAN LIDTH DE JEUDE (1971) (a student who assisted DOING in his dune research program), has also been used. This author carried out a landscape-study of the dune areas of Vlieland based on vegetation differences.

Vegetation maps of the study-plots 1 to 4 inclusive were made on a plant-community level (see for instance fig. 2 to 4 inclusieve) with the available altitude maps, (scale 1:2000) as a base. The four study-areas selected covered 10, 10, 25.9 and 14.2 ha, respectively. Their location is shown in figure 1. Homogeneous vegetation units were delineated (using the contour maps (scale 1:2000), made by the Board of Works ('Rijkswaterstaat') in 1968), as a base. Within these units the vegetation was described according to the standard Braun-Blanquet relevé

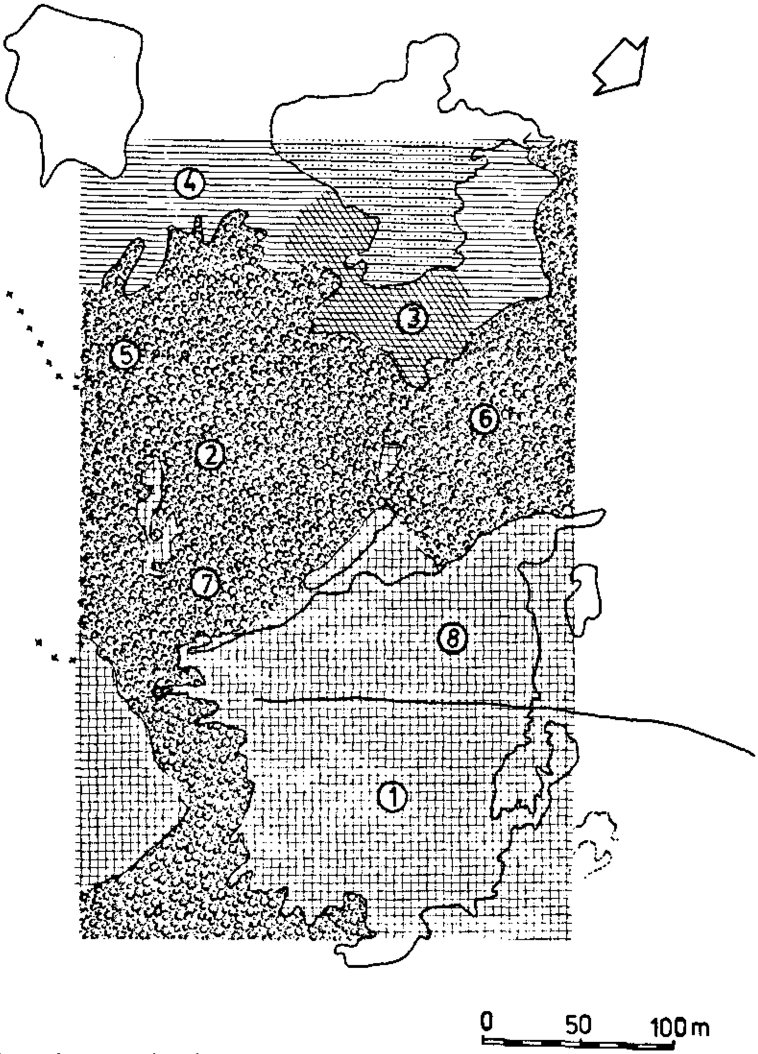

FIG. 2. Vegetation map of study-plot 1.

③ relevé point

Empetro-Ericetum

Polypodio-Salicetum

Polypodio-Empetretum

Elymo-Ammophiletum

Festuco-Galietum maritimi with *Polypodio-Empetretum* on N.-N.E. slopes

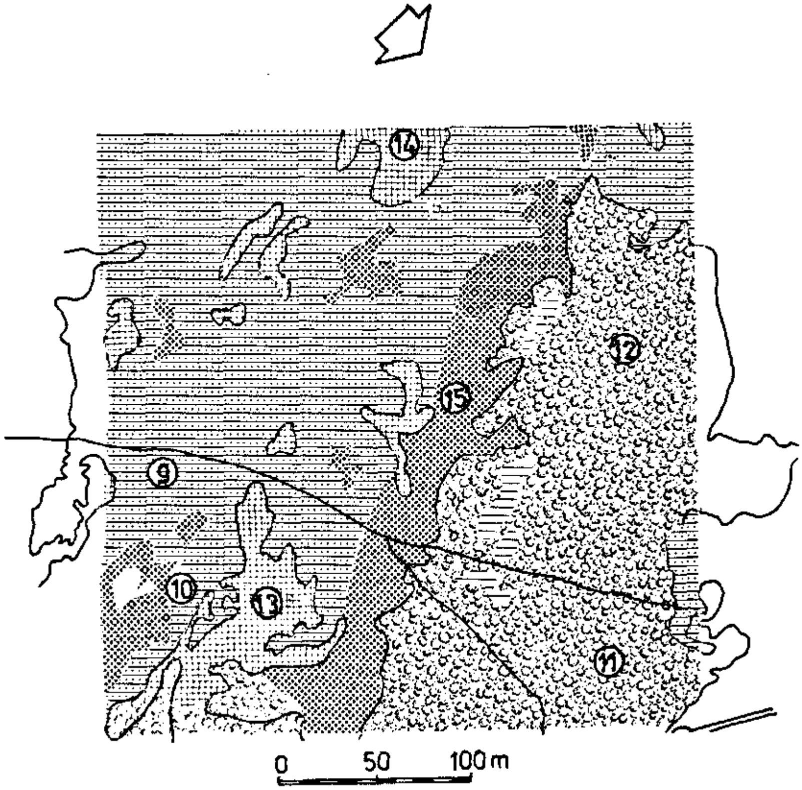

FIG. 3. Vegetation map of study-plot 2.

Empetro-Ericetum

Polypodio-Salicetum

Polypodio-Empetretum

x *Elymo-Ammophiletum*

Hippophao-Ligustretum

Festuco-Galietum maritimi with *Polypodio-Empetretum* on N.-N.E. slopes

method. The size of the relevés was 10 m^2 and in each delineated, relatively homogeneous, unit at least one and usually two or more relevés were recorded (see e.g. 2 to 4 inclusive). A total of 44 relevés was recorded and these could be grouped conveniently into five of the associations distinguished by WESTHOFF and DEN HELD (1975).

2.2.3. *Landscape data for study-plots 5 and 6*

In these plots the following major landscapes are distinguished: *Corynephorus*-landscape (C), *Empetrum*-landscape (P), *Oxycoccus macrocarpos/Salix arenaria*-landscape (E) and *Hippophaë*-landscape (H).

(1) The *Corynephorus canescens*-landscape (C) is formed on the oldest part of

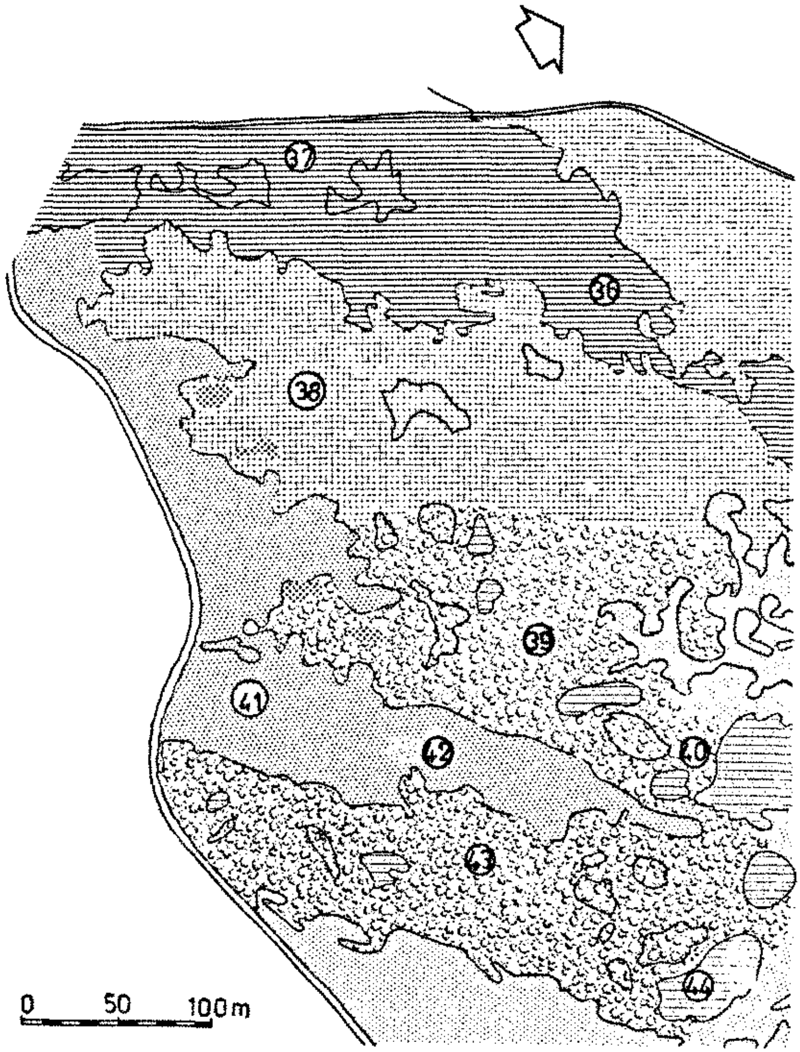

FIG. 4. Vegetation map of study-plot 4.

Empetro-Ericetum

Polypodio-Salicetum

Hippophao-Ligustretum

Elymo-Ammophiletum in blow outs

Festuco-Galietum maritimi with *Polypodio-Empetretum*

Elymo-Ammophiletum with *Polypodio-Salicetum*

the dry dunes which is deficient in lime. The soil is extremely decalcified a whitish in color or grey (owing to humus). This makes it less adhesive th lime rich sand, enabling it to drift more easily. The nutrition level is highe the dunes of mobile sand and because of a rapid turn-over of organi there is little humus formation and no erosion. The *Corynephorus*-landscape is subdivided in Ca (so called 'grey dunes'), Ci and Ch.

(1a) The *Corynephorus-Ammophila*-landscape (Ca) occurs in high, extensive, steep sided dune massifs. The vegetation is characteristic of extremely, dry, poor conditions and is open and low growing. It consists principally of grasses, mosses, lichens and winter-annuals, with much bare sand. The colour changes from grey to green (lichens), from white to yellow (sand) and even to purplish (*Corynephorus canescens*). The development of a secondary *Ammophiletum* in large blow outs with mobile sand has been observed in study-plots 5 and 6.

(1b) The *Corynephorus-Salix arenaria*-landscape (Ci) may arise from a *Schoenetum* which follows the closing of a wet valley by outer dunes. This *Schoenetum* is found in eutrophic valleys which are rather low in lime content and have fluctuating water-tables. Following the *Schoenetum* the valley may be covered with relatively lime rich sand and then a dry, eutrophic lime rich environment develops in which for example *Hippophaë*-shrubs or *Salix arenaria*-shrubs may occur. These last-mentioned shrub-formations belong to the Ci-landscape, which occurs on these formerly wet valleys. These valleys have been covered with sand later on and contain, low, dry dunes. The vegetation is dominated by *Salix arenaria* and is floristically very poor. The soil has a more compact structure than that of the Ca landscape; the sand is greyer and occurs in the central part of study-plot 5 as well as in the northern part of study-plot 6.

(1c) The *Corynephorus-Hippophaë*-landscape (Ch) is the transition between the *Corynephorus*-landscape (C) and *Hippophaë*-landscape (H) and occurs in very small patches in the study-plots 5 and 6, particularly in damp-wet valleys or on other places where the lime content remains relatively high.

(2) The *Empetrum nigrum*-landscape (P) occurs if the soil is more humid than in the Ca, Ci and H-landscapes. This vegetation is to be found in extensive valleys and in small depressions in the above-mentioned landscapes. There is a conspicuous difference in vegetation structure and colour between the more humid and dryer vegetation. A thick layer of fine humus is usually present in the *Empetrum nigrum* landscape.

(3) The *Oxycoccus macrocarpos/Salix repens*- landscape (E) is restricted to the dune slacks and includes vegetations dominated by *Salix repens* in the damp to wet valleys as well as vegetations dominated by *Oxycoccus macrocarpos*. The dwarf-shrub vegetation is locally suppressed by regular mowing, as e.g. behind the 'Oude Kooi' or north of the 'Nieuwe Kooi'. The Salix and Oxycoccus environments may differ in factors other than humidity-regime (DE ROOS, 1980). The development of a primary slack begins with a beach plain being cut off from the sea by newly developing fore dunes. A freshwater slack may develop following gradual desalination. One successional development in the slacks may follow flooding (i.e. the groundwater-tabel may rise during the accretion of the coast). Then dune lakes and associations of e.g. *Carex trinervis* and *Carex nigra* may develop, as e.g. in the northern part of the study-plots 5 and 6.

From a *Schoenetum* a humid heath with Empetrum nigrum, Erica tetralix, Carex nigra, etc. may develop if the water-table is not too high and does not fluctuate too much, as e.g. in the northern part of study-plot 2. If the table is permanently high, peat-formation occurs and a wet shrub-vegetation arises with *Alnus glutinosa* and *Salix arenaria* (e.g. in the northwestern part of study-plot 5).

(4) The *Hippophaë*-landscape (H) arises from the *Ammophila*-landscape (A) and mostly occurs behind the outer dunes. The lime content is lower than in the foredunes and there is an initial formation of humus. At a later stage the nutrient level is relatively high because of the fact that *Hippophaë* has the capacity to fix nitrogen from the air. The landscape is rather hilly and is influenced by wind- and water-erosion. In the dryer parts shrubs occur with mainly *Hippophaë* and sometimes *Sambucus nigra*, as in the western part of study-plot 5. Most of the *Hippophaë*-shrubs are low (< 1 m) and grow on uncompacted sand. *Hippophaë* may grow more than 1 m tall under sheltered and nutrient rich conditions, as e.g. at the eastern tip of Vlieland. This may happen in dry valleys, where humus accumulates.

2.2.4. *Vegetation data for study-plots 1 to 4 inclusive*

The results are shown in the synoptical table 1. In this table the first figure indicates the average value of the Braun-Blanquet cover-abundance scale in the relevés of the community; the second and third (between brackets) the lowest and highest value, respectively. Detailed information about the preference of each association for a particular altitude range is clearly demonstrated in DE ROOS (1980).

The six associations occuring in the four study-areas are: the *Violo-Corynephoretum*, *Polypodio-Empetretum*, *Festuco-Galietum maritimi*, *Polypodio-Salicetum*, *Empetro-Ericetum* and the *Hippophao-Ligustretum*. The last-mentioned association is not present in table 1, because no relevés have been made in this vegetation type. This is due to the small areas of this type.

(1) The *Violo-Corynephoretum* generally develops from the *Elymo-Ammophiletum* or the *Tortuleto-Phleëtum arenarii* and forms a climax vegetation of the xeroseries in dunes with a low lime content (WESTHOFF and DEN HELD, 1975). It is an open to a more or less closed, rather stable association in the dry dune area. All the characteristic lichen species appear in the initial stage of the association and the higher plants persist to the final stage. *Cornicularia aculeata* and *Cladonia* species dominate, but wherever on the southern slopes the phanerogams disappear, strong winds may destroy the vegetation and a phase with *Carex arenaria* follows, intermingled with *Ammophila arenaria*. The *Violo-Corynephoretum* mostly occurs in the area of altitude-class 10 m (above Amsterdam Ordnance datum, further indicated as: +NAP) on the dune tops and gentle southern slopes, which are very much exposed.

(2) The *Polypodio-Empetrum* is found on steep slopes (N.W., N. and N.E.) where it may develop particularly on isolated dunes. The steeper the slope, the more complete the association. The association develops from a stage of *Hippophaë rhamnoides* with *Polypodium vulgare* and is a climax vegetation type. The topsoil layer never dries out totally and the air-humidity is high owing to the aspect, inclination and the production of humus. The soil has an A–C profile. The

Table 1. Synoptical table of the five associations distinguished, showing the occurrence of spermatophytes*, pteridophytes, mosses,* and lichens.

Plant community		Violo-Corynephoretum	Polypodio-Empetretum	Festuco-Galietum maritimi	Polypodio-Salicetum	Empetro-Ericetum
Number of relevés;		7	10	9	8	10
% Cover	dwarf shrub layer:	–	62 (10–90)	–	57 (30–80)	76 (10–95)
	herb layer:	31 (25–40)	56 (25–90)	36 (15–80)	60 (35–90)	31 (5–90)
	moss layer:	3 (1–15)	65 (40–90)	38 (5–90)	9 (1–30)	46 (35–90)
	lichen layer:	10 (1–35)	5 (<1–20)	25 (10–50)	–	5 (1–15
Corynephorus canescens		1 (1–2)	–	–	–	–
Festuca rubra		+	–	–	–	–
Viola canina		r	r (r–+)	r	(+–r)	–
Ammophila arenaria		1 (1–2)	+ (r–+)	1 (1–3)	+ (r–1)	r
Carex arenaria		+ (r–+)	1 (+–1)	1 1–2)	1 (r–4)	+ (r–1)
Festuca ovina		(+–1)	+ (+–2)	1 (1–2)	+	+
Hieracium umbellatum		–	+ (r–+)	–	–	–
Luzula campestris		–	+ (r–+)	+	+	r
Salix repens		–	3 (+–4)	–	3 (2–4)	+ (+–5)
Empetrum nigrum		–	3 (1–4)	–	1	4 (4–5)
Polypodium vulgare		–	+ (r–+)	–	r	–
Rumex acetosella		–	r	+	–	–
Veronica officinalis		–	r (r–+)	–	+	–
Agrostis tenuis		–	+	–	r	–
Hypochaeris radicata		–	r	–	+	–
Holcus lanatus		–	r	–	+	–
Cerastium arvense		–	–	+	r	–
Aira praecox		–	–	+ (+–2)	–	–
Calamagrostis epigeios		–	–	–	1 (1–3)	+ (r–2)
Poa pratensis		–	–	–	+	r
Potentilla erecta		–	–	–	–	+
Oxycoccus macrocarpos		–	–	–	–	(+–3)
Hydrocotyle vulgaris		–	–	–	–	1
Carex trinervis		–	–	–	–	1
Erica tetralix		–	–	–	–	1 (+–2)
Dicranum scoparium		r	3 (+–4)	1 (+–4)	+ (r–1)	1 (+–3)
Hypnum cupressiforme		–	1 (+–2)	1	+	2 (1–4)
Pseudoscleropodium purum		–	(+–2)	–	+ (+–1)	(+–1)
Eurhynchium praelongum		–	+	–	r	–
Dicranoweisia cirrhata		–	–	r	–	–
Polytrichum piliferum		–	–	–	–	2
Cornicularia aculeata		+	–	+ (r–+)	–	–
Cladonia destricta		r	–	(+–3)	–	–
Cladonia coccifera		r	–	r	–	–
Cladonia foliaceae		(r–+)	–	+ (+–1)	r	–
Cladonia pyxidata		+	+ (r–+)	+ (r–+)	r	+ (r–+)
Cladonia furcata		–	+ (r–+)	(r–+)	r	+
Cladonia impexa		–	1 (+–2)	+ (+–3)	–	+
Parmelia physodes		–	+	+	–	+
Cladonia sylvatica var. mitis		–	r	–	r	+
Cladonia glauca		–	–	–	–	+

* Incidental species: Ranunculus flammula, Juncus alpino-articulatus, Juncus subuliflorus, Carex panicea, Potentilla anserina, Lotus corniculatus, Jasione montana, Galium verum; Ceratodon purpureus.

association was only found in two higher classes, above 7.5 m +NAP. The species combination of *Salix repens*, *Empetrum nigrum* and *Polypodium vulgare* is determining here. Their occurrence can be explained by the micro-climatic conditions, especially the humidity. According to DOING (1974) *Salix repens* is restricted to open and moist sand, where its establishment and germination are favoured. Its presence is primarily determined by the occurrence of areas which have been wet for at least some time in the past.

(3) The *Festuco-Galietum maritimi* forms rather closed grassy vegetations on nitrogen poor and humous, weakly acid, stabilised sands. The community may originate from the process of older stabilised dunes being continually grazed by rabbits (WESTHOFF and DEN HELD, 1975). This community occurs principally in the altitude class 5–7.70 m +NAP, where the area is slightly sloping.

(4) The *Polypodio-Salicetum* is a low shrub-association, developed optimally on northern slopes and in valleys. It is a stage in the xeroseries in the dunes on dry, somewhat decalcified sands or sandy soils not too deficient in lime (WESTHOFF and DEN HELD, 1975). The association is floristically poor. It was found throughout the altitude classes, but predominantly in the lower ranges and was very limited above 10 m +NAP (DE ROOS, 1980).

(5) If the water table approaches the surface, a wet heathland with *Empetrum nigrum*, *Erica tetralix*. *Carex nigra* develops. It is called the *Empetro-Ericetum* and may develop from a *Schoenetum-association*. It occurs in acid primary or secondary valleys in dunes which are deficient in lime (WESTHOFF and DEN HELD, 1975). A layer of humus of some 2–5 cm, covers the sand while the soil has an A–G profile. During winter the water-table rises above the surface.

(6) The *Hippophao-Ligustretum* proceeds from the *Elymo-Ammophiletum*. Note that the characteristics for the *Hippophaë*-landscape (H), mentioned in subsection 2.2.3, are also applicable here. The *Hippophao-Ligustretum* is mostly situated directly behind the outer dunes where the substrate is more stable. *Hippophaë rhamnoides* has the ability to fix atmospheric nitrogen. This increases the nutrient resources, and the shrub community becomes nitrophylic in a later stage. The association occurs on dry slopes (study-plot 4) or in damp valleys (study-plot 2) behind the outer dunes. The association does not have a homogenous floristic structure. *Hippophaë rhamnoides* changes its environment after some years by the building up of humus, and at the same time creates a more favourable micro-climate by screening against the wind and by enrichment of the environment with nitrogen. This enables species such as *Polypodium vulgare*, *Solanum dulcamara*, etc. to survive. In the older dune areas the zone in which *Hippophaë rhamnoides* plays a part is narrow and is sufficiently decalcified to support a mixture of the *Violo-Corynephoretum* and the *Festuco-Galietum*. The forms of the *Hippophaö-Ligustretum*, which are nutrient rich, occur in a later stage of the succession. Here the shrubs are less tall (< 1.5 m) and *Sambucus nigra* occurs more rarely with *Hippophaë rhamnoides*. These nutrient rich vegetation types are generally to be found in humus-rich soils which are rich to moderately rich in lime and occur in sheltered (eastern slopes, valleys) as well as in exposed (northern slopes) environments in the middle and inner dunes (WEST-

HOFF and DEN HELD, 1975). In the dunes of Vlieland fragments of these types are found in the study-plots 2 and 4.

2.3. ALTITUDE/HYDROLOGY

2.3.1. *The hydrological situation at Vlieland*

In the subsoil of Vlieland, where fresh and salt water occur side by side, a lens-shaped fresh-water body is formed (BEUKEBOOM, 1976). The dunes provide the source of the fresh-water lens and because of excess rainfall a water-table (which is higher than sealevel) is built up in the dunes. The balance between excess rainfall, transpiration, and drainage can create either a wet or a moist dune slack for various periods of the year. In certain years, the water-table in the wet dune slacks rises above the surface and may flood the area for a variable period of time, while the water-table in the damp slacks does not rise above the surface. The amplitude and duration of flooding mainly depends on the yearly amount of rainfall.

2.3.2. *Methods*

The altitude maps have been derived from the coastal contour maps of Vlieland (scale 1:2000) delineated by the Board of Works ('Rijkswaterstaat') in 1968. The areas of the altitude classes on the coastal contour maps were determined with a digital planimeter. The average of three readings was taken. Four altitude classes were applied to the areas < 5.0 m, 5.0–7.5 m, 7.5–10.0 m and > 10.0 m (above Amsterdam ordnance datum, comparable with A.M.S.L. (above mean sea level), further indicated as +NAP) (see fig. 5).

With regard to the hydrological data attention has been restricted to the years of investigation (1974 to 1979 inclusive). The contour maps are used as the basis and only the water-table fluctuations in altitude class 1 (< 5.0 m +NAP), the lowest altitude-class, are dicussed.

2.3.3. *Results*

(1) *Study-plot 1.* The altitude differences with respect to NAP are depicted in fig. 5, which show a secondary dune slack in the north-eastern part at altitudes ranging from 4.4–4.8 m + NAP. The central and western part consists of a hilly landcape with comparatively low ridges (6.7–7.5 m +NAP). In the western part this landscape changes into medium-high dunes with altitudes varying from 7.5–10.0 m + NAP (see fig. 5).

(2) *Study-plot 2.* The lowest part (3.5–5.2 m +NAP) is situated in the northern part of the study-area (fig. 6). South of this area is a hilly landscape (6.7–7.5 m +NAP). The orientation of these dunes is S.W./N.E. and they show a slightly parabolic shape. The most important blow out is situated in the south-eastern part of the study-plot, where the highest dune top is also found (8.8–10 m +NAP) (see fig. 5).

(3) *Study-plot 3.* This dune area consists of a ± 2.5 m wide ridge with a plateau

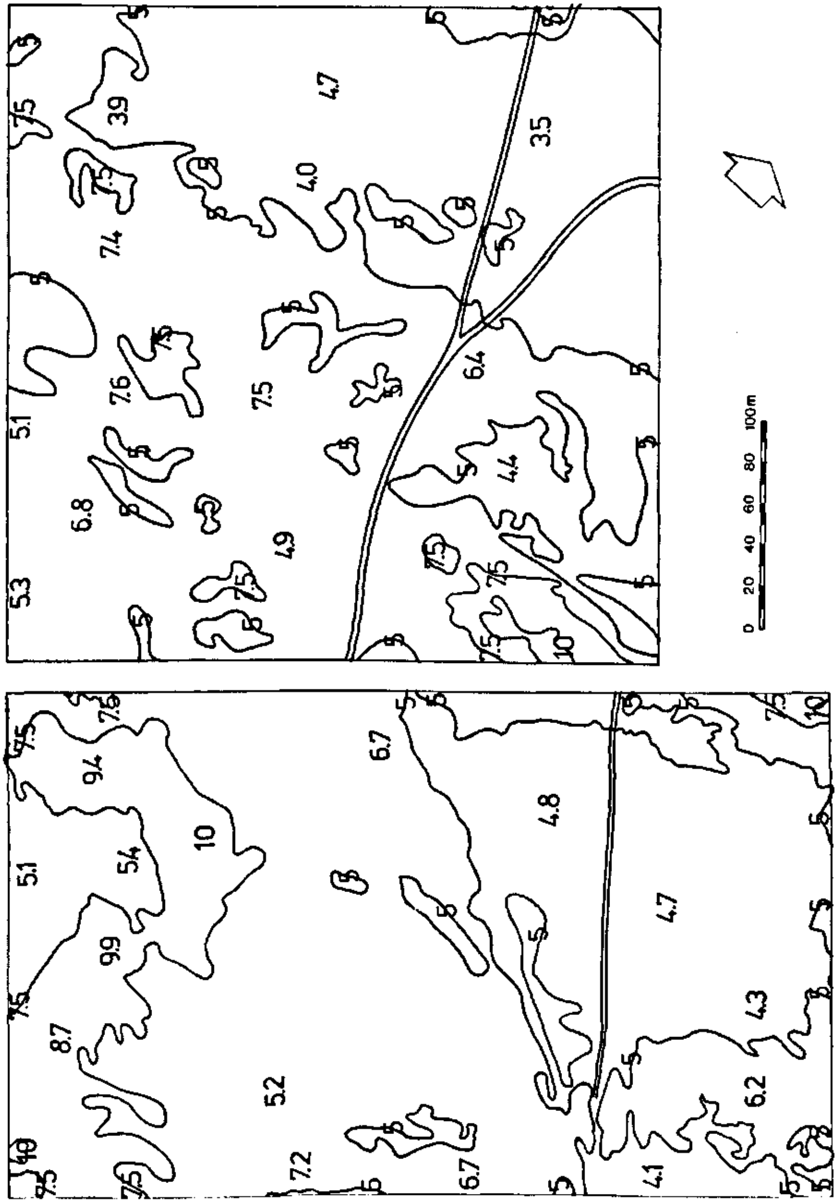

FIG. 5. Altitude maps of study-plots 1 (left) and 2 (right).

between 10 and 14 m +NAP and hills up to 18 m +NAP. On both the northern and southern sides, the ridges slope steeply. Blow outs have developed locally, particularly in the eastern part.

(4) *Study-plot 4*. This dune area, east of the 'Pad van 20' cannot be separated from the area to the west, because of a dune-ridge west of this path, which forms an offshoot of a large parabola. In the western part of study-plot 4 this ridge divides into a higher northern ridge (6–8 m + NAP) and a lower southern ridge. These ridges have a S.W./N.E. orientation and they extend eastward. Between these two ridges lies the valley of 'Het Veen': a flat humid depression, which is situated in the study-area. In the south-eastern part of the area, where the valley widens, there is a conspicuous steep sided dune with several blow outs. The highest dune tops are 10–12 m +NAP.

(5) *Study-plot 5*. The study-plots 1 (10 ha), 2 (10 ha) and 3 (25.9 ha) are incorporated in the larger study-plot 5 (250.6 ha). The central part of this study-area is characterized by extensive valleys, running east-west, varying in height from 5–7.2 m +NAP. Between these valleys there are medium-high to high dunes with heights varying from 7.5–20.2 m +NAP. The lowest part, a north-south running valley is situated in the western section. Here the height varies from 2.3–5 m +NAP. Further details may be found on the coastal maps (scale 1:2000) of Vlieland, delineated in 1968. (The Board of Works ('Rijkswaterstaat') map-leaves VD 8, 9, 19, 20, 30 and 31).

(6) *Study-plot 6*. This plot includes study-plot 4 (219.3 ha). The area is characterized by a series of east-west running valleys varying in height from 2.8–5 m +NAP. The central part consists of a complex of high dunes with heights varying from 7.5–10 m +NAP (see also the relevant coastal maps of Vlieland (the Board of Works ('Rijkswaterstaat') map-leaves VD 8, 18, 19 and 30).

Some hydrological data. In the spring of 1974 the water-table in the lowest part of altitude-class 1 (2.5 m +NAP) ranged from between 10–35 cm below the surface to between 35–70 cm below surface in summer. In the extremely wet spring of 1975 the water-table in the lowest part of altitude-class 1 fluctuated between 60 cm above and 10 cm below the surface and during the summer fell to between 10 and 53 cm below the surface.

In the extremely dry spring of 1976 the water-table fell from 10–35 cm below the surface to 36–60 cm below the surface in the summer.

In the spring of 1977 the water-table in the same altitude-class varied from 5 cm above to 40 cm below the surface and during the summer from 40–70 cm below the surface. This year was very similar to 1978 in being neither extremely wet and nor extremely dry.

Finally, in 1979, the water-table ranged from between 25 cm above to 30 cm below the surface in the spring and fell during the summer to between 30–60 cm below the surface. In 1979, therefore, spring was wetter than in 1977 and 1978, but not as wet as the extreme wet spring of 1975.

2.4. Tourism data collection

2.4.1. *Development of tourism*

Owing to more leisure time, prosperity and mobility, outdoor-recreation increased enormously in the Netherlands as in many other countries, during the seventies. Of course there were also changes in the distribution pattern of leisure time over the days, weekends, holidays and workingperiod (Bijkerk, 1971).

Eight to ten per cent of all summer holidays, spent in the Netherlands, is passed on the Dutch Wadden islands. The total number of tourists on Vlieland increased from 35000 in 1960 to 62000 in 1971 and to 70000 in 1980 (Dogterom, 1977).

Lodging of these tourists, especially takes place around and in the village of 'Oost-Vlieland' (fig. 1). For that purpose about 3300 sleeping-places are available in hotels, boarding- and camping houses, summer-cottages, private houses and a camping farm. Moreover a camping-site, east of the village, for about 3800 persons, another camping-site near the 'Lange Paal' for about 200 persons and a yacht-harbour with a capacity of about 360 persons, so that sleeping-accomodation for about 7700 guests is available (Grontmy, 1976).

Along the Wadden shore, the 'Postweg', a metalled road, connects the village of 'Oost-Vlieland' with the cavalry-shooting-camp. Along the northern side of the island, just behind the outer seadunes, lies a cycle-path, paved with shells. These mainroutes are connected by a cinder path and some shell paths.

Before 1940 the impact of tourism upon the landscape and its characteristic flora and fauna will have been negligible. Nowadays effects of the increased tourism are visible and insight in the development and significance is required.

2.4.2. *Methods for data collection*

Several authors discussed methods for recreational research (inclusive tourist counts) (Bijkerk, 1970; Burton, 1971; van Geelen, 1971; van Lier, 1971, 1973; Nelissen, 1972; Mulder, 1974). Actual recreational research was carried out in the Netherlands for the 'Amsterdamse Bos' (de Jonge, 1951), 'de Vinkeveense Plassen' (Jolles, 1954), 'Meyendel' (Coops, 1958; van der Werf, 1970, 'Hoge en Lage Vuurse' (Meys, 1959), 'de Kennemer Duinen' (Roderkerk, 1961), 'de Kortenhoefse Plassen' (de Zeeuw, 1968), the dune area of Oost-voorne' (Volker, 1969), the camping-site 'De Franse Kamp' near Bussum (Mulder, 1974) and the 'Wadden' area (van Ittersum and Kwakernaak, 1977). Moreover the recreational-research division of the Forestry Service investigated several forestries in Holland as e.g. near Nunspeet and on the isle of Texel.

The above-mentioned authors counted tourists on pathways or roads, or passing the entrance; they also determined the number of tourists per ha and observed the behaviour of the tourists, e.g. by means of inquiries. Instead of counting tourists, one also can use their after-effects (paths etc.) for measuring the impact of tourism.

In the van Ittersum and Kwakernaak (1977) study, the density of paths was introduced for the 'Wadden' area. We used both approaches, though no inquiries were made because this would have been too time consuming.

During the count-days, the behaviour of the tourists could be observed in areas around the counting sites. Concentrations of tourists can be explained by (1) the reachability of certain areas, (2) the tendency of people to settle down side by side during holiday-time, (3) the presence of facilities (e.g. swimming-pool, yacht-harbour), (4) other attractions (e.g. ponds ('Klaas Douwes'-and 'Toren' pond at Vlieland)), (5) the nature of the terrain (e.g. certain landscape types and view-points).

Aerial-photographs can give information about patterns of paths and roads in dune areas (DE BREUK et al., 1967; VLAANDEREN et al., 1977).

2.4.3. *Results*

To determine the number of tourists visiting the island one needs exact registrations of numbers of visitors, overnight-stays etc. Reliable data cannot easily be obtained (DOGTEROM, 1977). One only knows the maximum available lodging capacity on the island, which is about 7700 (see section 2.4.1).

To get an idea of tourism, the following counting sites were chosen: (1) the highest dune top in the 'Kooisplek' dune area, from which the study-plots 1, 2, 3 and 5 could be overviewed, (2) the highest dune top in the 'Nieuwe Kooi' dune area, from which the study-plots 4 and 6 could be overviewed.

Data were collected with respect to the numbers of tourist groups per count day.

The data for 7 April 1974 is presented in table 2 for the 'Kooisplek'. Similar tables were collected on 8, 12, 14 and 30 April 1974, 25 Mai 1974, 2 June 1974, 9 and 23 July 1974, 30 March 1975, 3 and 27 April 1975, 16 and 18 Mai 1975, 4, 10 and 22 June 1975, 3 July 1975, 13 and 18 april 1976, 9, 25 and 28 Mai 1976 and 6 June 1976. For the 'Nieuwe Kooi', data were collected on 15, 28 and 30 April 1974, 19 and 23 Mai 1974, 3 June 1974 and 9 July 1974 (the data is available on request).

To show that dune areas are already visited early in springtime, the data of March 30th and 31th, 1975 is discussed. At the 30th (Eastersunday) 135 groups of cyclists (373 in total) and 52 groups of walkers (148 in total) used the cycle-path along the outer dunes north of the 'Kooisplek'. Nine groups (35 in total) walked into study plot 1 and stayed there 10–45 minutes, 3 groups (9 persons) obviously looking for eggs. In 1974, Eastersunday was on April 14th. On this day 90 groups of cyclists (252 in total) and 62 groups of walkers (162 in total) were counted at the same cycle-path and, from these, 13 groups (33 in total) walked into the same study-plot and stayed there 5–25 minutes, 2 groups (3 persons) obviously looking for eggs. The shift from cyclists in walkers between 1974 and 1975 can possibly be explained by the difference in wind-velocity. On April 14th 1974 the wind-velocity was 7 m/sec (wind direction N.-NE.) and on March 30th 1975, 3 m/sec (wind direction N.).

Note that at a meteo-station on the 'Kooisplek' the following weather variables were measured: temperature (in °C), wind-velocity (in m/sec), wind-

TABLE 2. Numbers of tourist groups and group-size per type on the shell-path north of the 'Kooisplek' and in study-plot 1 on sunday 7th of April 1974.

Time	Shell-path		Plot 1		Temp.	Wind	Sun.
	Cyclists	Walkers	*Walkers	Egg collect.		D.V.	
9–10	2, 9, 4	2, 4, 3, 3	5 (20)	0	9	O 3	60
10–11	3, 11, 5, 2	4, 6, 2, 2	4(10); 2(10); 3(10); 3(10)	1(30)	11	O 3	60
11–12	10, 2, 4, 4, 5, 4, 5	2, 5, 2	3(10)	0	13	O 4	60
12–13	5, 4, 4	3, 2, 5, 2	0	0	13	O 4	60
13–14	2, 2, 5, 2, 2, 4, 3, 3, 4, 2	2, 3	0	1(30)	14	O 4	60
14–15	2, 4, 2, 3, 4, 2, 2, 3, 2, 5, 2, 2, 2, 2, 4	2, 4, 23	2(10); 2(10)	0	14	N 4	60
15–16	2, 3, 2, 2, 2, 4, 2, 4, 2, 4, 3, 1	3, 2, 3, 2, 2, 2, 2	4(10); 5(30)	0	12	N 5	60
16–17	3, 4, 2, 2, 4, 2, 4	1, 4, 3	5(15); 8(10); 4(10); 5(10)	0	11	N 5	60

Egg collect. = egg collectors; Temp. = temperature; D. = wind-direction; V.= wind-velocity; Sun. = sunshine duration and * = between brackets residence-time in minutes.

