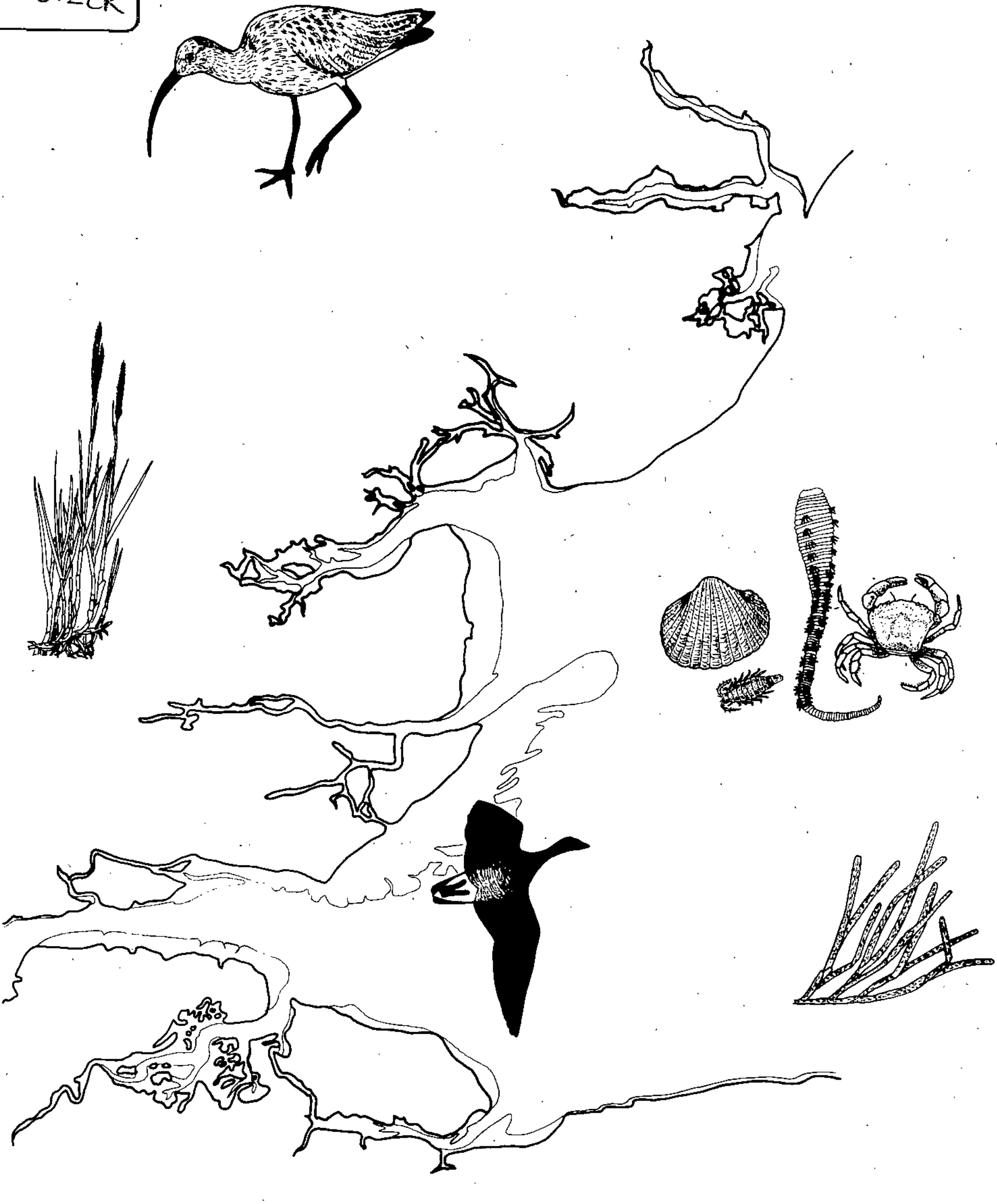
STUDIES ON THE ECOLOGY OF MAPLIN SANDS AND THE COASTAL ZONES OF SUFFOLK ESSEX AND NORTH KENT



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(65807.)

STUDIES ON THE ECOLOGY OF MAPLIN SANDS AND COASTAL ZONES OF SUFFOLK, ESSEX, AND NORTHERN KENT

Contents

PART I

SUMMARY

1. This report describes a three year (1973-75) scientific study of the ecology of the coastal zone between the Orwell estuary in Suffolk and the Kentish shore of the Thames Estuary.

2. The work was done by the Natural Environment Research Council's Institute of Terrestrial Ecology, with ornithological help from independent bodies, under contract to the Department of the Environment and formed part of the evaluation of the environmental impact of the proposed Third London Airport at Maplin.

3. The coasts of the study area are 'soft', composed of easily mobilised sediments. Maps of the intertidal flats, salt marshes, reclaimed marsh and margins of built up areas have been made from air photographs, validated by ground survey. About a fifth of all the salt marshes, and a substantial proportion of the tidal flats in Britain occur in the study area, and Maplin is the largest area of continuous inter-tidal flats on the British coast.

4. The mud flats support large populations of invertebrate animals, important as food to wading birds. The two most important plants on the flats are eelgrass (Zostera), the staple food of the Dark-bellied Brent goose, and a green alga (Enteromorpha), also important as food for wildfowl. The distribution and abundance of these plants and invertebrates has been determined for the first time. The vegetation of the salt marshes and reclaimed marsh has been described, again for the first time, and the distribution of rare or local species recorded.

5. The study area is internationally famous for the wading birds and wildfowl that winter there, including at least 20% of the world population of Dark-bellied Brent geese and over 1% of the European populations of 15 other species. The numbers and distribution of these birds have been determined, and related to habitat, including food. A detailed study of the Brent geese has confirmed increasing numbers, which could apparently exceed the capacity of the inter-tidal feeding grounds and has led to overspill onto agricultural land.

6. Had the airport been built at Maplin, 30% (Stage 1) to 60% (Stage 2) of the mudflat area would have been reclaimed, obliterating the winter habitat of 7,500-15,000 wading birds, and some 4,500 Dark-bellied Brent geese. It would also have destroyed the only viable pioneer population of the Small cord-grass (Spartina maritima) in Britain.

7. Airport construction would also have had indirect effects on the bird fauna, affecting up to 275,000 individuals. Some displaced birds would probably have found winter habitats elsewhere on the south-east coast: others (such as the geese) might have increased their pressure on farmland.

8. No 'alternative' area matching all the environmental features of Maplin was found, but a series of "substitute" sites which, if conserved collectively, would perpetuate the habitats of most of the species found there was identified. Management could enhance the value of such sites for wild-life, but would be unlikely to do so to such an extent that all the populations displaced from Maplin were accommodated.

9. The study has emphasised the inter-relationship between the processes of accretion and erosion on such coasts, water movement, sediment load and the flora and fauna and indicated topics for both background research and field experiment.

10. Although the Maplin Airport project did not proceed, therefore, the study has been of value in providing a mass of detailed scientific information about the environmental patterns and processes in a major coastal region that will certainly come under continuing pressure from development in future. It has also indicated the sites of most value for wild-life conservation, and demonstrated factors to be taken into account in their management.

M.W. HOLDGATE
16 March 1976

PART II

SYNOPSIS

BACKGROUND

1. The Natural Environment Research Council was commissioned in 1972 by the Department of the Environment to undertake ecological surveys of those parts of the coasts of Kent, Essex and Suffolk that might be affected by the proposed airport and seaport of Maplin (Foulness), to predict the possible impact of this development on wildlife, and to suggest ways in which this impact might be mitigated. The work was undertaken by Dr. L.A. Boorman, Mr. K. Charman, Miss Julia E. Head, Dr. D.G. Kay, Mr. R.D. Knights, Miss Anne Macey, Dr. N.W. Owens, Miss Julia S. Say, Miss Rosalind J. Waters, and Dr. D.W. Wyer, based at the Institute of Terrestrial Ecology, Colney Research Station, Norwich. Because there was particular concern for the effects on birds, some projects were sub-contracted to a consortium of the Wildfowl Trust, British Trust for Ornithology and The Royal Society for the Protection of Birds, and Durham University. The Nature Conservancy Council undertook a special study of the implications of the scheme for nature conservation.

2. This report describes what has been done in the three years, 1st September 1972 to 31st August 1975, in the study area from the Orwell estuary (Suffolk) to the Thames estuary (Kent) (Fig 1). The original contract between DOE and NERC was terminated on 30th November 1974 following the abandonment of the airport proposal. Arrangements were then made to continue some of the projects dealing with Brent geese under a new contract, in order to extract the best possible scientific returns from the money already invested. Data were originally collected to assess the impact of building an airport on wildlife and improve substitute areas by management, but data can be used in a similar relationship to any proposed large scale development on this coast.

3. This report is in three parts. Part I summarises the chief conclusions of the work. Part II consists of brief accounts of the component projects. Part III is an interpretation of results and proposals for further consideration.

4. The work was undertaken in liaison with other interested groups, especially in the Nature Conservancy Council, Hydraulics Research Station, Ministry of Agriculture, Fisheries and Food; Local Authorities; the Royal Society for the Protection of Birds; the Wildfowl Trust; the British Trust for Ornithology; the Wildfowlers Association of Great Britain and Ireland; County Naturalists Trusts and Natural History Societies. The work could not have been completed without the help of these bodies and the many helpers associated with the voluntary bodies.

OBJECTIVES

5. The contract between DOE and NERC specified six "objectives". Four of these outlined the scientific aims of the study and are quoted verbatum here:

"a. To provide information on the species, amount, distribution and habitats of the most important elements of the natural fauna and flora of the area to enable an evaluation to be made of the effects on these of the construction and operation of a major international airport.

b. To establish whether or not there are unique features of scientific interest which will be irretrievably lost and which should therefore be studied before completion of the airport.

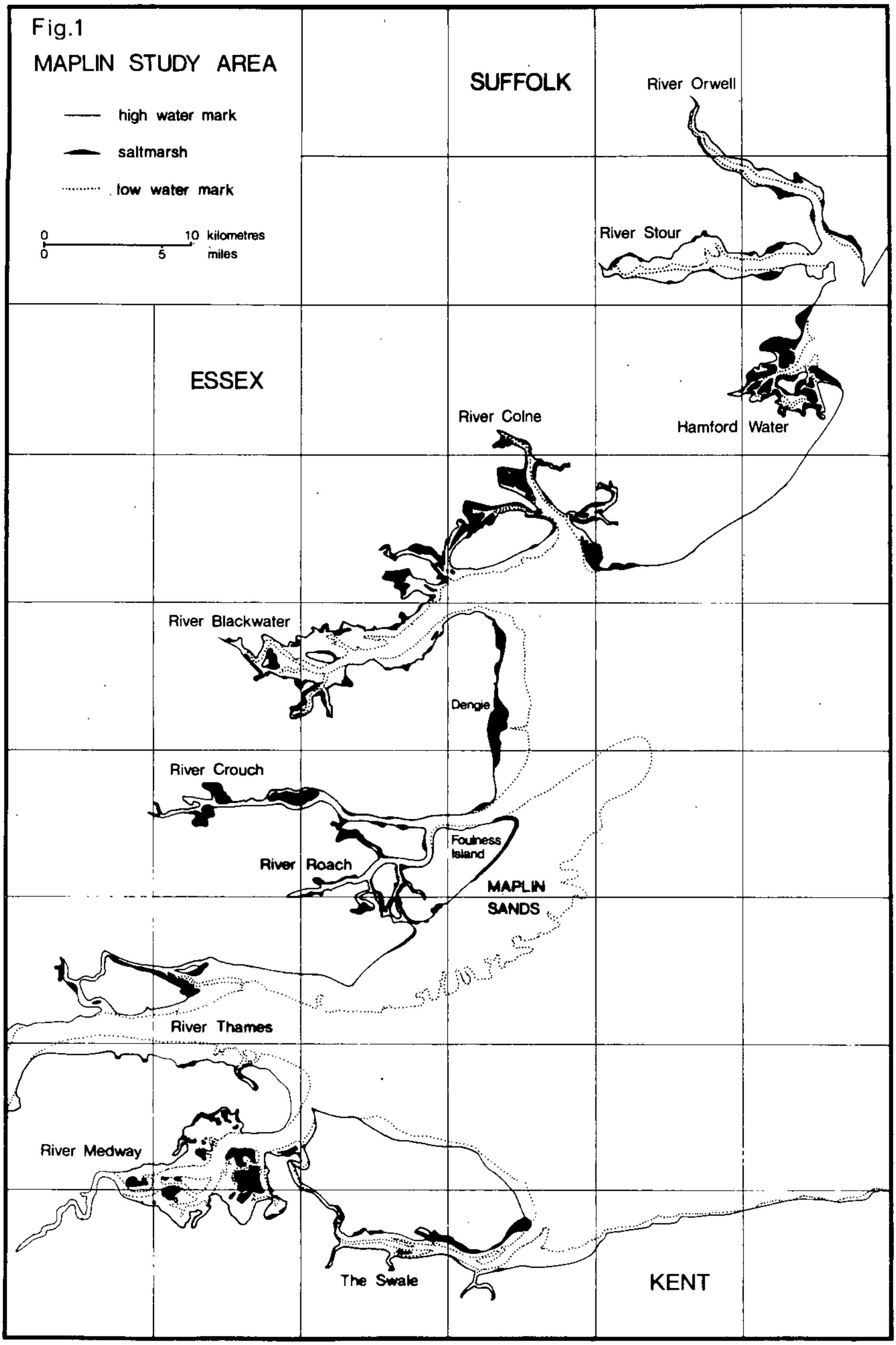


Fig.1
MAPLIN STUDY AREA
high water mark
saltmarsh
low water mark
0 10 kilometres
0 5 miles
SUFFOLK
River Orwell
River Stour
ESSEX
Hamford Water
River Colne
River Blackwater
Dengie
River Crouch
Foulness Island
River Roach
MAPLIN SANDS
River Thames
River Medway
The Swale
KENT

c. To provide information to enable the appropriate bodies to select the best substitute sites in their efforts to conserve as many as possible of the species and habitats that are associated with this part of the coast.

d. To undertake trials for the purpose of providing guidance for the future management and improvement of substitute sites to increase their wildlife potential."

6. The contract further instructed NERC: "To take responsibility for liaison work with other interested researchers, particularly in bodies such as the Ministry of Agriculture, Fisheries and Food, Royal Society for the Protection of Birds, Wildfowl Trust, County Naturalists Trusts, Natural History Societies, British Trust for Ornithology and Wildfowlers Association of Great Britain and Ireland."

7. Finally it was specified that: "The work should lead to recommendations and proposals for future action, including methods for implementing these proposals, and a final comprehensive report."

THE COASTAL SYSTEM

8. The study area consists of predominantly 'soft' coastline of easily mobilised sediments as opposed to hard rock. The habitats of mud and sand flats, shell and shingle spits; backed by salt marshes, sand dunes or man-made sea embankments, are critically dependent on the balance between accretion and erosion. Volume and flow pattern of drainage from the land, and tidal movement from the sea result in an intermingling of fresh and salt water which produces special ecological conditions. In recent decades conditions in many estuaries have been altered by polluting matter brought down the rivers or discharged directly into the estuarine zone.

9. The intertidal flats and banks are rich in invertebrate animals, many of which burrow into the substratum and feed upon detritus settling from above. Molluscs (such as mussels and cockles) and worms (such as the common lugworm, Arenicola) are abundant, together with small crustaceans. The bottom-living (or benthic) animals form food sources for demersal fish, and at low tide provide the staple food of wading birds and seabirds. The intertidal flats also support plants. Diatoms play a part in stabilising accreting sediments, and larger algae and eelgrass (Zostera) form extensive growths on which wildfowl (geese and ducks) feed.