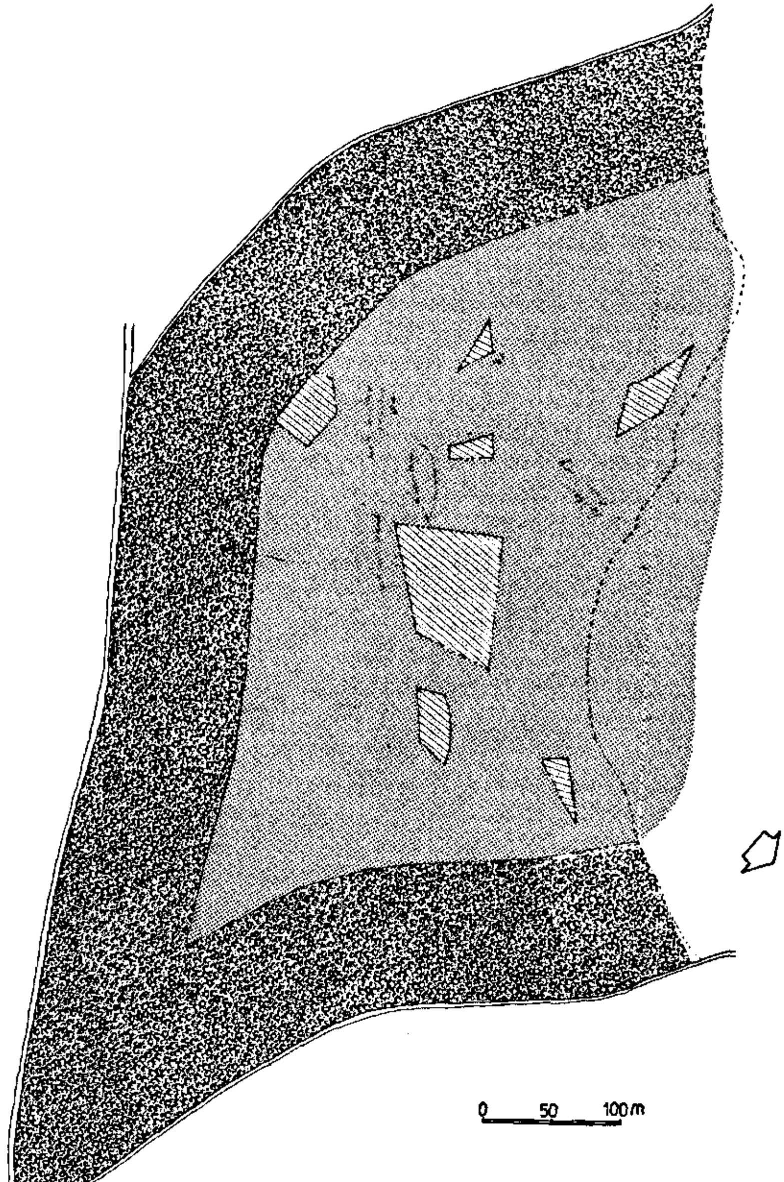

FIG. 6. Tourism zone map of study-plot 3.

Tourism zone 1

Tourism zone 2

Tourism zone 3

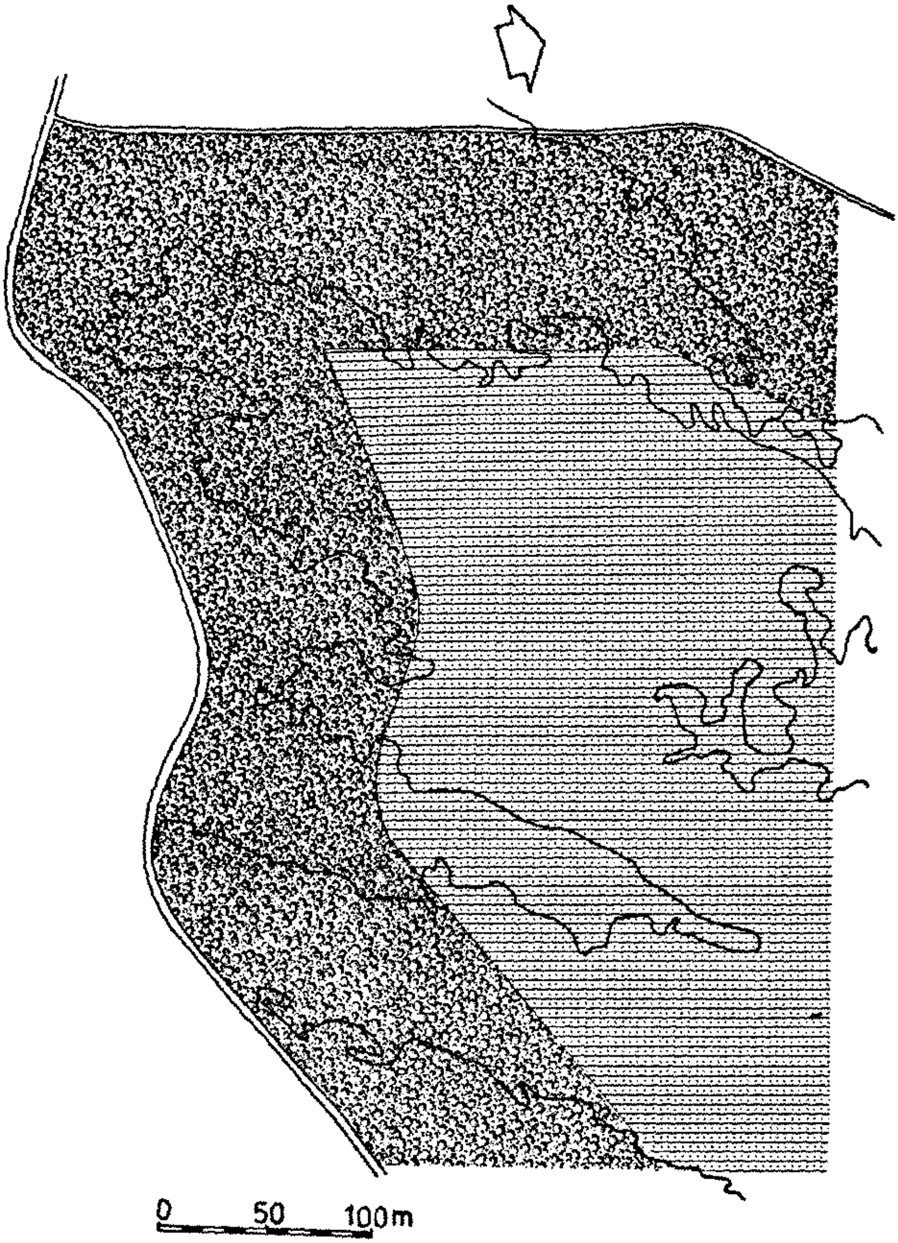

FIG. 7. Tourism zone map of study-plot 4.

Tourism zone 1

Tourism zone 3

direction and sunshine duration in min/hour).

It turned out that walkers preferred the vegetation type *Corynephoretum canescentis* over the types *Empetro-Ericetum* and *Polypodio-Salicetum*, possibly because it is more easily passable.

As a result of differences in view, altitude, lee and environment gradients, 'natural' concentration-sites also play a part at Vlieland. An important viewpoint, a concentration point for tourists, is located at the highest dune top of the 'Kooisplek' in study-plot 5. Another one is located in the western part of study-plot 6 (a high dune top with a large blow out). The 'Klaas Douwes' pond and 'Toren' pond are examples of concentration sites in the woods.

On the basis of aerial photographs, made by 'Hansa Luftbild', three tourism zones were defined as follows:

1. The zone of points at least 100 m from the nearest metalled path or road and at least 25 m from the nearest unmetalled winding path.
2. The zone of points at least 100 m from the nearest metalled path or road but at a distance < 25 m from the nearest unmetalled winding path.
3. The zone of points at a distance < 100 m to the nearest metalled path or road (see figures 6 and 7).

These definitions have been chosen with the idea in mind that tourism effects will be stronger as the zone number increases. This is trivial with respect to 1 < 2 and 1 < 3. However, the ordening 2 < 3 is based on the idea that metalled paths or roads cause much more disturbance than unmetalled winding paths.

2.5. Breeding birds

2.5.1. *Concept and function of territory*

Nearly all studies dealing with the possible effects of various factors upon breeding-bird populations, are based on mapping of territories and on the study of the alterations in territorial patterns, caused by such effects. Therefore special attention is paid here to the concept and definition of territory.

It is a well-known phenomenon that males of many breeding-bird species settle in a certain area or territory, which they defend from intruding males of their own species. Howard (1920) was one of the first ornithologists who studied territories of birds. Many ornithologists after him, like e.g. Lack (1966), have also published many papers about bird territories and their functions. The concept 'territory' is used as the unit of abundance, because this does not require a decision as to whether an observed bird is breeding or unmated; this question is of little interest for the present investigation, because all birds observed, whatever their status, form part of the total population. However, the 'territory' concept should be regarded as a purely methodological unit, obtained in the evaluation of the census maps. The enormous variation in territory-types enables a large number of species to breed in the same area (Nice, 1941; Armstrong, 1947). After a period of establishment, the birds identify their territory boundaries by topographical details.

The functions of the territory are outlined by HINDE (1956) and TINBERGEN (1956, 1957). These include functions related to reproduction, feeding behaviour and predation and may play an important part in the regulation of numbers of breeding bird populations. Variation in territory-size ranges from the extremes of the small territories of colonial sea-birds to the relatively large areas which are defended as feeding territories by many song-bird species. These song-birds use their territory as a breeding-area in which usually nearly all the food is collected (KLOMP et al., 1972), but some song-bird species also feed outside their territories.

In some cases breeding-territories are probable absent as, e.g. in the case of the Redshank (HALE, 1956). HARRIS (1970) concluded in his study on the isle of Skokholm that Oystercatchers have territories and that territory size limits the breeding population of Oystercatchers and that the birds need territories in which to feed their young and that most birds collect their food in their breeding territories. On Vlieland, however, the Oystercatchers collect all their food for their young on the mud flats outside the nesting area (see fig. 1).

The research on Vlieland, with regard to the investigated species, involved mapping the location of territory centres/nest sites.

2.5.2. *Methods for mapping*

Although many occasional attempts throughout the world have been made, it is only during the last 20 years that bird-mapping has been applied systematically on a large scale. This is reflected in both the number of methods which have been applied, the increase in the area covered, the time spent and the expertise of the observers.

The results of systematic, quantitative breeding-bird counts are becoming increasingly important in providing an indication of natural fluctuations. They can reveal possible decreasing tendencies, thereby indicating potential endangered or threatened species.

The methods applied in breeding-bird mapping are usually subdivided into four categories (BERTHOLD, 1976).

(1) Optical and or acoustical recording of individual singing males, using a study-plot, strip-survey or point-survey method.

(2) Searching for and counting of nests and clutches of breeding-birds.

(3) Capture, marking and releasing of a population sample and the calculation of the total population from the ratio of marked and unmarked individuals by recapture and observation.

(4) Photographing and filming of bird-concentrations and breeding-colonies and the subsequent counting of individuals, nests or contents of the nests in the research-area.

MERIKALLIO (1946, 1958) used the strip-survey method for the first time in Finland, relying on visual and auditory observations. TINBERGEN used the same method in Holland. TINBERGEN (1943) was the first worker in the Netherlands to start breeding-bird censuses and was followed by many others. Similar counts have been made on Vlieland as part of the investigation of the avifauna. From the total population of breeding-birds at Vlieland data are available for the following species: Common Eider (VAN OORDT, 1937; HOOGERHEIDE, 1950, 1963; WILCKE, 1956; HOOGERHEIDE J, and C., 1958; HOOGERWERF, 1973), Shelduck HOOGERHEIDE, 1946), Herring Gull (VAN DOBBEN, 1934; MÖRZER BRUYNS, 1958, 1959; SPAANS and SWENNEN, 1968)), Water Rail (DE KROON, 1976), Mealy Redpoll (*Carduelis flammea*) (BLOK and SPAANS, 1962). Note that SPAANS and SWENNEN (1968) give data for all breeding-bird species at Vlieland.

For the breeding-bird species in the study-plots on Vlieland the following methods were applied: (1) optical and or acoustic recording method of individual singing males (integral- or territory method) using a strip-survey or point-survey method and (2) locating and counting of nests.

In all the study-plots the strip-survey method was used for species such as Lapwing and Sky-lark (*Alauda arvensis*). The study-plots were divided into strips or transects using natural and artificial characteristics in the dunes. The area had to be crossed by many transects in order to be completely covered, so that it was not always possible to use existing roads and paths. At Vlieland visual observations were made over a strip with a minimum width of 25 m both sides of the transect and supported by acoustical data (the accurracy of the human ear in locating sound decreases rapidly above 100 m (e.g. MERIKALLIO, 1958). The distance between the transects was determined by the range of differences in altitude. The transects generally followed contour lines. A different starting point was chosen for each count and the observations were supported with counts of the numbers of individuals, giving alarm calls, or nesting individuals and of breeding-pairs with young.

Weather conditions, time of the day, the season and the speed of the observer are important variables to consider during the mapping. ENEMAR (1959), took these factors into account and concluded that three observations per season are sufficient to locate the number of different species, nesting within an area, and ten observations to determine the number of breeding pairs of each species; during a single count an average of 60–65 per cent of the population was noted. This is in agreement with the experiences of ornithologists in the Netherlands, who also became involved with bird counting. With these results in mind it was decided to make ten observations per year in the study-plots at Vlieland in an attempt to estimate the total number of breeding-pairs.

In counting songbirds the simultaneous singing or two opposing males was an important verification of the numbers of territories. For duck species special attention was paid to solitary males, which usually remain close to existing nests and, in the Common Eider counts were made of hatched clutches (BAUER et al., 1968).

These techniques were also used in the point-survey method. This method was particularly suitable for waders such as Redshank, Curlew and Oystercatcher, and was used in conjunction with the strip-survey method. From a top of a high dune, an area of about 250 m in radius was observed for 15–20 minutes. With the help of basic maps with contour lines (scale 1:2000) boundaries of the observation areas could easily be determined and the points of observation could be distributed evenly over a study-plot. The singing and/or courting males were plotted on the basic maps with a scale 1:2000. The advantage of this mapping method is that it is easy to observe breeding-pairs with young (giving alarm calls) and pursuing predators such as Carrion-Crow, Magpie, Herring Gull etc. The Redshank showed this pursuing behaviour only if there were young, while the Curlew, the Oystercatcher and the Lapwing showed this behaviour throughout the breeding period. During the tourist counts it was possible to locate most nests of the Curlew, the Redshank and the Oystercatcher.

The way to locate nests varied from species to species. For example as an observer approaches the Curlew, this species tends to run away from the nest and to fly up at some distance (often while the observer is still more than 200 m away from the nest, depending on the stage in the breeding cycle). This phenomenon is important only if the nesting or watching bird is able to see a person at a large distance as for example in dune valleys. However, if the nest is situated on a dune-slope and the breeding Curlew is suddenly confronted with a man, who shows up suddenly, than it flies directly from the nest, normally returning after some time, partly by flying and partly by walking. During high tide the male or female usually keeps watch from a dune top. By making use of this general pattern of behaviour it was possible to locate most of the nests, without having to search systematically the study-plots (BOOTSMA, 1977).

In the beginning of the breeding-season the Redshank also tends to fly from the nest when approached (often at a distance of 300–400 m, but the more days the bird has incubated the more reluctant it is to leave the nest). As with the Curlew, the Redshank, when returning to the nest, covers the final distance by walking. Similarly, this behaviour pattern helped to locate the nest sites. A count of the number of breeding-birds, giving alarm calls, was made at a later stage and turned out to be an excellent check of the numbers.

The Oystercatcher was much easier to map in this way because breeding pairs could be counted directly on the nest from high dune tops situated along the edges of the study-plots. A check on this mapping method was provided by comparing the sample number of nests, found during the transect method, with the number of nests, actually counted during the point-survey method. Both methods showed similar results.

The nests of Kentish Plovers on beaches and shell-banks were located with the aid of binoculars, through which birds, leaving and returning to their nests, could be observed. During these observations, natural elevations such as primary dune-tops and wood in the tidal litter zone were used.

2.5.3. *Mapping results*

(1) The data from study-plots 1 and 2 are given in tabel 3. The location of territories and/or nest sites are given in figs. 8 to 16 inclusive. The data for the Oystercatcher is suitable for a detailed statistical analysis, but the numbers of the remaining species are too small to draw statistically significant differences. Despite this the increase in number of Redshank breeding-pairs, following the enclosure of study-plot 1, was striking (from 3 and 2 pairs in 1974 and 1975,

TABLE 3. Numbers of territories/nest sites in the experimental study-plots 1 and 2 (10 ha each).

	Study-plot 1								Study-plot 2							
	Dunes				Valleys				Dunes				Valleys			
	Open		Closed		Open		Closed		Closed		Open		Closed		Open	
Species/Year	'74	'75	'76	'77	'74	'75	'76	'77	'74	'75	'76	'77	'74	'75	'76	'77
Anas platyrhynchos	0	0	0	0	2	0	1	1	0	0	0	0	2	1	1	1
Anas clypeata	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Somateria mollissima	1	0	0	0	3	2	1	0	0	0	0	0	0	0	0	0
Tadorna tadorna	4	2	4	4	0	0	0	0	3	3	3	3	0	0	0	1
Phasianus colchicus	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	1
Rallus aquaticus	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1
Haematopus ostralegus	15	12	27	27	4	1	1	5	5	13	5	6	1	1	1	0
Vanellus vanellus	2	2	3	2	0	0	0	0	0	0	0	0	0	0	0	0
Gallinago gallinago	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1
Numenius arquata	0	1	0	0	2	0	1	1	0	2	2	0	3	2	2	2
Tringa totanus	0	1	0	0	3	2	9	9	0	0	0	0	0	1	0	1
Larus canus	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Alauda arvensis	3	3	4	2	1	0	0	1	4	2	3	3	0	1	1	0
Anthus pratensis	1	1	2	1	3	2	2	3	2	1	1	1	5	6	6	6
Oenanthe oenanthe	1	1	1	1	0	0	1	1	4	4	3	3	0	1	1	0
Locustella naevia	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Emberiza schoeniclus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Carduelis cannabina	0	0	0	0	1	1	1	1	0	0	0	0	3	2	1	1

respectively to 9 pairs in the years 1976 and 1977). If the score of 2 for 1975 is compared with the score of 9 for 1977, than the difference is statistically significant at $\alpha = .05$ level and gives a valuable indication.

The presence of the Reed Bunting (*Emberiza schoeniclus*), Grasshopper Warbler (*Locustella naevia*) and Water Rail in study-plot 2 may be associated with the humid part of a valley with *Erica tetralix*, tall grasses (e.g.*Calamagrostis epigeios*, solitary *Hippophaë rhamnoides* and *Salix arenaria* shrubs.

(2) The data for the breeding-birds of study-plot 3 are summarized in table 4, which also gives the density of each species per 10 ha. The data for the Oystercatcher have been further analysed. The numbers of the remaining species could not be treated statistically. They appeared to be too small.

The breeding-bird composition of study-plot 3 was similar to that of study-plot 2. However study-plot 3 lacks damp valleys with solitary *Hippophaë rhamnoides* and *Salix repens* shrubs and probably because of this, Common snipe, Water Rail, Reed Bunting and Grasshopper Warbler were not present.

(3) The breeding-bird composition of study-plot 4 is shown in table 5 and is similar to that of study-plots 2 and 3. For study-plot 4 no data were collected for 1977, because the location of Curlew and Redshank nest sites was very time consuming. Species absent from study-plots 1, 2 and 3, but occurring in plot 4, are Black-tailed Godwit, Herring Gull and Stock-Dove (*Columba oenas*).

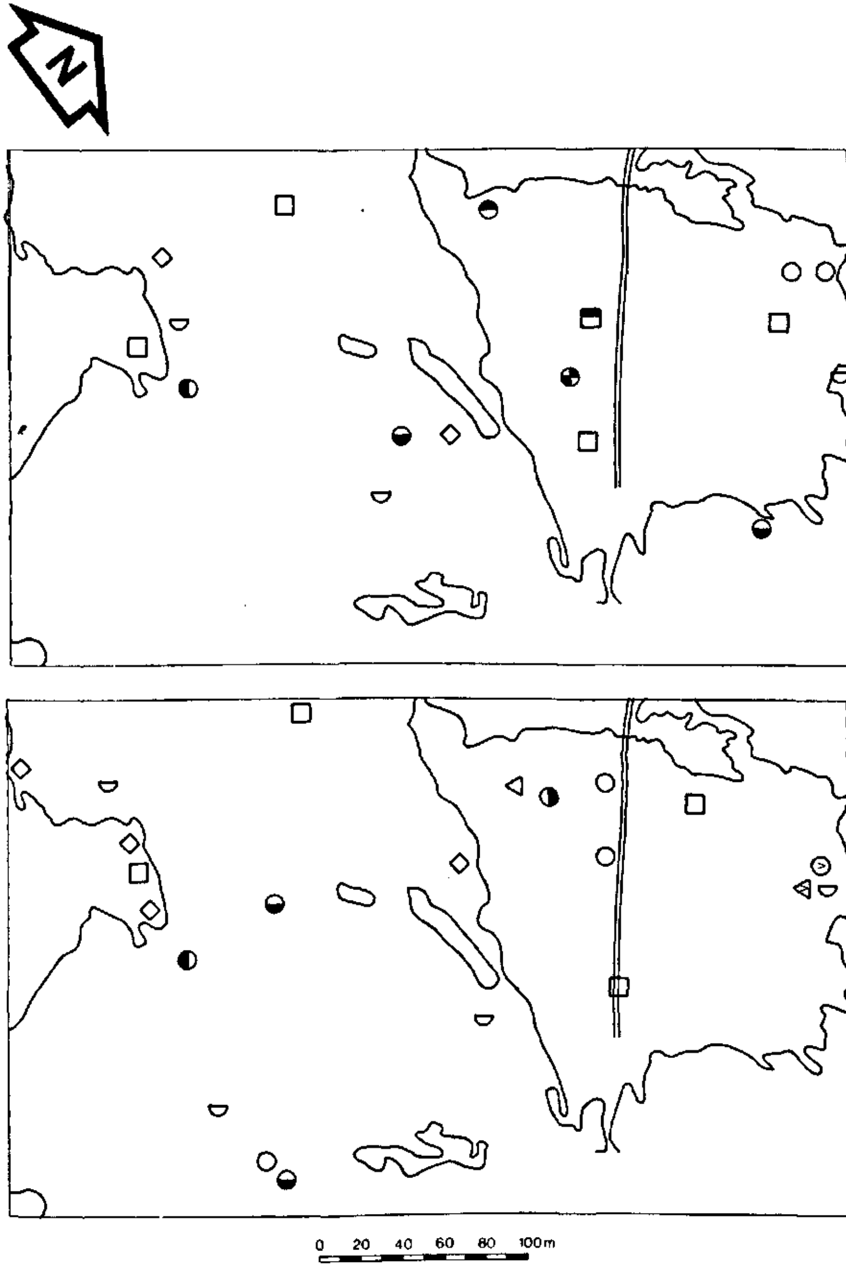

FIG. 8. Territory centre/nest site maps of breeding-birds for study-plot 1 in 1974 (left) and 1975 (right).

- *Anas clypeata*
- *Anas platyrhynchos*
- *Anas platyrhynchos* (disturbed)
- *Somateria mollissima*
- *Somateria mollissima* (disturbed)
- *Tadorna tadorna*
- *Vanellus vanellus*
- *Phasianus colchicus*
- *Gallinago gallinago*
- *Alauda arvensis*
- *Anthus pratensis*
- *Oenanthe oenanthe*
- *Carduelis cannabina*

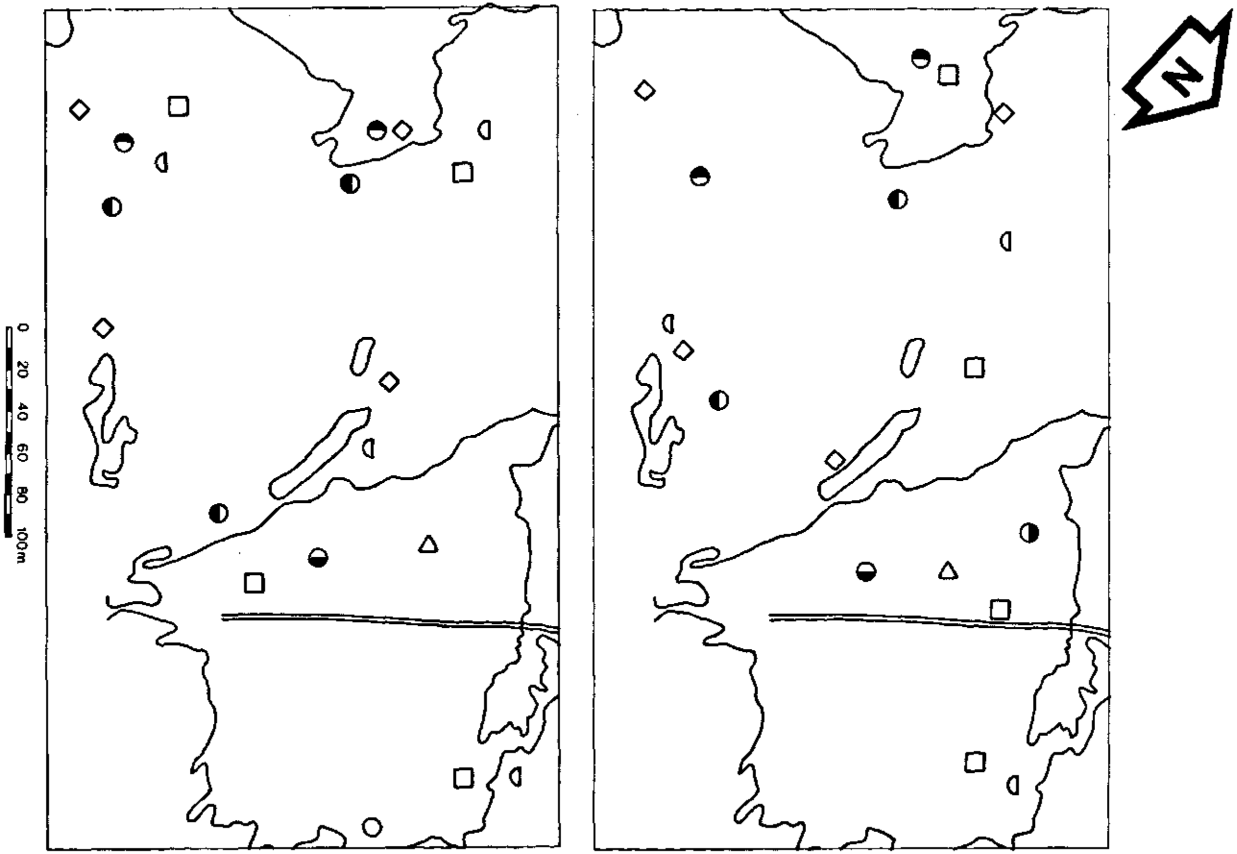

FIG. 9. Territory centre/nest site maps of breeding-birds for study-plot 1 (closed) in 1976 (left) and 1977 (right).

△ *Anas platyrhynchos*
○ *Somateria mollissima*
◇ *Tadorna tadorna*
◑ *Phasianus colchicus*
◐ *Vanellus vanellus*
◖ *Alauda arvensis*
□ *Anthus pratensis*
◓ *Oenanthe oenanthe*
◒ *Carduelis cannabina*

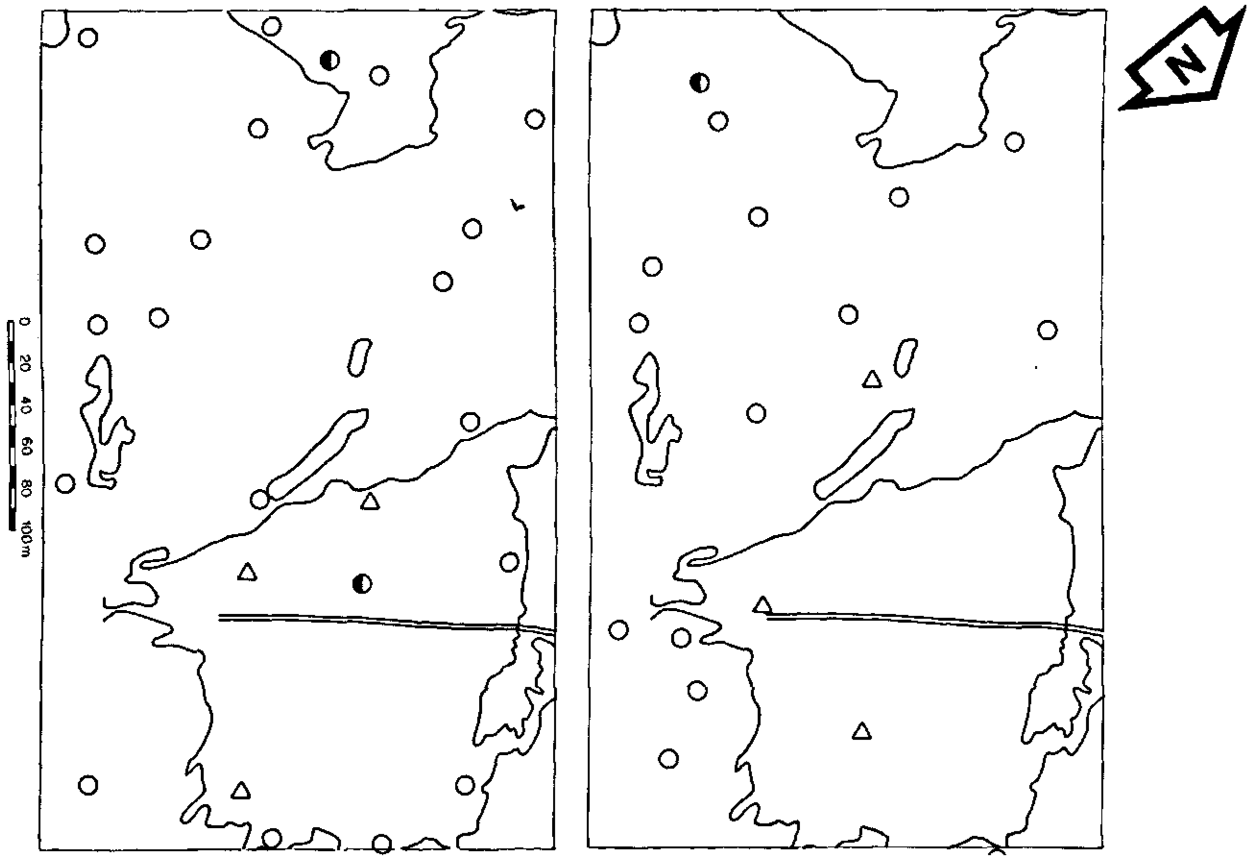

FIG. 10. Territory centre/nest site maps of some breeding wader species for study-plot 1 in 1974 (left) and 1975 (right).

○ *Haematopus ostralegus* (nest site)
◐ *Numenius arquata*
△ *Tringa totanus*

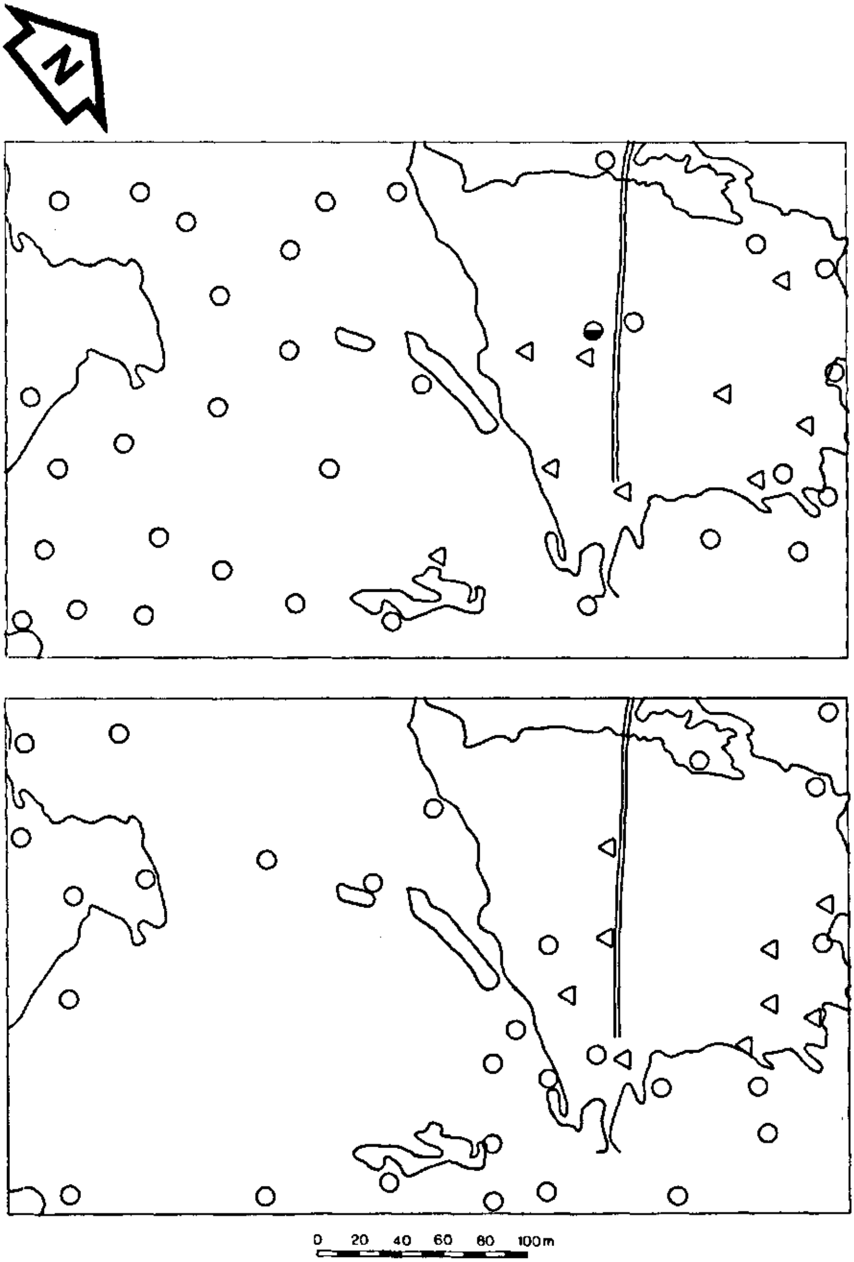

FIG. 11. Territory centre/nest site maps of some breeding wader species for study-plot 1 (closed) in 1976 (left) and 1977 (right).

○ *Haematopus ostralegus* (nest site)
◐ *Numenius arquata*
△ *Tringa totanus*

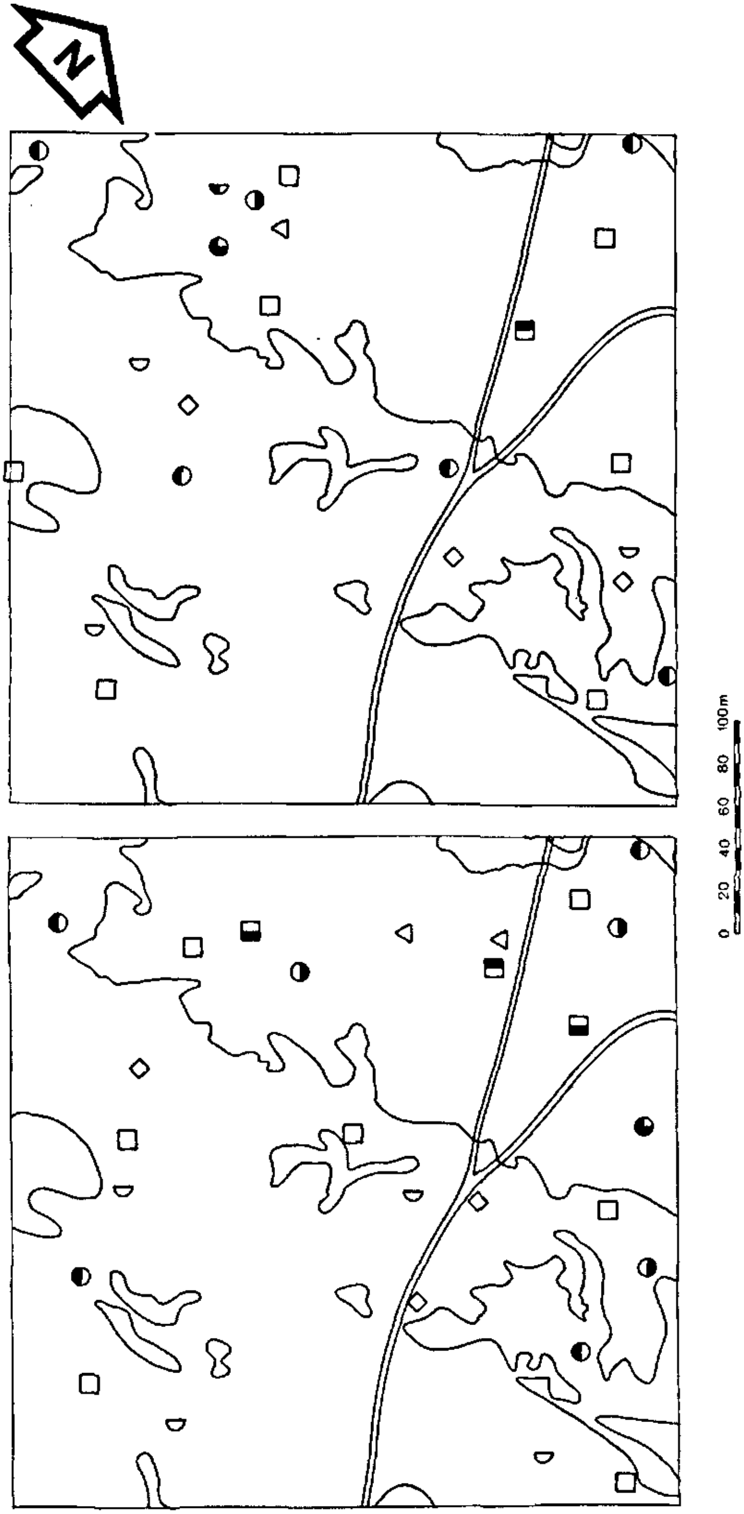

FIG. 12. Territory centre/nest site maps of breeding-birds for study-plot 2 (closed) in 1974 (left) and 1975 (right).

- △ *Anas platyrhynchos*
- ◇ *Tadorna tadorna*
- ◕ *Rallus aquaticus*
- ⬓ *Gallinago gallinago*
- ◖ *Alauda arvensis*
- □ *Anthus pratensis*
- ◐ *Oenanthe oenanthe*
- ◒ *Emberiza schoeniclus*
- ⬒ *Locustella naevia*
- ◑ *Carduelis cannabina*

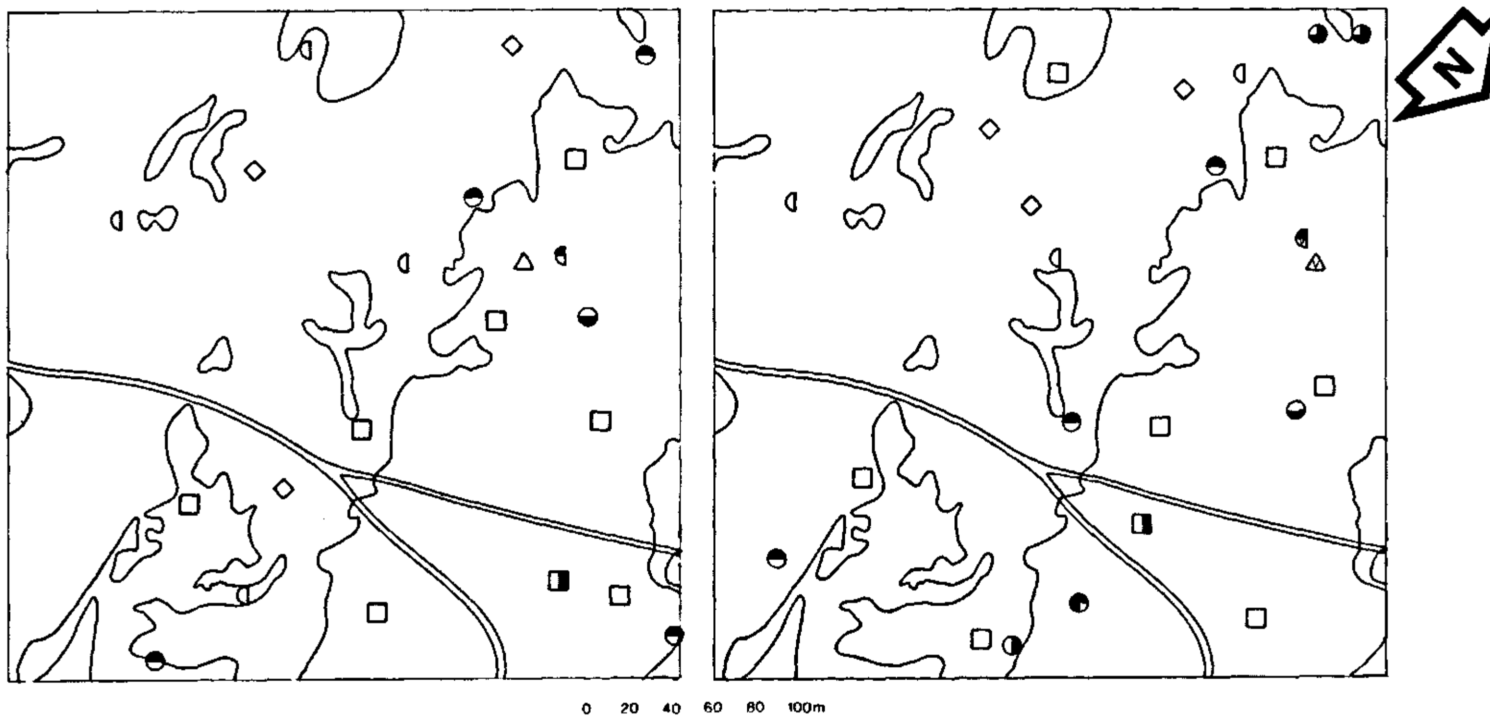

FIG. 13. Territory centre/nest site maps of breeding-birds for study-plot 2 in 1976 (left) and 1977 (right).