10. The soft coasts and estuaries of this country provide wintering grounds for a large number of birds that migrate north in summer to breed in the Arctic. These wintering grounds are particularly favoured because the big tidal ranges expose large areas of intertidal flats with abundant food in a mild oceanic situation at the western margin of Europe, rarely frozen or ice-covered in winter. Maplin lies centrally in this area and is favoured by a quarter of the world population of the Dark-bellied brent goose (Branta bernicla bernicla).

11. At higher levels, the stabilisation of the sediments is augmented by encroachment of salt marsh plants which form a more or less continuous sward whose composition varies with level. These salt marshes support substantial populations of terrestrial invertebrates and also provide grazing for wildfowl and feeding and breeding sites for other birds. Wave attack on the coast is reduced by the presence of salt marshes so they are an aid in sea defence. Their capacity to accrete silt and raise the surface level has led to extensive reclamation for agriculture behind sea embankments on this coast.

12. The coastal ecosystems of the area under study thus involve a number of interacting species, among which the plants are important both in constructing the habitat and as food for grazing wildfowl and stock, and the invertebrates are important as food for fish and wading birds. Changes in the habitat whether direct, affecting the areas occupied by marsh or flats; or indirect, by altering the balance of accretion, erosion, or plant and animal populations, can have repercussions throughout the system.

SCIENTIFIC STUDIES

HABITAT SURVEY

Some idea of the status of the survey area in the natural context can be gained from the facts that a substantial proportion of the tidal flats and about one quarter of the total area of salt marsh in Britain occur in the study area.

The objective of this project was a survey of the semi-natural habitats of the coastal zone, using specially commissioned aerial photographs to produce up-to-date, large scale maps showing the extent of tidal flats, the character of coastal vegetation, and built up areas.

The aerial survey was carried out with stereoscopic panchromatic photography, taken with a minus-blue filter, at a scale of 1:10,560 and from a height of 5000 ft. with a six-inch focal length lens. The overall quality achieved by the photography carried out by Meridian Airmaps Ltd., was good. The scale was accurate and there was little noticeable distortion due to tilt. The clarity of detail in some areas was excellent and the tonal contrast striking, especially in the Dengie marshes and Colne saltings photographs. The total cost of the 950 photographs received was £7,500 (in 1973).

The air photographs covered the zone from low water to three quarters of a mile inland over 150 square miles of coast from Felixstowe (Suffolk) to Whitstable (Kent). These were used to produce a set of 49 maps at a scale of six inches to the mile (Fig 2). Effective mapping would have been impossible without this specially commissioned air photography.

Techniques for much closer interpretation than usual were developed especially for survey of this type of coastal terrain. Photographs were interpreted, with validation on the ground, to show the items of information in Table 1.

These maps provide much of the information needed to achieve the first objective of the study: the recording of the abundance and distribution of the main habitat types. It is estimated there are 28,000 ha of intertidal flats, 7,043 ha of salt marsh and 4,340 ha of semi-natural reclaimed marsh in the study area and the exact distribution of these habitat types on this coast has been defined.

Maplin consists of 10,500 ha of intertidal flats as a single unit occupying 38% of this category in the study area. No other single unit of continuous intertidal flats of this size occurs on the British Coast. This is a significant feature for easily disturbed birds like geese and waders.

The maps provide a basis for selection of substitute sites and incidentally a valuable planning aid for all subsequent development proposals likely to affect this coast.

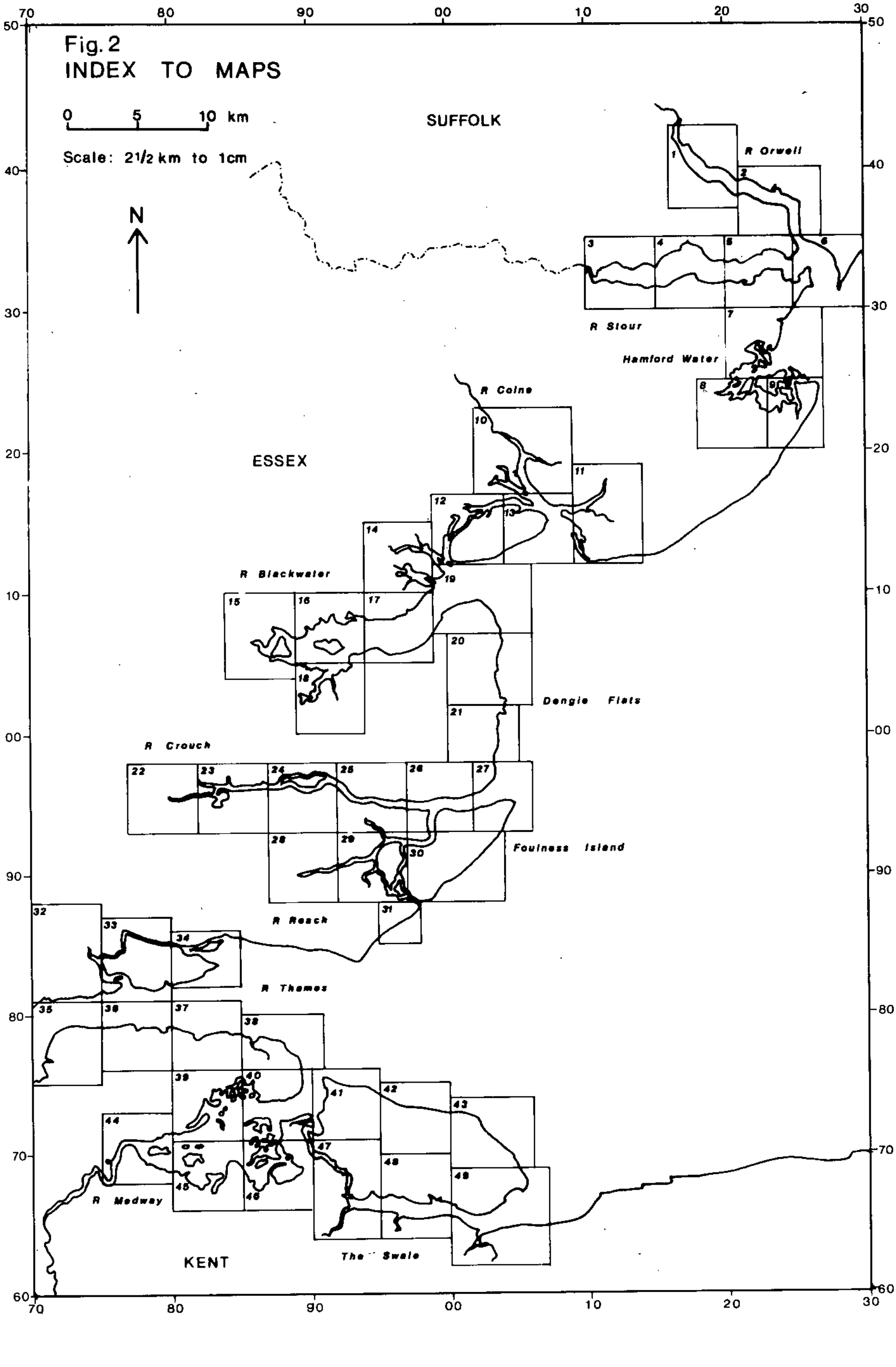


Fig. 2
INDEX TO MAPS

Salt marsh	Reclaimed marsh	Other items
Zostera species	Unimproved ungrazed marsh	Intertidal flats (limited by low water mark)
Large beds of green algae	Unimproved grazed marsh	Sand/shell/shingle accumulations
Pioneer salt marsh	Semi-improved pasture	Oyster pits
Aster tripolium		
Salicornia species	Improved pasture	Degraded salt marsh
Spartina species		Sea embankments
	Seasonally flooded wetland	Nature reserves
Mature salt marsh		Boating facilities
Youthful *Puccinellia*	Arable and other land usage	
Wet *Puccinellia*		Caravan sites
Grazed *Puccinellia*	Drainage channels	
Trampled *Puccinellia*		Chalet sites
Species rich (salt pan)		
Eroded marsh		Railways
Runnels		
Agropyron pungens,		Roads and tracks
Limonium spp. and		
Halimione portulacoides		Rubbish dumps
In combination with		
above		Sewage works
Reeds		Gravel pits
		25ft contour
		Streams and rivers

Table 1. Items of information on habitat maps

TIDAL FLAT VEGETATION

The two principal types of plants found on the tidal flats are green macro-algae (seaweeds), mainly Enteromorpha species, and eelgrass (Zostera species).