△ *Anas platyrhynchos*	◨ *Gallinago gallinago*	*Emberiza schoeniclus*
Anas platyrhynchos (disturbed)	*Larus canus*	*Emberiza schoeniclus* (disturbed)
◇ *Tadorna tadorna*	*Alauda arvensis*	*Carduelis cannabina.*
◑ *Phasianus colchicus*	□ *Anthus pratensis*	
Rallus aquaticus	*Oenanthe oenanthe*	

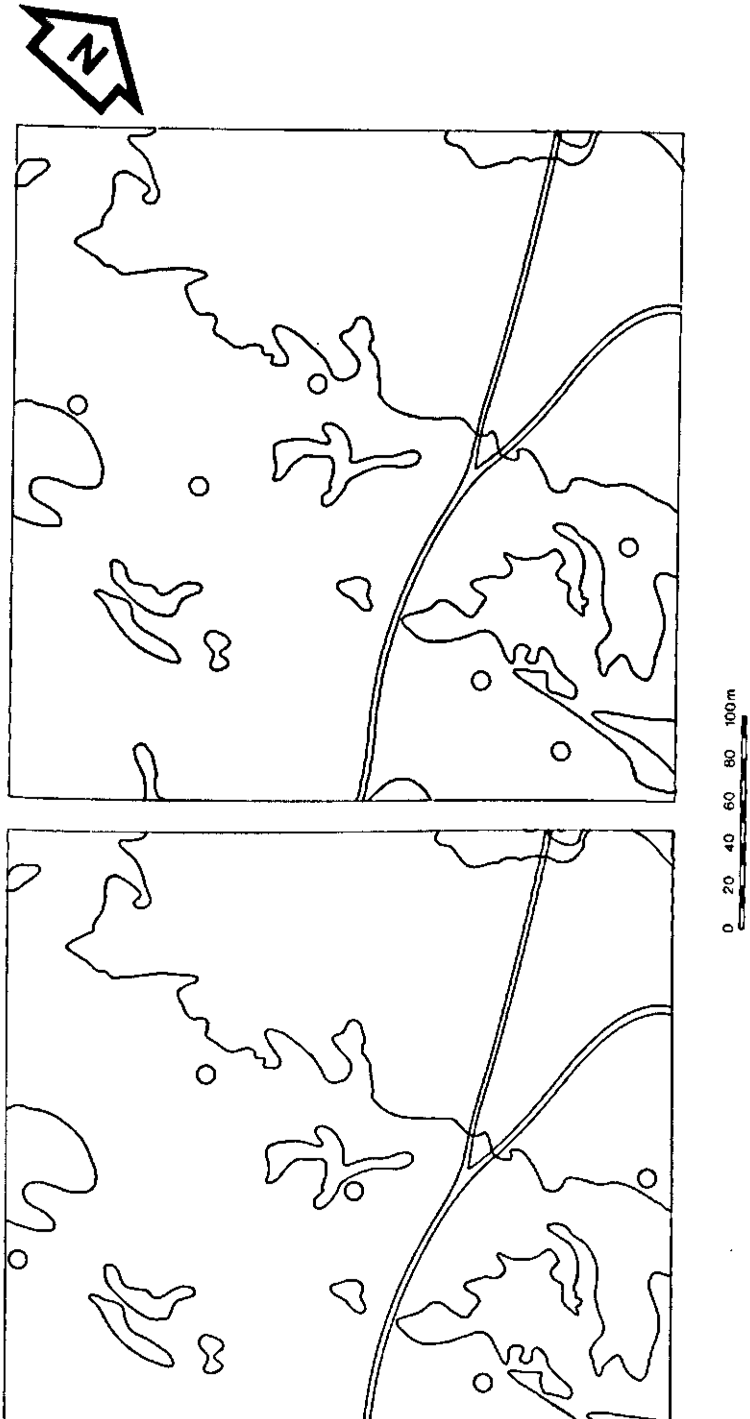

FIG. 14. Nest site maps of the Oystercatcher (*Haematopus ostralegus*) for study-plot 2 in 1976 (left) and 1978 (right).
○ Nest site

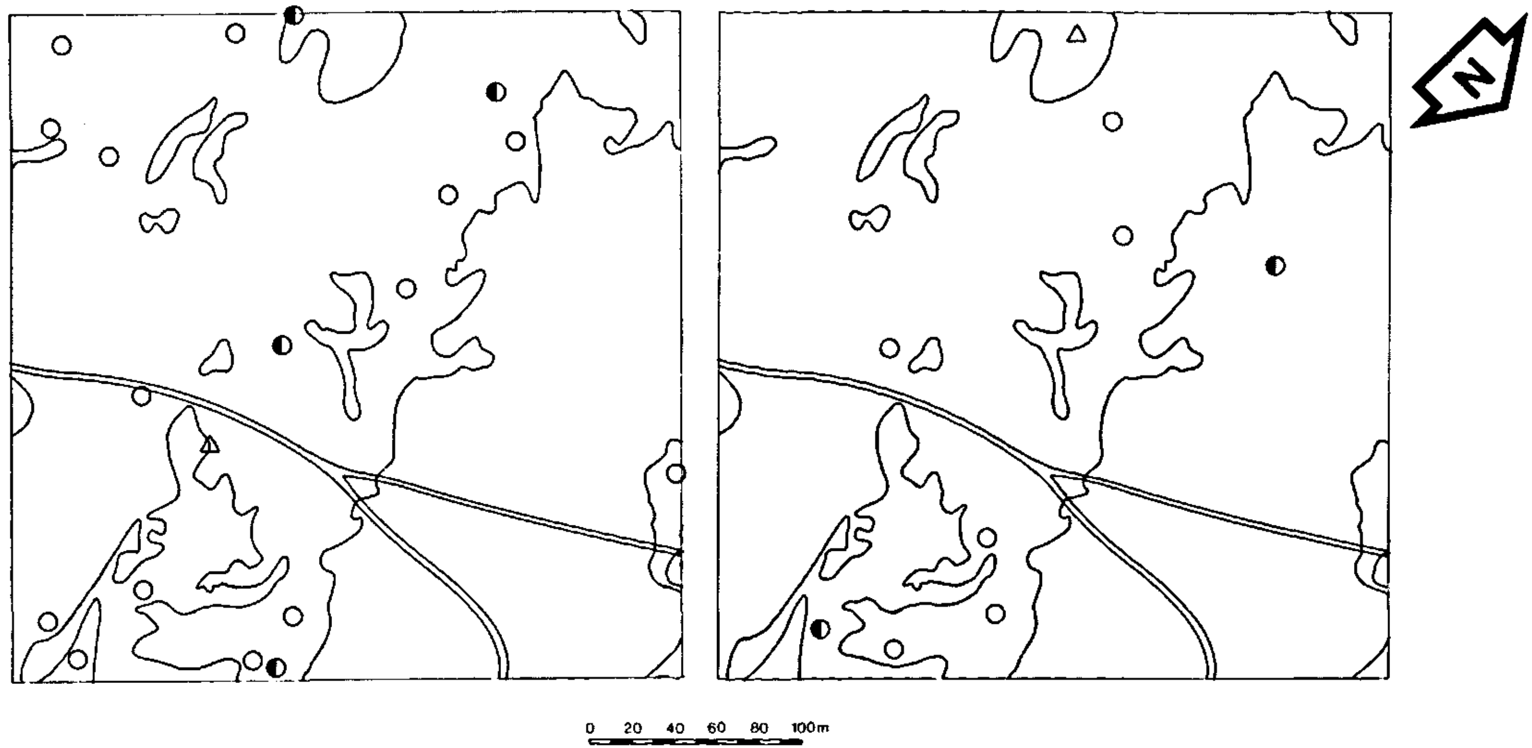

FIG. 15. Territory centre/nest site maps of some breeding wader species for study-plot 2 (closed) in 1975 (left) and study-plot 2 (open) in 1977 (right).
○ *Haematopus ostralegus* (nest site)
◐ *Numenius arquata*
△ *Tringa totanus*

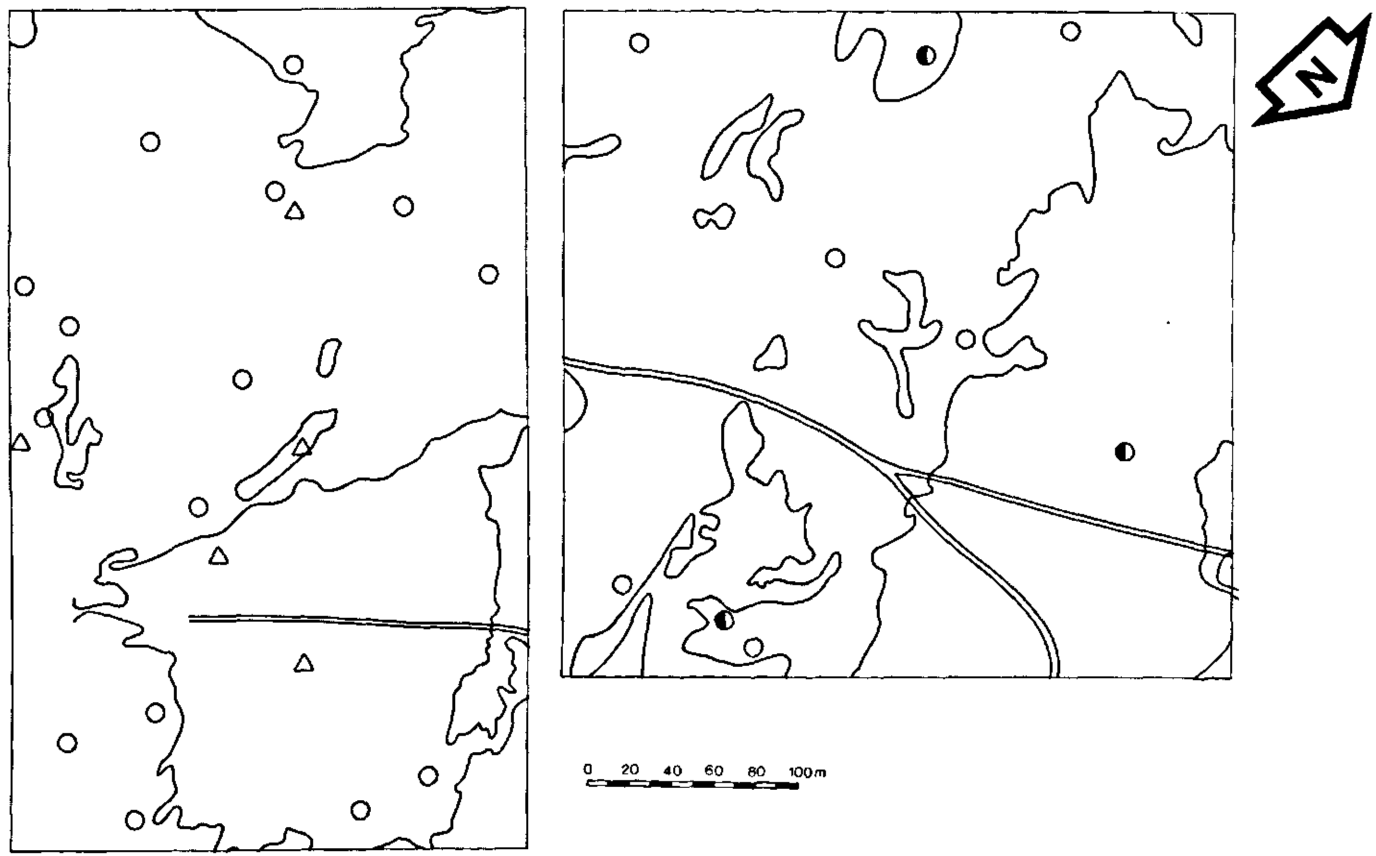

FIG. 16. Territory centre/nest site maps of some breeding wader species for study-plot 1 in 1978 (left) and study-plot 2 (closed) in 1974 (right).

○ *Haematopus ostralegus* (nest site)

◐ *Numenius arquata*

△ *Tringa totanus*

TABLE 4. Numbers of territories/nest sites in the non-experimental study-plot 3 (25.9 ha, subdivided in dunes (21.8 ha) and valleys (4.1 ha)).

Species	1974				1975				1976				1977			
	Dunes		Valleys		Dunes		Valleys		Dunes		Valleys		Dunes		Valleys	
	*T.	10 ha	T.	10 ha	T.	10 ha	T.	10 ha	T.	10 ha	T.	10 ha	T.	10 ha	T.	10 ha
Anas platyrhynchos	0	0	1	2.4	0	0	1	2.4	0	0	0	0	0	0	0	0
Tadorna tadorna	3	1.2	0	0	4	1.5	0	0	4	1.5	0	0	3	1.2	0	0
Phasianus colchicus	0	0	1	2.4	0	0	0	0	0	0	0	0	0	0	0	0
Haematopus ostralegus	32	12.4	6	14.6	27	10.4	3	7.3	32	12.4	8	19.5	36	13.9	3	7.3
Numenius arquata	1	.4	0	0	1	.4	0	0	1	.4	0	0	0	0	0	0
Tringa totanus	0	0	0	0	0	0	1	2.4	0	0	1	2.4	0	0	1	2.4
Larus canus	1	.4	0	0	2	.8	0	0	2	.8	0	0	2	.8	0	0
Cuculus canorus	1	.4	0	0	0	0	0	0	1	.4	0	0	1	.4	0	0
Alauda arvensis	10	3.9	0	0	9	3.5	0	0	6	2.3	0	0	6	2.3	0	0
Anthus pratensis	0	0	12	29.3	0	0	8	19.5	0	0	12	29.3	0	0	11	26.8
Motacilla alba	1	.4	0	0	2	.8	0	0	1	.4	0	0	1	.4	0	0
Oenanthe oenanthe	1	.4	0	0	0	0	0	0	1	.4	0	0	1	.4	0	0
Carduelis cannabina	0	0	2	4.9	0	0	2	4.9	0	0	2	4.9	0	0	2	4.9

*T = Total numbers of territories/nest sites.

TABLE 5. Numbers of territories/nest sites in study-plot 4 (14.2 ha, subdivided in 11.2 ha dunes and 3.0 ha valleys).

Species	1974				1975				1976			
	Dunes		Valleys		Dunes		Valleys		Dunes		Valleys	
	*T.	10 ha	T.	10 ha	T.	10 ha	T.	10 ha	T.	10 ha	T.	10 ha
Tadorna tadorna	11	9.8	0	0	9	8.0	0	0	9	8.0	0	0
Haematopus ostralegus	13	11.6	4	13.3	19	16.9	8	26.6	23	20.5	6	20.0
Numenius arquata	0	0	4	13.3	0	0	5	16.7	0	0	3	10.0
Limosa limosa	0	0	0	0	0	0	1	3.3	0	0	1	3.3
Tringa totanus	0	0	0	0	0	0	1	3.3	0	0	0	0
Larus argentatus	3	2.7	0	0	4	3.6	0	0	4	3.6	0	0
Larus canus	4	3.6	0	0	7	6.2	0	0	9	8.0	0	0
Columba oenas	1	.9	0	0	1	.9	0	0	1	.9	0	0
Alauda arvensis	5	4.5	0	0	5	4.5	0	0	5	4.5	0	0
Anthus pratensis	0	0	9	30.0	0	0	5	16.7	0	0	5	16.7
Motacilla alba	0	0	0	0	1	.9	0	0	1	.9	0	0
Oenanthe oenanthe	5	4.5	0	0	3	2.7	0	0	4	3.6	0	0

*T = Total numbers of territories/nest sites.

TABLE 6. Numbers of territories/nest sites in a wet dune-valley of study-plot 5, east of the 'Pad van 30' (13.86 ha).

Species	1974		1975		1976	
	*T.	10 ha	T.	10 ha	T.	10 ha
Anas platyrhynchos	8	5.8	8	5.8	6	4.3
Anas crecca	0	0	4	2.9	0	0
Anas clypeata	0	0	6	4.3	0	0
Somateria mollissima	0	0	2	1.4	2	1.4
Phasianus colchicus	4	2.9	4	2.9	4	2.9
Rallus aquaticus	2	1.4	6	4.3	2	1.4
Gallinago gallinago	6	4.3	6	4.3	2	1.4
Numenius arquata	10	7.2	10	7.2	8	5.8
Limosa limosa	2	1.4	2	1.4	0	0
Tringa totanus	2	1.4	2	1.4	2	1.4
Alauda arvensis	2	1.4	0	0	2	1.4
Anthus pratensis	16	11.5	14	10.1	14	10.1
Locustella naevia	6	4.3	2	1.4	0	0
Troglodytes troglodytes	0	0	0	0	2	1.4
Emberiza schoeniclus	2	1.4	2	1.4	4	2.9

*T. = Total numbers of territories/nest sites.

(4) Study-plot 5 includes plots 1, 2 and 3, while study-plot 6 includes plot 4. The numerical data for the wader species, collected from the study-plots 5, 6 and the remaining part of the island (west of the 'Pad van 20') (see fig. 1), are given in tables 6, ..., 9 and figures 17, ..., 21. From tables 7, 8 and 9 it can be concluded that Curlew, Redshank, Black-tailed Godwit and Common snipe maintained a

TABLE 7. Numbers of Redshank territories/nest sites in study-plots 5 (250.6 ha), 6 (219.3 ha) and in the closed area west of the 'Pad van 20' (534.9 ha).

	Study-plot		
	5	6	Closed area
1975	17	24	31
1976	18	22	38
1977	14	26	38
1978	8	28	33

TABLE 8. Numbers of Curlew territories/nest sites in study-plots 5 (250.6 ha), 6 (219.3 ha) and in the closed area west of the 'Pad van 20' (534.9 ha).

	Study-plot		
	5	6	Closed area
1974	18	14	27
1975	17	17	32
1976	19	15	27
1977	13	14	31
1978	12	11	26

TABLE 9. Numbers of territories/nest sites of some wader species in study-plots 5 (250.6 ha), 6 (219.3 ha) and in the closed area west of the 'Pad van 20' (534.9 ha).

	1972 Study-plot			1976 Study-plot			1977 Study-plot		
	5	6	Closed area	5	6	Closed area	5	6	Closed area
Vanellus vanellus	5	18	24	4	11	14	4	9	11
Gallinago gallinago	4	3	11	3	2	7	2	3	7
Limosa limosa	0	4	5	0	4	3	0	3	4

rather constant population level in the area west of study-plot 6. This area is closed during the breeding season. The Lapwing, however, showed a decreasing tendency in the same area. Note that nearly all territories/nest sites of the abovementioned species were situated along the edge of existing Herring Gull colonies. This suggests that these species avoid the centres of the colonies. Table 10 shows that the Kentish Plover disappeared completely from accessible areas (see section 7). Note that the 1964 data for the Kentish Plover were collected partly by mr. K. TERPSTRA.

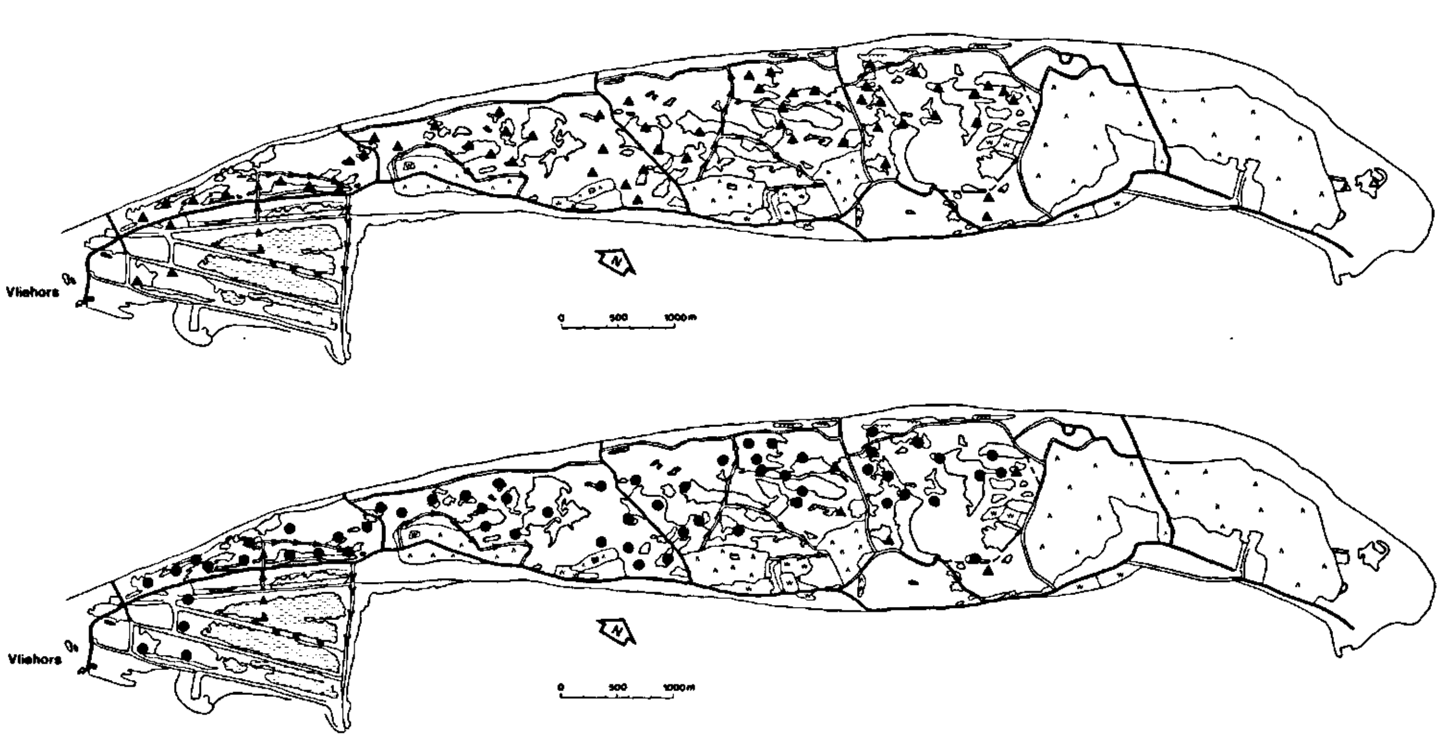

FIG. 17. Territory centre/nest site maps of the Curlew (*Numenius arquata*) for the isle of Vlieland in 1974 (top) and 1975 (bottom).
▲ Nest site in 1975
● Territory centre in 1975
▲ Territory centre in 1974
△ Territory centre disappeared in 1973
⋀ Excursion way
⋀ Walking way

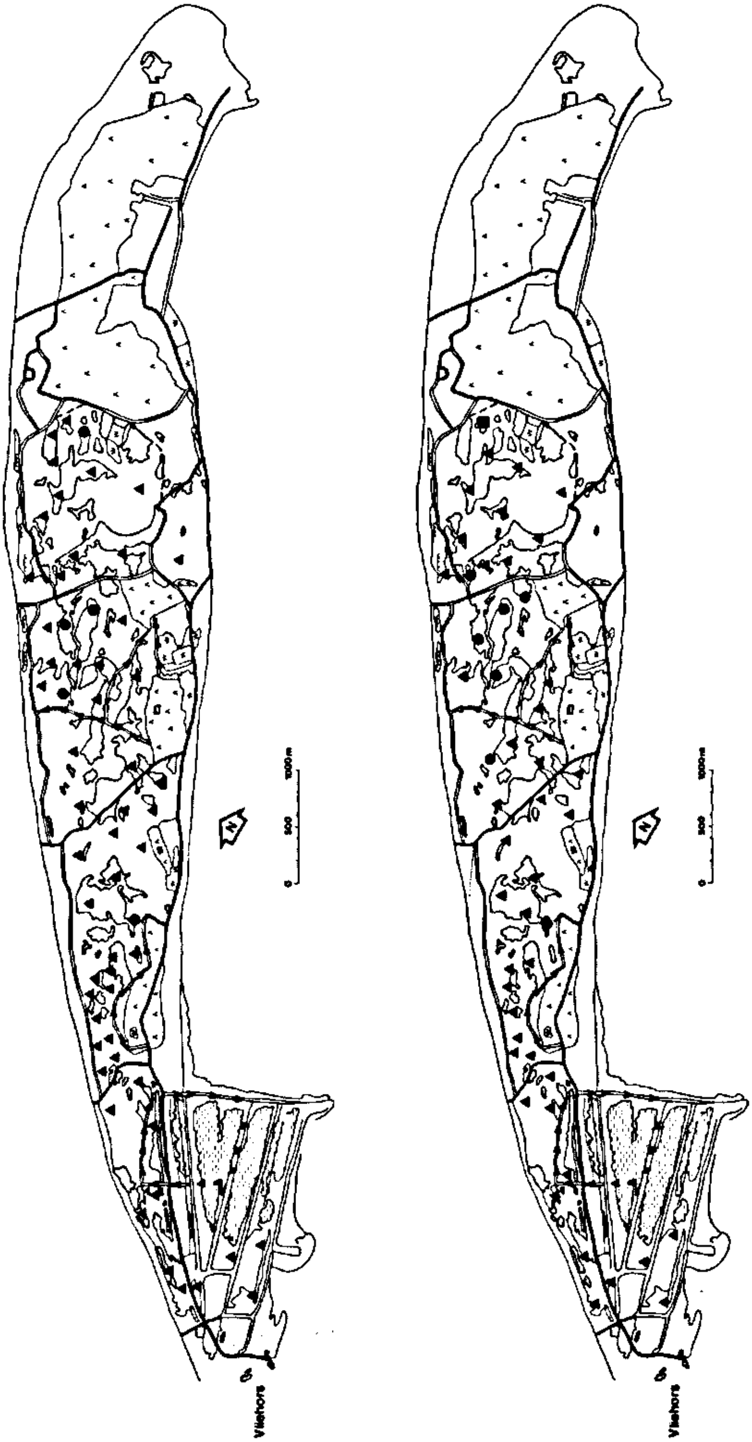

FIG. 18. Territory centre/nest site maps of the Curlew (*Numenius arquata*) for the isle of Vlieland in 1977 (top) and 1978 (bottom).
● Nest site
▲ Territory centre
■ Clutch, disappeared

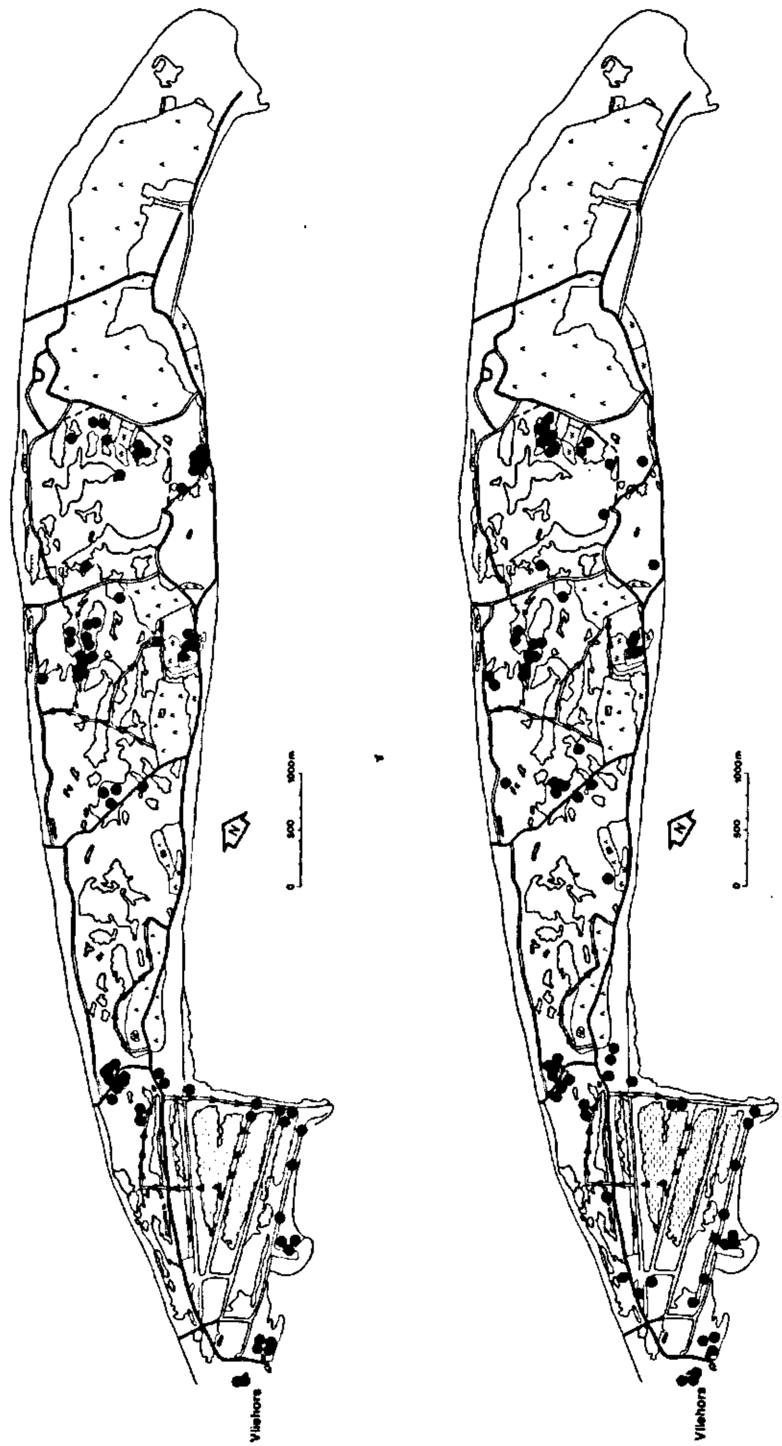

FIG. 19. Nest site maps of the Redshank (*Tringa totanus*) for the isle of Vlieland in 1975 (top) and 1976 (bottom).
● Nest site

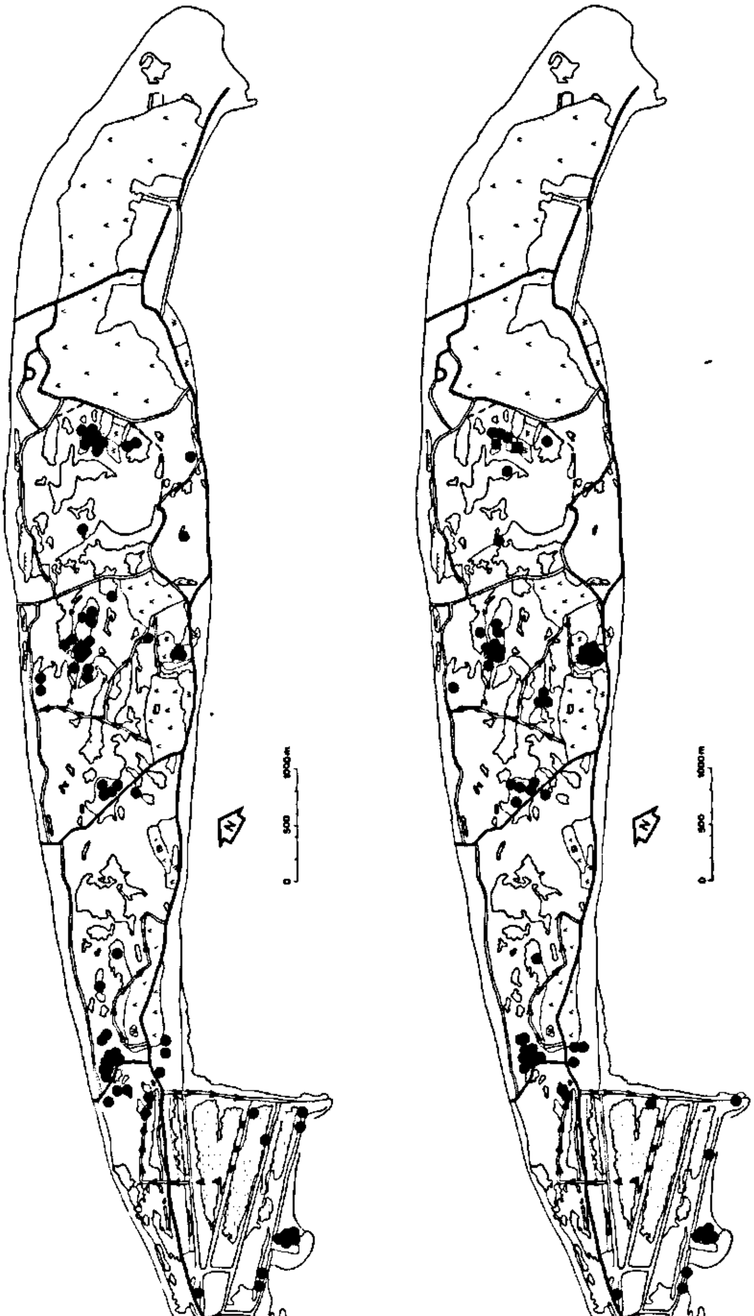

FIG. 20. Nest site maps of the Redshank (*Tringa totanus*) for the isle of Vlieland in 1977 (top) and 1978 (bottom).
● Nest site
■ Clutch, disappeared

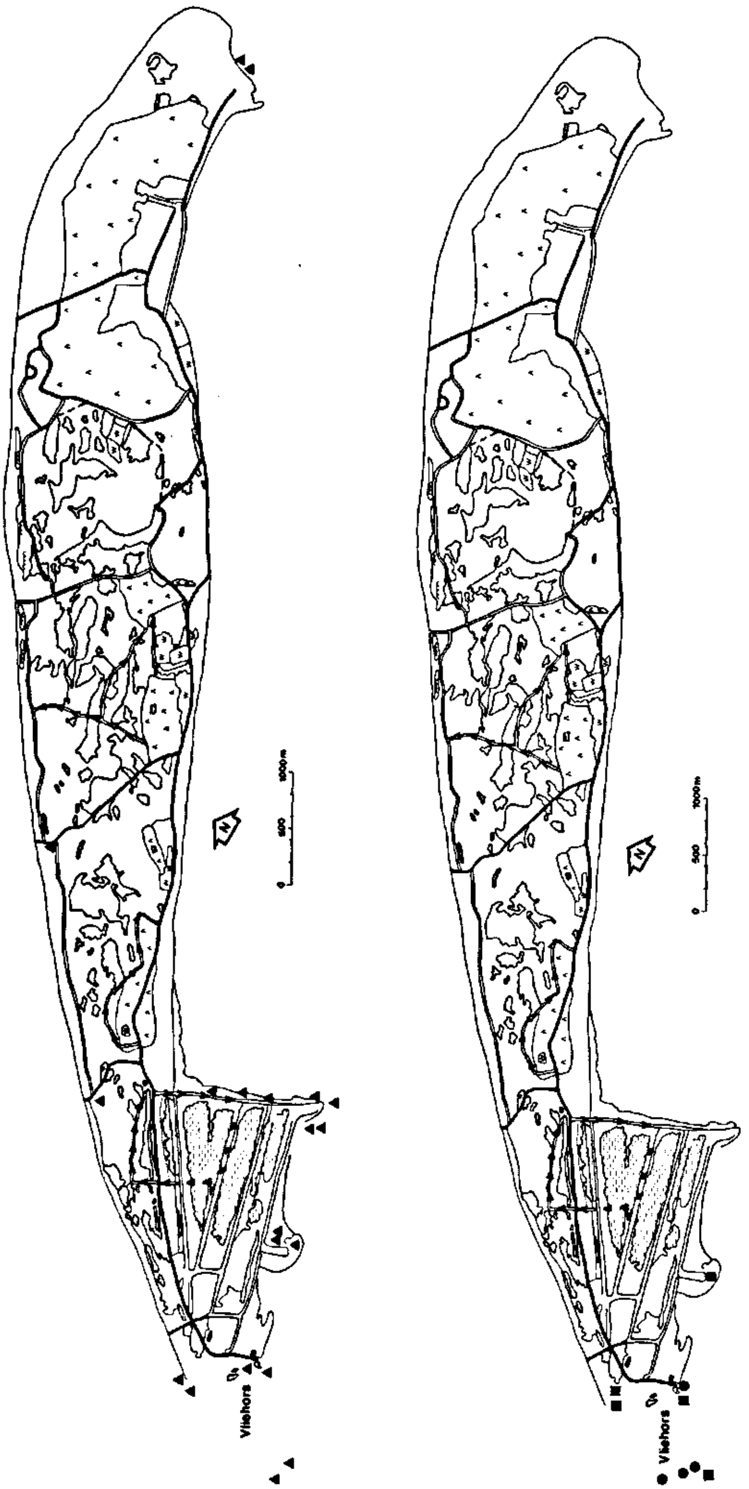

FIG. 21. Nest site maps of the Kentish Plover (*Charadrius alexandrinus*) for the isle of Vlieland in 1964 (top) and 1977/1980 (bottom).
▲ Nest site 1964
■ Nest site 1977
● Nest site 1980

TABLE 10. Numbers of Kentish Plover (*Charadrius alexandrinus*) nests.

	Altitude class < 2.5 m.	
	Open	Closed
1964	14	6
1976	0	5
1977	1	4
1978	1	4
1979	0	4
1980	0	4

From table 6 it is obvious that the occurrence of the Teal (*Anas crecca*) and the Shoveler (A. clypeata) were limited to the extremely wet year 1975. The large number of Water Rails in 1975, as is the low number of Common snipes in the extremely dry year 1976, was really striking as compared with 1974 and 1975. However these differences are not significant (χ^2-test with 1 degree of freedom).