These plants create distinctive communities, stabilize mudflats, act as precursors to salt marsh formation, and provide food for wildfowl.

The objectives of this study were to locate and measure these food resources in such a way that their amount and energy content could be estimated relative to the food requirements of specific populations of Brent geese. It must be appreciated that seasonal variations in growth introduce error which could not be fully assessed in the time available for the study though every effort was made to reduce errors at each stage of measurement.

Two species of Zostera occur on the tidal flats, Zostera noltii and Zostera marina var. angustifolia. They were estimated to occupy 844 ha (783 ha on the Suffolk/Essex coast and 61 ha on the Kent coast) and to produce a standing crop of 917 tonnes fresh weight in 1973. Since so little Zostera was found on the Kent coast, only the Suffolk/Essex populations are discussed further here. Zostera noltii was partially winter-green and showed some growth in the mild winters at the time of the study and was thus available to the geese, especially in early winter Zostera noltii occupied an estimated area of 440 ha and produced a standing crop of 249 tonnes fresh weight in 1973 and bomb calorimetric measurements indicated a total calorific value of 2.02×10^8 Kcals.

Zostera marina var. angustifolia was estimated to occupy 343 ha and produced 576 tonnes fresh weight standing crop in 1973 with a total calorific value of 2.94×10^8 Kcals. However this species had shed most of its leaves by October before the main flocks of geese settled in.

Enteromorpha was estimated to occupy 2,222 ha with a standing crop fresh weight of 4,450 tonnes (evenly balanced between Suffolk/Essex and Kent) and had a total calorific value of 4.86×10^8 Kcals.

Table 2 shows that the relative fresh weight calorific value of Zostera noltii is nearly four times that of Enteromorpha so that geese presumably have to eat only a quarter the amount of Zostera noltii compared with Enteromorpha to obtain the same amount of energy. The special significance of the Maplin area derives from the fact that half the total Zostera noltii occurs there, with $\frac{3}{4}$ on Maplin and the neighbouring mud-flats at Leigh. Thus Leigh is the only site which could approach Maplin as a substitute but is so close that it might easily be affected by any major changes at Maplin.

SALT MARSHES

Nearly one fifth of the total salt marsh area in Great Britain occurs in the study area, and this proportion is more than one and a half times the saltmarsh area in the whole of the Wash. On an area basis alone therefore, the salt marsh habitats of the study area form a greater proportion of the total than any of the other habitats within it.

The objectives of this study were to determine the amount, distribution and composition of the salt marsh vegetation and to locate populations of rare species or those best represented in the study area in order to aid in the selection of substitute sites.

Species	Calorific value Kcals/g	
	Dry weight	Fresh weight
Ulva	3.01	0.30
Z. marina	3.19	0.41
Enteromorpha	3.34	0.22
Z. noltii	3.84	0.81

Table 2. Calorific values of *Zostera* and green macroalgae

A total of 7,043 ha of salt marsh (5,142 ha in Suffolk/Essex and 1,901 ha in Kent) were estimated to occur in the study area. Samples were taken of the flora and soil at a total of 307 sites in 71 salt marsh systems.

Detailed descriptions of the species composition of the vegetation and the physical and chemical properties of the soil at each site were made. Prior to this survey, virtually nothing was known about the floristic composition and soil type of most of these marshes.

Maplin contains the only extensive population in Britain (possibly in Europe) of the rare salt marsh grass *Spartina maritima*. There it is a pioneer colonist on mudflats. Before the survey, this plant was only known as sparse populations at higher salt marsh levels.

Many marshes of the study area are notably rich in lime and this favours the growth of the local species Golden samphire (*Inula crithmoides*) which has its headquarters in the study area. The biggest populations are in the high-level marshes at Hamford Water and in the Medway.

Analysis of cover value vegetation data separates five floristic groups accounting for 87% of the sample variance. Four of the groups consist of components with a single species dominant: *Aster tripolium*, *Halimione portulacoides*, *Limonium vulgare* and *Puccinellia maritima*. The fifth group is dominated by a pair of species: *Armeria maritima* and *Plantago maritima*. The results emphasise the single species dominance which is characteristic of salt marsh vegetation. The groups include opportunist species such as short-lived perennials like *Aster tripolium* capable of rapidly colonising temporary gaps, longer lived perennial woody species characteristic of more permanent ungrazed marsh areas like *Halimione* and *Limonium* and perennial short grass and herb species characteristic of grazed marsh areas such as *Puccinellia*, *Plantago maritima* and *Armeria*.

Further analysis indicated the presence of gradients from low level pioneer marsh to two types of high level marsh, one with low species diversity and the other with high species diversity clearly related to the types of ungrazed and grazed marsh mentioned above. The fact that this second analysis only accounted for a third of the sample variance suggests that other factors which could not be measured in the time available for the present study (such as past grazing activity as a cause of present floristic patterns) may be of critical importance.

Soil analysis revealed a group of 24 lime-rich sites, predominantly in middle marsh levels at Dengie and Hamford Water possibly related to localised shell accumulations.

The nine most important salt marsh sites (Table 3) are selected on the basis of those combining high species diversity, presence of rare species, or those at the edge of their geographical range, presence of the best examples of plant communities, and those with the lowest levels of human disturbance to the habitat.

RECLAIMED MARSHES

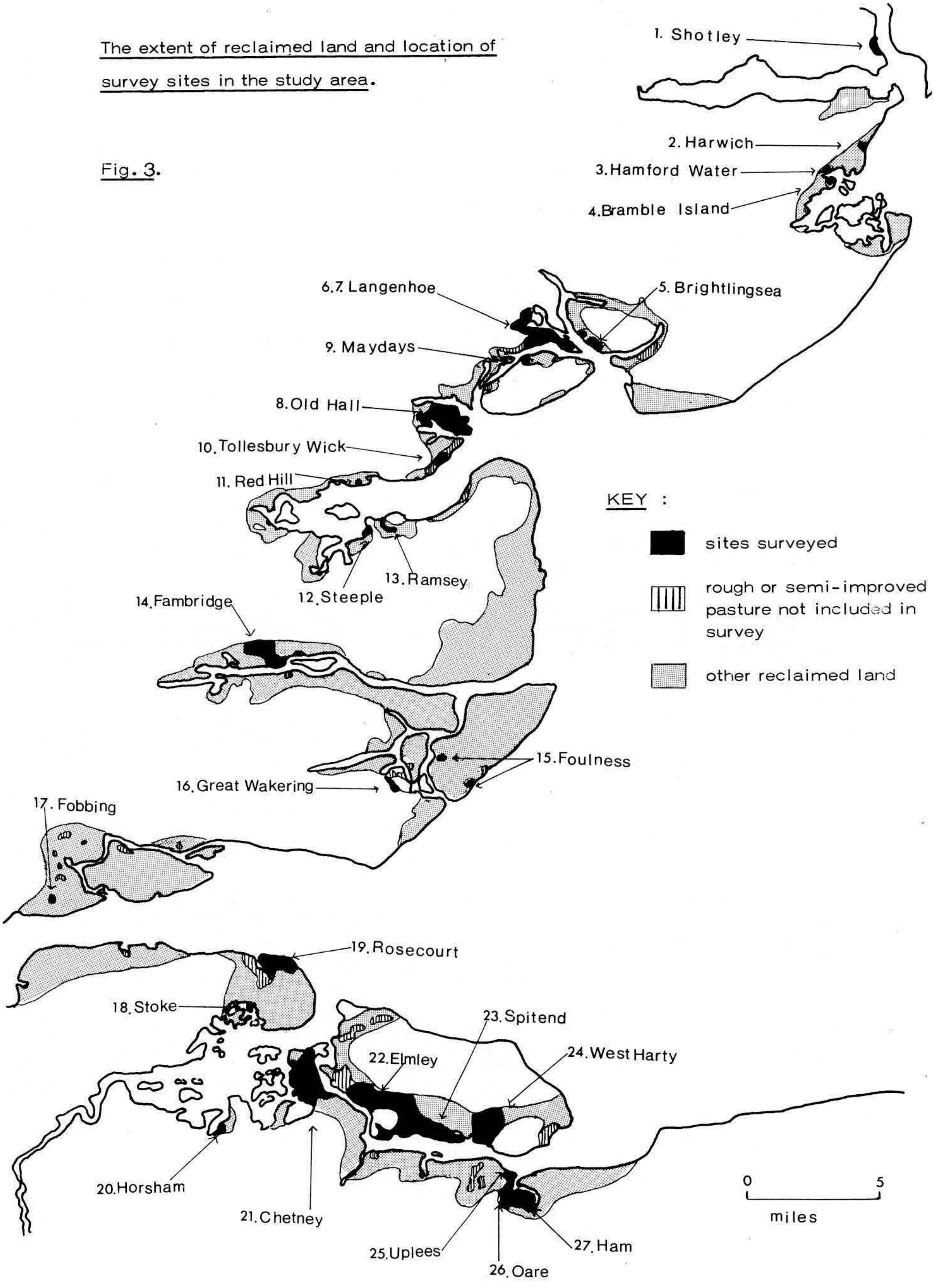
Since the Roman occupation, reclamation of salt marshes on the inherently fertile clay/silt soils of this coast has been undertaken whenever economic conditions allowed. There are now 4,340 ha of semi-natural reclaimed land in the study area. With improved protection from inundation from the sea, increased values of agricultural land, and better access, this type of land is being increasingly drained and ploughed.

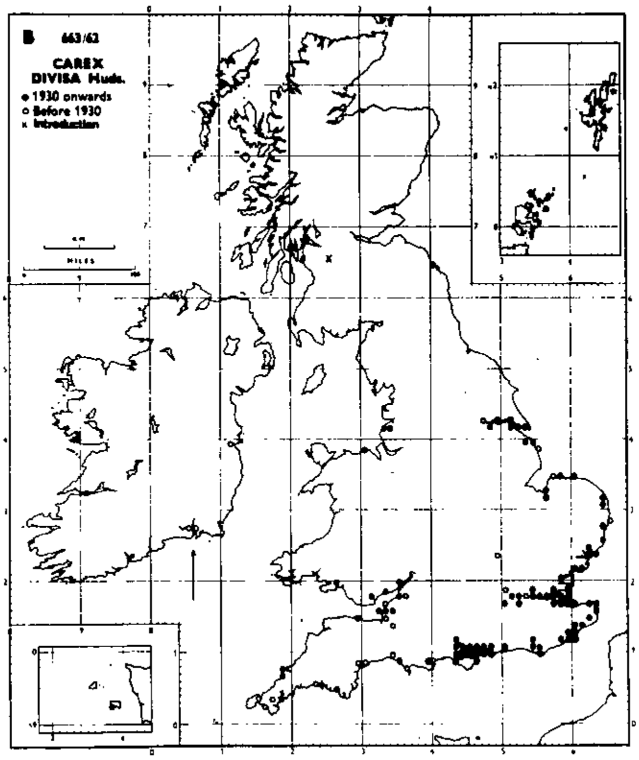
County	Site	Area (ha)
Suffolk	Orwell (N-side)	80
Essex	Blackwater	917
Essex	Colne	656
Essex	Dengie	542
Essex	Hamford Water	971
Essex	Maplin	609
Kent	Medway	1468
Kent	Swale	433
Kent	Yantlet	20

Table 3. The nine most important salt marsh sites

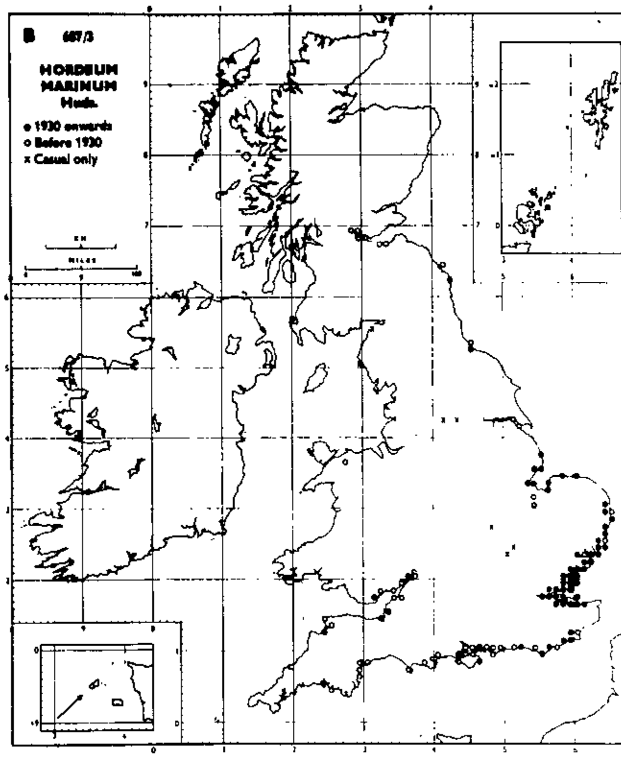
The extent of reclaimed land and location of survey sites in the study area.

Fig. 3.





BOTANICAL SOCIETY OF THE BRITISH ISLES DISTRIBUTION MAPS SCHEME



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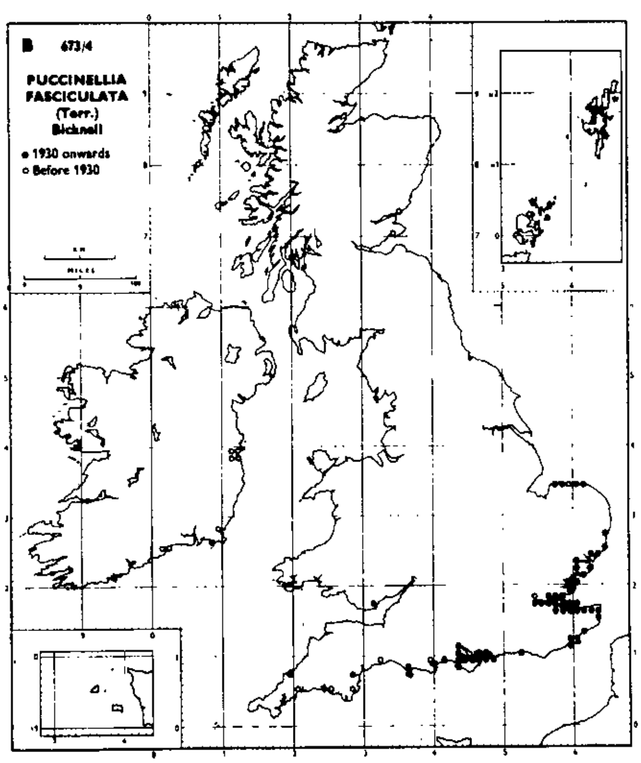