3. STATISTICAL EVALUATION OF THE EFFECTS OF SEPARATE FACTORS FOR THE NON-EXPERIMENTAL STUDY-PLOTS

3.1. INTRODUCTION AND SUMMARY

The data in the subsections 2.2.3, 2.3.3, 2.4.3 and 2.5.3 provide information with regard to (1) landscape/vegetation, (2) altitude/hydrology, (3) tourism and (4) breeding-birds). The vegetation maps reveal how an area is subdivided into smaller areas of different vegetation types, the altitude maps indicate the different altitude classes, etc. The breeding bird maps provide the nestsites or the territory centres.

The question is whether the (expected) nest densities depend on the vegetation type. The statistical analysis to solve this problem is outlined in section 3.2. An example is given in subsection 3.2.2 for the Oystercatcher in study plot 4.

The factors altitude and tourism are treated in the same way as the factor vegetation.

With regard to the effects of vegetation the following results for the Oystercatcher were obtained; vegetation type 1 (*Empetro-Ericetum*) is significantly less attractive than types 2 (*Festuco-Galietum maritimi*), 3 (*Polypodio-Salicetum*), 4 (*Polypodio-Empetretum*) and 5 (*Violo-Corynephoretum*), while 3 is less attractive than 5 (see table 13).

With regard to the effects of landscape the results for the Curlew were as follows: landscape type Ca (*Corynephorion* with secondary *Ammophilion*) is significantly less attractive than type E (see table 14). The corresponding results for the Redshank were that types Ca, E (vegetations dominated by *Oxycoccus macrocarpos* and locally *Salix repens*) and Ci (*Corynephorion* with *Salix arenaria*) are significantly less attractive than type P, while Ci is less attractive than E (see table 15).

With regard to the effects of altitude the following results for the Oystercatcher were obtained: altitude classes 1 (< 5 m) and 2 (5–7.5 m) are significantly less attractive than class 3 (7.5–10 m) (see table 16). For the Curlew no significant results were obtained (see table 17), but for the Redshank altitude classes 2, 3 and 4 (> 10 m) are significantly less attractive than class 1, while 3 is less attractive than 2 (see table 18).

With regard to the effects of tourism, the following results for the Oystercatcher were obtained: tourism zones 2 and 3 are significantly less attractive than zone 1 (see table 19). The corresponding result for the Curlew was: zone 3 is significantly less attractive than zone 1 and for the Redshank: zones 3 and 2 are significantly less attractive than zone 1, while 3 is less attractive than 2.

3.2.1. *The formulation of the statistical problem*

As an example the data in table 11 are considered. The question is whether the two vegetation types have different (expected) nest density. Assuming that 'each of all breeding pairs has the same, very small probability to settle in an area and moreover that all pairs act independently, the number n of nests observed in that area is the outcome of a random variable N, which approximately, has the Poisson distribution with parameter λ equal to the product of the number of breeding pairs and the small probability.'

Remark. The underlying model-assumptions are doubtful, especially if territorial-behaviour, colony-forming, return-behaviour etc. involve certain dependencies. The breeding-bird species to be considered show territorial, but not colonial behaviour (HINDE, 1956; HOWARD, 1920; VON FRISCH, 1956; HARRIS, 1970; KLOMP, 1972). HALE (1956) mentions the lack of territory in the Redshank). Unfortunately they show return behaviour (JUNGFER, 1954; GROSSKOPF, 1958, 1959, 1963; HARRIS, 1967; VON FRISCH, 1965). For that reason the statistical analyses will be performed for each year separately.

The question stated at the beginning of this subsection will be formulated as a testing-problem with the null-hypothesis that 'both vegetation types have the same nest density'. More precisely: n_1 and n_2 are outcomes of independent random variables N_1 and N_2, where N_h has the Poisson distribution with parameter λ_h ($h = 1,2$), and where the null-hypothesis states that the 'density' λ_1/a_1 in vegetation type 1 equals the 'density' in vegetation type 2. With the notation $c=a_2/a_1$, the null-hypothesis $\mathrm{H}: c\lambda_1=\lambda_2$ has to be tested against the alternative $\mathrm{A}: c\lambda_1 \neq \lambda_2$.

3.2.2. *Construction of the test*

This testing-problem can be solved with standard methods (HOEL, 1945; LEHMANN, 1959); DE ROOS and SCHAAFSMA, 1981).

Proposition. The conditional distribution of N_2, given $N_1+N_2=n$, under the null-hypothesis, is the binomial $B(n;p)$ distribution with probability $p=c/(c+1)$ of success.

Proof. $N=N_1+N_2$ has the Poisson-distribution with parameter $\lambda_1+\lambda_2$ and hence

TABLE 11. Oystercatcher (*Haematopus ostralegus*) data for 1976 and study-plot 4.

	Vegetation type	
	1 *Empetro-Ericetum*	2 *Festuco-Galietum maritimi*
Numbers of nests	$n_1=1$	$n_2=15$
Area in m^2	$a_1=30\,480$	$a_2=40\,092$

$$P(N_2 = n_2 | N = n) = P(N_1 = n{-}n_2;\ N_2 = n_2)/P(N = n)$$
$$= P(N_1 = n{-}n_2)P(N_2 = n_2)/P(N = n)$$

$$= \frac{e^{-\lambda_1}\lambda_1^{n-n_2}}{(n-n_2)!}\ \frac{e^{-\lambda_2}\lambda_2^{n_2}}{n_2!} \Bigg/ \frac{e^{-(\lambda_1+\lambda_2)}(\lambda_1+\lambda_2)^n}{n!}$$

$$= \binom{n}{n_2} p^{n_2}(1-p)^{n-n_2}$$

where $p = \lambda_2/(\lambda_1 + \lambda_2) = c\lambda_1/(\lambda_1 + c\lambda_1) = c/(c+1)$

The test is performed by testing the outcome of N_2 in the $B(n;p)$ distribution, n denoting the outcome of N.

Evaluating the example. The number $n_1 = 1$ of Oystercatcher nests in vegetation type 1 (*Empetro-Ericetum*) is compared with the number $n_2 = 15$ in vegetation type 2 (*Festuco-Galietum maritimi*). The area covered with vegetation type 2 was $c = 1.32$ times as large as that with type 1. Hence $p = c/(c+1) = 1.32/2.32 = .57$ and $n_2 = 15$ has to be tested in the binominal $B(16;.57)$ distribution. The outcome will be significant if the sum of the probabilities for this result and all less-probable results is smaller than 5% (Fisher's strategy to collect small probabilities (FISHER, 1935)). In this example the probabilities

$P(N_2 = s | N = 16) = P(S = s) = \binom{16}{s}(.57)^s(.43)^{16-s}$

for the binomial distribution are given in table 12

TABLE 12. The $B(16;.57)$ distribution.

S	$P(S=s)$	S	$P(S=s)$	S	$P(S=s)$	S	$P(S=s)$
0	.000001	5	.024424	10	.183267	15	.001499
1	.000029	6	.059355	11	.132510	16	.000124
2	.000288	7	.112400	12	.073189		
3	.001782	8	.167620	13	.029852		
4	.007677	9	.197505	14	.008479		

such that the obtained result $n_2 = 15$ is significant e.g. at the level $\alpha = .01$, because $P(S \in \{0, 1, 16, 2, 15\}) = .0019412 < .01$.

3.2.3. *Combination for the different years*

In the same way as in subsection 3.2.2 the years 1974 and 1975 can be treated. In fact 1976 was chosen because it looked more significant than 1974. This implies that the result in table 12 should certainly not be considered significant at the level .002 though this is suggested at the end of subsection 3.2.2. A conservative method to evaluate the results of the 3 different years for testing the combined null-hypothesis H, that for each year two vegetation types show the same nest density, is as follows:

'Reject H if and only if the most significant result is significant at the $\alpha/3$ level'.

In this case $\alpha = .01$ would still lead to significance because $.01/3 > .0019412$. Note that 1975 is even more significant than 1976. The corresponding P value being $.0009837 < .005/3$ shows that the corresponding result is even significant at the level $\alpha = .005$.

3.3. Effects of landscape and vegetation

3.3.1. *Oystercatcher*

The data in table 13 are used along the lines of section 3.2. to compare the remaining pairs of vegetation types.

TABLE 13. Vegetation data for the Oystercatcher.

	Study-plot 3					Study-plot 4		
	Vegetation-type					Vegetation-type		
	1	2	3	4	5	1	2	3
1974	1	3	0	14	20	2	7	8
1975	0	2	0	9	19	0	13	14
1976	1	3	0	9	27	1	15	13
1977	0	2	0	11	26	no data (see section 2.5)		
Area	40704	6704	28330	65844	117094	30480	40092	71870

Type 1 = *Empetro-Ericetum*
Type 2 = *Festuco-Galietum maritimi*
Type 3 = *Polypodio-Salicetum*
Type 4 = *Polypodio-Empetretum*
Type 5 = *Violo-Corynephoretum*
The area in m^2.

Results. For plot 3 and $\alpha = .05$ was obtained that $1 < 2$; $1 < 4$ (even if $\alpha = .01$); $1 < 5$ (even if $\alpha = .005$); $3 < 5$. The notation $a < b$ means that vegetation type a is significantly less attractive than b.
For plot 4: $1 < 2$ (even if $\alpha = .005$); $1 < 3$.

3.3.2. *Curlew*

In connection with the large area of the study-plots 5 and 6, landscape type is chosen instead of vegetation type.

TABLE 14. Landscape data for the Curlew.

	Study-plot 5					Study-plot 6				
	Landscape-type					Landscape-type				
	Ca	Ch	Ci	P	E	Ca	Ch	Ci	P	E
1974	4	1	6	2	5	2	0	4	3	5
1975	3	1	7	1	5	2	0	6	5	4
1976	3	2	5	1	8	1	1	7	3	3
1977	3	1	5	0	4	1	1	5	4	3
1978	2	1	5	0	4	1	0	3	5	2
1979	1	0	3	0	3	1	0	3	4	5
Area	790000	537500	437500	418289	322915	724998	120832	687500	411581	247874

Type Ca = *Corynephorion* with open, very low vegetation.
Type Ch = *Corynephorion* with scattered, low *Hippophaë* shrubs.
Type Ci = *Corynephorion* with many *Salix arenaria* dwarf shrubs.
Type P = Vegetations dominated by *Empetrum nigrum*.
Type E = Vegetations dominated by *Oxycoccus macrocarpos* and locally *Salix repens* in wet to damp valleys.
The area in m^2.

Results. For plots 5 and 6 and $\alpha = .05$ was obtained that: Ca < E. The other results were not significant.

3.3.3. *Redshank*

TABLE 15. Landscape data for the Redshank.

	Study-plot 5			Study-plot 6		
	Landscape-type			Landscape-type		
	Ca	P	E	Ci	P	E
1975	7	9	1	1	10	13
1976	3	14	1	3	10	9
1977	1	13	0	2	11	13
1978	0	7	1	1	17	10
1979	0	7	2	0	18	3
Area	790000	418289	322915	687500	411581	247874

Results. For plot 5 and $\alpha = .05$ was obtained that E < P; Ca < P (even if $\alpha = .0001$). The other results did not show significant differences.
For plot 6: Ci < P (even if $\alpha = .000001$); Ci < E (even if $\alpha = .00001$).

3.4. EFFECTS OF ALTITUDE

The data in table 16 are used along the lines of section 3.2 with the altitude class instead of the vegetation type.

3.4.1. *Oystercatcher*

TABLE 16. Altitude data for the Oystercatcher.

	Study-plot 3				Study-plot 4			
	Altitude-class				Altitude-class			
	1(<5 m)	2(5–7.5 m)	3(7.5–10 m)	4(>10 m)	1(<5 m)	2(5–7.5 m)	3(7.5–10 m)	4(>10 m)
1974	0	6	9	23	3	1	11	2
1975	0	3	8	19	5	3	17	2
1976	0	8	8	24	2	4	21	2
1977	0	3	11	25	no data (see section 2.5)			
Area	24356	56504	36621	141195	59872	48344	29466	4759

Results: For plot 3 and $\alpha = .05$ was obtained that $1 < 3$; $2 < 3$. For plot 4: $1 < 3$ (even if $\alpha = .0000005$); $2 < 3$ (even if $\alpha = .00005$).

3.4.2. *Curlew*

TABLE 17. Altitude data for the Curlew.

	Study-plot 5				Study-plot 6			
	Altitude-class				Altitude-class			
	1(<5 m)	2(5–7.5 m)	3(7.5–10 m)	4(>10 m)	1(<5 m)	2(5–7.5 m)	3(7.5–10 m)	4(>10 m)
1974	7	8	1	2	8	6	0	0
1975	5	9	1	2	8	9	0	0
1976	9	6	2	2	6	9	0	0
1977	5	5	1	2	5	9	0	0
1978	5	5	1	1	5	6	0	0
1979	3	3	0	1	8	5	0	0
Area	522455	893749	599453	490547	667788	1274997	223540	26460

Results. For study plots 5 and 6 no significant results were found. This is partly due to our method. If we would have added the figures for the different plots together, then we would have obtained: $3 < 1$ ($\alpha = .05$).

3.4.3. *Redshank*

TABLE 18. Altitude data for the Redshank.

	Study-plot 5				Study-plot 6			
	Altitude-class				Altitude-class			
	1(<5 m)	2(5–7.5 m)	3(7.5–10 m)	4(>10 m)	1(<5 m)	2(5–7.5 m)	3(7.5–10 m)	4(>10 m)
1975	4	6	7	0	18	6	0	0
1976	3	12	1	2	16	6	0	0
1977	3	10	0	1	21	5	0	0
1978	2	6	0	0	27	1	0	0
1979	4	5	0	0	13	8	0	0
Area	522455	893749	599453	490547	667788	1274997	223540	26460

Results. For plot 5 and $\alpha = .05$ was obtained that $3 < 2$.
For plot 6: $2 < 1$ (even if $\alpha = .000001$); $3 < 1$ (even if $\alpha = .005$); $4 < 1$ (even if $\alpha = .01$).

3.5. Effects of tourism

The tourism data for the Oystercatcher, the Curlew and the Redshank are given in tables 19, 20 and 21 and used along the lines of section 3.2 with the tourism zone instead of the vegetation type.

The different tourism-zones were defined as follows:

1. The zone of points at least 100 m from the nearest metalled path or road and at least 25 m from the nearest unmetalled winding path.
2. The zone of points at least 100 m from the nearest metalled path or road but at a distance <25 m from the nearest unmetalled winding path.
3. The zone of points at a distance <100 m to the nearest metalled path or road.

3.5.1. *Oystercatcher*

TABLE 19. Tourism data for the Oystercatcher.

	Study-plot 3			Study-plot 4		
	Tourism-zone			Tourism-zone		
	1	2	3	1	2	3
1974	9	20	9	11	0	6
1975	5	17	8	18	0	9
1976	9	19	12	18	0	11
1977	11	16	12	no data (see section 2.5)		
Area	7994	150715	99964	44381	0	98058

Results. For plot 3 and $\alpha = .05$ was obtained that $2 < 1$ (even if $\alpha = .0000005$); $3 < 1$ (even if $\alpha = .0000005$) where the notation $a < b$ means that tourism zone a is significantly less attractive than b.
For plot 4: $3 < 1$.

3.5.2. *Curlew*

TABLE 20. Tourism data for the Curlew.

	Study-plot 5			Study-plot 6		
	Tourism-zone			Tourism-zone		
	1	2	3	1	2	3
1974	2	5	11	7	0	7
1975	2	7	8	10	0	7
1976	2	6	11.	9	1	5
1977	2	5	6	8	1	5
1978	2	3	7	8	0	3
1979	2	4	1	12	0	1
Area	56250	749188	1700692	738331	281249	1173205

Results. For plot 5 and $\alpha = .05$ was obtained that $3 < 1$.
For plot 6: $3 < 1$ (even if $\alpha = .0001$).

3.5.3. *Redshank*

TABLE 21. Tourism data for the Redshank.

	Study-plot 5			Study-plot 6		
	Tourism-zone			Tourism-zone		
	1	2	3	1	2	3
1975	1	6	10	20	1	3
1976	1	11	6	18	0	4
1977	0	13	1	20	1	5
1978	1	7	0	24	0	4
1979	2	7	0	15	1	5
Area	56250	749188	1700692	738331	281249	1173205

Results. For plot 5 and $\alpha = .05$ was obtained that $3 < 1$; $3 < 2$ (even if $\alpha = .00005$).
For plot 6: $2 < 1$; $3 < 1$ (even if $\alpha = .000005$).

4. THE INTERACTION BETWEEN LANDSCAPE/VEGETATION AND ALTITUDE IN RELATION TO DENSITIES OF BREEDING WADERS

4.1. Introduction and summary

In section 3.3 effects of landscape/vegetation were established and in section 3.4 also of the altitude. Now the interaction of landscape/vegetation and altitude is investigated in order to find out whether the effects of one factor can be explained as caused by the other one. If the effects of a factor cannot be explained in this way, then confidence intervals will be based on a multiplicative model. The statistical analysis to solve the above-mentioned problems is outlined in section 4.2.

Oystercatcher results. The evidence for rejecting the null-hypothesis that no vegetational effects exist if the altitude is taken into account is not sufficient, though the confidence intervals [1.85, > 100] and [2.8, > 100] for the parameters β_2/β_1 and β_5/β_1, with respect to plot 3, suggest that vegetation type 1 (*Empetro-Ericetum*) is less attractive than types 2 (*Festuco-Galietum maritimi*) and 5 (*Violo-Corynephoretum*), while the confidence interval [3.3, ∞] for the parameter β_2/β_1, with respect to plot 4, also suggests that type 1 is less attractive than type 2.

On the other hand for plot 4 sufficient evidence was obtained to reject the null-hypothesis that no altitude effects exist if the vegetation is taken into account. Altitude class 3 (7.5–10 m) is more attractive than the classes 1 (< 5 m), 2(5–7.5 m) and 4(> 10 m). A possible explanation might be that class 3 in plot 4 is not often visited by tourists (see chapter 6).

Curlew results. The null-hypothesis that no landscape effects exist if the altitude is taken into account, and the null-hypothesis that no altitude effects exist if the landscape is taken into account, were not rejected. Hence no significant evidence for landscape and altitude effects were obtained.

Redshank results. The null-hypothesis that no landscape effects exist if the altitude is taken into account can be rejected. Landscape types P (vegetations dominated by *Empetrum nigrum*) and E (vegetations dominated by *Oxycoccus macrocarpos* and locally *Salix repens*) are more attractive than the other types.

On the other hand, the null-hypothesis that no altitude effects exist if the landscape is taken into account could be rejected for plot 5, but not for 6. Though the evidence for plot 6 is not completely sufficient, it strongly suggests that such effects do exist. The confidence interval [1.45, 13.25] for the parameter β_2/β_1, with respect to plot 6, suggests that altitude class 2(5–7.5 m) is more attractive than class 1 (< 5 m), which was clearly not the case with respect to plot 5.

4.2. The statistical technique to be used

In section 3.3 landscape/vegetation effects were established and in section 3.4 also altitude effects. The interaction of landscape/vegetation and altitude is investigated in order to find out whether the effects of one factor can be explained as caused by the effects of the other one.

4.2.1. *Formulating the statistical problem*

Consider table 22, study plot 3. Note that not all Poisson variables are independent because some positive dependence will exist between consecutive years. This is a serious complication which implies that numbers for different years should not simply be added.

For table 22 it seems reasonable to study the four different years separately. Of course the results should not be combined as if they were independent. It is proposed to test the most significant result at the $\alpha/5$ level (5 vegetation types).

TABLE 22. Vegetation-altitude data for the Oystercatcher.

			Study-plot 3					Study-plot 4		
			Vegetation-type					Vegetation-type		
			1	2	3	4	5	1	2	3
Altitude class	1	1974	0	0	0	0	0	2	0	1
		1975	0	0	0	0	0	0	2	3
		1976	0	0	0	0	0	1	1	0
		1977	0	0	0	0	0	no data (see section 2.5)		
		Area	5042	0	19316	0	0	28448	2598	28826
	2	1974	1	3	0	0	2	0	0	1
		1975	0	2	0	0	1	0	2	1
		1976	1	3	0	0	4	0	2	2
		1977	0	2	0	0	1	no data (see section 2.5)		
		Area	34546	6704	9014	0	6240	2032	14773	31537
	3	1974	0	0	0	6	3	0	6	5
		1975	0	0	0	3	5	0	8	9
		1976	0	0	0	3	5	0	11	10
		1977	0	0	0	4	7	no data (see section 2.5)		
		Area	825	0	0	11560	24236	0	21241	8225
	4	1974	0	0	0	8	15	0	1	1
		1975	0	0	0	6	13	0	1	1
		1976	0	0	0	6	18	0	1	1
		1977	0	0	0	7	18	no data (see section 2.5)		
		Area	293	0	0	54284	86618	0	1479	3280

TABLE 23. Vegetation-altitude data for the Oystercatcher on plot 3 in 1976.

	Vegetation type					
	1	2	3	4	5	Totals
Altitude class 1	$x_{11}=0$ $\omega_{11}=5042$	$x_{12}=0$ $\omega_{12}=0$	$x_{13}=0$ $\omega_{13}=19316$	$x_{14}=0$ $\omega_{14}=0$	$x_{15}=0$ $\omega_{15}=0$	$x_{1.}=0$ $\omega_{1.}=24358$
Altitude class 2	$x_{21}=1$ $\omega_{21}=34546$	$x_{22}=3$ $\omega_{22}=6704$	$x_{23}=0$ $\omega_{23}=9014$	$x_{24}=0$ $\omega_{24}=0$	$x_{25}=4$ $\omega_{25}=6240$	$x_{2.}=8$ $\omega_{2.}=56504$
Altitude class 3	$x_{31}=0$ $\omega_{31}=825$	$x_{32}=0$ $\omega_{32}=0$	$x_{33}=0$ $\omega_{33}=0$	$x_{34}=3$ $\omega_{34}=11560$	$x_{35}=5$ $\omega_{35}=24236$	$x_{3.}=8$ $\omega_{3.}=36621$
Altitude class 4	$x_{41}=0$ $\omega_{41}=293$	$x_{42}=0$ $\omega_{42}=0$	$x_{43}=0$ $\omega_{43}=0$	$x_{44}=6$ $\omega_{44}=54284$	$x_{45}=18$ $\omega_{45}=86618$	$x_{4.}=24$ $\omega_{4.}=141195$
Totals	$x_{.1}=1$ $\omega_{.1}=40706$	$x_{.2}=3$ $\omega_{.2}=6704$	$x_{.3}=0$ $\omega_{.3}=28330$	$x_{.4}=9$ $\omega_{.4}=65844$	$x_{.5}=27$ $\omega_{.5}=117094$	$x_{..}=40$ $\omega_{..}=258678$

Focussing on 1976 (the most significant year) table 23 is extracted from table 22 with the purpose of introducing the notations $x_{u,v}$ and $\omega_{u,v}$ and to describe the statistical evaluation. The $x_{u,v}$'s are regarded as outcomes of independent random variables $X_{u,v}$ having Poisson distributions with parameter $\xi_{u,v}$. It seems sensible to postulate a multiplicative model for the corresponding 'intensities' or 'densities' $\lambda_{u,v} = \xi_{u,v}/\omega_{u,v}$, especially because such log-linear models (BISHOP et al., 1975; HABERMANN, 1974) admit an exact treatment. There are no compelling reasons to prefer these models over the 'f-linear' models which appear if additivity of effects is postulated for the transformation $f(\lambda_{u,v})$ and f is not a logarithmic function. Note that $f(\lambda) = \lambda^{\frac{1}{2}}$ has certain advantages from a technical asymptotic point of view because $X^{\frac{1}{2}}$ is asymptotically distributed as $N(\lambda^{\frac{1}{2}}, 4^{-1})$ if X has Poisson distribution. Hence, favouring the multiplicative or log-linear model 'on the basis of mathematical convenience from an exact point of view' we postulate

$$\begin{aligned} &\lambda_{u,v} = \lambda\, \alpha_u \beta_v \,(u = 1, 2, 3, 4;\ v = 1, \ldots, 5) \\ &\alpha_1\alpha_2\alpha_3\alpha_4 = 1;\ \beta_1\beta_2 \ldots \beta_5 = 1 \end{aligned} \tag{4.1}$$

where α_u is the effect of altitude class u and β_v is the effect of vegetation type v. If (4.1) holds, then λ, α_u and β_v are completely determined by the $\lambda_{u,v}$'s

$$\lambda = (\Pi\lambda_{u,v})^{1/20};\alpha_u = \left(\prod_{v=1}^{5} \lambda_{u,v}\right)^{1/5}\lambda^{-1};\ \beta_v = \left(\prod_{u=1}^{4} \lambda_{u,v}\right)^{1/4}\lambda^{-1} \tag{4.2}$$

We become interested in the testing problem with null-hypothesis $H: \beta_1 = \ldots = \beta_5 = 1$ and alternative hypothesis $A: \beta_v \neq 1$ for at least one $v \in \{1,\ldots,5\}$, or in other words in testing whether the vegetation/landscape affects the number of nests if altitude is taken into account.

4.2.2. *Construction of the test*

In the past, problem (H, A) was tackled by making pairwise comparisons. In fact confidence intervals were constructed for the β_v/β_w's by restricting the attention to the data $\{X_{u,v}; X_{u,w} (u = 1,2,3,4)\}$ and adding the figures for 1974, 1975 and 1977 to those in table 23. This is now regarded as a mistake because of the existence of return behaviour (GLUTZ VON BLOTZHEIM, 1975). The approach with pairwise comparisons for separate years might be recommendable if one is already convinced that H has to be rejected: the comparisons would facilitate the interpretation of the differences. However, we shall first focus on problem (H, A). Note that $(X_{1.},\ldots,X_{4.})$ is a complete sufficient statistic for the null-hypothesis H. The sufficiency implies that the conditional null-distribution of $(X_{11},\ldots,X_{35})$, given $(X_{1.},X_{2.},X_{3.},X_{4.}) = (x_{1.},x_{2.},x_{3.},x_{4.}) = (0,8,8,24)$, the observed outcome, does not depend on the unknown α's. Using an intuitive approach (the theses SCHAAFSMA (1966) and SNIJDERS (1979) find their origin in attempts to replace such intuitive approaches by formal optimality theory), the test will be based on the marginal totals $(X_{.1},\ldots,X_{.5})$ (with outcome (1,3,0,9,27). Using the notation $p_{uv} = \omega_{uv}/\omega_{u.}$ we find that the conditional null-distribution of $(X_{.1},\ldots,X_{.5})$ given $(X_{1.},X_{2.},X_{3.},X_{4.})$, is that of the sum of four independent multinomial $M\ (x_{u.};\ p_{u1},\ldots,p_{u5})$ random vectors $(X_{u1},\ldots,X_{u5})$ $(u = 1,2,3,4)$ where X_{uv} has the binomial $B(x_u;p_{uv})$) distribution. Hence, conditionally upon $(x_{1.},x_{2.},x_{3.},x_{4.})$, $X_{.v}$ has expectation

$$\mu_v = \sum_{u=1}^{4} x_{u.} p_{uv}$$

and variance

$$\sigma_v^2 = \sum_{u=1}^{4} x_{u.} p_{uv} (1-p_{uv})$$

Hence $H: \beta_1 = \ldots = \beta_5$ can be tested on the basis of $(X_{.1},\ldots,X_{.5})$ by testing each $X_{.v}$ in the normal $N(\mu_v, \sigma_v^2)$ distribution using the obvious continuity correction. If significance is obtained at the level $\alpha/5$ for at least one value of v, then H is rejected in favor of A. Notice that a χ^2 approach based on the multivariate normal approximation to the above-mentioned conditional distribution of $(X_{.1}, \ldots, X_{.5})$ would require much more work than the above recommended conservative approach.

Application to the data of table 23.

Table 24 shows that the absolute value of the deviation $(x_{.v}-\mu_v)/\sigma_v$ is maximal if $v = 1$. Its value 2.83 is such that $P(|U| > 2.83) = .0047$. However, the maximum was taken for 5 vegetation types. A conservative approach (subsection 3.2.3) would require that the maximum absolute value obtained should be significant at the level $\alpha/5$. The observed value $P(|U| > 2.83 = .0047$ is smaller than $\alpha/5$. The corresponding P values for the years 1974, 1975 and 1977 were successively: .0040, .00346 and .00346 which are also smaller than $\alpha/5$. Hence table 23 provides sufficient evidence to reject the null-hypothesis that no vegetational effects exist if the altitude is taken into account. Note that the test was carried out without a correction for continuity. If such correction were applied then

$P(X_{.1} \leqq 1) \approx P(N \leqq 1^1/_2) = P(U \leqq \sigma_1^{-1}(1^1/_2-\mu_1)) = P(U \leqq -2.47) = .0067.$

would be obtained, or rather .0134 because a two-sided test is required. Hence .0134 should be compared with .0047 which was obtained without continuity correction. Now .0134 is larger than $\alpha/5$ (if $\alpha = .05$). The corresponding values

TABLE 24. Evaluation of table 23.

u	$x_{u.}$	p_{u1}	p_{u2}	p_{u3}	p_{u4}	p_{u5}	$p_{u1}-p_{u1}^2$	$p_{u2}-p_{u2}^2$	$p_{u3}-p_{u3}^2$	$p_{u4}-p_{u4}^2$	$p_{u5}-p_{u5}^2$
1	0	.207	0	.793	0	0	.164	0	.164	0	0
2	8	.611	.119 .	.160	0	.110	.237	.105	.135	0	.098
3	8	.023	0	0	.316	.662	.022	0	0	.216	.224
4	24	.002	0	0	.384	.613	.002	0	0	.236	.237

v	μ_v	σ_v	$x_{.v}$	$(x_{.v}-\mu_v)/\sigma_v$
1	5.12	1.46	1	−2.83
2	.95	.92	3	+2.23
3	1.28	1.04	0	−1.23
4	11.74	2.72	9	−1.01
5	20.89	2.87	27	+2.13

for the years 1974, 1975 and 1977 were .0244, .0417 and .0417 which are also larger than $\alpha/5$ and hence the evidence in table 22 should not be regarded as completely sufficient for rejecting the null-hypothesis. Nevertheless it may be interesting to establish confidence intervals for the vegetational effects (though these intervals will usually contain the number 1 because H was not rejected).

Such intervals might give an impression of the actual effects. Model (4.1) is postulated and, though H: $\beta_1 = \ldots = \beta_5 = 1$ was not rejected, a confidence interval for β_2/β_1 will be derived by testing $H_\rho:\beta_2/\beta_1 = \rho$ against $A_\rho:\beta_2/\beta_1 \neq \rho$ (the effects β_3/β_2 etc. can be treated similarly). This testing problem was considered in DE ROOS and SCHAAFSMA (1981). It was shown that some information, relevant for H_ρ, A_ρ, gets lost if the attention is restricted to the observations belonging to the vegetation types 1 and 2. Nevertheless, for convenience 'sake, the test wil be based on these observations only. In terms of the corresponding random variables (X_{uv}; $u = 1,\ldots, 4$; $v = 1,\ldots, 5$), having Poisson distributions with parameters $\xi_{uv} = \lambda_{uv}\omega_{uv}$, H can be expressed as H_ρ: $\lambda_{u2} = \rho\lambda_{u1}$ (see 4.1) or equivalently as H_ρ: $\xi_{u2}\omega_{u1} = \rho\xi_{u1}\omega_{u2}$.

Note that the conditional distribution of $X_{.2}$, given the observed outcomes of $X_{11}+X_{12},\ldots, X_{41}+X_{42}$, is the convolution of the four binomial distributions $B\{x_{u1} + x_{u2}, \omega_{u2}\rho(\omega_{u2}\rho + \omega_{u1})^{-1}\}$ ($u = 1,\ldots, 4$) if H_ρ is true. A normal approximation (with continuity correction $\frac{1}{2}$ because $X_{1.}$ is integer-valued) can be based on expectation μ_ρ and variance σ_ρ^2 of this conditional distribution. Of course

$$
\begin{aligned}
\mu_\rho &= \sum_{u=1}^{4} (x_{u1} + x_{u2})\omega_{u2}\rho(\omega_{u2}\rho + \omega_{u1})^{-1} \\
\sigma_\rho{}^2 &= \sum_{u=1}^{4} (x_{u1} + x_{u2})\omega_{u2}\omega_{u1}\rho(\omega_{u2}\rho + \omega_{u1})^{-2}
\end{aligned}
\quad (4.3)
$$

The confidence interval for β_2/β_1 consists of all numbers ρ such that H_ρ is not

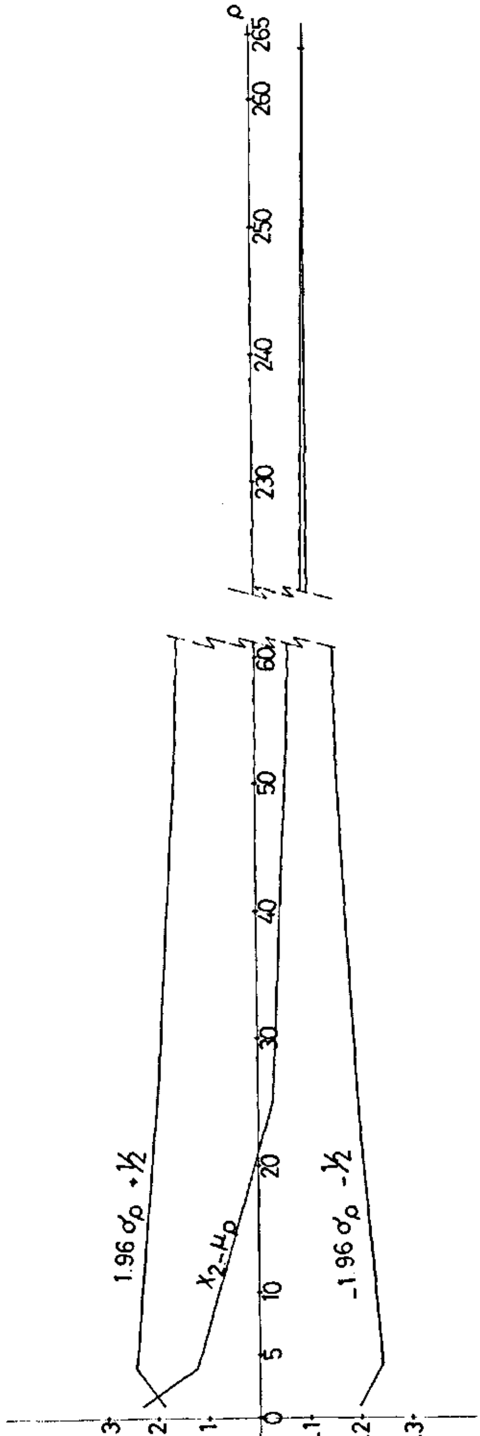

FIG. 22. Construction of the confidence interval [1.85, 264] for the parameter β_2/β_1 for the Oystercatcher on plot 3 in 1976.

rejected, i, e, using the normal approximation with continuity correction, such that $|x_{.2}-\mu_\rho| < 1.96\,\sigma_\rho + {}^1/_2$. Some iterations are necessary in order to find the upper and lower bounds $\bar{\rho}$ and $\underline{\rho}$ of the .95 confidence interval for $\rho = \beta_2/\beta_1$. The required computations and iterations were carried out by plotting $x_{.2}-\mu_\rho$, 1.96 $\sigma_\rho + \frac{1}{2}$ and $-1.96\,\sigma_\rho - \frac{1}{2}$ as functions of ρ. The bound $\bar{\rho}$ is obtained as the point of intersection between the first curve and the third one and the bound $\underline{\rho}$ as the point of intersection between the first curve and the second one. Along these lines for 1976 the .95 confidence intervals [1.85, 2.64] (see fig. 22), [.1, >100] and [2.8, >100] were obtained for β_2/β_1, β_4/β_1 and β_5/β_1 respectively. Note that the parameters β_2/β_1, β_4/β_1 and β_5/β_1 were preferred over β_1/β_2, β_1/β_4 and β_1/β_5 in connection with practical considerations: we wanted to restrict the number of computations and to consider ratios which looked larger than 1.

Though no sufficient evidence was found to reject H: $\beta_1 = ... = \beta_5 = 1$, it is likely that $\beta_2/\beta_1 > 1$ and that even $\beta_2/\beta_1 > 1.85$, which means that vegetation type 2 (*Festuco-Galietum maritimi*) is more attractive than type 1 (*Empetro-Ericetum*). In comparison with the heather vegetation (1), vegetation types 2 and 5 (*Violo-Corynephoretum*) are grassy, open vegetations with a loose substrate (see section 2.2 and VAN DIEREN (1934) and WESTHOFF and DEN HELD (1975)). HEPPLESTON (1971) also suggested preference of the Oystercatcher for such vegetation types and that these birds prepare their nest by scraping away the surface soil with their legs whilst resting against their breast, thus forming a shallow rounded depression. Such a method would be mechanically easier in a loose substrate than in a firm one such as heather.

4.3. OYSTERCATCHER

4.3.1. *Does the vegetation have an effect if the altitude is taken into account?*

The data in table 25 for study plot 4 are used along the lines of plot 3 in section

TABLE 25. Vegetation-altitude data for the Oystercatcher on plot 4 in 1975.

	Vegetation-type			Totals
	1	2	3	
Altitude class 1	$x_{11}=0$ $\omega_{11}=28448$	$x_{12}=2$ $\omega_{12}=2598$	$x_{13}=3$ $\omega_{13}=28826$	$x_{1.}=5$ $\omega_{1.}=59872$
Altitude class 2	$x_{21}=0$ $\omega_{21}=2032$	$x_{22}=2$ $\omega_{22}=14773$	$x_{23}=1$ $\omega_{23}=31537$	$x_{2.}=3$ $\omega_{2.}=48342$
Altitude class 3	$x_{31}=0$ $\omega_{31}=0$	$x_{32}=8$ $\omega_{32}=21241$	$x_{33}=9$ $\omega_{33}=8225$	$x_{3.}=17$ $\omega_{3.}=29466$
Altitude class 4	$x_{41}=0$ $\omega_{41}=0$	$x_{42}=1$ $\omega_{42}=1479$	$x_{43}=1$ $\omega_{43}=3280$	$x_{4.}=2$ $\omega_{4.}=4759$
Totals	$x_{.1}=0$ $\omega_{.1}=30480$	$x_{.2}=13$ $\omega_{.2}=40091$	$x_{.3}=14$ $\omega_{.3}=71868$	$x_{..}=27$ $\omega_{..}=142439$

TABLE 26. Evaluation of table 25.

u	$x_{u.}$	p_{u1}	p_{u2}	p_{u3}	$p_{u1}-p_{u1}^2$	$p_{u2}-p_{u2}^2$	$p_{u3}-p_{u3}^2$
1	5	.475	.043	.481	.249	.041	.249
2	3	.042	.306	.652	.040	.213	.226
3	17	0	.721	.279	0	.201	.201
4	2	0	.311	.689	0	.214	.214

v	μ_v	σ_v	$x_{.v}$	$(x_{.v}-\mu_v)/\sigma_v$
1	2.50	1.17	0	−2.14
2	14.01	2.17	13	− .47
3	10.48	2.40	14	+1.47

4.2. Table 26 can be derived from table 25 and shows that the absolute value of the deviation $(x_{.v}-\mu_v)/\sigma_v$ is maximal if $v=1$. The deviation −2.14 is such that $P(|U|>2.14) = .0324$. Note that the maximum was taken for 3 vegetation types. The maximum absolute value obtained should be significant at the level $\alpha/3$. The observed value $P(|U|>2.14) = .0324$ is larger than $\alpha/3$ if $\alpha = .05$. The corresponding P values for the years 1974 and 1976 were successively .248 and .374 which are also larger than $\alpha/3$, even if $\alpha = .5$. Hence table 25 does not provide sufficient evidence to reject the null-hypothesis that no vegetational effects exist if the altitude is taken into account. If a continuity correction were applied for 1975 then

$$P(X_{.1} \leqq 0) \approx P(N \leqq {}^1/_2) = P(U \leqq \sigma_1^{-1}({}^1/_2-\mu_1)) = P \leqq -1.71 = .0436.$$

Of course a two-sided test is required. Hence .087 should be compared with the approximation .0324 without continuity correction. Now .087 is even larger than $\alpha = .05$ and hence table 25 provides no hard evidence to reject the null-hypothesis, though for 1975 the confidence intervals [3.3, ∞], [1/4, ∞] and [.7, 9.25] for the parameters β_2/β_1, β_3/β_1 and β_3/β_2 were established and the interval [3.3, ∞] suggests that vegetation type 2 (*Festuco-Galietum maritimi*) is more attractive than type 1 (*Empetro-Ericetum*) as was the case for plot 3.