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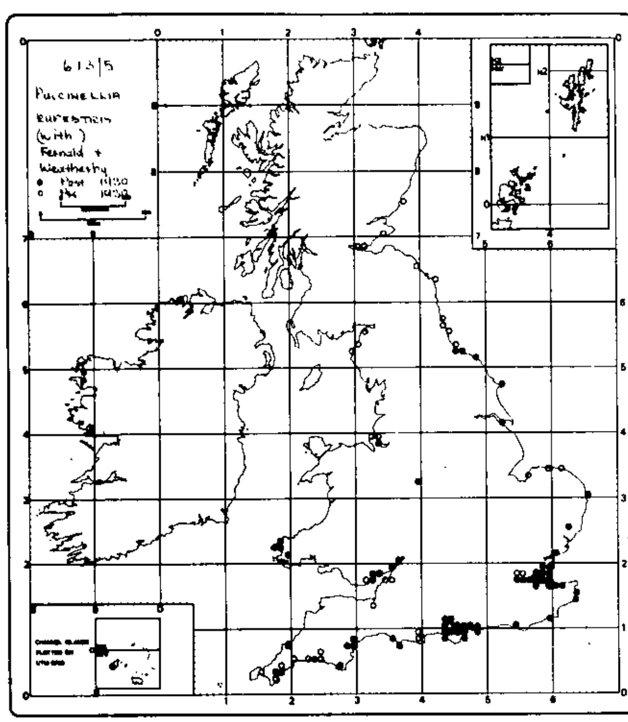
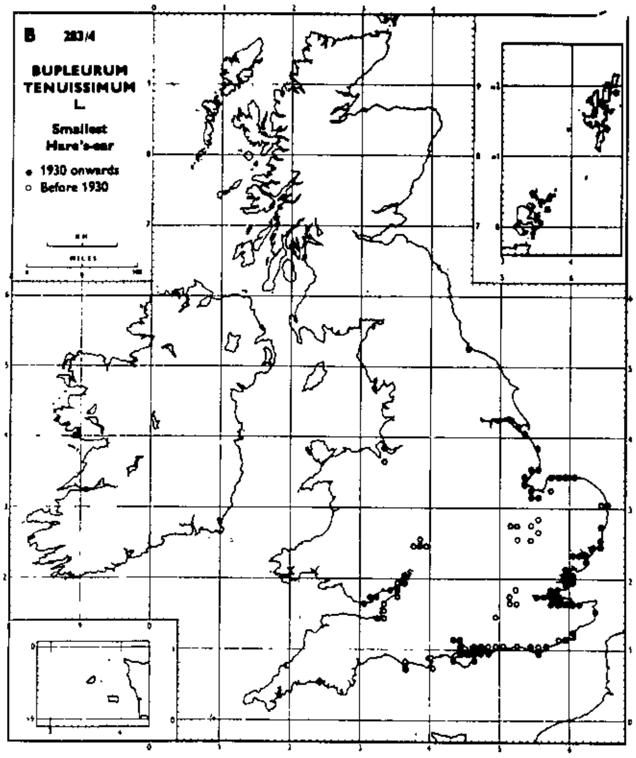


Biological Records Centre

FIG 4. PLANT DISTRIBUTION OF RECLAIMED MARSH SPECIES



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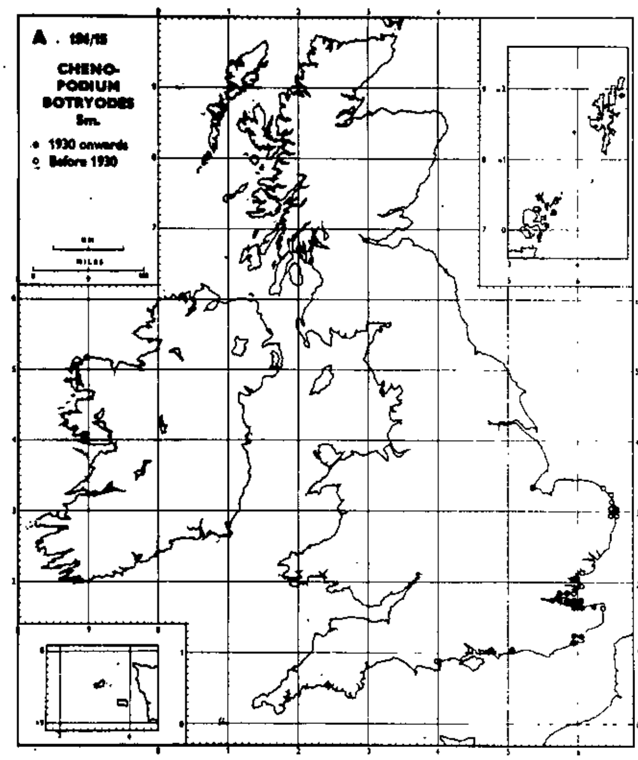

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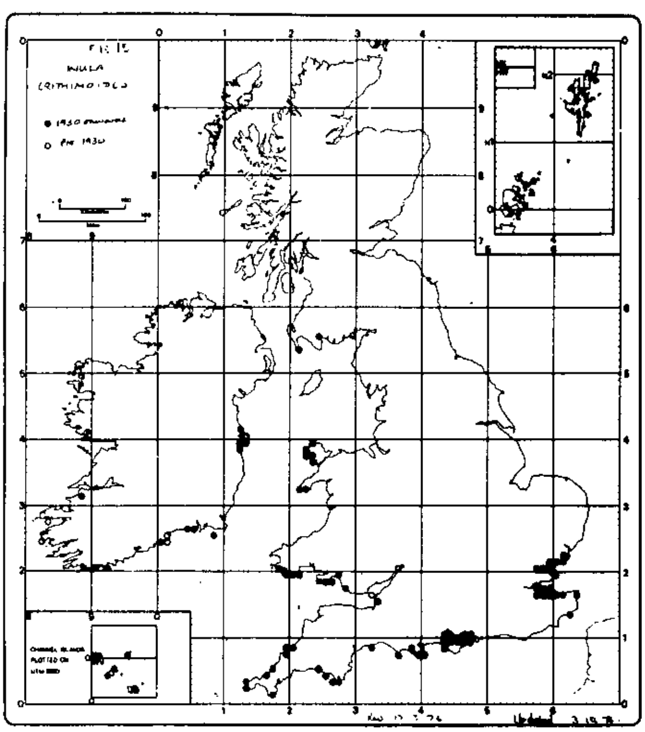
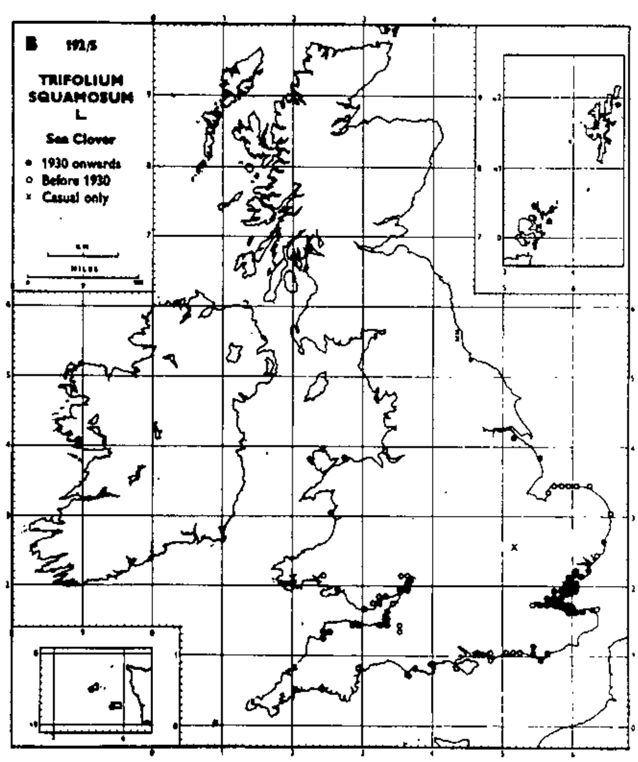




BOTANICAL SOCIETY OF THE BRITISH ISLES DISTRIBUTION MAPS SCHEME

FIG 6. PLANT DISTRIBUTION OF RECLAIMED MARSH SPECIES

The objectives of this study were similar to those of salt marsh. Techniques for identifying seven categories of reclaimed marsh from aerial photographs were developed (Table 1). Geographically representative blocks of semi-natural reclaimed marsh above 10 ha in size were examined with an average of twenty 5 x 5 m quadrats per site in 27 sites (Table 4) representing 3,095 ha, i.e. about three quarters of the total area of this habitat in the study area (Fig 3).

Over 200 species of flowering plants were recorded in semi-natural reclaimed marsh in the study area and up to 90 species in sites of no more than 80 ha. This type of land is the optimum habitat for a number of very locally distributed species which have their headquarters in the study area in this part of Britain (Fig 4 and 5).

This is the first analytical study of this habitat in Britain. The structural uniformity imposed on this type of habitat by man provides a basis for classifying sub-habitats of reclaimed marsh wherever they occur on the north-west European coastline. The significant sub-habitats of semi-natural reclaimed marsh were distinguished as:-

1. Sea walls, seaward side
2. Sea walls, landward side
3. Borrowdyke
4. Pasture
5. Old creek beds
6. Inland banks
7. Fleets and ditches
8. Trackway

Three types of marshes were distinguished using similarity coefficient analyses:-

1. Cattle and sheep grazed marshes of mean size 230 ha (e.g. Chetney and Ham marshes, Kent).
2. Cattle grazed marshes north of the Thames of mean size 60 ha (e.g. Brightlingsea, Suffolk and Shotley marshes, Essex).
3. Ungrazed marshes mainly in Essex of mean size 50 ha (e.g. Langenhoe and Bramble Island, Essex).

This report is not only concerned with the flora of reclaimed marsh habitats but a full assessment should take into account their use by birds, mammals, amphibia and invertebrates. The relative isolation of these sites from human disturbance increases the importance of the marshes as a wildlife refuge. Emergent vegetation of fleets and dykes provides nesting sites for a variety of birds, and seeds from the extensive stands of *Scirpus maritimus* form an important part of waterfowl diet. Pasture areas are used as feeding and roosting areas by large flocks of waders, ducks and geese, and provide breeding habitats for many bird species. Amphibia and small mammals occur and the invertebrate fauna is likely to be rich in local species compared with that of agricultural land, for example the rare Frosted orange moth (*Gortina borelli*) which feeds on *Peucedanum officinale* found nowhere else in Britain but in the study area.

INTERTIDAL MACRO-INVERTEBRATES

The aim of this study was to provide information about the distribution of populations of macro-invertebrate species inhabiting the extensive intertidal sand and mudflats in the study area. These flats are used as a winter-feeding ground for around 140,000 wading birds and consequently a study of their potential food is essential to a study of the likely ecological implications of any major development in the Maplin area.

Sampling was on a 1 x 0.5 km grid basis and 692 sample units of mud cores were taken within the 28,000 ha of intertidal flat. Unlike the other species, the invertebrates recorded were in general hidden from the eye beneath the mud surface. Sample units were sieved to a 1 mm mesh size to recover the macro-invertebrates which were counted, oven-dried, and weighed.

Identification of these little-studied animals presented special problems and in some cases it was only possible to identify to groups above the species level. However over 80 of the more conspicuous macro-invertebrates were identified to species. These large areas of level, featureless flats harbour very large populations of relatively few species (e.g. the mollusc Hydrobia ulvae in densities up to 128,000/m^2) and are less notable for their species diversity than for the invertebrate food they supply for birds. The number of species per site was usually less than 10. It is of interest therefore that the survey proved sufficiently sensitive to detect the marine worm, Clymenella torquata on Dengie flats at the mouth of the Blackwater estuary, a species hitherto only recorded elsewhere in Europe at Whitstable.

A comparative assessment of the invertebrate resources of each estuary is presented. The numbers of animals present and the total standing crop biomass were highest in the large mudflat areas of the Medway-Swale group and in the varied substrata associated with the Orwell, Stour and Blackwater group. These groupings were derived by association analysis (Table 5). This shows that species number increases markedly from the smaller estuaries (Group 1) to the larger ones (Group 3) which have a greater range of substrata. The average number of animals per site is very much larger in the big mudflat areas (Group 2), compared with big sandflat areas (Group 5). The big sandy/silt flats of Group 4 are intermediate between Groups 2 and 5 in this respect (Table 5).

In terms of potential food resources for waders overwintering in the area, the estuaries in Group 3 (Orwell, Stour and Blackwater) are shown to be the most productive in terms of standing crop biomass of potential macro-invertebrate food for waders. Of these three areas the Orwell had the highest average biomass (52.9 g dry wt/m^2) the next highest was the Stour (32.1 g dry wt/m^2), and the lowest was the Blackwater (11.2 g dry wt/m^2).

WADING BIRDS AND WILDFOWL

By virtue of its position in south-east England, at the southern end of the North Sea and close to the Continent, the study region is most important for passage populations of waders in both autumn and spring. For most species the passage in the autumn is heavier and more prolonged than in spring. A total of 24 species of waders is regularly recorded in autumn.

In 1962 European representatives at the Mar Conference of the International Union for the Conservation of Nature and other international bodies made a special plea that the United Kingdom should preserve as much of the intertidal flats of the south east English coast as possible. This was to conserve migratory waders displaced by reclamation activities elsewhere on the European coast. At that time detailed knowledge of wader populations was limited, though wildfowl populations were better known.

Site	County	Size (ha)	Age (years)	Grazing	Management	Total No. species recorded	Seawall seaward	Seawall landward	Borrowdyke	Pasture or ungrazed	Low pasture	Banks	Fleets & ditches	Trackway	Total No. quadrats
Shotley	Suffolk	20	-	Cattle	herbicide	67	8	3	5	19	20	22	19	6	9
Harwich	Essex	7.5	200+	Ungrazed	walls mown	45	14	17	3	7	6	18	-	9	7
Hamford Water	Essex	5	-	ungrazed		37	6	17	5	12	-	10	12	4	7
Bramble Island	Essex	10.5	100	ungrazed		26	5	5	2	7	-	-	-	6	6
Brightlingsea	Essex	80	200-400	cattle	walls mown	90	26	39	3	16	32	28	7	22	25
Langenhoe	Essex	173	150	ungrazed		64	12	21	8	23	9	13	5	27	35
Langenhoe	Essex	57	150	sheep/cattle		47	13	18	2	22	7	-	6	6	13
Old Hall	Essex	294	-	cattle		70	21	30	5	23	14	27	8	12	48
Maydays	Essex	25	200+	cattle		50	16	18	1	13	6	15	11	13	8
Tollesbury Wick	Essex	69	200+	cattle	walls mown	54	15	14	6	22	13	23	2	11	19
Redhill	Essex	11	200-400			39	8	8	2	13	11	11	7	-	11
Steeple	Essex	15	150	cattle		43	5	10	2	15	11	20	3	8	8
Ramsay	Essex	15	150	cattle		57	7	12	8	18	13	15	1	20	12
Fambridge	Essex	140	200	cattle	walls mown	68	14	11	4	19	16	37	12	-	25
Foulness	Essex	35	150	ungrazed		55	11	16	2	7	24	22	3	8	16
Gt. Wakering	Essex	23	200	cattle		50	4	6	2	19	9	21	4	7	11
Fobbing	Essex	11	150	cattle		40	-	19	-	12	7	20	2	9	6
Stoke	Kent	24	-	cattle		68	18	16	10	19	7	13	3	7	9
Rosecourt	Kent	133	-	cattle		85	47	49	3	23	21	42	4	-	29
Horsham	Kent	38	-	cattle		48	7	17	2	19	15	16	1	7	8
Chetney	Kent	357	200+	cattle/sheep	herbicide	83	29	50	4	33	28	41	9	20	52
Elmley	Kent	818	-	cattle/sheep		91	37	37	4	34	24	50	13	18	61
Spitend	Kent	218	-	cattle/sheep		72	43	42	7	28	27	41	7	13	39
W. Harty	Kent	326	-	cattle/sheep	herbicide mole ploughing	89	22	42	6	31	15	39	12	14	39
Uplees	Kent	38	-	cattle		53	3	15	10	12	12	15	3	-	8
Oare	Kent	19	-	ungrazed		31	11	8	1	11	6	-	-	-	6
Ham	Kent	102	-	cattle/sheep		80	36	41	7	15	16	42	15	10	32