4.3.2. *Does the altitude have an effect if the vegetation is taken into account?*

Table 27 can be derived from table 23 and shows that the absolute value of the deviation $(x_{u.}-\mu_u)/\sigma_u$ is maximal if $u = 2$. Its value 2.24 is such that $P(|U|>2.24) = .0252$. However the maximum was taken for 4 altitude classes and should be significant at the level $\alpha/4$. The observed value $P(|U|>2.24) = .0252$ is larger than $\alpha/4$ if $\alpha = .05$. The corresponding P values for the years 1974, 1975 and 1977 were .1676, .1188 and .1286 which are also larger than $\alpha/4$, even if $\alpha = .1$. Hence table 22 does not provide sufficient evidence to reject the null-hypothesis that no altitude effects exist if the vegetation is taken into account. If a continuity correction were applied for 1976 then

$$P(X_{.2} \geqq 8) \approx P(N \geqq 7^1/_2) = P(U \geqq \sigma_2^{-1}(7^1/_2-\mu_2)) = P \geqq 1.83 = .0336.$$

Of course a two-sided test is required. Hence .0672 should be compared with the earlier approximation .0252. Now .0672 is even larger than $\alpha = .05$ and

TABLE 27. Evaluation of table 23.

v	$x_{v.}$	p_{v1}	p_{v2}	p_{v3}	p_{v4}	$p_{v1}-p_{v1}^2$	$p_{v2}-p_{v2}^2$	$p_{v3}-p_{v3}^2$	$p_{v4}-p_{v4}^2$
1	1	.124	.849	.020	.007	.109	.129	.020	.007
2	3	0	1	0	0	0	0	0	0
3	0	.682	.318	0	0	.218	.217	0	0
4	9	0	0	.176	.824	0	0	.145	.144
5	27	0	.053	.207	.740	0	.050	.164	.193

u	μ_u	σ_u	$x_{.u}$	$(x_{.u}-\mu_u)/\sigma_u$
1 (< 5 m)	.12	.33	0	− .38
2 (5–7.5 m)	5.28	1.22	8	+2.24
3 (7.5–10 m)	7.19	2.40	8	+ .34
4 (> 10 m)	27.4	2.55	24	−1.33

TABLE 28. Altitude-vegetation data for the Oystercatcher on Plot 4 in 1976.

	Altitude-class			
	1 (< 5 m)	2 (5–7.5 m)	3 (7.5–10 m)	4 (> 10 m)
Vegetation type 1	$x_{11}=1$ $\omega_{11}=28448$	$x_{12}=0$ $\omega_{12}=2032$	$x_{13}=0$ $\omega_{13}=0$	$x_{14}=0$ $\omega_{14}=0$
Vegetation type 2	$x_{21}=1$ $\omega_{21}=2598$	$x_{22}=2$ $\omega_{22}=14773$	$x_{23}=11$ $\omega_{23}=21241$	$x_{24}=1$ $\omega_{24}=1479$
Vegetation type 3	$x_{31}=0$ $\omega_{31}=28826$	$x_{32}=2$ $\omega_{32}=31537$	$x_{33}=10$ $\omega_{33}=8225$	$x_{34}=1$ $\omega_{34}=3280$

TABLE 29. Evaluation of table 28.

v	$x_{v.}$	p_{v1}	p_{v2}	p_{v3}	p_{v4}	$p_{v1}-p_{v1}^2$	$p_{v2}-p_{v2}^2$	$p_{v3}-p_{v3}^2$	$p_{v4}-p_{v4}^2$
1	1	.933	.067	0	0	.062	.063	0	0
2	15	.065	.368	.530	.037	.061	.232	.249	.036
3	13	.401	.439	.114	.046	.240	.246	.101	.044

u	μ_u	σ_u	$x_{.u}$	$(x_{.u}-\mu_u)/\sigma_u$
1 (< 5 m)	7.12	2.02	2	−2.53
2 (5–7.5 m)	11.29	2.60	4	−2.80
3 (7.5–10 m)	9.43	2.25	21	+5.14
4 (> 10 m)	1.15	1.05	2	+ .81

hence table 23 provides certainly no sufficient evidence to reject the null-hypothesis. For 1976 the confidence intervals [.7, 17.2]; [.9, 11.7] and [.6, 12.5] were established for the parameters β_2/β_3, β_2/β_4 and β_3/β_4. Note that they all contain the number 1 indicating that no difference exists.

For plot 4 the data is evaluated along the lines of section 4.2. Note that table 29 can be derived from table 28 and shows that the absolute value of the deviation $(x_{.u}-\mu_u)/\sigma_u$ is maximal if u = 3. Its value 5.14 is such that $P(|U|>5.14)<.0006$ which is smaller than $\alpha/4$ for every reasonable α. The corresponding P values for the years 1974 and 1975 successively satisfied $P<.0006$ and $P<.0006$. Hence table 22 provides ample evidence to reject the null-hypothesis that no altitude effects exist if the vegetation is taken into account. If altitude class 3(7.5–10 m) is deleted from the data then no significance remained. Hence the interpretation might be that altitude class 3 is preferred over the other classes. This interpretation does not agree with the impressions obtained for plot 3. A possible explanation might be that class 3 in plot 4 is only rarely visited by tourists.

TABLE 30. Landscape-altitude data for the Curlew.

Altitude class		Study-plot 5					Study-plot 6				
		Landscape-type					Landscape-type				
		Ca	Ch	Ci	P	E	Ca	Ch	Ci	P	E
	1974	2	0	0	0	5	0	0	0	3	5
	1975	1	0	0	0	4	0	0	0	4	4
	1976	1	0	0	0	8	0	0	0	3	3
1	1977	1	0	0	0	4	0	0	0	2	3
	1978	1	0	0	0	4	0	0	0	3	2
	1979	0	0	0	0	3	0	0	0	3	5
	Area	68750	0	0	155790	297915	54166	29163	0	336582	247874
	1974	0	0	6	2	0	2	0	4	0	0
	1975	0	0	7	1	1	2	0	6	1	0
	1976	0	0	5	1	0	1	1	7	0	0
2	1977	0	0	5	0	0	1	1	5	2	0
	1978	0	0	5	0	0	1	0	3	2	0
	1979	0	0	3	0	0	1	0	3	1	0
	Area	0	168750	437500	262499	25000	420830	91663	687502	74999	0
	1974	0	1	0	0	0	0	0	0	0	0
	1975	0	1	0	0	0	0	0	0	0	0
	1976	0	2	0	0	0	0	0	0	0	0
3	1977	0	1	0	0	0	0	0	0	0	0
	1978	0	1	0	0	0	0	0	0	0	0
	1979	0	0	0	0	0	0	0	0	0	0
	Area	230703	368750	0	0	0	223540	0	0	0	0
	1974	2	0	0	0	0	0	0	0	0	0
	1975	2	0	0	0	0	0	0	0	0	0
	1976	2	0	0	0	0	0	0	0	0	0
4	1977	2	0	0	0	0	0	0	0	0	0
	1978	1	0	0	0	0	0	0	0	0	0
	1979	1	0	0	0	0	0	0	0	0	0
	Area	490547	0	0	0	0	26460	0	0	0	0

4.4.1. *Does the landscape have an effect if the altitude is taken into account?*

Table 31 is extracted from table 30 with the purpose of introducing the notations $x_{u,v}$ and $\omega_{u,v}$. Accordingly table 32 can be derived from table 31 and shows that the absolute value of the deviation $(x_{.v}-\mu_v)/\sigma_v$ is maximal if $v = 3$. Its value 2.28 is such that $P(|U| > 2.28) = .0225$. However, the maximum was taken for 5 landscape types. The maximum absolute value should be significant at the level $\alpha/5$. The observed value $P|U| > 2.28) = .0225$ is larger than $\alpha/5$ if $\alpha = .05$. The corresponding P values for the years 1974, 1975, 1976, 1977 and 1979 were .1416, .0663, .0513, .0225 and .0774, successively and also larger than $\alpha/5$. Hence table 30 does not provide sufficient evidence to reject the null-hypothesis that no landscape effects exist if the altitude is taken into account. If a continuity correction were applied for 1978 then

TABLE 31. Landscape-altitude data for the Curlew on plot 5 in 1978.

	Landscape-type					Totals
	Ca	Ch	Ci	P	E	
Altitude	$x_{11}=1$	$x_{12}=0$	$x_{13}=0$	$x_{14}=0$	$x_{15}=4$	$x_{1.}=5$
class 1	$\omega_{11}=68750$	$\omega_{12}=0$	$\omega_{13}=0$	$\omega_{14}=155790$	$\omega_{15}=297915$	$\omega_{1.}=522455$
Altitude	$x_{21}=0$	$x_{22}=0$	$x_{23}=5$	$x_{24}=0$	$x_{25}=0$	$x_{2.}=5$
class 2	$\omega_{21}=0$	$\omega_{22}=168750$	$\omega_{23}=437500$	$\omega_{24}=262499$	$\omega_{25}=25000$	$\omega_{2.}=893749$
Altitude	$x_{31}=0$	$x_{32}=1$	$x_{33}=0$	$x_{34}=0$	$x_{35}=0$	$x_{3.}=1$
class 3	$\omega_{31}=230703$	$\omega_{32}=368750$	$\omega_{33}=0$	$\omega_{34}=0$	$\omega_{35}=0$	$\omega_{3.}=599453$
Altitude	$x_{41}=1$	$x_{42}=0$	$x_{43}=0$	$x_{44}=0$	$x_{45}=0$	$x_{4.}=1$
class 4	$\omega_{41}=490547$	$\omega_{42}=0$	$\omega_{43}=0$	$\omega_{44}=0$	$\omega_{45}=0$	$\omega_{4.}=490547$
Totals	$x_{.1}=2$	$x_{.2}=1$	$x_{.3}=5$	$x_{.4}=0$	$x_{.5}=4$	$x_{..}=12$
	$\omega_{.1}=790000$	$\omega_{.2}=537500$	$\omega_{.3}=437500$	$\omega_{.4}=418289$	$\omega_{.5}=322915$	$\omega_{..}=2506204$

TABLE 32. Evaluation of table 31

u	$x_{u.}$	p_{u1}	p_{u2}	p_{u3}	p_{u4}	p_{u5}	$p_{u1}-p_{u1}^2$	$p_{u2}-p_{u2}^2$	$p_{u3}-p_{u3}^2$	$p_{u4}-p_{u4}^2$	$p_{u5}-p_{u5}^2$
1	5	.132	0	0	.298	.570	.115	0	0	.209	.245
2	5	0	.189	.490	.294	.028	0	.153	.250	.208	.027
3	1	.385	.615	0	0	0	.237	.237	0	0	0
4	1	1	0	0	0	0	0	0	0	0	0

v	μ_v	σ_v	$x_{.v}$	$(x_{.v}-\mu_v)/\sigma_v$
1	2.05	.90	2	-.05
2	1.56	1.00	1	-.56
3	2.45	1.12	5	+2.28
4	2.96	1.44	0	-2.05
5	2.99	1.17	4	+ .87

TABLE 34. Altitude-landscape data for the Redshank on plot 5 in 1975.

	Altitude-class				Totals
	1 (<5 m)	2 (5–7.5 m)	3 (7.5–10 m)	4 (>10 m)	
Landscape	$x_{11}=0$	$x_{12}=0$	$x_{13}=7$	$x_{14}=0$	$x_{1.}=7$
type 1	$\omega_{11}=68750$	$\omega_{12}=0$	$\omega_{13}=230703$	$\omega_{14}=490547$	$\omega_{1.}=790000$
Landscape	$x_{21}=0$	$x_{22}=0$	$x_{23}=0$	$x_{24}=0$	$x_{2.}=0$
type 2	$\omega_{21}=0$	$\omega_{22}=168750$	$\omega_{23}=368750$	$\omega_{24}=0$	$\omega_{2.}=537500$
Landscape	$x_{31}=0$	$x_{32}=0$	$x_{33}=0$	$x_{34}=0$	$x_{3.}=0$
type 3	$\omega_{31}=0$	$\omega_{32}=437500$	$\omega_{33}=0$	$\omega_{34}=0$	$\omega_{3.}=437500$
Landscape	$x_{41}=3$	$x_{42}=6$	$x_{43}=0$	$x_{44}=0$	$x_{4.}=9$
type 4	$\omega_{41}=155790$	$\omega_{42}=262499$	$\omega_{43}=0$	$\omega_{44}=0$	$\omega_{4.}=418289$
Landscape	$x_{51}=1$	$x_{52}=0$	$x_{53}=0$	$x_{54}=0$	$x_{5.}=1$
type 5	$\omega_{51}=297915$	$\omega_{52}=25000$	$\omega_{53}=0$	$\omega_{54}=0$	$\omega_{5.}=322915$
Totals	$x_{.1}=4$	$x_{.2}=6$	$x_{.3}=7$	$x_{.4}=0$	$x_{..}=17$
	$\omega_{.1}=522455$	$\omega_{.2}=893749$	$\omega_{.3}=599453$	$\omega_{.4}=490547$	$\omega_{..}=2506204$

TABLE 35. Evaluation of table 34.

v	$x_{v.}$	p_{v1}	p_{v2}	p_{v3}	p_{v4}	$p_{v1}-p_{v1}^2$	$p_{v2}-p_{v2}^2$	$p_{v3}-p_{v3}^2$	$p_{v4}-p_{v4}^2$
1	7	.087	0	.292	.621	.079	0	.207	.235
2	0	0	.314	.686	0	0	.215	.215	0
3	0	0	1	0	0	0	0	0	0
4	9	.372	.628	0	0	.233	.234	0	0
5	1	.923	.077	0	0	.072	.071	0	0

u	μ_u	σ_u	$x_{.u}$	$(x_{.u}-\mu_u)/\sigma_u$
1 (< 5 m)	4.88	1.65	4	− .53
2 (5–7.5 m)	5.73	1.48	6	+ .18
3 (7.5–10 m)	2.04	1.20	7	+4.12
4 (>10 m)	4.35	1.28	0	−3.39

TABLE 36. Landscape-altitude data for the Redshank on plot 6 in 1979.

	Landscape-type				
	Ca	Ch	Ci	P	E
Altitude	$x_{11}=0$	$x_{12}=0$	$x_{13}=0$	$x_{14}=10$	$x_{15}=3$
class 1	$\omega_{11}=54166$	$\omega_{12}=29163$	$\omega_{13}=0$	$\omega_{14}=336582$	$\omega_{15}=247874$
Altitude	$x_{21}=0$	$x_{22}=0$	$x_{23}=0$	$x_{24}=8$	$x_{25}=0$
class 2	$\omega_{21}=420830$	$\omega_{22}=91663$	$\omega_{23}=687502$	$\omega_{24}=74999$	$\omega_{25}=0$
Altitude	$x_{31}=0$	$x_{32}=0$	$x_{33}=0$	$x_{34}=0$	$x_{35}=0$
class 3	$\omega_{31}=223540$	$\omega_{32}=0$	$\omega_{33}=0$	$\omega_{34}=0$	$\omega_{35}=0$
Altitude	$x_{41}=0$	$x_{42}=0$	$x_{43}=0$	$x_{44}=0$	$x_{45}=0$
class 4	$\omega_{41}=26460$	$\omega_{42}=0$	$\omega_{43}=0$	$\omega_{44}=0$	$\omega_{45}=0$

TABLE 37. Evaluation of table 36.

v	$x_{.v}$	p_{1v}	p_{2v}	p_{3v}	p_{4v}	$p_{1v}-p_{1v}^2$	$p_{2v}-p_{2v}^2$	$p_{3v}-p_{3v}^2$	$p_{4v}-p_{4v}^2$
1	0	.075	.580	.308	.036	.069	.243	.213	.035
2	0	.241	.759	0	0	.183	.184	0	0
3	0	0	1	0	0	0	0	0	0
4	18	.818	.182	0	0	.149	.149	0	0
5	3	1	0	0	0	0	0	0	0

u	μ_u	σ_u	$x_{u.}$	$(x_{u.}-\mu_u)/\sigma_u$
1 (<5 m)	17.72	1.64	13	−2.88
2 (5–7.5 m)	3.28	1.64	8	+2.89
3 (7.5–10 m)	0	0	0	0
4 (>10 m)	0	0	0	0

$\alpha/4$. The observed value $P(|U|>2.89) = .00390$ and smaller than $\alpha/4$ if $\alpha = .05$. The corresponding P values for the years 1975, 1976, 1977 and 1978 were .00919, .3332, .436 and .05192. These values are, except the value .00919 for 1975, larger than $\alpha/4$. Table 33 provides sufficient evidence to reject the null-hypothesis that no altitude effects exist if the landscape is taken into account, if we take our statistical approach seriously. The confidence interval [1.45, 13.25] for the parameter β_2/β_1 in the year 1979 suggests that altitude class 2(5–7.5 m) is more attractive than class 1(<5 m). However, examining table 33 more carefully, the 1978 data show that class 1 is more attractive than class 2. Hence no statements should be made on the basis of table 33 for plots 5 and 6. It looks as if some kind of concentration of nest sites appears.

5. THE INTERACTION BETWEEN LANDSCAPE/VEGETATION AND TOURISM IN RELATION TO DENSITIES OF BREEDING WADERS

5.1. INTRODUCTION AND SUMMARY

In section 3.3 effects of landscape/vegetation were established and in section 3.5 also of tourism. Now the interaction of landscape/vegetation and tourism is investigated in order to find out whether the effects of one factor can be explained as caused by the other one. If the effects of a factor cannot be explained in this way, then they will be estimated by means of confidence intervals. The statistical analysis, based on a multiplicative model, is outlined in section 5.2.

Oystercatcher results. The evidence for tourism effects if the vegetation is taken into account, is sufficient both for plot 3 and plot 4. The corresponding confidence intervals [2.95, 59.7] and [2.1, 10.1] for the parameter α_1/α_3 indicate that tourism zone 1 (the quiet zone) is about 3–10 times as attractive as zone 3 (that along the paved paths).

On the other hand there exist also vegetational effects if tourism is taken into account, at least for plot 4. The corresponding intervals [2, >100] and [1.85, >100] for the parameters β_2/β_1 and β_3/β_1 indicate that vegetation types 2 (*Festuco-Galietum maritimi*) and 3 (*Polypodio-Salicetum*) are more attractive than type 1 (*Empetro-Ericetum*). Plot 3 shows no significant results.

Curlew results. The evidence for rejecting the null-hypothesis that no tourism effects exist if the landscape is taken into account is sufficient both for plot 5 and plot 6, because of the year 1979. The other years point into the same direction though none of these years provides sufficient evidence on its own. The corresponding confidence intervals [.6, >100] and [2.4, >100] for the parameter α_1/α_3 indicate that zone 1 is more attractive than zone 3.

For the reverse problem the evidence for rejecting the null-hypothesis was also neither sufficient for plot 5 nor for plot 6. For plot 5 the confidence intervals [1.65, 85.5], [1.25, 90] and [1.35, 107] for the parameters β_5/β_1, β_5/β_2 and β_5/β_4 nevertheless indicate that type 5 (E = Vegetations dominated by *Oxycoccus macrocarpos* and locally *Salix repens*) might very well be more attractive than types 1 (Ca = *Corynephorion* with open, very low vegetation), 2 (Ch = *Corynephorion* with scattered, low *Hippophaë* shrubs) and 4 (P = Vegetations dominated by *Empetrum nigrum*). These indications were not supported by the results for plot 6.

Redshanks results. The null-hypothesis that no tourism effects exist if the landscape is taken into account could be rejected both for plot 5 and for plot 6. For plot 5, the confidence interval [13.5, ∞] for α_2/α_3 indicates that tourism zone 2 is much more attractive than zone 3. For plot 6, the confidence interval [2.55, 20.2] for α_1/α_3 similarly indicates that zone 1 is much more attractive than zone 3.

For the reverse problem the evidence for rejecting the null-hypothesis is sufficient for plot 5 and 6. For plot 5, the confidence intervals [3.15, 81.5] and [2.7, 100] for the parameters β_2/β_1 and β_2/β_3 indicate that landscape type 2 (P = Vegetations dominated by *Empetrum nigrum*) is much more attractive than the types 1 (Ca = *Corynephorion* with open, very low vegetation) and 3 (E = Vegetations dominated by *Oxycoccus macrocarpos* and locally *Salix repens*). For plot 6, the confidence intervals [4.1, ∞], [2.1, 42], [1.65, ∞] and [7.05, ∞] for the parameters β_2/β_1, β_2/β_3, β_3/β_4 and β_2/β_4 indicate that type 2 is more attractive than types 1 and 3 while types 2 and 3 are more attractive than 4 (Ci = *Corynephorion* with many *Salix arenaria* shrubs).

5.2. THE STATISTICAL TECHNIQUE TO BE USED

In section 3.3 effects of landscape/vegetation were established and in section 3.5 also of tourism. The interaction between landscape/vegetation and tourism is investigated in order to find out whether the effects of one factor can be explained as caused by the effects of the other one. A detailed exposition of the theory can be found in DE ROOS and SCHAAFSMA (1981); here the essentials are presented.

5.2.1. *Formulation of the statistical problem*

Consider table 38, study plot 3. Focussing on 1974 (the 'most significant' year), table 39 is extracted from table 38 with the purpose of introducing the notations $x_{u,v}$ and $\omega_{u,v}$ and to describe the statistical evaluation. It seems sensible to postulate the following multiplicative model (5.1) for the corresponding 'intensities' or 'densities' $\lambda_{u,v} = \xi_{u,v}/\omega_{u,v}$ (see 4.2.1)

$$\begin{aligned} &\lambda_{u,v} = \lambda\, \alpha_u \beta_v \, (u = 1, 2, 3; v = 1, \ldots, 5) \\ &\alpha_1\alpha_2\alpha_3 = 1; \beta_1\beta_2 \cdots \beta_5 = 1 \end{aligned} \tag{5.1}$$

where α_u is the effect of tourism zone u and β_v is the effect of vegetation type v. If (5.1) holds, then α_u and β_v are completely determined by the $\lambda_{u,v}$'s because

$$\begin{aligned} &\lambda = \left(\prod_{u=1}^{3}\prod_{v=1}^{5} \lambda_{u,v}\right)^{1/15}; \alpha_u = \left(\prod_{v=1}^{5} \lambda_{u,v}\right)^{1/5} \lambda^{-1}; \\ &\beta_v = \left(\prod_{u=1}^{3} \lambda_{u,v}\right)^{1/3} \lambda^{-1} \end{aligned} \tag{5.2}$$

We now become interested in the testing problem with

$$\begin{array}{ll} \text{Null-hypothesis} & H_1 : \alpha_1 = \alpha_2 = \alpha_3 = 1, \\ \text{Alternative} & A_1 : \alpha_1 > \alpha_2 > \alpha_3 \end{array} \tag{5.3}$$

and, if H_1 is rejected, in the estimation of the effects of tourism, preferably by means of confidence intervals.

TABLE 38. Vegetation-tourism data for the Oystercatcher.

			Study-plot 3					Study-plot 4		
			Vegetation-type					Vegetation-type		
			1	2	3	4	5	1	2	3
Tourism zone	1	1974	1	2	0	1	5	0	5	6
		1975	0	0	0	1	4	0	10	8
		1976	1	1	0	0	7	0	11	7
		1977	0	2	0	2	7	no data (see section 2.5)		
		Area	387	2000	0	119	5488	8137	20420	15824
	2	1974	0	0	0	9	11	0	0	0
		1975	0	2	0	4	11	0	0	0
		1976	0	2	0	4	13	0	0	0
		1977	0	0	0	4	12	0	0	0
		Area	22342	4204	0	47701	76468	0	0	0
	3	1974	0	1	0	4	4	2	2	2
		1975	0	0	0	4	4	0	3	6
		1976	0	0	0	5	7	1	4	6
		1977	0	0	0	5	7	no data (see section 2.5)		
		Area	17989	510	28325	18000	35140	22353	19660	56045

Type 1 = *Empetro-Ericetum*
Type 2 = *Festuco-Galietum maritimi*
Type 3 = *Polypodio-Salicetum*
Type 4 = *Polypodio-Empetretum*
Type 5 = *Violo-Corynephoretum*
The area in m²

5.2.2. *Construction of the test*

In the earlier mentioned paper it is recommended that H_1 has to be rejected for large values of $X_{1.}-X_{3.}$, conditionally upon $X_{.1},..., X_{.5}$, where $X_{u.} = \sum_{v=1}^{5} X_{uv}$ and $X_{.v} = \sum_{u=1}^{3} X_{uv}$. In order to derive the null-distribution of $X_{1.}-X_{3.}$, we first consider that of $(X_{11},..., X_{35})$. Note that H_1 implies $\xi_{u\,v} = \omega_{uv}\,\lambda\beta_v$ for the parameter of the Poisson distribution of X_{uv} and if problem (H_1, A_1) has to be solved, that it is convenient to reparametrize (5.1) by substituting $\gamma_v = \lambda\beta_v$. Hence

$$
\begin{aligned}
&P_o(X_{11} = x_{11},..., X_{35} = x_{35} \mid X_{.1} = x_{.1},..., X_{.5} = x_{.5}) \\
&= \left\{\prod_{u,v} \exp\,(-\omega_{uv}\gamma_v)(\omega_{uv}\gamma_v)^{x_{uv}}/x_{uv}!\right\} \Big/ \left\{\prod_{v} \exp(-\omega_{.v}\gamma_v)(\omega_{.v}\gamma_v)^{x_{.v}}/x_{.v}!\right\} \\
&= \prod_{v} \binom{x_{.v}}{x_{1v};\, x_{2v};\, x_{3v}} p_{1v}{}^{x_{1v}}\, p_{2v}{}^{x_{2v}}\, p_{3v}{}^{x_{3v}}
\end{aligned}
\tag{5.4}
$$

where $p_{uv} = \omega_{uv}/\omega_{.v}$ and $\exp(y) = e^y$ denotes the exponential function, where $e \approx 2.71828$. Hence the $X_{1v}-X_{3v}$'s are conditionally independent under the null-hypothesis and the distribution of $X_{1v}-X_{3v}$ is determined by the fact that (X_{1v}, X_{2v}, X_{3v}) has the multinomial $M(x_{.v}; p_{1v}, p_{2v}, p_{3v})$ distribution. The expectation μ and variance σ^2 of the conditional null-distribution of $X_{1.}-X_{3.}$ follow immediately:

$$\mu = \sum_{v=1}^{5} x_{.v}(p_{1v} - p_{3v})$$

$$\sigma^2 = \sum_{v=1}^{5} x_{.v}\{p_{1v} + p_{3v} - (p_{1v} - p_{3v})^2\} \tag{5.5}$$

Note that $X_{1.}-X_{3.}$ is integer-valued: a continuity correction can be applied to the normal approximation. Next the theory is applied to the data of table 39 by composing table 40.

TABLE 39. Tourism-vegetation data for the Oystercatcher on plot 3 in 1974.

	Vegetation-type					Totals
	1	2	3	4	5	
Tourism zone 1	$x_{11}=1$ $\omega_{11}=387$	$x_{12}=2$ $\omega_{12}=2000$	$x_{13}=0$ $\omega_{13}=0$	$x_{14}=1$ $\omega_{14}=119$	$x_{15}=5$ $\omega_{15}=5488$	$x_{1.}=9$ $\omega_{1.}=7994$
Tourism zone 2	$x_{21}=0$ $\omega_{21}=22342$	$x_{22}=0$ $\omega_{22}=4204$	$x_{23}=0$ $\omega_{23}=0$	$x_{24}=9$ $\omega_{24}=47701$	$x_{25}=11$ $\omega_{25}=76468$	$x_{2.}=20$ $\omega_{2.}=150715$
Tourism zone 3	$x_{31}=0$ $\omega_{31}=17989$	$x_{32}=1$ $\omega_{32}=510$	$x_{33}=0$ $\omega_{33}=28325$	$x_{34}=4$ $\omega_{34}=18000$	$x_{35}=4$ $\omega_{35}=35140$	$x_{3.}=9$ $\omega_{3.}=99964$
Totals	$x_{.1}=1$ $\omega_{.1}=40718$	$x_{.2}=3$ $\omega_{.2}=6714$	$x_{.3}=0$ $\omega_{.3}=28325$	$x_{.4}=14$ $\omega_{.4}=65820$	$x_{.5}=20$ $\omega_{.5}=117096$	$x_{..}=38$ $\omega_{..}=258673$

The critical level is determined by
$P_0(X_{1.} - X_{3.} \geqq 9-9 \mid X_{.1} = 1, \ldots, X_{.5} = 20) \approx P(N \geqq 0-{}^1/_2)$
where N has the normal distribution with expectation μ and variance σ^2. Hence
$P(N \geqq -{}^1/_2) = P\{U \geqq (-{}^1/_2-\mu)/\sigma\} = P(U \geqq 2.61) = .00455$
is obtained. The value .00455 is smaller than α (even if $\alpha = .005$). Hence table 39 provides ample evidence to reject the null-hypothesis that no tourism effects exist if the vegetation is taken into account. The corresponding P values for the years 1975, 1976 and 1977 were .1190, .04487 and .00855. These values are, except the value .11190 for 1975, smaller than α if $\alpha = .05$. Hence table 38 consistently

TABLE 40. Evaluation of table 39.

$x_{.1}=1$	$x_{.2}=3$	$x_{.3}=0$	$x_{.4}=14$	$x_{.5}=20$
$\omega_{.1}=40718$	$\omega_{.2}=6714$	$\omega_{.3}=28325$	$\omega_{.4}=65820$	$\omega_{.5}=117096$
$x_{1.}=9$	$x_{2.}=20$	$x_{3.}=9$		
$p_{11} = .010$	$p_{12} = .298$	$p_{13} = 0$	$p_{14} = .002$	$p_{15} = .047$
$p_{31} = .442$	$p_{32} = .076$	$p_{33} = 1$	$p_{34} = .273$	$p_{35} = .300$
$\mu=-8.635$	$\sigma^2=9.716$	$\sigma=3.117$		

provides ample evidence to reject the null-hypothesis. Confidence intervals can be computed along the lines of section 4.2 because the restriction $\alpha_1 > \alpha_2 > \alpha_3$ will then no longer be of interest. Note that the parameters α_1/α_2, α_1/α_3 and α_2/α_3 are the quantities of interest because they tell us what one might expect if certain measures are taken (i.e. admitting more trespassers by planning roads or paths).

The confidence intervals [2.95, 59.7], [5.45, 44.5] and [.7, 2.5] for the parameters α_1/α_3, α_1/α_2 and α_2/α_3 for the 1977 data, suggest that tourism zone 1 is much more attractive than zones 2 and 3. Similar results were obtained for the 1975 data (α_1/α_3 = [2.55, 75.5], α_1/α_2 = [1.35, 46.5] and α_2/α_3 = [.55, 7.65]).

5.3. OYSTERCATCHER

5.3.1. *Does tourism have an effect if the vegetation is taken into account?*

The data in table 41 is taken from table 38 and used along the lines of section 5.2. Accordingly table 42 is derived from table 41 and the critical level is determined by

$P_0(X_{1.} - X_{3.} \geqq 18-9 \mid X_{.1} = 0, \ldots, X_{.3} = 14) \approx P(N \geqq 9 - {}^1/_2)$

TABLE 41. Tourism-vegetation data for the Oystercatcher on plot 4 in 1975.

	Vegetation-type			Totals
	1	2	3	
Tourism-zone 1	$x_{11}=0$ $\omega_{11}=8137$	$x_{12}=10$ $\omega_{12}=20420$	$x_{13}=8$ $\omega_{13}=15824$	$x_{1.}=18$ $\omega_{1.}=44381$
Tourism zone 3	$x_{31}=0$ $\omega_{31}=22353$	$x_{32}=3$ $\omega_{32}=19660$	$x_{33}=6$ $\omega_{33}=56045$	$x_{3.}=9$ $\omega_{3.}=98058$
Totals	$x_{.1}=0$ $\omega_{.1}=30490$	$x_{.2}=13$ $\omega_{.2}=40080$	$x_{.3}=14$ $\omega_{.3}=71869$	$x_{..}=27$ $\omega_{..}=142439$

TABLE 42. Evaluation of table 41.

$x_{.1}=0$		$x_{.2}=13$		$x_{.3}=14$	
$\omega_{.1}=30490$		$\omega_{.2}=40080$		$\omega_{.3}=71869$	
$x_{1.}=18$				$x_{3.}=9$	
$p_{11}=.267$		$p_{12}=.509$		$p_{13}=.220$	
$p_{31}=.733$		$p_{32}=.491$		$p_{33}=.780$	
	$\mu=-7.588$		$\sigma^2=22.610$		$\sigma=4.755$

where N has the normal distribution with expectation μ and variance σ^2. Hence

$P(N \geqq 8^1/_2) = P\{U \geqq (8^1/_2 - \mu)/\sigma\} = P(U \geqq +3.38) = .00032$

is obtained. The value is smaller than α (even if α = .0005). Hence table 41 provides ample evidence to reject the null-hypothesis that no tourism effects exist

TABLE 43. Vegetation-tourism data for the Oystercatcher on plot 3 in 1977.

	Vegetation-type					Totals
	1	2	3	4	5	
Tourism zone 1	$x_{11}=0$ $\omega_{11}=387$	$x_{12}=2$ $\omega_{12}=2000$	$x_{13}=0$ $\omega_{13}=0$	$x_{14}=2$ $\omega_{14}=119$	$x_{15}=7$ $\omega_{15}=5488$	$x_{1.}=11$ $\omega_{1.}=7994$
Tourism zone 2	$x_{21}=0$ $\omega_{21}=22342$	$x_{22}=0$ $\omega_{22}=4204$	$x_{23}=0$ $\omega_{23}=0$	$x_{24}=4$ $\omega_{24}=47701$	$x_{25}=12$ $\omega_{25}=76468$	$x_{2.}=16$ $\omega_{2.}=150715$
Tourism zone 3	$x_{31}=0$ $\omega_{31}=17989$	$x_{32}=0$ $\omega_{32}=510$	$x_{33}=0$ $\omega_{33}=28325$	$x_{34}=5$ $\omega_{34}=18000$	$x_{35}=7$ $\omega_{35}=35140$	$x_{3.}=12$ $\omega_{3.}=99964$
Totals	$x_{.1}=0$ $\omega_{.1}=40718$	$x_{.2}=2$ $\omega_{.2}=6714$	$x_{.3}=0$ $\omega_{.3}=28325$	$x_{.4}=11$ $\omega_{.4}=65820$	$x_{.5}=26$ $\omega_{.5}=117096$	$x_{..}=39$ $\omega_{..}=258673$

if the vegetation is taken into account. The corresponding P values for the years 1974 and 1976 were .004595 and .00252, successively. These values are smaller than α (even if $\alpha = .005$). Hence table 38 consistently provides ample evidence to reject the null-hypothesis. Along the lines of sub-section 4.2.2 the confidence interval [2.1, 10.1] for the parameter α_1/α_3 has been computed with regard to the 1975 data. It suggests that tourism zone 1 is more attractive than zone 3. This agrees with the results in 5.2 for plot 3.

5.3.2. *Does the vegetation have an effect if tourism is taken into account?*

The subject of this section can be studied along the lines of section 4.2. The data in table 43 is taken from table 38, because 1977 looks the most significant year, and evaluated along the lines of subsection 4.2.2 by first deriving table 44 which shows that the absolute value of the deviation $(x_{.v}-\mu_v)/\sigma_v$ is maximal if $v = 1$. Its value 2.44 is such that $P(|U|>2.44) = .0146$. Note that the maximum was taken for 5 vegetation types. The maximum absolute value obtained should be significant at the level $\alpha/5$. The observed value $P(|U|>2.44) = .0146$ is larger than $\alpha/5$. The corresponding P values for the years 1974, 1975 and 1976 were

TABLE 44. Evaluation of table 43.

u	$x_{u.}$	p_{u1}	p_{u2}	p_{u3}	p_{u4}	p_{u5}	$p_{u1}-p_{u1}^2$	$p_{u2}-p_{u2}^2$	$p_{u3}-p_{u3}^2$	$p_{u4}-p_{u4}^2$	$p_{u5}-p_{u5}^2$
1	11	.048	.250	0	.015	.687	.046	.188	0	.0147	.215
2	16	.148	.028	0	.316	.507	.126	.027	0	.216	.250
3	12	.180	.005	.283	.180	.352	.148	.005	.203	.148	.228

v	μ_v	σ_v	$x_{.v}$	$(x_{.v}-\mu_v)/\sigma_v$
1	5.06	2.07	0	−2.44
2	3.26	1.60	2	− .79
3	3.40	1.56	0	−2.18
4	7.38	2.32	11	+1.56
5	19.89	3.02	26	+2.02

.0138, .0264 and .0234, successively. We see that, after all, 1977 is not the 'most significant' year. Note that even .0138 is slightly larger than $\alpha/5$. The margin is so narrow that it makes sense to apply the correction for continuity. If such correction were applied then

$P(X_{.1} \leqq 0) \approx P(N \leqq \frac{1}{2}) = P(U \leqq \sigma_1^{-1}(\frac{1}{2}-\mu_1)) = P(U \leqq -2.20) = .0139$

is obtained. Of course a two-sided test is required. Hence .0278 should be compared with the approximation .0146 without continuity correction. Now .0278 is larger than $\alpha/5$ (if $\alpha = .05$). The corresponding values for the years 1974, 1975 and 1976 were .0241, .0506 and .0358, successively and also larger than $\alpha/5$. Hence table 38 provides no sufficient evidence to reject the null-hypothesis at the level $\alpha = .05$, though the data for the year 1977 strongly suggests that H_1 does not hold and the confidence intervals [3.1, ∞], [1.25, > 100], [2.3, ∞], [.6, 3.1], [.7, 18.6] and [1, ∞] for the parameters β_4/β_1, β_4/β_2, β_5/β_1, β_4/β_5, β_5/β_2 and β_5/β_3 suggest that vegetation types 4 (*Polypodio-Empetretum*) and 5 (*Violo-Corynephoretum*) are more attractive than type 1 (*Empetro-Ericetum*) while type 4 seems more attractive than type 2 (*Festuco-Galietum maritimi*).

TABLE 45. Evaluation of table 41.

u	$x_{u.}$	p_{u1}	p_{u2}	p_{u3}	$p_{u1}-p_{u1}^2$	$p_{u2}-p_{u2}^2$	$p_{u3}-p_{u3}^2$
1	18	.183	.460	.357	.150	.248	.230
3	9	.504	.200	.572	.250	.160	.245

v	μ_v	σ_v	$x_{.v}$	$(x_{.v}-\mu_v)/\sigma_v$
1	7.83	2.22	0	−3.53
2	10.08	2.43	13	+1.20
3	11.57	2.52	14	+ .96

For plot 4 the data is evaluated along the lines of section 4.2. Table 45 is derived from table 41 and shows that the absolute value of the deviation $(x_{.v}-\mu_v)/\sigma_v$ is maximal if $v = 1$. Its value 3.53 is such that $P(|U| > 3.53) < .0006$. However, the maximum absolute deviation, being taken from 3 vegetation types, should be significant at the level $\alpha/3$. The observed value $P(|U| > 3.53) < .0006$ is smaller than $\alpha/3$ for every reasonable α. The corresponding P values for the years 1974 and 1976 were .0870 and .0007. Hence table 41 provides ample evidence to reject the null-hypothesis that no vegetational effects exist if tourism is taken into account. The confidence intervals [2, > 100], [1.85, > 100] and [.55, 2.95] for the parameters β_2/β_1, β_3/β_1 and β_2/β_3 indicate that vegetation types 2 (*Festuco-Galietum maritimi*) and 3 (*Polypodio-Salicetum*) are much more attractive than type 1 (*Empetro-Ericetum*).

Summarizing the results for plots 3 and 4 we see that vegetation type 1 (*Empetro-Ericetum*) is less attractive than most other vegetation types. This is in agreement with GLUTZ VON BLOTZHEIM et al. (1975) who state that the Oystercatcher prefers 'open plains with short grasses' and 'a lose substrate'. These conditions are characteristic for types 2 and 5.

5.4.1. *Does tourism have an effect if the landscape is taken into account?*

The data in table 46 are used along the lines of section 5.2. Hence table 47 is derived from table 46 and table 48 from table 47. The critical level is determined by

$P_0(X_{1.}-X_{3.} \geqq 2-1 \mid X_{.1}=1,\ldots,X_{.5}=3) \approx P(N \geqq 1-\frac{1}{2})$

where N has the normal distribution with the expectation μ and variance σ^2 obtained in table 48. Hence

$P(N \geqq \frac{1}{2}) = P\{U \geqq (\frac{1}{2}-\mu)/\sigma\} = P(U \geqq +2.29) = .01109$

is obtained. The value is smaller than α (if $\alpha = .05$). Hence table 47 does provide sufficient evidence to reject the null-hypothesis if 1979 is considered. However this year was selected because it looked most promising. The P values for the

TABLE 46. Landscape-tourism data for the Curlew.

			Study-plot 5					Study-plot 6				
			Landscape type					Landscape type				
			Ca	Ch	Ci	P	E	Ca	Ch	Ci	P	E
Tourism zone	1	1974	0	0	0	0	2	1	0	0	1	5
		1975	0	0	0	0	2	1	0	3	3	3
		1976	0	0	0	0	2	0	0	4	2	3
		1977	0	0	0	0	2	0	0	3	2	3
		1978	0	0	0	0	2	0	0	2	4	2
		1979	0	0	0	0	2	1	0	3	3	5
		Area	0	0	0	0	56250	135416	0	254166	154166	194583
	2	1974	1	0	4	0	0	0	0	0	0	0
		1975	2	0	4	0	1	0	0	0	0	0
		1976	3	0	2	0	1	1	0	0	0	0
		1977	2	0	3	0	0	1	0	0	0	0
		1978	0	0	3	0	0	0	0	0	0	0
		1979	1	0	2	0	1	0	0	0	0	0
		Area	226625	93750	254125	104063	70625	243750	0	0	37499	0
	3	1974	3	1	2	2	3	1	0	4	2	0
		1975	1	1	3	1	2	1	0	3	2	1
		1976	0	2	3	1	5	0	1	3	1	0
		1977	1	1	2	0	2	0	1	2	2	0
		1978	2	1	2	0	2	1	0	1	1	0
		1979	0	0	1	0	0	0	0	0	1	0
		Area	563300	443750	183375	314227	196040	345832	120832	433334	219916	53291

Type Ca = *Corynephorion* with open, very low vegetation.
Type Ch = *Corynephorion* with scattered, low *Hippophaë* shrubs.
Type Ci = *Corynephorion* with many *Salix arenaria* dwarf shrubs.
Type P = Vegetations dominated by *Empetrum nigrum*.
Type E = Vegetations dominated by *Oxycoccus macrocarpos* and locally *Salix repens* in wet to humid valleys.
The area in m^2.

TABLE 47. Tourism-landscape data for the Curlew on plot 5 in 1979.

	Landscape-type					Totals
	1 (Ca)	2 (Ch)	3 (Ci)	4 (P)	5 (E)	
Tourism	$x_{11}=0$	$x_{12}=0$	$x_{13}=0$	$x_{14}=0$	$x_{15}=2$	$x_{1.}=2$
zone 1	$\omega_{11}=0$	$\omega_{12}=0$	$\omega_{13}=0$	$\omega_{14}=0$	$\omega_{15}=56250$	$\omega_{1.}=56250$
Tourism	$x_{21}=1$	$x_{22}=0$	$x_{23}=2$	$x_{24}=0$	$x_{25}=1$	$x_{2.}=4$
zone 2	$\omega_{21}=226625$	$\omega_{22}=93750$	$\omega_{23}=254125$	$\omega_{24}=104063$	$\omega_{25}=70625$	$\omega_{2.}=749188$
Tourism	$x_{31}=0$	$x_{32}=0$	$x_{33}=1$	$x_{34}=0$	$x_{35}=0$	$x_{3.}=1$
zone 3	$\omega_{31}=563300$	$\omega_{32}=443750$	$\omega_{33}=183375$	$\omega_{34}=314227$	$\omega_{35}=196040$	$\omega_{3.}=1700692$
Totals	$x_{.1}=1$	$x_{.2}=0$	$x_{.3}=3$	$x_{.4}=0$	$x_{.5}=3$	$x_{..}=7$
	$\omega_{.1}=789925$	$\omega_{.2}=537500$	$\omega_{.3}=437500$	$\omega_{.4}=418290$	$\omega_{.5}=322915$	$\omega_{..}=2506130$

years 1974, 1975, 1976, 1977 and 1978 were .440, .1648, .4106, .1364 and .3884. The values are larger than α if $\alpha = .05$. In our opinion table 46 does not provide sufficient evidence to reject the null-hypothesis, though it points into the expected direction. For 1979 the confidence intervals [.6, > 100], [.4, 42] and [.55, 100] for the parameters α_1/α_3, α_1/α_2 and α_2/α_3 were computed. The products of upper and lower bounds are consistently larger than 1. The evidence points into the expected direction though it is not sufficient for making definite statements.

For plot 6 the data is evaluated along the lines of section 5.2. Table 49 is derived from table 46 and table 50 from table 49. The critical level is determined by

$P_0(X_{1.}-X_{3.} \geqq 12-1 \mid X_{.1} = 1, ..., X_{.5} = 5) \approx P(N \geqq 11-\frac{1}{2})$

where N has the normal distribution with expectation μ and variance σ^2 and

$P(N \geqq 10^1/_2) = P\{U \geqq (10^1/_2-\mu)/\sigma\} = P(U \geqq +2.92) = .0018$

is obtained. The value .0018 is significant at the level α for any reasonable value of α. Hence table 49 provides ample evidence to reject the null-hypothesis that no tourism effects exist if the landscape is taken into account. The corresponding P values for the years 1974, 1975, 1976, 1977 and 1978 were .464, .1996, .0543, .111 and .0196. Hence table 46 provides sufficient evidence to reject the null-hypothesis because of the year 1979. The other years point into the same direction though none of the other years provides sufficient evidence on its own. For 1979 the confidence intervals [2.4, > 100], [.3, ∞] and [.1, ∞] were computed for α_1/α_3, α_1/α_2 and α_2/α_3, respectively. The interval for the parameter α_1/α_3 is in line with the expectations and indicates that zone 1 > 3.

TABLE 48. Evaluation of table 47.

$x_{.1}=1$	$x_{.2}=0$	$x_{.3}=3$	$x_{.4}=0$	$x_{.5}=3$
$\omega_{.1}=789925$	$\omega_{.2}=537500$	$\omega_{.3}=437500$	$\omega_{.4}=418290$	$\omega_{.5}=322915$
$x_{1.}=2$	$x_{2.}=4$	$x_{3.}=1$		
$p_{11}=0$	$p_{12}=0$	$p_{13}=0$	$p_{14}=0$	$p_{15}=.174$
$p_{31}=.713$	$p_{32}=.826$	$p_{33}=.419$	$p_{34}=.751$	$p_{35}=.607$
$\mu=-3.269$	$\sigma^2=2.716$	$\sigma=1.648$		

TABLE 49. Tourism-landscape data for the Curlew on plot 6 in 1979.

	Landscape-type				
	1 (Ca)	2 (Ch)	3 (Ci)	4 (P)	5 (E)
Tourism	$x_{11}=1$	$x_{12}=0$	$x_{13}=3$	$x_{14}=3$	$x_{15}=5$
zone 1	$\omega_{11}=135416$	$\omega_{12}=0$	$\omega_{13}=254166$	$\omega_{14}=154166$	$\omega_{15}=194583$
Tourism	$x_{21}=0$	$x_{22}=0$	$x_{23}=0$	$x_{24}=0$	$x_{25}=0$
zone 2	$\omega_{21}=243750$	$\omega_{22}=0$	$\omega_{23}=0$	$\omega_{24}=37499$	$\omega_{25}=0$
Tourism	$x_{31}=0$	$x_{32}=0$	$x_{33}=0$	$x_{34}=1$	$x_{35}=0$
zone 3	$\omega_{31}=345832$	$\omega_{32}=120832$	$\omega_{33}=433334$	$\omega_{34}=219916$	$\omega_{35}=53291$

TABLE 50. Evaluation of table 49.

$x_{.1}=1$	$x_{.2}=0$	$x_{.3}=3$	$x_{.4}=4$	$x_{.5}=5$
$\omega_{.1}=724998$	$\omega_{.2}=120832$	$\omega_{.3}=687500$	$\omega_{.4}=411581$	$\omega_{.5}=247874$
$x_{1.}=12$	$x_{2.}=0$	$x_{3.}=1$		
$p_{11}=.187$	$p_{12}=0$	$p_{13}=.370$	$p_{14}=.375$	$p_{15}=.785$
$p_{31}=.480$	$p_{32}=1$	$p_{33}=.630$	$p_{34}=.534$	$p_{35}=.215$
$\mu=+1.19$	$\sigma^2=10.19$	$\sigma=3.19$		

Summarizing the results for plots 5 and 6 it is not completely clear whether tourism effects exist. However strong indications that tourism zone 1 is more attractive than zone 3 are available especially for 1979.

5.4.2. *Does the landscape have an effect if tourism is taken into account?*

The data in table 51 is taken from table 46 and used along the lines of section 4.2. Accordingly table 52 is derived from table 51 and shows that the absolute value of the deviation $(x_{.v}-\mu_v)/\sigma_v$ is maximal if $v = 5$. Its value 3.27 is such that $P(|U|>3.27) = .00128$. However, the maximum was taken for 5 landscapes. The maximum absolute value should be significant at the level $\alpha/5$. The observed value $P(|U|>3.27) = .00128$ is smaller than $\alpha/5$ (even if $\alpha = .01$). Hence table 51 seems to provide sufficient evidence to reject the null-hypothesis that no land-

TABLE 51. Landscape-tourism data for the Curlew on plot 5 in 1976.

	Landscape-type					Totals
	1 (Ca)	2 (Ch)	3 (Ci)	4 (P)	5 (E)	
Tourism	$x_{11}=0$	$x_{12}=0$	$x_{13}=0$	$x_{14}=0$	$x_{15}=2$	$x_{1.}=2$
zone 1	$\omega_{11}=0$	$\omega_{12}=0$	$\omega_{13}=0$	$\omega_{14}=0$	$\omega_{15}=56250$	$\omega_{1.}=56250$
Tourism	$x_{21}=3$	$x_{22}=0$	$x_{23}=2$	$x_{24}=0$	$x_{25}=1$	$x_{2.}=6$
zone 2	$\omega_{21}=226625$	$\omega_{22}=93750$	$\omega_{23}=254125$	$\omega_{24}=104063$	$\omega_{25}=70625$	$\omega_{2.}=749188$
Tourism	$x_{31}=0$	$x_{32}=2$	$x_{33}=3$	$x_{34}=1$	$x_{35}=5$	$x_{3.}=11$
zone 3	$\omega_{31}=563300$	$\omega_{32}=443750$	$\omega_{33}=183375$	$\omega_{34}=314227$	$\omega_{35}=196040$	$\omega_{3.}=1700692$
Totals	$x_{.1}=3$	$x_{.2}=2$	$x_{.3}=5$	$x_{.4}=1$	$x_{.5}=8$	$x_{..}=19$
	$\omega_{.1}=789925$	$\omega_{.2}=537500$	$\omega_{.3}=437500$	$\omega_{.4}=418290$	$\omega_{.5}=322915$	$\omega_{..}=2506130$

TABEL 52. Evaluation of table 51.

u	$x_{u.}$	p_{u1}	p_{u2}	p_{u3}	p_{u4}	p_{u5}	$p_{u1}-p_{u1}^2$	$p_{u2}-p_{u2}^2$	$p_{u3}-p_{u3}^2$	$p_{u4}-p_{u4}^2$	$p_{u5}-p_{u5}^2$
1	2	0	0	0	0	1	0	0	0	0	0
2	6	.302	.125	.339	.139	.094	.211	.109	.224	.120	.085
3	11	.331	.261	.108	.185	.115	.221	.193	.096	.151	.102

v	μ_v	σ_v	$x_{.v}$	$(x_{.v}-\mu_v)/\sigma_v$
1 (Ca)	5.45	1.92	3	−1.28
2 (Ch)	3.62	1.67	2	− .97
3 (Ci)	3.22	1.55	5	+1.15
4 (P)	2.87	1.54	1	−1.21
5 (E)	3.83	1.28	8	+3.27

scape effects exist if tourism is taken into account. The corresponding P values for the years 1974, 1975, 1977, 1978 and 1979 were .0346, .0137, .0413, .0054 and .1236. These values are so small that they point into the same direction. However, for the years 1974, 1975, 1977, 1978 and 1979 not type $v = 5$ (Ca) but type $v = 3$ (Ci) was most attractive. Table 46 seems to provide sufficient evidence for rejecting the null-hypothesis but the above-mentioned inconsistency weakens the evidence. Note that the tests were carried out without a correction for continuity. If such correction were applied then

$P(X_{.5} \geqq 7\frac{1}{2}) \approx P(N \geqq 7\frac{1}{2}) = P(U \geqq \sigma_5^{-1}(7\frac{1}{2}-\mu_5)) = P(U \geqq +3.27) = .00205$

is obtained for 1976. Of course a two-sided test is required. Hence .00410 should be compared with the approximation .00128 without continuity correction. Now .00410 is still smaller than $\alpha/5$ and hence the evidence in table 51 should be regarded as sufficient to reject the null-hypothesis. The corresponding approximations with continuity correction for the years 1974, 1975, 1977, 1978 were .0768, .0324, .0970 and .0187. If the P value for the most significant year (.0054 × 5) is multiplied by the number of years (.0054 × 25 = .135), then a value $> \alpha = .05$ is obtained. Hence it remains doubtful whether table 46 provides suf-

TABLE 53. Landscape-tourism data for the Curlew on plot 6 in 1974.

	Landscape-type				
	1 (Ca)	2 (Ch)	3 (Ci)	4 (P)	5 (E)
Tourism	$x_{11}=1$	$x_{12}=0$	$x_{13}=0$	$x_{14}=1$	$x_{15}=5$
zone 1	$\omega_{11}=135416$	$\omega_{12}=0$	$\omega_{13}=254166$	$\omega_{14}=154166$	$\omega_{15}=194583$
Tourism	$x_{21}=0$	$x_{22}=0$	$x_{23}=0$	$x_{24}=0$	$x_{25}=0$
zone 2	$\omega_{21}=243750$	$\omega_{22}=0$	$\omega_{23}=0$	$\omega_{24}=37499$	$\omega_{25}=0$
Tourism	$x_{31}=1$	$x_{32}=0$	$x_{33}=4$	$x_{34}=2$	$x_{35}=0$
zone 3	$\omega_{31}=345832$	$\omega_{32}=120832$	$\omega_{33}=433334$	$\omega_{34}=219916$	$\omega_{35}=53291$

TABLE 54. Evaluation of table 53.

u	$x_{u.}$	p_{u1}	p_{u2}	p_{u3}	p_{u4}	p_{u5}	$p_{u1}-p_{u1}^2$	$p_{u2}-p_{u2}^2$	$p_{u3}-p_{u3}^2$	$p_{u4}-p_{u4}^2$	$p_{u5}-p_{u5}^2$
1	7	.183	0	.344	.209	.264	.149	0	.226	.165	.195
2	0	.867	0	0	.133	0	.116	0	0	.115	0
3	7	.295	.103	.369	.187	.045	.208	.092	.233	.152	.043

v	μ_v	σ_v	$x_{.v}$	$(x_{.v}-\mu_v)/\sigma_v$
1 (Ca)	3.35	1.58	2	− .85
2 (Ch)	.72	.80	0	− .90
3 (Ci)	4.99	1.79	4	− .55
4 (P)	2.77	1.49	3	+ .15
5 (E)	2.16	1.29	5	+2.20

ficient evidence to reject the null-hypothesis. For 1976 the confidence intervals [1.65, 85.5],[1.25, 90], [.6, 67] and [1.35, 107] for the parameters β_5/β_1, β_5/β_2, β_5/β_3, β_5/β_4 and β_3/β_4 suggest that landscape type 5 (E = Vegetations dominated by Oxycoccus macrocarpos and locally Salix repens in wet to damp valleys) is more attractive than types 1 (Ca = *Corynephorion* with open, very low vegetation), 2 (Ch = *Corynephorion* with scattered, low *Hippophaë* shrubs) and 4 (P = Vegetations dominated by *Empetrum nigrum*), but this preference for type 5 is not confirmed if other years are considered. Hence some effect of the landscape seems to be present but the evidence is not very convincing and hence no interpretations are made.

For plot 6 the data in table 53 is taken from table 46 and used along the lines of section 4.2. Accordingly table 54 is derived from table 53 and shows that the absolute value of the deviation $(x_{.v}-\mu_v)/\sigma_v$ is maximal if $v = 5$. Its value 2.20 is such that $P(|U| > 2.20) = .02787$. However, the maximum absolute value, being taken from 5 landscape types, should be significant at the level $\alpha/5$. The observed value $P(|U| > 2.20) = .02787$ is larger than $\alpha/5$. The corresponding P values for the years 1975, 1976, 1977, 1978 and 1979 were .2696, .0587, .0671, .0376 and .2460. Hence 1974 is indeed the 'most significant' year and the corresponding value $.028 > \alpha/5$ if $\alpha = .05$. Hence table 46 does not provide sufficient evidence to reject the null-hypothesis. Note that the tests were carried out without a correction for continuity. If such correction were applied then
$P(X_{.5} \geq 4\frac{1}{2}) \approx P(N \geq 4\frac{1}{2}) = P(U \geq \sigma_5^{-1}(4\frac{1}{2}-\mu_5) = P(U \geq +1.81) = .0351$
is obtained for 1974. Of course a two-sided test is required. Hence .0702 should be used instead of .02787 which was the approximation without continuity correction. This shows that there is hardly any evidence for deviations from the null-hypothesis and certainly not 'sufficient' evidence.

Summarizing the results for plots 5 and 6 no proof for the existence of landscape effects could be obtained though slight indications are available. Note that GLUTZ VON BLOTZHEIM et al. (1977) state that, in coastal areas, the Curlew prefers grey dunes ('Graudünen') with *Corynephorus canescens*, *Salix repens*, solitary shrubs of *Hippophaë rhamnoides* or brown dunes ('Braundünen') with

Calluna vulgaris and *Empetrum nigrum*, but these authors use another classification of the landscapes.

5.5. Redshank

5.5.1. *Does tourism have an effect if the landscape is taken into account?*

The data in table 56 is taken from table 55 and used along the lines of section 5.2. Accordingly table 57 is derived from table 56. The critical level is determined by

$P_0(X_{1.}-X_{3.} \geqq 2-0 | X_{.1} = 0, \ldots, X_{.3} = 2) \approx P(N \geqq 1\frac{1}{2})$

where N has the normal distribution with expectation μ and variance σ^2. Hence

$P(N \geqq 1\frac{1}{2}) = P\{U \geqq (1\frac{1}{2}-\mu)/\sigma\} = P(U \geqq +4.82) < .0003$

is obtained. Hence table 56 provides ample evidence to reject the null-hypothesis that no tourism effects exist if the landscape is taken into account. The corresponding P values for the years 1975, 1976, 1977 and 1978 were .1932, .00118, <.0003 and <.0003. These values don't suggest that rejection of the null-hypothesis is incorrect. For 1979 the confidence intervals [.9, ∞], [.1, >100] and [13.5, ∞] for the parameters α_1/α_3, α_1/α_2 and α_2/α_3 were computed, indicating that $\alpha_1, \alpha_2 > \alpha_3$ or in other words that zone 3 is less attractive than the other zones. It is tempting to conclude that this is caused by zone 3, being the most visited zone. Looking at the data it looks as if some kind of concentration of nest

Table 55. Landscape-tourism data for the Redshank.

			Study-plot 5					Study-plot 6				
			Landscape type					Landscape type				
			Ca	Ch	Ci	P	E	Ca	Ch	Ci	P	E
Tourism zone	1	1975	0	0	0	0	1	0	0	0	8	12
		1976	0	0	0	0	1	0	0	0	10	8
		1977	0	0	0	0	0	0	0	0	8	12
		1978	0	0	0	0	1	0	0	0	14	10
		1979	0	0	0	0	2	0	0	0	12	3
		Area	0	0	0	0	56250	135416	0	254166	154166	194583
	2	1975	0	0	0	6	0	0	0	0	1	0
		1976	1	0	0	10	0	0	0	0	0	0
		1977	0	0	0	13	0	0	0	0	1	0
		1978	0	0	0	7	0	0	0	0	0	0
		1979	0	0	0	7	0	0	0	0	1	0
		Area	226625	0	0	104063	70625	243750	0	0	37499	0
	3	1975	7	0	0	3	0	0	0	1	1	1
		1976	2	0	0	4	0	0	0	3	0	1
		1977	1	0	0	0	0	0	0	2	2	1
		1978	0	0	0	0	0	0	0	1	3	0
		1979	0	0	0	0	0	0	0	0	5	0
		Area	563300	0	0	314227	196040	345832	0	433334	219916	53291

sites appears. This of course could explain significance because all our theory is based on the assumption of independent behaviour of different pairs. Note that colony forming under the Redshank is not mentioned in the literature.

For plot 6 the data in table 58 is taken from table 55 and also evaluated along the lines of section 5.2. Accordingly table 59 is derived from table 58. The critical level is determined by

$P_0(X_{1.}-X_{3.} \geqq 24-4 | X_{.1} = 0, \ldots, X_{.4} = 1) \approx P(N \geqq 19\frac{1}{2})$

where N has the normal distribution with expectation μ and variance σ^2. Hence

$P(N \geqq 19\frac{1}{2}) = P\{U \geqq (19\frac{1}{2}-\mu)/\sigma\} = P(U \geqq +3.52) < .0003$

is obtained. The value $< .0003$ is significant for any reasonable value of α. Table 58 provides sufficient evidence to reject the null-hypothesis that no tourism effects exist if the landscape is taken into account. The corresponding P values for the years 1975, 1976, 1977 and 1979 were .0055, .0053, .0190 and .0059. Hence there is no reason to believe that rejection of the null-hypothesis was incorrect. For 1978 the confidence interval [2.55, 20.2] for the parameter α_1/α_3 was computed, indicating that zone 1 is more attractive than zone 3. Note that zone 3 will be most frequently visited. For 1979 the confidence intervals [1.4, 16], [.8, 51] and [.1, 14.3] were computed for the parameters α_1/α_3, α_1/α_2 and α_2/α_3. They indicate that zone 1 is more attractive than zones 2 and 3. This result is similar to that for plot 5.

Summarizing the results for plots 5 and 6 we see that tourism effects certainly exist.

TABLE 56. Tourism-landscape data for the Redshank on plot 5 in 1979.

	Landscape-type			Totals
	1 (Ca)	2 (P)	3 (E)	
Tourism zone 1	$x_{11}=0$ $\omega_{11}=0$	$x_{12}=0$ $\omega_{12}=0$	$x_{13}=2$ $\omega_{13}=56250$	$x_{1.}=2$ $\omega_{1.}=56250$
Tourism zone 2	$x_{21}=0$ $\omega_{21}=226625$	$x_{22}=7$ $\omega_{22}=104063$	$x_{23}=0$ $\omega_{23}=70625$	$x_{2.}=7$ $\omega_{2.}=401313$
Tourism zone 3	$x_{31}=0$ $\omega_{31}=563300$	$x_{32}=0$ $\omega_{32}=314227$	$x_{33}=0$ $\omega_{33}=196040$	$x_{3.}=0$ $\omega_{3.}=1073567$
Totals	$x_{.1}=0$ $\omega_{.1}=789925$	$x_{.2}=7$ $\omega_{.2}=418290$	$x_{.3}=2$ $\omega_{.3}=322915$	$x_{..}=9$ $\omega_{..}=1531130$

TABLE 57. Evaluation of table 56.

$x_{.1}=0$	$x_{.2}=7$	$x_{.3}=2$
$\omega_{.1}=789925$	$\omega_{.2}=418290$	$\omega_{.3}=322915$
$x_{1.}=2$	$x_{2.}=7$	$x_{3.}=0$
$p_{11}=0$	$p_{12}=0$	$p_{13}=.174$
$p_{31}=.713$	$p_{32}=.751$	$p_{33}=.607$
$\mu=-6.12$	$\sigma^2=2.49$	$\sigma=1.58$

TABLE 58. Tourism-landscape data for the Redshank on plot 6 in 1979.

	Landscape-type			
	1 (Ca)	2 (P)	3 (E)	4 (Ci)
Tourism	$x_{11}=0$	$x_{12}=12$	$x_{13}=3$	$x_{14}=0$
zone 1	$\omega_{11}=135416$	$\omega_{12}=154166$	$\omega_{13}=194583$	$\omega_{14}=254166$
Tourism	$x_{21}=0$	$x_{22}=1$	$x_{23}=0$	$x_{24}=0$
zone 2	$\omega_{21}=243750$	$\omega_{22}=37499$	$\omega_{23}=0$	$\omega_{24}=0$
Tourism	$x_{31}=0$	$x_{32}=5$	$x_{33}=0$	$x_{34}=0$
zone 3	$\omega_{31}=345832$	$\omega_{32}=219916$	$\omega_{33}=53291$	$\omega_{34}=433334$

TABLE 59. Evaluation of table 58.

$x_{.1}=0$	$x_{.2}=18$	$x_{.3}=3$	$x_{.4}=0$
$\omega_{.1}=724998$	$\omega_{.2}=411581$	$\omega_{.3}=247874$	$\omega_{.4}=687500$
$x_{1.}=15$	$x_{2.}=1$	$x_{3.}=5$	
$p_{11}=.187$	$p_{12}=.375$	$p_{13}=.785$	$p_{14}=.370$
$p_{31}=.477$	$p_{32}=.534$	$p_{33}=.215$	$p_{34}=.630$
$\mu=-1.17$	$\sigma^2=17.93$	$\sigma=4.23$	

5.5.2. *Does the landscape have an effect if tourism is taken into account?*

The data in table 60 is taken from table 55 and used along the lines of section 4.2. Accordingly table 61 is derived from table 60 and shows that the absolute value of the deviation $(x_{.v}-\mu_v)/\sigma_v$ is maximal if $v=2$. Its value 5.13 is such that $P(|U|>5.13)<.0006$. Hence table 60 seems to provide ample evidence to reject the null-hypothesis that no landscape effects exist if tourism is taken into account. The corresponding P values for the years 1975, 1977, 1978 and 1979 were .0119, <.0006, <.0006 and <.0006. Hence table 55 also provides sufficient evidence for rejecting the null-hypothesis. Note that the tests were carried out without a correction for continuity. If such a test is applied for 1976, 1977, 1978

TABLE 60. Landscape-tourism data for the Redshank on plot 5 in 1976.

	Landscape-type			Totals
	1 (Ca)	2 (P)	3 (E)	
Tourism	$x_{11}=0$	$x_{12}=0$	$x_{13}=1$	$x_{1.}=1$
zone 1	$\omega_{11}=0$	$\omega_{12}=0$	$\omega_{13}=56250$	$\omega_{1.}=56250$
Tourism	$x_{21}=1$	$x_{22}=10$	$x_{23}=0$	$x_{2.}=11$
zone 2	$\omega_{21}=226625$	$\omega_{22}=104063$	$\omega_{23}=70625$	$\omega_{2.}=401313$
Tourism	$x_{31}=2$	$x_{32}=4$	$x_{33}=0$	$x_{3.}=6$
zone 3	$\omega_{31}=563300$	$\omega_{32}=314227$	$\omega_{33}=196040$	$\omega_{3.}=1073567$
Totals	$x_{.1}=3$	$x_{.2}=14$	$x_{.3}=1$	$x_{..}=18$
	$\omega_{.1}=789925$	$\omega_{.2}=418290$	$\omega_{.3}=322915$	$\omega_{..}=1531130$

TABLE 61. Evaluation of table 60.

u	$x_{u.}$	p_{u1}	p_{u2}	p_{u3}	$p_{u1}-p_{u1}^2$	$p_{u2}-p_{u2}^2$	$p_{u3}-p_{u3}^2$
1	1	0	0	1	0	0	0
2	11	.565	.259	.176	.246	.192	.145
3	6	.525	.293	.183	.249	.207	.150

v	μ_v	σ_v	$x_{.v}$	$(x_{.v}-\mu_v)/\sigma_v$
1 (Ca)	9.37	2.05	3	−3.10
2 (P)	4.61	1.83	14	+5.13
3 (E)	4.03	1.58	1	−1.92

TABLE 62. Landscape-tourism data for the Redshank on plot 6 in 1979.

	Landscape type			
	1 (Ca)	2 (P)	3 (E)	4 (Ci)
Tourism zone 1	$x_{11}=0$ $\omega_{11}=135416$	$x_{12}=12$ $\omega_{12}=154166$	$x_{13}=3$ $\omega_{13}=194583$	$x_{14}=0$ $\omega_{14}=254166$
Tourism zone 2	$x_{21}=0$ $\omega_{21}=243750$	$x_{22}=1$ $\omega_{22}=37499$	$x_{23}=0$ $\omega_{23}=0$	$x_{24}=0$ $\omega_{24}=0$
Tourism zone 3	$x_{31}=0$ $\omega_{31}=345832$	$x_{32}=5$ $\omega_{32}=219916$	$x_{33}=0$ $\omega_{33}=53291$	$x_{34}=0$ $\omega_{34}=433334$

TABLE 63. Evaluation of table 62.

u	$x_{u.}$	p_{u1}	p_{u2}	p_{u3}	p_{u4}	$p_{u1}-p_{u1}^2$	$p_{u2}-p_{u2}^2$	$p_{u3}-p_{u3}^2$	$p_{u4}-p_{u4}^2$
1	15	.183	.209	.264	.344	.149	.165	.195	.226
2	1	.867	.133	0	0	.116	.115	0	0
3	5	.329	.209	.051	.412	.221	.165	.048	.242

v	μ_v	σ_v	$x_{.v}$	$(x_{.v}-\mu_v)/\sigma_v$
1 (Ca)	5.26	1.86	0	− 2.83
2 (P)	4.31	1.85	18	+ 7.40
3 (E)	4.22	1.78	3	− .69
4 (Ci)	7.22	2.14	0	−3.37

and 1979 then everything is still extremely significant. The confidence intervals [3.15, 81.5], [.35, > 100] and [2.7, > 100] for the parameters β_2/β_1, β_1/β_3 and β_2/β_3 in the year 1976 were computed and indicate that landscape type 2 (P = Vegetations dominated by *Empetrum nigrum*) is more attractive than type 1 (Ca = *Corynephorion* with open, very low vegetation) and 3 (E = Vegetations dominated by *Oxycoccus macrocarpos* and locally *Salix repens*). GROSSKOPF (1959, 1963) states that the Redshank also prefers dry areas (e.g. dunes with 'Silbergras-Fluren *Corynephoretea canescentis* der Graudünen' along the North

Sea coast) if a tidal zone with a favourable food supply is in the vicinity.

For plot 6 the data in table 62 is taken from table 55 and also evaluated along the lines of section 4.2. Accordingly table 63 is derived from table 62 and shows that the absolute value of the deviation $(x_{.v}-\mu_v)/\sigma_v$ is maximal if $v = 2$. Its value 7.40 is such that $P(|U| > 7.40 < .0006$. Hence table 62 seems to provide sufficient evidence to reject the null-hypothesis that no landscape effects exist if tourism is taken into account. The corresponding P values, based on a continuity correction, for the years 1975, 1976, 1977 and 1978 were $<.0006$, .0047, $<.0006$ and $<.0006$. Hence table 55 provides ample evidence for rejecting the null-hypothesis. The confidence intervals [4.1, ∞], [2.1, 42], [1.65, ∞], [7.05, ∞[and [.35, ∞] for the parameters β_2/β_1, β_2/β_3, β_3/β_4, β_2/β_4 and β_3/β_1 were computed. They indicate that type 2 (P = Vegetations dominated by *Empetrum nigrum*) is more attractive than landscape types 1 (Ca = *Corynephorion* with open, very low vegetation), 3 (E = Vegetations dominated by *Oxycoccus macrocarpos* and locally *Salix repens*) and 4 (Ci = *Corynephorion* with many *Salix arenaria* shrubs), which was in line with the results for plot 5. Types 2 and 3 are more attractive than type 4. Note that it looks as if some kind of concentration of nest sites appears.

Summarizing the results for plots 5 and 6, our interpretation is that landscape type 2(P) is preferred over most other ones, though plot 6 in 1975 and 1977 shows that type E may be a serious competitor for P.

6. THE INTERACTION BETWEEN ALTITUDE AND TOURISM IN RELATION TO DENSITIES OF BREEDING WADERS

6.1. Introduction and summary

In section 3.4 effects of the altitude were established and in section 3.5 also of tourism. Now altitude-tourism interaction is investigated in order to find out whether the effects of one factor can be explained as caused by the other one. If the effects of a factor cannot be explained in this way, then they will be estimated by means of confidence intervals. The statistical analysis is based on the theory in section 5.2.

Oystercatcher results. The evidence for the existence of tourism effects, if the altitude is taken into account, is sufficient for plot 3; the confidence intervals [3.85, 20.3] and [3.4, 76.9] for the parameters α_1/α_2 and α_1/α_3 indicate that zone 1 (the quiet zone) is more attractive than zones 2 and 3. Note that zone 3 is the zone along paved paths. Plot 4 does not provide sufficient evidence.

For the reverse problem the evidence for rejecting the null-hypothesis is sufficient both for plot 3 and plot 4. The confidence intervals [1.7, ∞] and [2.95, >100] for the parameters β_3/β_1 and β_3/β_2 show that altitude class 3 (7.5–10 m) is more attractive than the classes 1 (<5 m) and 2 (5–7.5 m). The corresponding confidence intervals [5.65, >100] and [3.05, 80.5] for plot 4 have the same interpretation.

Curlew results. The evidence for rejecting the null-hypothesis that no tourism effects exist if the altitude is taken into account is sufficient for the 1979 data of plots 5 and 6. The corresponding confidence intervals [1.9, >100] and [2.55, >100] for the parameter α_1/α_3 indicate that tourism zone 3 (the zone along paved paths) is less attractive than zone 1 (the quiet zone). For the other investigated years no sufficient evidence exists.

For the reverse problem no evidence exist for rejecting the null-hypothesis.

Redshank results. The null-hypothesis that no tourism effects exist if the altitude is taken into account can be rejected both for plot 5 and plot 6. The confidence intervals [1.9, ∞] and [2.5, 19.5] for the parameter α_1/α_3 indicate that tourism zone 1 (the quiet one) is more attractive than zone 3 (the zone along paved paths).

On the other hand there also exist altitude effects if tourism is taken into account, at least for plot 6 where the confidence interval [12.1, 69.7] for β_1/β_2 indicates that altitude class 1 (<5 m) is much more attractive than class 2 (5–7.5 m). Plot 5 shows no significant results.

In section 3.4 effects of altitude were established and in section 5.3 also of tourism. Using the theory in section 5.2, the interaction between altitude and tourism is investigated in order to find out whether the effects of one factor can be explained as caused by the effects of the other one.

6.3. OYSTERCATCHER

6.3.1. *Does tourism have an effect if the altitude is taken into account?*

The data in table 64 is used along the lines of section 5.2. Hence table 65 is derived from table 64 and table 66 from table 65. The critical level is determined by

$P_0(X_{1.}-X_{3.} \geqq 9-12 \mid X_{.1} = 0, \ldots, X_{.4} = 24) \approx P(N \geqq -3\frac{1}{2})$

where N has the normal distribution with expectation μ and variance σ^2. Hence

$P(N \geqq -3\frac{1}{2}) = P\{U \geqq (-3\frac{1}{2}-\mu)/\sigma\} = P(U \geqq +3.69) < .0003$

is obtained. The value $<.0003$ is significant at the level α for any reasonable α. Hence table 65 provides ample evidence to reject the null-hypothesis that no tourism effects exist if the altitude is taken into account. The corresponding P values for the years 1974, 1975 and 1977 were $<.0003$, .03188 and .00094, successively. These values are smaller than α (if α = .05). Hence table 64 consistently provides ample evidence to reject the null-hypothesis. The confidence intervals [3.85, 20.3], [3.4, 76.9] and [.5, 8.85] for the parameters α_1/α_2,

TABLE 64. Altitude-tourism data for the Oystercatcher.

			Study-plot 3				Study-plot 4			
			Altitude class				Altitude class			
			1	2	3	4	1	2	3	4
		1974	0	3	0	6	0	0	9	2
		1975	0	1	0	4	0	0	16	2
	1	1976	0	2	0	7	0	0	16	2
		1977	0	2	0	9	no data (see section 5.2)			
		Area	0	2365	0	5628	11214	12989	18702	1470
		1974	0	0	6	14	0	0	0	0
Tourism		1975	0	2	3	12	0	0	0	0
zone	2	1976	0	2	2	15	0	0	0	0
		1977	0	0	5	11	0	0	0	0
		Area	365	21006	17296	112047	0	0	0	0
		1974	0	3	3	3	3	1	2	0
		1975	0	0	5	3	5	3	1	0
	3	1976	0	4	6	2	2	4	5	0
		1977	0	1	6	5	no data (see section 5.2)			
		Area	23973	33129	19335	23523	48658	35355	10764	3289

TABLE 65. Tourism-altitude data for the Oystercatcher on plot 3 in 1976.

	Altitude-class				Totals
	1 (< 5 m)	2 (5–7.5 m)	3 (7.5–10 m)	4 (> 10 m)	
Tourism	$x_{11}=0$	$x_{12}=2$	$x_{13}=0$	$x_{14}=7$	$x_{1.}=9$
zone 1	$\omega_{11}=0$	$\omega_{12}=2365$	$\omega_{13}=0$	$\omega_{14}=5628$	$\omega_{1.}=7993$
Tourism	$x_{21}=0$	$x_{22}=2$	$x_{23}=2$	$x_{24}=15$	$x_{2.}=19$
zone 2	$\omega_{21}=365$	$\omega_{22}=21006$	$\omega_{23}=17296$	$\omega_{24}=112047$	$\omega_{2.}=150714$
Tourism	$x_{31}=0$	$x_{32}=4$	$x_{33}=6$	$x_{34}=2$	$x_{3.}=12$
zone 3	$\omega_{31}=23973$	$\omega_{32}=33129$	$\omega_{33}=19335$	$\omega_{34}=23523$	$\omega_{3.}=99960$
Totals	$x_{.1}=0$	$x_{.2}=8$	$x_{.3}=8$	$x_{.4}=24$	$x_{..}=40$
	$\omega_{.1}=24338$	$\omega_{.2}=56500$	$\omega_{.3}=36631$	$\omega_{.4}=141198$	$\omega_{..}=258667$

α_1/α_3 and α_2/α_3 indicate that tourism zone 1 (the quiet zone) is much more attractive than zones 2 and 3 (the most visited zone).

For plot 4 the data is evaluated along the lines of section 5.2. Table 67 is derived from table 64 and table 68 from table 67. The critical level is determined by

$P_0(X_{1.}-X_{3.} \geqq 18-9 | X_{.1} = 5, \ldots, X_{.5} = 2) \approx P(N \geqq 8\frac{1}{2})$

where N has the normal distribution with the expectation μ and variance σ^2 obtained in table 68. Hence

$P(N \geqq 8\frac{1}{2}) = P\{N \geqq (8\frac{1}{2}-\mu)/\sigma\} = P(U \geqq +1.92) = .0274.$

The value .0274 is significant at the level $\alpha = .05$. Hence table 67 provides some evidence to reject the null-hypothesis that no tourism effects exist if the altitude is taken into account. However, table 67 corresponds with the year 1975 which was selected because it seemed most promising. The P values for the years 1974 and

TABLE 66. Evaluation of table 65.

$x_{.1}=0$	$x_{.2}=8$	$x_{.3}=8$	$x_{.4}=24$
$\omega_{.1}=24338$	$\omega_{.2}=56500$	$\omega_{.3}=36631$	$\omega_{.4}=141198$
$x_{1.}=9$	$x_{2.}=19$	$x_{3.}=12$	
$p_{11}=0$	$p_{12}=.042$	$p_{13}=0$	$p_{14}=.040$
$p_{31}=.985$	$p_{32}=.586$	$p_{33}=.528$	$p_{34}=.167$
$\mu=-11.62$	$\sigma^2=4.84$	$\sigma=2.20$	

TABLE 67. Tourism-altitude data for the Oystercatcher on plot 4 in 1975.

	Altitude-class			
	1 (< 5 m)	2 (5–7.5 m)	3 (7.5–10 m)	4 (> 10 m)
Tourism	$x_{11}=0$	$x_{12}=0$	$x_{13}=16$	$x_{14}=2$
zone 1	$\omega_{11}=11214$	$\omega_{12}=12989$	$\omega_{13}=18702$	$\omega_{14}=1470$
Tourism	$x_{31}=5$	$x_{32}=3$	$x_{33}=1$	$x_{34}=0$
zone 3	$\omega_{31}=48658$	$\omega_{32}=35355$	$\omega_{33}=10764$	$\omega_{34}=3289$

TABLE 68. Evaluation of table 67.

$x_{.1}=5$	$x_{.2}=3$	$x_{.3}=17$	$x_{.4}=2$
$\omega_{.1}=59872$	$\omega_{.2}=48344$	$\omega_{.3}=29466$	$\omega_{.4}=4759$
$x_{1.}=18$		$x_{3.}=9$	
$p_{11}=.187$	$p_{12}=.269$	$p_{13}=.635$	$p_{14}=.309$
$p_{31}=.813$	$p_{32}=.731$	$p_{33}=.365$	$p_{34}=.691$
$\mu=-.70$	$\sigma^2=22.88$	$\sigma=4.78$	

1976 were .111 and .176. These values are larger than α (if α = .05). Hence table 64 does not provide sufficient evidence to reject the null-hypothesis, though it points into the expected direction. For 1975 the confidence interval [.95, 8.6] for the parameter α_1/α_3 was computed. The product of the upper and lower bound is larger than 1. Thus the evidence points into the expected direction though it is not sufficient for definitive statements.

Summarizing the results both for plot 3 and plot 4 we see that tourism effects certainly exist, at least for plot 3, while for plot 4 strong indications, that zone 1 is more attractive than zone 3, are available, especially for 1975.

Summarizing the results we see that tourism effects certainly exist for plot 3, while it is also likely for plot 4 that zone 1 is more attractive than zone 3, especially for 1975.

SWENNEN and DE BRUYN (1980) found at Vlieland in 1977 that in a strip of 75 meter width on both sides of metalled paths and roads the density of Oystercatcher nests was 1.8/10 ha, but in a strip which borders on the 75 m strip the density was 8.8/10 ha (χ^2 = 28.45; P < .005). Likewise they found in a strip with a width of 100 m around woods a density of 2.8 pair/10 ha and in the adjacent strip a density of 9.3 pair/10 ha (χ^2 = 15.16; P<.005). They suggest that the lower density in the last-mentioned strip is caused by disturbance by human activities, because such differences were absent around woods to which the public had no access. Note that the applied test is not most powerful.

6.3.2. *Does the altitude have an effect if tourism is taken into account?*

The data in table 69 is taken from table 64 and used along the lines of section 4.2. Accordingly table 70 is derived from table 69. It shows that the absolute value of the deviation $(x_{.\nu}-\mu_\nu)/\sigma_\nu$ is maximal if $\nu = 3$. Its value 3.66 is such that $P(|U|>3.66) < .0006$. However, the maximum absolute deviation, being taken from 4 altitude classes, should be significant at the level $\alpha/4$ (if α = .05). The observed value $P(|U|>3.66) < .0006$ is smaller than $\alpha/4$ for every reasonable α. The corresponding P values for the years 1974, 1975 and 1976 were .00750, .00922 and .05, successively. Hence table 64 provides ample evidence to reject the null-hypothesis that no altitude effects exist if tourism is taken into account. Hence there is no reason to believe that rejection of the null-hypothesis is incorrect. For 1977 the confidence intervals [.05, ∞], [1.7, ∞], [2.95, >100], [.95, ∞], [1.35, 19.1] and [.9, 11.5] for β_2/β_1, β_3/β_1, β_3/β_2, β_4/β_1, β_4/β_2 and β_3/β_4 respectively were computed, indicating that altitude class 3 (7.5–10 m) is more attractive than classes 1 (<5 m), 2 (5–7.5 m) and 4 (>10 m), while 4 seems more

TABLE 69. Altitude-tourism data for the Oystercatcher on plot 3 in 1977.

	Altitude-class				Totals
	1 (< 5 m)	2 (5–7.5 m)	3 (7.5–10 m)	4 (> 10 m)	
Tourism	$x_{11}=0$	$x_{12}=2$	$x_{13}=0$	$x_{14}=9$	$x_{1.}=11$
zone 1	$\omega_{11}=0$	$\omega_{12}=2365$	$\omega_{13}=0$	$\omega_{14}=5628$	$\omega_{1.}=7993$
Tourism	$x_{21}=0$	$x_{22}=0$	$x_{23}=5$	$x_{24}=11$	$x_{2.}=16$
zone 2	$\omega_{21}=365$	$\omega_{22}=21006$	$\omega_{23}=17296$	$\omega_{24}=112047$	$\omega_{2.}=150714$
Tourism	$x_{31}=0$	$x_{32}=1$	$x_{33}=6$	$x_{34}=5$	$x_{3.}=12$
zone 3	$\omega_{31}=23973$	$\omega_{32}=33129$	$\omega_{33}=19335$	$\omega_{34}=23523$	$\omega_{3.}=99960$
Totals	$x_{.1}=0$	$x_{.2}=3$	$x_{.3}=11$	$x_{.4}=25$	$x_{..}=39$
	$\omega_{.1}=24338$	$\omega_{.2}=56500$	$\omega_{.3}=36631$	$\omega_{.4}=141198$	$\omega_{..}=258667$

TABLE 70. Evaluation of table 69.

u	$x_{u.}$	p_{u1}	p_{u2}	p_{u3}	p_{u4}	$p_{u1}-p_{u1}^2$	$p_{u2}-p_{u2}^2$	$p_{u3}-p_{u3}^2$	$p_{u4}-p_{u4}^2$
1	11	0	.296	0	.704	0	.208	0	.208
2	16	.002	.139	.115	.743	.002	.120	.102	.191
3	12	.240	.331	.193	.235	.182	.221	.156	.180

v	μ_v	σ_v	$x_{.v}$	$(x_{.v}-\mu_v)/\sigma_v$
1 (< 5 m)	2.91	1.49	0	−1.96
2 (5–7.5 m)	9.45	2.62	3	−2.46
3 (7.5–10 m)	4.16	1.87	11	+3.66
4 (> 10 m)	22.45	2.74	25	+ .93

TABLE 71. Altitude-tourism data for the Oystercatcher on plot 4 in 1976.

	Altitude-class			
	1 (< 5 m)	2 (5–7.5 m)	3 (7.5–10 m)	4 (> 10 m)
Tourism	$x_{11}=0$	$x_{12}=0$	$x_{13}=16$	$x_{14}=2$
zone 1	$\omega_{11}=11214$	$\omega_{12}=12989$	$\omega_{13}=18702$	$\omega_{14}=1470$
Tourism	$x_{21}=0$	$x_{22}=0$	$x_{23}=0$	$x_{24}=0$
zone 2	$\omega_{21}=0$	$\omega_{22}=0$	$\omega_{23}=0$	$\omega_{24}=0$
Tourism	$x_{31}=2$	$x_{32}=4$	$x_{33}=5$	$x_{34}=0$
zone 3	$\omega_{31}=48658$	$\omega_{32}=35355$	$\omega_{33}=10764$	$\omega_{34}=3289$

attractive than 2. For 1976 the confidence intervals [1.8, ∞] and [.75, 14.55] for the parameters β_3/β_1 and β_3/β_2 have a similar interpretation.

For plot 4 the data in table 71 is taken from table 64 and used along the lines of section 4.2. Accordingly table 72 is derived from table 71 and shows that the absolute value of the deviation $(x_{.v}-\mu_v)/\sigma_v$ is maximal if $v = 3$. Its value 5.23 is such that $P(|U| > 5.23) < .0006$. Hence table 71 seems to provide ample evidence

TABLE 72. Evaluation of table 71.

u	$x_{u.}$	p_{u1}	p_{u2}	p_{u3}	p_{u4}	$p_{u1}-p_{u1}^2$	$p_{u2}-p_{u2}^2$	$p_{u3}-p_{u3}^2$	$p_{u4}-p_{u4}^2$
1	18	.253	.293	.421	.033	.189	.207	.243	.032
3	11	.496	.361	.110	.034	.250	.231	.098	.033

v	μ_v	σ_v	$x_{.v}$	$(x_{.v}-\mu_v)/\sigma_v$
1 (< 5 m)	10.01	2.48	2	−3.23
2 (5–7.5 m)	9.25	2.50	4	−2.10
3 (7.5–10 m)	8.79	2.33	21	+5.23
4 (> 10 m)	.97	.97	2	+1.06

to reject the null-hypothesis that no altitude effects exist if tourism is taken into account. The corresponding P values for the years 1974 and 1975 were .00224 and <.0006. Hence there is no reason to believe that rejection of the null-hypothesis is incorrect. For 1976 the confidence intervals [.55, 82.5], [5.65, >100], [1.05, >100], [3.05, 80.5], [.7, 62.8] and [.1, 4.15] for the parameters β_2/β_1, β_3/β_1, β_4/β_1, β_3/β_2, β_4/β_2 and β_4/β_3 indicate that altitude class 3 (7.5–10 m) is more attractive than classes 1 (< 5 m) and 2 (5–7.5 m), while class 4 (> 10 m) is more attractive than class 1.

Summarizing the results for plots 3 and 4 we see that altitude effects certainly exist and that altitude classes 3 and 4 seem more attractive than the others. The interpretation of this preference might be that Oystercatchers like to have a good view in order to localise predators more quickly.

6.4. CURLEW

6.4.1. *Does tourism have an effect if the altitude is taken into account?*

The data in table 74 for study-plot 5 is taken from table 73 and used along the lines of section 5.2. Accordingly table 75 is derived from table 74 and the critical level is determined by

$P_0(X_{1.}-X_{3.} \geqq 2-1 | X_{.1} = 3, \ldots, X_{.4} = 1) \approx P(N \geqq \frac{1}{2})$

where N has the normal distribution with expectation μ and variance σ^2. Hence

$P(N \geqq \frac{1}{2}) = P\{U \geqq (\frac{1}{2}-\mu)/\sigma\} = P(U \geqq +2.84) = .0023$

is obtained. The value .0023 is significant at the level α for any reasonable α. Hence table 74 provides ample evidence to reject the null-hypothesis that no tourism effects exist if the altitude is taken into account. The corresponding P values for the years 1974, 1975, 1976, 1977 and 1978 were .3590, .0751, .2118, .0590 and .2090, successively. These values are larger than α (if $\alpha = .05$). Hence table 73 provides sufficient evidence to reject the null-hypothesis, though some doubts remain because the evidence is only slightly supported by most other years. For 1979 the confidence intervals [1.9, >100], [.25, >100] and [.7, >100] for the parameters α_1/α_3, α_1/α_2 and α_2/α_3 were computed, indicating that zones 1 (the quiet zone) and 2 are more attractive than zone 3 (the most visited zone).

TABLE 73. Altitude-tourism data for the Curlew.

			Study-plot 5				Study-plot 6			
			Altitude-class				Altitude-class			
			1	2	3	4	1	2	3	4
		1974	2	0	0	0	6	1	0	0
		1975	2	0	0	0	5	5	0	0
		1976	2	0	0	0	5	4	0	0
	1	1977	2	0	0	0	3	5	0	0
		1978	2	0	0	0	4	4	0	0
		1979	2	0	0	0	7	5	0	0
		Area	56250	0	0	0	338332	399999	0	0
		1974	0	4	0	1	0	0	0	0
		1975	1	4	0	2	0	0	0	0
		1976	2	2	0	2	0	1	0	0
Tourism	2	1977	0	3	0	2	0	1	0	0
zone		1978	0	3	0	0	0	0	0	0
		1979	1	2	0	1	0	0	0	0
		Area	105938	427000	0	216250	37499	243750	0	0
		1974	5	4	1	1	2	5	0	0
		1975	2	5	1	0	3	4	0	0
		1976	5	4	2	0	1	4	0	0
	3	1977	3	2	1	0	2	3	0	0
		1978	3	2	1	1	1	2	0	0
		1979	0	1	0	0	1	0	0	0
		Area	360268	466749	599453	274222	291957	631248	223540	26460

For plot 6 the data is also evaluated along the lines of section 5.2 by deriving tables 76 and 77 from table 73. The critical level is determined by
$P_0(X_{1.}-X_{3.} \geqq 12-1 | X_{.1} = 8, ..., X_{.4} = 0) \approx P(N \geqq 10\frac{1}{2})$
where N has the normal distribution with expectation μ and variance σ^2. Hence
$P(N \geqq 10\frac{1}{2}) = P\{U \geqq (10\frac{1}{2}-\mu)/\sigma\} = P(U \geqq +3.21) = .00068$
is obtained. This provides ample evidence to reject the null-hypothesis that no tourism effects exist if the altitude is taken into account. The corresponding P values for the years 1974, 1975, 1976, 1977 and 1978 were $>.500$, .174, .0921, .1336 and .0432. These values are, except the value .0432 for 1978, larger than α (if $\alpha = .05$). In our opinion table 73 does not provide sufficient evidence to reject the null-hypothesis, though it points into the expected direction. For the years 1974, 1975, 1976, 1977, 1978 and 1979 the confidence intervals [.4, 10.95], [.7, 13.4], [.8, 15.85], [.7, 18.85], [.9, 19.2] and [2.55, >100] for the parameter α_1/α_3 were computed, indicating that tourism zone 1 is more attractive than zone 3. For 1979 the confidence intervals [.85, ∞] and [$<.25$, >100] for the parameters α_1/α_2 and α_2/α_3 imply similar indications.

Summarizing the results for plots 5 and 6 it is not completely clear whether tourism effects exist. However, strong indications that tourism zone 1 is more

TABLE 74. Tourism-altitude data for the Curlew on plot 5 in 1979.

	Altitude-class				Totals
	1 (< 5 m)	2 (5–7.50 m)	3 (7.5–10 m)	4 (> 10 m)	
Tourism zone 1	$x_{11}=2$ $\omega_{11}=56250$	$x_{12}=0$ $\omega_{12}=0$	$x_{13}=0$ $\omega_{13}=0$	$x_{14}=0$ $\omega_{14}=0$	$x_{1.}=2$ $\omega_{1.}=56250$
Tourism zone 2	$x_{21}=1$ $\omega_{21}=105938$	$x_{22}=2$ $\omega_{22}=427000$	$x_{23}=0$ $\omega_{23}=0$	$x_{24}=1$ $\omega_{24}=216250$	$x_{2.}=4$ $\omega_{2.}=749188$
Tourism zone 3	$x_{31}=0$ $\omega_{31}=360268$	$x_{32}=1$ $\omega_{32}=466749$	$x_{33}=0$ $\omega_{33}=599453$	$x_{34}=0$ $\omega_{34}=274222$	$x_{3.}=1$ $\omega_{3.}=1700692$
Totals	$x_{.1}=3$ $\omega_{.1}=522456$	$x_{.2}=3$ $\omega_{.2}=893749$	$x_{.3}=0$ $\omega_{.3}=599453$	$x_{.4}=1$ $\omega_{.4}=490472$	$x_{..}=7$ $\omega_{..}=2506130$

TABLE 75. Evaluation of table 74.

$x_{.1}=3$	$x_{.2}=3$	$x_{.3}=0$	$x_{.4}=1$
$\omega_{.1}=522456$	$\omega_{.2}=893749$	$\omega_{.3}=599453$	$\omega_{.4}=490472$
$x_{1.}=2$	$x_{2.}=4$	$x_{3.}=1$	
$p_{11}=.108$	$p_{12}=0$	$p_{13}=0$	$p_{14}=0$
$p_{31}=.690$	$p_{32}=.522$	$p_{33}=1$	$p_{34}=.559$
$\mu=-3.87$	$\sigma^2=2.37$	$\sigma=1.54$	

TABLE 76. Tourism-altitude data for the Curlew on plot 6 in 1979.

	Altitude class			
	1 (< 5 m)	2 (5–7.50 m)	3 (7.5–10 m)	4 (> 10 m)
Tourism zone 1	$x_{11}=7$ $\omega_{11}=338332$	$x_{12}=5$ $\omega_{12}=399999$	$x_{13}=0$ $\omega_{13}=0$	$x_{14}=0$ $\omega_{14}=0$
Tourism zone 2	$x_{21}=0$ $\omega_{21}=37499$	$x_{22}=0$ $\omega_{22}=243750$	$x_{23}=0$ $\omega_{23}=0$	$x_{24}=0$ $\omega_{24}=0$
Tourism zone 3	$x_{31}=1$ $\omega_{31}=291957$	$x_{32}=0$ $\omega_{32}=631248$	$x_{33}=0$ $\omega_{33}=223540$	$x_{34}=0$ $\omega_{34}=26460$

TABLE 77. Evaluation of table 76.

$x_{.1}=8$	$x_{.2}=5$	$x_{.3}=0$	$x_{.4}=0$
$\omega_{.1}=667788$	$\omega_{.2}=1274997$	$\omega_{.3}=223540$	$\omega_{.4}=26460$
$x_{1.}=12$	$x_{2.}=0$	$x_{3.}=1$	
$p_{11}=.507$	$p_{12}=.314$	$p_{13}=0$	$p_{14}=0$
$p_{31}=.437$	$p_{32}=.495$	$p_{33}=1$	$p_{34}=1$
$\mu=-.35$	$\sigma^2=11.39$	$\sigma=3.38$	

TABLE 78. Altitude-tourism data for the Curlew on plot 5 in 1976.

	Altitude-class				Totals
	1 (< 5 m)	2 (5–7.5 m)	3 (7.5–10 m)	4 (> 10 m)	
Tourism zone 1	$x_{11}=2$ $\omega_{11}=56250$	$x_{12}=0$ $\omega_{12}=0$	$x_{13}=0$ $\omega_{13}=0$	$x_{14}=0$ $\omega_{14}=0$	$x_{1.}=2$ $\omega_{1.}=56250$
Tourism zone 2	$x_{21}=2$ $\omega_{21}=105938$	$x_{22}=2$ $\omega_{22}=427000$	$x_{23}=0$ $\omega_{23}=0$	$x_{24}=2$ $\omega_{24}=216250$	$x_{2.}=6$ $\omega_{2.}=749188$
Tourism zone 3	$x_{31}=5$ $\omega_{31}=360268$	$x_{32}=4$ $\omega_{32}=466749$	$x_{33}=2$ $\omega_{33}=599453$	$x_{34}=0$ $\omega_{34}=274222$	$x_{3.}=11$ $\omega_{3.}=1700692$
Totals	$x_{.1}=9$ $\omega_{.1}=522456$	$x_{.2}=6$ $\omega_{.2}=893749$	$x_{.3}=2$ $\omega_{.3}=599453$	$x_{.4}=2$ $\omega_{.4}=490472$	$x_{..}=19$ $\omega_{..}=2506130$

attractive than zone 3 are available, especially for 1979.

6.4.2. *Does the altitude have an effect if tourism is taken into account?*

The subject of this subsection can be studied along the lines of section 4.2. Hence table 78 is derived from table 73. Accordingly table 79, derived from table 78, shows that the absolute value of the deviation $(x_{.v}-\mu_v)/\sigma_v$ is maximal if $v = 1$. The deviation $+2.39$ is such that $P(|U|>2.39 = .0170$. Note that the maximum was taken for 4 altitude classes. The maximum absolute value should be significant at the level $\alpha/4$ (if $\alpha = .05$). The observed value $P(|U|>2.39 = .0170$. Note that the maximum was taken for 4 altitude classes. The maximum absolute value should be significant at the level $\alpha/4$ (if $\alpha = .05$). The observed value $P(|U|>2.39 = .0170$. Note that this test was carried out without a correction for continuity. If such correction were applied to the 1976 data then
$P(X_{.1} \geqq 8\frac{1}{2}) \approx P(N \geqq 8\frac{1}{2}) = P(U \geqq \sigma_1^{-1}(8\frac{1}{2}-\mu_1) = P(U \geqq +2.08) = .0188$
is obtained. Of course a two-sided test is required. Now .0376 is larger than $\alpha/4$ and hence table 78 does not provide sufficient evidence to reject the null-hypothesis. For 1976 the confidence intervals [.7, 58], [.9, 87.5] and [.9, > 100] for the parameters β_1/β_2, β_1/β_3 and β_1/β_4 were computed, indicating that altitude

TABLE 79. Evaluation of table 78.

u	$x_{u.}$	p_{u1}	p_{u2}	p_{u3}	p_{u4}	$p_{u1}-p_{u1}^2$	$p_{u2}-p_{u2}^2$	$p_{u3}-p_{u3}^2$	$p_{u4}-p_{u4}^2$
1	2	1	0	0	0	0	0	0	0
2	6	.141	.570	0	.289	.121	.246	0	.206
3	11	.212	.274	.352	.161	.167	.199	.228	.135

v	μ_v	σ_v	$x_{.v}$	$(x_{.v}-\mu_v)/\sigma_v$
1 (< 5 m)	5.18	1.60	9	+2.39
2 (5–7.5 m)	6.43	1.91	6	− .23
3 (7.5–10 m)	3.87	1.58	2	−1.18
4 (> 10 m)	3.51	1.65	2	− .91

class 1 (< 5 m) might be more attractive than classes 3 (7.5–10 m) and 4 (> 10 m).

No significant results were obtained for plot 6 and hence no evaluation tables are presented.

Summarizing the results for plots 5 and 6 it is not clear whether altitude effects exist, though indications are available.

6.5. Redshank

6.5.1. *Does tourism have an effect if the altitude is taken into account?*

The data in table 81 is taken from table 80 and used along the lines of section 5.2. Accordingly table 82 is derived from table 81 and the critical level is determined by

$P_0(X_{1.}-X_{3.} \geqq 2-0 | X_{.1} = 4, \ldots, X_{.4} = o) \approx P(N \geqq 1\frac{1}{2})$

where N has the normal distribution with expectation μ and variance σ^2, presented in table 82. Hence

$P(N \geqq 1\frac{1}{2}) = P\{U \geqq (1\frac{1}{2}-\mu)/\sigma\} = P(U \geqq +3.66) < .0003$

is obtained. This value is smaller than α, even if $\alpha = .0005$. Hence table 81 provides ample evidence to reject the null-hypothesis that no tourism effects exist if the altitude is taken into account.

The corresponding P values for the years 1975, 1976, 1977 and 1978 were

Table 80. Tourism-altitude data for the Redshank.

			Study-plot 5				Study-plot 6			
			Altitude class				Altitude class			
			1	2	3	4	1	2	3	4
Tourism zone	1	1975	1	0	0	0	14	6	0	0
		1976	1	0	0	0	13	5	0	0
		1977	0	0	0	0	17	3	0	0
		1978	1	0	0	0	24	0	0	0
		1979	2	0	0	0	10	5	0	0
		Area	56250	0	0	0	338332	399999	0	0
	2	1975	3	3	0	0	1	0	0	0
		1976	2	8	0	1	0	0	0	0
		1977	3	10	0	0	1	0	0	0
		1978	1	6	0	0	0	0	0	0
		1979	2	5	0	0	1	0	0	0
		Area	105938	427000	0	216250	37499	243750	0	0
	3	1975	0	3	7	0	3	0	0	0
		1976	0	4	1	1	3	1	0	0
		1977	0	0	0	1	3	2	0	0
		1978	0	0	0	0	3	1	0	0
		1979	0	0	0	0	2	3	0	0
		Area	360268	466749	599453	274222	291957	631248	223540	26460

TABLE 81. Tourism-altitude data for the Redshank on plot 5 in 1979.

	Altitude class				Totals
	1 (< 5 m)	2 (5–7.5 m)	3 (7.5–10 m)	4 (> 10 m)	
Tourism	$x_{11}=2$	$x_{12}=0$	$x_{13}=0$	$x_{14}=0$	$x_{1.}=2$
zone 1	$\omega_{11}=56250$	$\omega_{12}=0$	$\omega_{13}=0$	$\omega_{14}=0$	$\omega_{1.}=56250$
Tourism	$x_{21}=2$	$x_{22}=5$	$x_{23}=0$	$x_{24}=0$	$x_{2.}=7$
zone 2	$\omega_{21}=105938$	$\omega_{22}=427000$	$\omega_{23}=0$	$\omega_{24}=216250$	$\omega_{2.}=749188$
Tourism	$x_{31}=0$	$x_{32}=0$	$x_{33}=0$	$x_{34}=0$	$x_{3.}=0$
zone 3	$\omega_{31}=360268$	$\omega_{32}=466749$	$\omega_{33}=599453$	$\omega_{34}=274222$	$\omega_{3.}=1700692$
Totals	$x_{.1}=4$	$x_{.2}=5$	$x_{.3}=0$	$x_{.4}=0$	$x_{..}=9$
	$\omega_{.1}=522456$	$\omega_{.2}=893749$	$\omega_{.3}=599453$	$\omega_{.4}=490472$	$\omega_{..}=2506130$

TABLE 82. Evaluation of table 81.

$x_{.1}=4$	$x_{.2}=5$	$x_{.3}=0$	$x_{.4}=0$
$\omega_{.1}=522456$	$\omega_{.2}=893749$	$\omega_{.3}=599453$	$\omega_{.4}=490472$
$x_{1.}=2$	$x_{2.}=7$	$x_{3.}=0$	
$p_{11}=.108$	$p_{12}=0$	$p_{13}=0$	$p_{14}=0$
$p_{31}=.690$	$p_{32}=.522$	$p_{33}=1$	$p_{34}=.559$
$\mu=-4.94$	$\sigma^2=3.08$	$\sigma=1.76$	

.0526, .0179, .0015 and .0010. These values, except the value .0526 for 1975, don't suggest that rejection of the null-hypothesis is incorrect. For 1979 the confidence intervals [1.9, ∞], [2.7, ∞] and [.1, 19.5] for the parameters α_1/α_3, α_2/α_3 and α_1/α_2 were computed. They indicate that tourism zones 1 (the quiet zone) and 2 are more attractive than zone 3 (the most visited zone). Looking at the data it looks as if some kind of concentration of nest sites appears. This of course could explain significance because all our theory is based on the assumption of independent behaviour of different pairs.

For plot 6 the data is also evaluated along the lines of section 5.2. Table 83 is derived from table 80 and table 84 from table 83. The critical level is determined by

$$P_0(X_{1.}-X_{3.} \geqq 24-4 | X_{.1} = 27, \ldots, X_{.4} = 0) \approx P(N \geqq 19\tfrac{1}{2})$$

TABLE 83. Tourism-altitude data for the Redshank on plot 6 in 1978.

	Altitude class			
	1 (< 5 m)	2 (5–7.5 m)	3 (7.5–10 m)	4 (> 10 m)
Tourism	$x_{11}=24$	$x_{12}=0$	$x_{13}=0$	$x_{14}=0$
zone 1	$\omega_{11}=338332$	$\omega_{12}=399999$	$\omega_{13}=0$	$\omega_{14}=0$
Tourism	$x_{21}=0$	$x_{22}=0$	$x_{23}=0$	$x_{24}=0$
zone 2	$\omega_{21}=37499$	$\omega_{22}=243750$	$\omega_{23}=0$	$\omega_{24}=0$
Tourism	$x_{31}=3$	$x_{32}=1$	$x_{33}=0$	$x_{34}=0$
zone 3	$\omega_{31}=291957$	$\omega_{32}=631248$	$\omega_{33}=223540$	$\omega_{34}=26460$

TABLE 84. Evaluation of table 83.

$x_{.1}=27$	$x_{.2}=1$	$x_{.3}=0$	$x_{.4}=0$
$\omega_{.1}=667788$	$\omega_{.2}=1274997$	$\omega_{.3}=223540$	$\omega_{.4}=26460$
$x_{1.}=24$	$x_{2.}=0$	$x_{3.}=4$	
$p_{11}=.507$	$p_{12}=.314$	$p_{13}=0$	$p_{14}=0$
$p_{31}=.437$	$p_{32}=.495$	$p_{33}=1$	$p_{34}=1$
$\mu=+1.69$	$\sigma^2=26.13$	$\sigma=5.11$	

where N has the normal distribution with expectation μ and variance σ^2. Hence
$P(N \geqq 19\frac{1}{2}) = P\{U \geqq (19\frac{1}{2}-\mu)/\sigma\} = P(U \geqq +3.48) < .0003$
is obtained. Hence table 83 provides ample evidence to reject the null-hypothesis that no tourism effects exist if the altitude is taken into account. The corresponding P values for the years 1975, 1976, 1977 and 1979 were <.0028, .0028, .0021 and .0193, successively. These values are smaller than α (if $\alpha = .05$). Hence table 80 consistently provides ample evidence to reject the null-hypothesis. For 1978 the confidence intervals [2.5, 19.5], [.8, ∞] and [.1, ∞] for the parameters α_1/α_3, α_1/α_2 and α_3/α_2 were computed. They indicate that tourism zone 1 is more attractive than zone 3. For the years 1975, 1976, 1977 and 1978 the confidence intervals [3.8, 48.5], [2.55, 36.8], [1.9, 16.75] and [1.35, 15.3] for the parameter α_1/α_3 have a similar interpretation. Note that it looks as if some colony behaviour appears.

Summarizing the results for plots 5 and 6 we see that tourism effects certainly exist, and that zone 1 (the quiet zone) is more attractive than zone 3 (the zone along paved roads and paths).

6.5.2. *Does the altitude have an effect if tourism is taken into account?*

The data in table 85 is taken from table 80 and used along the lines of section 4.2. Accordingly table 86 is derived from table 85 and shows that the absolute value of the deviation $(x_{.v}-\mu_v)/\sigma_v$ is maximal if $v = 3$. Its value 2.30 is such that $P(|U| > 2.30) = .0214$. If we apply the correction for continuity then
$P(X_{.3} \geqq 6\frac{1}{2}) \approx P(N \geqq 6\frac{1}{2}) = P(U \geqq \sigma_3^{-1}(6\frac{1}{2}-\mu_3) = P(U \geqq +1.97) = .0244$

TABLE 85. Altitude-tourism data for the Redshank on plot 5 in 1975.

	Altitude class				Totals
	1 (<5 m)	2 (5–7.5 m)	3 (7.5–10 m)	4 (>10 m)	
Tourism	$x_{11}=1$	$x_{12}=0$	$x_{13}=0$	$x_{14}=0$	$x_{1.}=1$
zone 1	$\omega_{11}=56250$	$\omega_{12}=0$	$\omega_{13}=0$	$\omega_{14}=0$	$\omega_{1.}=56250$
Tourism	$x_{21}=3$	$x_{22}=3$	$x_{23}=0$	$x_{24}=0$	$x_{2.}=6$
zone 2	$\omega_{21}=105938$	$\omega_{22}=427000$	$\omega_{23}=0$	$\omega_{24}=216250$	$\omega_{2.}=749188$
Tourism	$x_{31}=0$	$x_{32}=3$	$x_{33}=7$	$x_{34}=0$	$x_{3.}=10$
zone 3	$\omega_{31}=360268$	$\omega_{32}=466749$	$\omega_{33}=599453$	$\omega_{34}=274222$	$\omega_{3.}=1700692$
Totals	$x_{.1}=4$	$x_{.2}=6$	$x_{.3}=7$	$x_{.4}=0$	$x_{..}=17$
	$\omega_{.1}=522456$	$\omega_{.2}=893749$	$\omega_{.3}=599453$	$\omega_{.4}=490472$	$\omega_{..}=2506130$

TABLE 86. Evaluation of table 85.

u	$x_{u.}$	p_{u1}	p_{u2}	p_{u3}	p_{u4}	$p_{u1}-p_{u1}^2$	$p_{u2}-p_{u2}^2$	$p_{u3}-p_{u3}^2$	$p_{u4}-p_{u4}^2$
1	1	1	0	0	0	0	0	0	0
2	6	.141	.570	0	.289	.121	.246	0	.206
3	10	.212	.274	.352	.161	.167	.199	.228	.135

v	μ_v	σ_v	$x_{.v}$	$(x_{.v}-\mu_v)/\sigma_v$
1 (< 5 m)	3.97	1.55	4	+ .02
2 (5–7.5 m)	6.16	1.86	6	− .09
3 (7.5–10 m)	3.52	1.51	7	+2.30
4 (> 10 m)	3.34	1.61	0	−2.08

TABLE 87. Evaluation of table 83.

u	$x_{u.}$	p_{u1}	p_{u2}	p_{u3}	p_{u4}	$p_{u1}-p_{u1}^2$	$p_{u2}-p_{u2}^2$	$p_{u3}-p_{u3}^2$	$p_{u4}-p_{u4}^2$
1	24	.458	.542	0	0	.248	.249	0	0
2	0	.133	.867	0	0	.115	.116	0	0
3	4	.249	.538	.191	.022	.187	.249	.155	.022

v	μ_v	σ_v	$x_{.v}$	$(x_{.v}-\mu_v)/\sigma_v$
1 (< 5 m)	11.99	2.59	27	+5.80
2 (5–7.5 m)	15.16	2.64	1	−5.36
3 (7.5–10 m)	.76	.79	0	− .97
4 (> 10 m)	.09	.30	0	− .30

is obtained. Of course a two sided-test is required. Hence .0488 should be used instead of .0214 which was the approximation without continuity correction. Now .0488 is much larger than $\alpha/4$ (note that there were four altitude classes) and hence table 85 should certainly not be regarded as sufficient for rejecting the null-hypothesis. For 1975 the confidence intervals [.9, > 100],[.9,∞],[.25, 82.5],[.75,∞] and [.75, ∞] for the parameters β_3/β_1, β_1/β_4, β_3/β_2, β_2/β_4 and β_3/β_4 suggest that altitude class 3 (7.5–10 m) is more attractive than class 1 (< 5 m), though the results are not convincing.

For plot 6 the data is evaluated along the lines of section 4.2. Table 87 is derived from table 83 and shows that the absolute value of the deviation $(x_{.v}-\mu_v)/\sigma_v$ is maximal if $v = 1$. Its value 5.80 is such that $P(|U| > 5.80) < .0006$. Hence table 83 seems to provide ample evidence to reject the null-hypothesis that no altitude effects exist if tourism is taken into account. The corresponding P values for the years 1975, 1976, 1977 and 1979 were .0008, .0030, < .0006 and .029 (.0517 with continuity correction). These values don't suggest that rejection of the null-hypothesis is incorrect. Hence table 80 provides sufficient evidence to reject the null-hypothesis. The confidence intervals [12.1, 69.7], [.75, ∞], [< .1, ∞], [< .1, ∞] and [< .1, ∞] for the parameters β_1/β_2, β_1/β_3, β_1/β_4, β_2/β_3 and β_2/β_4

in the year 1978 were computed.

Summarizing the results for plots 5 and 6 we see that altitude effects certainly exist for plot 6, while for plot 5 strong indications are available, especially for 1975.

7. STATISTICAL EVALUATION OF THE OYSTERCATCHER DATA FOR THE EXPERIMENTAL PLOTS AND OF SOME KENTISH PLOVER DATA

7.1. INTRODUCTION AND SUMMARY

For the Oystercatcher two experimental study plots were considered. During the years 1974, 1975 plot 1 was open to the public, whereas plot 2 was closed by means of no-trespassing signs. During the years 1976, 1977 the situation was reversed.

Attention will be focussed on the following statistical problems: (1) is there sufficient evidence for the statements that 'higher tourist intensity leads to lower Oystercatcher nest intensity' or equivalently 'that positive effects are caused by the no-trespassing signs', (2) if such effects are statistically significant, how should they be estimated by means of confidence intervals.

The statistical analysis to solve these problems is outlined in subsections 7.2.2 and 7.2.3.

Oystercatcher results. It looks as if some time is needed before the effects of no-trespassing signs become visible. (Note that this phenomenon is a matter of common knowledge to many bird watchers and other people dealing with field research). This may explain why the data for 1974/1976 does not lead to rejection of the null-hypothesis whereas the data for 1975/1977 does. The confidence interval [1.2, 4.1] could be obtained for the 1975/1977 data and means that if an area like plot 1 or plot 2 is closed by means of no-trespassing signs, then two years later one may expect 1.2–4.1 times as many Oystercatcher nests (the actual numbers to be obtained may be different because of chance fluctuations). Since 1977 both plots have been open to the public. The data for 1978 and 1979 are in line with the above-mentioned conclusions: the figures for plot 2 are not markedly different from those in 1976/1977 when plot 2 was also open to the public, the figures for plot 1 show a decrease when compared with those in 1976 and 1977, obviously because plot 1 was closed to the public in 1976/1977.

Kentish Plover. The numbers of Kentish Plover nests in two study plots were considered. One study plot (beach area) was open to the public, while the other (military-training grounds) was closed to the public. In order to test whether the year has an effect upon the number of Kentish Plover nests, the two above-mentioned study plots were compared.

The statistical analysis to solve this problem has already been described in section 3.2.

The theory in section 5.2. is used to test the null-hypothesis whether tourism has an effect if the distance to high tide level is taken into account and the theory in section 4.2 to test the null-hypothesis whether the distance to high tide level has an effect if tourism is taken into account.

Kentish Plover results. In the open area the evidence for effect of the year was sufficient if the most promising years 1964 and 1980 were compared, while this was not the case if the same years and the closed (military) area were compared.

Sufficient proof was obtained for tourism effects if the 1980 data were used and the distance to high tide level was taken into account. This was not the case for the 1964 data.

No sufficient evidence for effects of the distance to high tide level was obtained if tourism is taken into account.

The decline of the number of Kentish Plover nests in the open area is interpreted as the result of an increase in the number of visitors in the open area.

7.2. Oystercatcher

7.2.1. *Formulation of the statistical problem*

Consider table 88, study plots 1 and 2. During the years 1974, 1975 plot 1 was open to the public whereas plot 2 was closed by means of no-trespassing signs. During the years 1976, 1977 the situation was reversed: plot 1 was closed and plot 2 was open.

TABLE 88. Numbers of Oystercatcher (Haematopus ostralegus) nests.

	Testing Plot 1			Testing Plot 2		
	Altitude in m above sea-level			Altitude in m above sea-level		
Year	> 7.5	5–7.5	< 5	> 7.5	5–7.5	< 5
1974	2	13	4	$\boxed{1}$	$\boxed{5}$	$\boxed{0}$
1975	2	11	0	$\boxed{0}$	$\boxed{13}$	$\boxed{1}$
1976	$\boxed{4}$	$\boxed{21}$	$\boxed{3}$	0	5	1
1977	$\boxed{9}$	$\boxed{19}$	$\boxed{4}$	0	6	0
Area	1.4 ha	5.3 ha	3.3 ha	.5 ha	5.2 ha	4.3 ha

$\boxed{}$ = closed.

Note that it looks as if the number of nests almost double if a plot is closed by means of no-trespassing signs. Attention is focussed on the following statistical problems with respect to table 88: (1) Does this table provide sufficient evidence for the statement that positive effects are caused by the no-trespassing signs, (2) if the effects are statistically significant, how should they be estimated by means of confidence intervals.

Return behaviour inplies that one should not add figures for 1974 and 1975 together, nor for 1976 and 1977 (subsection 3.2.1). It was decided to compare the results for 1974 with those of 1976 and to make a similar comparison for the years 1975 and 1977. Tables 89 and 90 can be derived from table 88. We postulate that the y_{hij}'s are outcomes of independent random variables Y_{hij} having Poisson distribution with parameter η_{hij}. Correct interpretation of tables 89 and 90 requires that the areas (see the last row in table 88) are taken into account.

TABLE 89. Numbers of nests in 1974 and 1976.

	j = 1		j = 2		j = 3	
	i = 1	i = 2	i = 1	i = 2	i = 1	i = 2
h = 1 (1974)	$y_{111} = 2$	$y_{121} = 1$	$y_{112} = 13$	$y_{122} = 5$	$y_{113} = 4$	$y_{123} = 0$
h = 2 (1976)	$y_{211} = 4$	$y_{221} = 0$	$y_{212} = 21$	$y_{222} = 5$	$y_{213} = 3$	$y_{223} = 1$

TABLE 90. Numbers of nests in 1975 and 1977.

	j = 1		j = 2		j = 3	
	i = 1	i = 2	i = 1	i = 2	i = 1	i = 2
h = 1 (1975)	$y_{111} = 2$	$y_{121} = 0$	$y_{112} = 11$	$y_{122} = 13$	$y_{113} = 0$	$y_{123} = 1$
h = 2 (1977)	$y_{211} = 9$	$y_{221} = 0$	$y_{212} = 19$	$y_{222} = 6$	$y_{213} = 4$	$y_{223} = 0$

Moreover one should recall that the pairs (h, i) in tables 89 and 90 with $h = i$ correspond with the situation that this plot i is open to the public during this year whereas $h \neq i$ corresponds with the situation where trespassing is forbidden.

A multiplicative (or log-linear) model will be postulated for the 'intensities' or 'densities' $\lambda_{hij} = \eta_{hij}/\omega_{ij}$ where ω_{ij} denotes the area in ha of the part of plot i which belongs to altitude class j. Now it is convenient to take $\lambda_{11j} = \gamma$ as the basic intensity and (1) to multiply by a factor κ (or κ_j) if year 1 is replaced by year 2, (2) to multiply by ρ (or ρ_j) if plot 1 is replaced by plot 2, (3) to multiply by ν (or ν_j) if an area is closed by means of no-trespassing signs. Accordingly one can write

$$\begin{aligned} \lambda_{11j} &= \gamma_j & ; \lambda_{12j} &= \gamma_j \rho_j \nu_j \\ \lambda_{21j} &= \gamma_j \kappa_j \nu_j & ; \lambda_{22j} &= \gamma_j \rho_j \kappa_j \end{aligned} \tag{7.1}$$

and there exists a simple 1:1 correspondence between the original 12-dimensional parameter $(\lambda_{111}, \ldots, \lambda_{223})$ and $\theta = (\gamma_1, \rho_1, \kappa_1, \nu_1, \ldots, \nu_3)$: 'the multiplicative' model (7.1) imposes no restrictions at all. However, it seems very reasonable to impose the inequality restrictions

$$\nu_1 \geqq 1, \nu_2 \geqq 1, \nu_3 \geqq 1 \tag{7.2}$$

because keeping trespassers away will certainly not do any harm. Note that the testing problem

$$\begin{aligned} &\text{Null-hypothesis} \quad && H: \nu_1 = \nu_2 = \nu_3 = 1 \\ &\text{Alternative} && A: \nu_j \geqq 1 \ (j = 1, 2, 3) \\ & && \text{(where at least one inequality is strict)} \end{aligned} \tag{7.3}$$

for the 12-dimensional parameter $\theta = (\gamma_1,...,\nu_3)$ becomes of interest.

It was decided to construct a test which is particularly sensitive if $\nu_1 = \nu_2 = \nu_3 = \nu > 1$ where ν is an arbitrary constant. The model assumptions $\nu_1 = \nu_2 = \nu_3 = \nu$ would imply that

$$P_{(\gamma_1,\ldots,\kappa_3,\nu)}(Y_{111}=y_{111},\ldots, Y_{223}=y_{223}) =$$

$$\prod_{h,i,j} \exp(-\eta_{hij})\exp(y_{hij}\log\eta_{hij})/y_{hij}!$$

$$= c(\gamma_1,\ldots,\kappa_3,\nu)\, h(y_{111},\ldots,y_{223}) \exp \sum_{k=o}^{9} \theta_k s_k \tag{7.4}$$

where the dependence of c and h upon the areas ω_{ij} has not been expressed in the notation because these areas are given constants. The so called 'natural' parameters $\theta_k = \theta_k(\gamma_1,\ldots,\kappa_3,\nu)$ and corresponding statistics $s_k = s_k(y_{111},\ldots,y_{223})$ are given in table 91.

TABLE 91. Natural parameters and corresponding statistics.

k	θ_k	s_k	k	θ_k	s_k
0	$\log \nu$	$y_{12.} + y_{21.}$	5	$\log \rho_2$	$y_{.22}$
1	$\log \gamma_1$	$y_{..1}$	6	$\log \rho_2$	$y_{.23}$
2	$\log \gamma_2$	$y_{..2}$	7	$\log \kappa_1$	$y_{2.1}$
3	$\log \gamma_3$	$y_{..3}$	8	$\log \kappa_2$	$y_{2.2}$
4	$\log \rho_1$	$y_{.21}$	9	$\log \kappa_3$	$y_{2.3}$

7.2.2. *The construction of the test*

A test for problem (H, A) has been described in DE ROOS and SCHAAFSMA (1981). This test follows from the general theory for multiparameter exponential families. Table 91 shows that H should be rejected in favor of A if $S_0 = Y_{12.} + Y_{21.}$ is sufficiently large when tested in its conditional null-distribution given the observed outcome of $(S_1,\ldots,S_9) = (Y_{..1},\ldots,Y_{2.3})$. Note that this condition is equivalent to prescribing all marginal totals of the three 2×2 tables in table 89 or 90. Accordingly one may equally well reject for small values of $Y_{11.}$, conditionally upon the marginal totals. The conditional null-distribution of $Y_{11.} = Y_{111} + Y_{112} + Y_{113}$ is the convolution of three hypergeometric ones. The expectation μ and variance σ^2 of this conditional null-distribution of $Y_{11.}$ are

$$\mu = \sum_{j=1}^{3} Y_{1.j}\, Y_{.1j}\, Y_{..j}^{-1}$$
$$\sigma^2 = \sum_{j=1}^{3} Y_{..j}^{-2}(Y_{..j}-1)^{-1}\, Y_{1.j}\, Y_{2.j}\, Y_{.1j}\, Y_{.2j} \tag{7.5}$$

7.2.3. *Application to the data of tables 89 and 90*

For table 89 the outcome $y_{11.} = 19$ has to be tested in a discrete distribution with $\mu = 19.98$ and $\sigma = 1.56$. Let N denote a normal variable with these parameters. The approximation $\mathrm{P}(Y_{11.} \leqq 19 | \text{marginal totals}) \approx \mathrm{P}(N \leqq 19\frac{1}{2}) = \mathrm{P}\{U \leqq (19\frac{1}{2}-\mu)/\sigma\} = \mathrm{P}(U \leqq -.307) = .38 > .05$ shows that table 89 does not provide sufficient evidence for rejecting H in favor of A.

For table 90 we obtain $y_{11.} = 13$, $\mu = 17.49$, $\sigma = 1.76$ and $\mathrm{P}(N \leqq 13\frac{1}{2}) = \mathrm{P}(U < -2.267) = .0117 < .05$ shows that H has to be rejected in favor of A. The exact probability $\mathrm{P}(Y_{11.} \leqq 13 | \text{marginal totals}) = .02308$ is not too far from the above-mentioned approximation and has been computed along the lines of table 92 (with $v = 1$ instead of $v = 1.4$).

Interpretation. The non significance for 1974/1976 and clear significance for 1975/1977 suggest that some time is needed before the effects of no-trespassing signs become visible.

It seems reasonable to try to construct a confidence interval for v on the basis of table 90 and not to consider table 89 from this point of view.

The confidence interval for v will be obtained under the assumption that $v_1 = v_2 = v_3 = v$. We have to construct all values $v^{(o)}$ such that $\mathrm{H}_{v^{(o)}}: v = v^{(o)}$ is not rejected when tested against $\mathrm{A}_{v^{(o)}}: v \neq v^{(o)}$ on the basis of table 90. Again the conditional distribution of $Y_{11.}$ has to be studied, given all outcomes of the marginal totals $Y_{1.1}, \ldots, Y_{.23}$ of the three 2×2 tables in table 90. Writing v instead of $v^{(o)}$

$$\mathrm{P}_v(Y_{111} = y_{111}, Y_{112} = y_{112}, Y_{113} = y_{113} \mid Y_{1.1} = y_{1.1}, \ldots, Y_{.23} = y_{.23}) =$$

$$= \frac{\mathrm{P}_v(Y_{111} = y_{111}, Y_{121} = y_{1.1} - y_{111}, \ldots, Y_{223} = y_{113} - y_{1.3} + y_{.23})}{\sum\limits_{y_{111}, y_{112}, y_{113}} \mathrm{P}_v(Y_{111} = y_{111}, \ldots, Y_{223} = y_{113} - y_{1.3} + y_{.23})}$$

$$= \prod_{j=1}^{3} \left[v^{-2y_{11j}} \binom{y_{.1j}}{y_{11j}} \binom{y_{.2j}}{y_{1.j} - y_{11j}} \Big/ \left\{ \sum_{y_{11j}} v^{-2y_{11j}} \binom{y_{.1j}}{y_{11j}} \binom{y_{.2j}}{y_{1.j} - y_{11j}} \right\} \right]$$

is obtained by using $\eta_{11j} = \omega_{1j}$, etc. (see 7.1). Hence the conditional distribution of $Y_{11.}$, given all relevant totals, is the distribution of the sum of three independent random variables Y_{111}, Y_{112} and Y_{113} where

$$\mathrm{P}_v(Y_{11j} = y_{11j} | \text{marginal totals}) = c v^{-2y_{11j}} \binom{y_{.1j}}{y_{11j}} \binom{y_{.2j}}{y_{1.j} - y_{11j}} \quad (7.6)$$

where c is the normalizing constant such that the sum of all probabilities equals 1 (y_{11j} varying over all integers from $\max(0, y_{1.j} - y_{.2j})$ to $\min(y_{.1j}, y_{1.j})$). It is a pity that expectation and variance of these three conditional distributions do not admit simple formulas.

Application to the data of table 90. By using easier but less compelling approaches, confidence intervals like [1.4, 4.3] were obtained (DE ROOS and SCHAAFSMA, 1981). Accordingly we start out by investigating whether $\nu = 1.4$ belongs to the confidence interval, or in other words, whether $H: \nu = 1.4$ is not rejected when tested against $A: \nu \neq 1.4$. The essential figures are presented in table 92 where

$$a(y_{112}) = \log \binom{y_{.12}}{y_{112}},\ b(y_{112}) = \log \binom{y_{.22}}{y_{1.2} - y_{112}},\ c(v_{112}) = -2y_{112}\log(1.4).$$

Note that $y_{11.} = 13$ restricts the number of essential entries in table 90.

TABLE 92. Does $\nu = 1.4$ belong to the confidence interval?

$j = 1; y_{.11} = 11, y_{.21} = 0; P_\nu(Y_{111} = 2 \mid \text{marginal totals}) = 1$ for all ν
$j = 2; y_{.12} = 30, y_{.22} = 19; y_{1.2} = 24; y_{2.2} = 25$

y_{112}	8	9	10	11	...	15	16	17	18
$a(y_{112})$	6.7674	7.1556	7.4778	7.7374	...	8.1907	8.1626	8.0783	7.9370
$b(y_{112})$	2.9863	3.5884	4.0655	4.4335	...	4.9656	4.8784	4.7023	4.4335
$c(y_{112})$	-2.3381	-2.6303	-2.9226	-3.2149	...	-4.3839	-4.6762	-4.9684	-5.2607
a+b+c	7.4156	8.1136	8.6207	8.9560	...	8.7723	8.3649	7.8122	7.1098
$P(y_{112} \mid \text{marg})$	.004	.021	.067	.144	...	.094	.037	.010	.002

$j = 3; y_{.13} = 4, y_{.23} = 1, y_{1.3} = 1, y_{2.3} = 4$

$$(1.4)^{-2y_{113}} \binom{y_{.13}}{y_{113}} \binom{y_{.23}}{y_{1.3} - y_{113}} = 1\ (2.04) \text{ if } y_{113} = 0\ (1)$$

$P(Y_{113} = y_{113} \mid \text{marginal totals}) = 1/3.04 = .33\ (.67)$ if $y_{113} = 0\ (1)$

$y_{11.}$	11	12	13	...	18	19	20
$.33P(Y_{112} = y_{11.}-2 \mid \text{marg})$	.0068	.0220	.0476	...	.0122	.0034	.0007
$.67P(Y_{112} = y_{11.}-3 \mid \text{marg})$	.0028	.0139	.0446	...	.0633	.0248	.0069
$P(Y_{11.} = y_{11.} \mid \text{marg})$	.0096	.0359	.0923	...	.0755	.0282	.0076

The sum of all probabilities

$$P_{\nu=1.4}\ (Y_{11.} = y_{11.} \mid Y_{1.1} = 2, \ldots, Y_{.23} = 1)$$

smaller than or equal to that for $y_{11.} = 13$ (the observed value) is equal to .092 + .076 + .036 + .028 + .010 + .008 + ... $\geqq$ .05. Hence $H: \nu = 1.4$ is not rejected and $\nu = 1.4$ belongs to the confidence interval. By consideration of $\nu = 1.3$, $\nu = 1.2$, $\nu = 4.2$ etc. in a similar manner, the confidence interval [1.2, 4.1] for ν has been computed ($1-\alpha = .95$).

Interpretation. If an area like plot 1 or plot 2 is closed by means of no-trespassing signs, then two years later one may expect 1.2–4.1 times as many Oystercatcher nests (the actual numbers to be obtained may be different because of chance fluctuations). This would not necessarily imply that e.g. the total number of breeding pairs on the isle of Vlieland would benefit from e.g. banning tourists from the greater part of the island. The interpretation of e.g. a doubling effect might simply be that Oystercatchers move to areas where it looks as quiet as possible, e.g. nature reserves.

7.2.4. *Oystercatcher results in the study plots 1 and 2 for 1978, 1979 and 1980*

At the end of subsection 7.2.3 the interpretation of the confidence interval [1.2, 4.1] for v was discussed. Since 1977 both plots have been open to the public. The numbers of nests given in table 93 for the years 1978, 1979 and 1980 are in line with the general conclusion of previous subsections:
the figures for plot 2 are not markedly different from those in 1976 and 1977 when plot 2 was open to the public, while the figures for plot 1 show a decrease if compared with those in 1976 and 1977, obviously because plot 1 was closed to the public in those years (see table 88). This shows that removal of the fence results in a decrease of the number of Oystercatcher nests in the consecutive years.

TABLE 93. Extension of table 88 for 1978, 1979 and 1980.

	Testing plot 1 ($i=1$)			Testing plot 2 ($i=2$)		
	$j=1$ (> 7.5 m)	$j=2$ (5–7.5 m)	$j=3$ (< 5 m)	$j=1$ (> 7.5 m)	$j=2$ (5–7.5 m)	$j=3$ (< 5 m)
1978	4	14	2	0	5	0
1979	4	9	1	0	3	0
1980	3	10	2	1	5	0

7.3. KENTISH PLOVER

7.3.1. *Does the year have an effect upon the number of Kentish Plover nests?*

The theory of section 3.2 is used and the data is presented in table 94.

TABLE 94. High tide level-tourism data for the Kentish Plover at Vlieland.

	Closed (military) area		Area open to the public	
	Distance to high tide level		Distance to high tide level	
	< 50 m	> 50 m	< 50 m	> 50 m
1964	1	5	6	8
1976	1	4	0	0
1977	0	4	0	1
1978	0	4	0	1
1979	0	4	0	0
1980	0	4	0	0
Area	520	1610	3050	4940

In order to test whether the year has an effect upon the number of Kentish Plover nests, the attention is restricted to the first and last investigated year, because the differences between these years are most promising. The areas are investigated separately because it might happen that for one area an increase appears whereas for the other area the number of nests decreases. If one considers the total numbers, 6 in 1964 and 4 in 1980, for the closed area, then it is obvious that no significance can be obtained if one applies the relevant sign test (see section 3.2 where $c = 1/2$). If the total numbers, 14 in 1964 and 0 in 1980, for the open area are considered, then it is obvious that a very significant decrease has appeared (sign test).

Possible interpretation. In our opinion the decline of nests in the open area finds its origin in an increase of the number of visitors in the course of the years. In this connection the following is worth mentioning. In 1978 the last clutch in the open area disappeared because it was taken away by school-children who put it down near a stove in a camping farm. Probably the children had the opinion that the eggs were deserted.

7.3.2. *Does tourism have an effect if the distance to high tide level is taken into account?*

The theory of section 5.2 is applied to the data in table 94. Note that the factor distance to high tide level is taken into account because Kentish Plover nests, in the vicinity of the high tide level, are more threatened by occasionally flooding.

Table 95 can be derived from table 94 and table 96 from table 95. The critical level is approximately determined by
$P_0(X_{1.}-X_{2.} \geqq 6-14 | X_{.1} = 7, \ldots, X_{.2} = 13) \approx P(N \geqq -8-\frac{1}{2})$
where N has the normal distribution with expectation μ and variance σ^2.

TABLE 95. High tide level distance-tourism data for the Kentish Plover at Vlieland in 1964.

	Distance to high tide level <50 m	>50 m
Closed (military) area	$x_{11}=1$	$x_{12}=5$
	$\omega_{11}=520$	$\omega_{12}=1610$
Area open to the public	$x_{21}=6$	$x_{22}=8$
	$\omega_{21}=3050$	$\omega_{22}=4940$

TABLE 96. Evaluation of table 95.

$x_{.1}=7$	$x_{.2}=13$	
$\omega_{.1}=3570$	$\omega_{.2}=6550$	
$x_{1.}=6$	$x_{2.}=14$	
$p_{11}=.146$	$p_{12}=.854$	
$p_{21}=.246$	$p_{22}=.754$	
$\mu=-11.57$	$\sigma^2=13.12$	$\sigma=3.62$

$P_0(N \geqq -8\frac{1}{2}) = P\{U \geqq (-8\frac{1}{2}-\mu)/\sigma\} = P(U \geqq +.85) = .1986$
is obtained. Hence table 95 for the year 1964 provides no evidence to reject the null-hypothesis that no tourism effects exist if the distance to high tide level is taken into account.

If the 1980 data are considered, then $\mu = -2.033$, $\sigma^2 = 2.966$ and $\sigma = 1.722$ are obtained and the critical level is approximately determined by
$P_0(X_{1.}-X_{2.} \geqq 4-0 | X_{.1} = 0, \ldots, X_{.2} = 4) \approx P(N \geqq 3\frac{1}{2})$
where N has the normal distribution with expectation μ and variance σ^2.
$P_0(N \geqq 3\frac{1}{2}) = P\{U \geqq (3\frac{1}{2}-\mu)/\sigma\} = P(U \geqq +3.21) = .00068$
is obtained. Hence the 1980 data in table 94 provides sufficient evidence to reject the null-hypothesis that no tourism effects exist if the distance to high tide level is taken into account.

The interpretation of the difference between the results for 1964 and 1980 is in our opinion that the level of tourism increased considerably between 1964 and 1980. Along the lines of subsection 5.2.2 the confidence interval [2.5, ∞] for the parameter α_1/α_2 has been constructed.

7.3.3. *Does the distance to high tide level have an effect if tourism is taken into account?*

The theory of section 4.2 can be used. The attention is restricted to the 1964 and 1980 data in table 94. No significant results were obtained and hence no evaluation tables are presented.

SUMMARY AND CONCLUDING REMARKS

Birds and man are of importance to eachother, directly and indirectly, positively or negatively.

Populations of wild birds may decrease or even become extinct due to human activities because they are threatened directly or because theire characteristic habitats are destroyed. On the other hand, human effects might consist of protection or the creation of new habitats, e.g. by constructing dikes of drift sand or basalt piers on Vlieland.

Direct protection by establishing bird sanctuaries is often necessary to prevent local extinction of certain species. On the other hand protection of species like Herring Gull (*Larus argentatus*) may have negative effects upon other species.

In order to convince people that certain nature management measures should be taken, solid knowledge should be available of the effects and interactions of various factors affecting bird populations.

Though the original motivation was to study the effects of tourism upon numbers of nest sites or territories, effects of the factors landscape/vegetation and altitude (above Amsterdam ordnance datum (+NAP))/hydrology were investigated in the same way. The literature concerning the effects of the three above-mentioned factors has been reviewed.

The isle of Vlieland in the Dutch Wadden Sea was chosen as the research area because it attracts many of tourists and contains many different habitats attracting large numbers of birds, in particular waders. Attention was restricted to the (European) Oystercatcher (*Haematopus ostralegus*), the Curlew (*Numenius arquata*), the Redshank (*Tringa totanus*) and the Kentish Plover (*Charadrius alexandrinus*).

In order to study the effects of and interactions between the factors (1) landscape/vegetation, (2) altitude/hydrology and (3) tourism upon numbers of nest sites or territories, data were collected and mapped as outlined in chapter 2. The vegetation maps reveal how an area is subdivided into smaller areas of different vegetation types, the altitude maps indicate the different altitude classes. Three tourism zones were defined for the interpretation of aerial photographs. Yearly breeding bird maps give the precise location of nest sites or approximate territory centres. Various tables were obtained by combining breeding bird maps with those for the three above-mentioned factors.

For the 'non-experimental' study plots 3, ..., 6 chapter 3 outlines the statistical evaluation of the effects of separate factors upon the (expected) nest density, while chapters 4, 5 and 6 outline the interaction between the three factors.

Two 'experimental' plots were considered in order to investigate more carefully in chapter 7 tourism effects. During the years 1974, 1975, plot 1 was open to the public whereas plot 2 was closed by means of no-trespassing signs. During the years 1976, 1977 the situation was reversed.

The relations between the results, mentioned in sections 3.1, ..., 7.1, are as follows:

Conclusions for the Oystercatcher.

(1) Results for the non-experimental study-plots. All three factors (vegetation, altitude and tourism) have an effect if they are considered separately for the non-experimental study-plots (section 3.1), which means that Oystercatchers prefer to nest in certain vegetation types, altitude classes and tourism zones (section 3.1).

No sufficient proof for effects of the vegetation was obtained if the altitude is taken into account, while the evidence for altitude effects was sufficient if the vegetation is taken into account, which means that the null-hypothesis that no altitude effects exist if the vegetation is taken into account could be rejected (section 4.1).

Even if the vegetation is taken into account, tourism zone 1 is more attractive than zone 3. However taking tourism into account, vegetation effects could be established for plot 4, but not for plot 3 (section 5.1).

If the altitude is taken into account, when tourism effects could be proved for plot 3, but not for 4, though indications also exist here. For the reverse problem sufficient evidence is available for the existence of altitude effects, if tourism is taken into account (section 6.1).

Summarizing the Oystercatcher results for the non-experimental study-plots we obtain the opinion that tourism is an important factor though altitude effects are not negligible.

(2) Results for the experimental study-plots. The experimental study-plots suggest that some time is needed before the effects of no-trespassing signs become noticeable: the data for 1974/1976 does not lead to sufficient evidence for such effects which clearly exist for 1975/1977. The confidence interval [1.2, 4.1] for the parameter v, which describes the effect of the no trespassing signs, means that if an area like plot 1 or plot 2 is closed by means of such signs, then two years later one may expect 1.2–4.1 times as many Oystercatcher nests (the actual numbers to be obtained may fall beyound these bounds because of chance fluctuations) (section 7.1). In 1978 both plots were open to the public and this remained so afterwards. The data for 1978, 1979 and 1980 are in line with the above-mentioned conclusions: the figures for plot 2 are not markedly different from those in 1976/1977 when plot 2 was also open to the public, the figures for plot 1 show a decrease when compared with those in 1976 and 1977, obviously because plot 1 was closed to the public then.

Conclusions for the Curlew. Landscape and tourism but no altitude effects could be established if the factors were considered separately (section 3.1).

If landscape/altitude relations are investigated then possible effects of each factor can be explained as caused by the other. The interpretation of the difference between this result and the above-mentioned significance of landscape effects will be that some kind of dependence exists between landscape and altitude (section 4.1).

No sufficient proof was obtained for tourism effects if the landscape is taken into account, though the data still suggests that such effects exist. No landscape effects seem to exist if tourism is taken into account (section 5.1).

Sufficient evidence was obtained for tourism effects if the altitude is taken into account. No altitude effects seem to exist if tourism is taken into account (section 6.1).

Summarizing the results for the Curlew, tourism seems an important factor.

Conclusions for the Redshank. Landscape effects, altitude effects and tourism effects could be established if these factors were considered separately (section 3.1).

Sufficient evidence for landscape effects was obtained for plots 5 and 6 if the altitude is taken into account. On the other hand, altitude effects exist for plot 5 if the landscape is taken into account, while the results for plot 6 were not significant (section 4.1).

Sufficient evidence was obtained for tourism effects if the landscape is taken into account, while the evidence for landscape effects was also sufficient if tourism is taken into account (section 5.1).

Tourism has effect if the altitude is taken into account. On the other hand altitude effects, if tourism is taken into account, were significant for plot 6 but not for 5 (section 6.1).

Summarizing the results for the Redshank it is clear that both tourism effects and landscape effects exist.

Conclusions for the Kentish Plover. The number of Kentish Plover nests in the open area shows a significant decrease if the most separate years 1964 and 1980 are compared. For the closed (military) area the decrease was not significant.

Sufficient evidence was obtained for tourism effects if the 1980 data were used and the distance to high tide level is taken into account. This was not the case if the 1964 data were used.

No effects of the distance to high tide level seem to exist if tourism is taken into account.

In our opinion, the decline of the number of nests in the open area is the result of an increase in the number of visitors.

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SAMENVATTING EN SLOTOPMERKINGEN

Zoals de vogel van belang is voor de mens, zo is ook de mens van belang voor de vogel. Deze wederzijdse beïnvloeding kan zowel direkt als indirekt zijn en zowel positief als negatief.

Dit proefschrift is gemotiveerd door de wens om onze gevederde vrienden zo goed mogelijk te beschermen en te beheren.

Populaties van vogels in het wild kunnen afnemen of zelfs tengevolge van menselijke aktiviteiten uitsterven doordat hun leven direkt wordt bedreigd of doordat hun karakteristieke biotopen worden vernietigd. Aan de andere kant kennen wij het verschijnsel van de vogelbescherming en kan het onbewust scheppen van nieuwe biotopen, b.v. door de konstruktie van stuifdijken of strekdammen van basalt op Vlieland, ook een gunstige invloed hebben op de vogelstand.

Directe bescherming door de instelling van reservaten lijkt noodzakelijk om eventuele lokale uitroeiing van bepaalde soorten te voorkomen, hoewel bescherming van soorten zoals de zilvermeeuw (*Larus argentatus*) negatieve effecten op andere soorten kan hebben.

Gedegen kennis van de effecten en interacties van de verschillende factoren die vogelpopulaties beïnvloeden moet beschikbaar zijn als bepaalde natuurbeheersmaatregelen worden overwogen.

Naast de effecten van het toerisme op het aantal nestplaatsen of territorium centra zijn die van de factoren landschap/vegetatie en hoogte/hydrologie op dezelfde wijze onderzocht. Een literatuur overzicht van de effecten van de drie bovengenoemde factoren wordt gegeven.

Het Wadden eiland Vlieland werd als onderzoeksgebied gekozen omdat het eiland veel door toeristen wordt bezocht en het diverse biotopen bevat waardoor grote aantallen vogels, met name steltlopers, worden aangetrokken.

De aandacht werd beperkt tot de scholekster (*Haematopus ostralegus*), de wulp (*Numenius arquata*), de tureluur (*Tringa totanus*) en de strandplevier (*Charadrius alexandrinus*).

Teneinde de effecten van en interacties tussen de factoren (1) landschap/vegetatie, (2) hoogte (+ NAP)/hydrologie, en (3) toerisme op het aantal nestplaatsen/territorium centra te bestuderen werden gegevens verzameld zoals in hoofdstuk 2 is uiteengezet. De vegetatiekaarten geven aan hoe een gebied in deelgebieden van verschillende vegetatietypen is verdeeld, de hoogtekaarten geven de verschillende hoogteklassen aan. In verband met de interpretatie van luchtfoto's werden drie toerisme zones gedefinieerd. Broedvogelkaarten geven per jaar de juiste plaats van de nestplaatsen of benaderde territorium centra aan. Diverse tabellen werden vervaardigd door de broedvogelkaarten met de kaarten voor de verschillende factoren te kombineren.

Met betrekking tot de 'niet-experimentele' proefgebieden 3, ..., 6 geeft hoofdstuk 3 de statistische waardebepaling van de effecten der afzonderlijke factoren op de (verwachte) nestdichtheid, terwijl de hoofdstukken 4, 5 en 6 de interacties tussen de drie factoren behandelen.

Twee experimentele gebieden werden beschouwd om de effecten van het toerisme zorgvuldiger te kunnen onderzoeken. Gedurende de jaren 1974, 1975, was proefgebied 1 open voor het publiek, terwijl proefgebied 2 toen was afgesloten. In de jaren 1976, 1977 was de situatie omgekeerd. De resultaten zijn vermeld in hoofdstuk 7.

Het verband tussen de resultaten, uiteengezet in de paragraven 3.1, ..., 7.1, is als volgt:

Conclusies voor de Scholekster.

(1) Resultaten voor de niet-experimentele proefgebieden. Alle 3 factoren (vegetatie, hoogte en toerisme) hebben effect indien deze voor de niet-experimentele proefvakken afzonderlijk worden beschouwd (paragraaf 3.1). Dit betekent dat scholeksters een voorkeur hebben om in bepaalde vegetatietypen, hoogteklassen en toerisme zones te broeden.

Er is onvoldoende bewijs voor effecten van de vegetatie, indien rekening met de hoogte wordt gehouden. Effecten van de hoogte werden vastgesteld voor proefgebied 4, maar niet voor gebied 3, indien met de vegetatie rekening is gehouden (paragraaf 4.1).

Toerisme zone 1 (de rustigste zone) is aantrekkelijker dan zone 3 (de zone langs verharde wegen en paden) indien met de vegetatie rekening wordt gehouden. Effecten van de vegetatie konden worden aangetoond voor gebied 4, maar niet voor gebied 3, indien met de factor toerisme rekening is gehouden (paragraaf 5.1).

Effecten van het toerisme konden worden aangetoond voor proefgebied 3 maar niet voor 4, hoewel hier aanwijzingen bestaan, indien de factor hoogte in rekening wordt gebracht. Omgekeerd is er voldoende bewijs beschikbaar voor het bestaan van effecten van de hoogte, indien met de factor toerisme rekening wordt gehouden (paragraaf 6.1).

Indien de resultaten van de Scholekster voor de niet-experimentele proefgebieden worden samengevat, lijkt het aannemelijk dat toerisme een belangrijke factor is, hoewel de effecten van de hoogte niet mogen worden verwaarloosd.

(2) Resultaten voor de experimentele proefgebieden.

De resultaten voor de experimentele proefgebieden suggereren dat er enige tijd verstrijkt voordat de effecten van openstellen of afsluiten van een gebied merkbaar worden: de data voor 1974/1976 leverden onvoldoende bewijs voor het bestaan van zulke effecten in tegenstelling tot 1975/1977. Het betrouwbaarheidsinterval [1.2, 4.1] voor de parameter v, die het effect van het plaatsen van verbodsborden beschrijft, geeft aan dat als een gebied 'zoals proefgebied 1 of 2' afgesloten wordt door middel van dergelijke borden, men twee jaar later 1.2–4.1 keer zo veel scholekster nesten mag verwachten (de werkelijke waar te nemen aantallen kunnen buiten deze grenzen vallen in verband met toevalsfluctuaties). In 1978 waren beide proefgebieden voor het publiek opengesteld en dit bleef daarna zo. De resultaten voor 1978, 1979 en 1980 zijn in overeenstemming met de bovengenoemde conclusies: de aantallen voor proefgebied 2 verschillen niet opvallend van die in 1976/1977 toen gebied 2 open was voor het publiek. De aantallen voor proefgebied 1 vertonen een afname in vergelijking met die voor 1976 en 1977, klaarblijkelijk omdat gebied 1 toen afgesloten was voor het publiek.

Conclusies voor de wulp. Bij het beschouwen van de afzonderlijke factoren werden effecten van het landschap en van het toerisme vastgesteld, terwijl geen effecten van de hoogte aanwezig lijken te zijn (paragraaf 3.1).

Bij het onderzoek van de gezamelijke invloed van landschap en hoogte kon het mogelijke effect van iedere factor verklaard worden vanuit dat van de andere. De interpretatie van het verschil tussen dit resultaat en het eerdervermelde bestaan van effecten van het landschap moet worden gezocht in een zekere afhankelijkheid tussen landschap en hoogte (paragraaf 4.1).

Er was niet voldoende bewijs aanwezig voor effecten van het toerisme indien met het landschap rekening wordt gehouden, hoewel de gegevens suggereren dat zulke effecten bestaan. Effecten van het landschap lijken niet te bestaan, als met het toerisme rekening wordt gehouden (paragraaf 5.1).

Er werd voldoende bewijs voor effecten van het toerisme gevonden indien met de hoogte rekening wordt gehouden. Effecten van de hoogte schijnen niet te bestaan indien met de factor toerisme rekening wordt gehouden (paragraaf 6.1).

Indien de resultaten voor de wulp worden samengevat, dan ziet het er naar uit dat de factor toerisme een belangrijke factor is, maar de effecten van de factoren laten zich moeilijk vergelijken omdat bepalend is hoe sterk een factor wordt gevarieerd.

Conclusies voor de Tureluur. Effecten van het landschap, de hoogte en het toerisme konden worden vastgesteld indien deze factoren afzonderlijk worden beschouwd (paragraaf 3.1).

Voor beide proefgebieden was er voldoende bewijs voor effecten van het landschap indien de hoogte in beschouwing wordt genomen. Aan de andere kant bestaan er effecten van de hoogte voor proefgebied 5 als het landschap in beschouwing wordt genomen, terwijl de resultaten voor proefgebied 6 niet significant waren (paragraaf 4.1).

Er was voldoende bewijs aanwezig voor effecten van het toerisme indien met het landschap rekening wordt gehouden, terwijl er tevens voldoende bewijs werd gevonden voor effecten van het landschap indien met de factor toerisme rekening wordt gehouden (paragraaf 5.1).

De factor toerisme heeft effect indien de hoogte in beschouwing wordt genomen. Aan de andere kant heeft de factor hoogte effect indien de factor toerisme in beschouwing wordt genomen.

Samenvattend is het duidelijk dat zowel effecten van het toerisme als van het landschap bestaan.

Conclusies voor de Strandplevier. Het aantal nesten van de strandplevier in het open gebied vertoont een significante afname indien de jaren 1964 en 1980 worden vergeleken. Voor het afgesloten (militaire) gebied was de afname niet significant.

Er werd voldoende bewijs voor het bestaan van effecten van het toerisme gevonden indien de afstand tot de hoogwaterlijn in beschouwing wordt genomen en de gegevens van 1980 worden gebruikt (paragraaf 7.1). Het bewijs voor het bestaan van effecten van het toerisme, indien met de afstand tot de hoogwaterlijn rekening wordt gehouden en de data voor 1964 worden gebruikt, was onvoldoende.

Er lijken geen effecten van de afstand tot de hoogwaterlijn uit te gaan, als rekening wordt gehouden met de factor toerisme.

De afname van het aantal nesten in het open gebied is naar de mening van de auteur het gevolg van een toename van het bezoek in dat gebied.

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CURRICULUM VITAE

Gerlof Thijs de Roos werd op 26 mei 1941 geboren te Leeuwarden en behaalde in 1960 het diploma der Middelbare Landbouwschool.

Van 1960 tot 1964 volgde hij de opleiding aan de Hogere Bosbouw- en Cultuurtechnische School te Arnhem en behaalde in 1964 het diploma Bosbouw-Rentmeester.

In 1966 werd met de studie Biologie aan de Rijksuniversiteit te Groningen begonnen. Voor het doctoraal examen, behaald in 1974, werden achtereenvolgens de volgende onderzoeken uitgevoerd: een jaar historisch-vegetatiekundig onderzoek aan broekbossen in 'de Lindevallei' ten behoeve van de afdeling Vegetatiekunde van het Rijksinstituut voor Natuurbeheer te Leersum en het Biologisch Archeologisch Instituut van de Rijksuniversiteit te Groningen; 3 maanden Planologie aan de Rijksuniversiteit te Groningen en een 9 maandelijks onderzoek naar de invloed van verstoringen op broed- en trekvogels in het Staatsnatuurreservaat 'de Kroonspolders' te Vlieland voor de Vakgroep Natuurbeheer der Landbouwhogeschool te Wageningen onder leiding van Prof. Dr. M. F. MÖRZER BRUYNS. Wijlen Prof. Dr. D. BAKKER, hoofd van het Laboratorium voor Plantenoecologie der Rijksuniversiteit te Groningen, was studieleider.

Na het behalen van het doctoraal examen werd het onderzoek op Vlieland voor de Vakgroep Natuurbeheer voortgezet. De resultaten van dit onderzoek zijn verwerkt in dit Proefschrift.