Table 4. Number of species in the different habitats in semi-natural reclaimed marsh sites

Group	1	3	2	4	5
Sites	Roach Crouch Colne Inner Hamford	Stour Orwell Blackwater	Medway Inner Swale	Dengie S.Thames N.Thames	Foulness Outer Swale Sheppey Outer Hamford
No. species identified	36	68	40	49	49
Average no. species/sample units	7.0	9.9	7.4	6.8	7.2
Average no. animals/sample unit	131	194	257	74	52
Average total biomass/sample unit (g)	0.35	1.11	1.12	0.77	0.76

Table 5. Classification of intertidal sites in relation to their macro-invertebrate populations.

The aim of our project was to record the populations of waders, wildfowl and seabirds in the study area which is the most extensively used section of the south east coast. The Kent shore of the lower Thames estuary had to be excluded from the survey because of limited counting resources.

A team of about 110 volunteer amateur bird watchers was assembled and each allotted a particular stretch of shore about 3 to 4 miles long. They were asked to count all estuarine birds once per month. Counts were synchronised for Sundays with high spring tides as birds are easier to count when concentrated at the top of the shore. When bad weather reduced visibility, repeat counts were made when the weather improved.

The numbers in large flocks of birds were estimated by a partition technique, where a section of the flock is counted as accurately as possible and the flock size estimated by multiplying the number in a section by the number of sections estimated in the flock.

Amateur bird watchers were found to underestimate populations **originally** by up to 20% especially with small birds in large flocks. Special efforts were made by the organiser to check counters' errors and improve their accuracy. However the nature of the task was such that it could only have been done by the ornithological force available and though precise limits of error cannot be placed on the counts, current experience from the National 'Birds in Estuaries Enquiry' suggests that the figures obtained are fairly close to true values.

Bird numbers are expressed in two ways. The wintering populations of each species are estimated for the estuaries or tidal flat units of the study area (Fig 6) as the average of the November to February counts. Peak numbers give the only available estimate of holding capacity. However, it must be emphasised that detailed studies of behaviour over a much longer period than the three years available for the study would be required to estimate throughput or maximum sustained holding capacity of the different species in sub units of the study area.

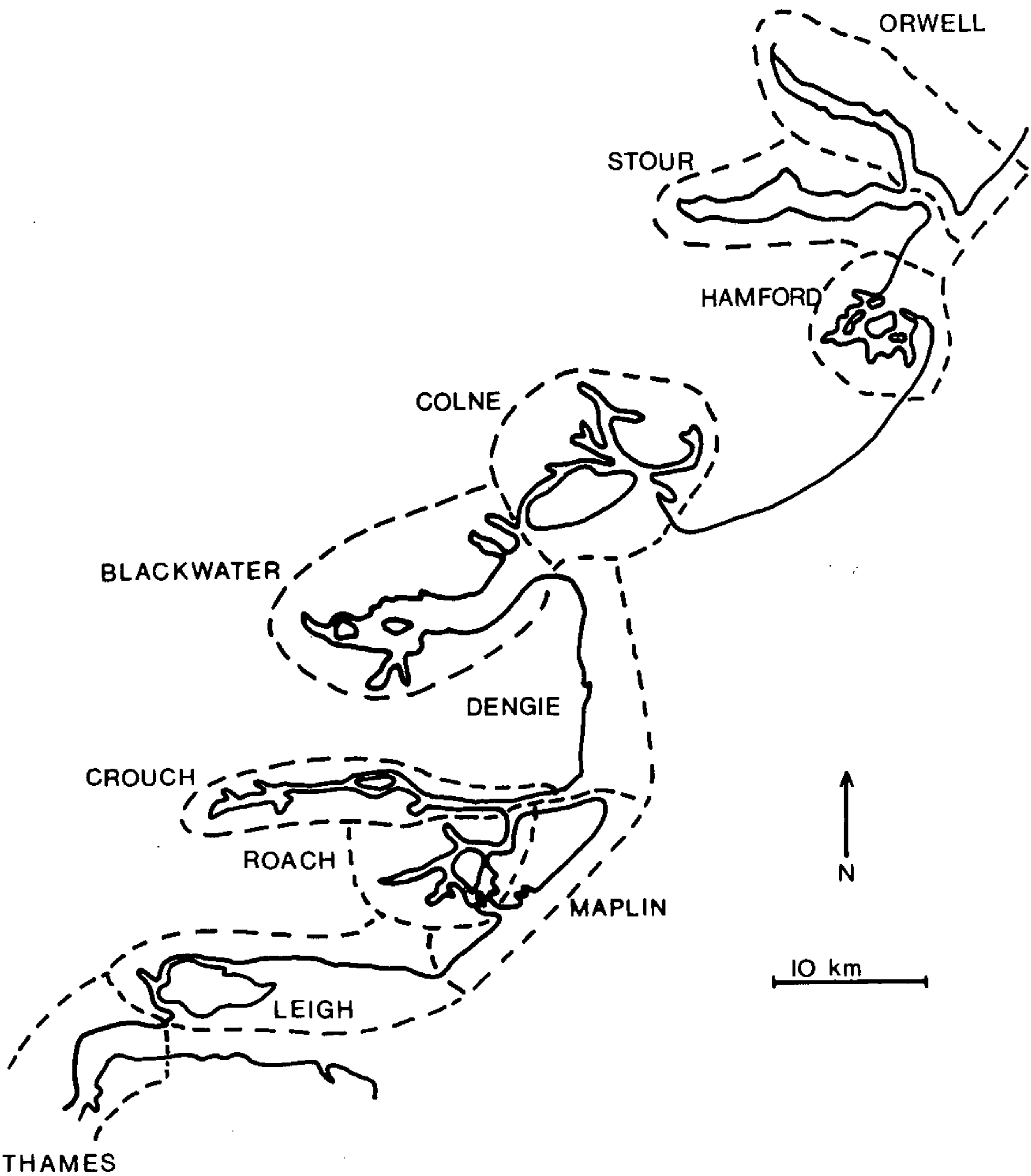
A site is considered of 'international significance' to a species if it holds at least 1% of the European wintering population and of 'national significance' if it holds at least 1% of the British Isles wintering population, as defined in the Report on the International Conference on the Conservation of Wetlands and Waterfowl held at Heiligenhafen (West Germany) 1974 published by the International Waterfowl Research Bureau, Slimbridge, Gloucestershire.

All the estuaries or tidal flat units of the study were found to contain at least one species with wintering populations of 'international significance' with the exception of the smallest, the Roach estuary. The coastal units holding seven or more species in this category were the Hamford Water Inlet, the Stour, Colne and Blackwater estuaries, and the Foulness flats (Table 6).

About 45,000 wildfowl winter in the study area and peak numbers of 56,000 have been recorded. The study area has been found to hold at least 20% of the world population of Dark-bellied brent geese and populations of 1% or more of the European populations of shelduck (7%), pintail (2%), wigeon (2%), teal (1½%), and Mute swan (1%).

The populations of British populations greater than one per cent held by the study area, together with population percentages and in estuaries and tidal flat units are given in Table 7. Seven species breed fairly regularly in the region: mallard, teal, gadwall, shoveler, Tufted duck, pochard and shelduck.

Fig. 6 Bird Study Areas



Species	Orwell	Stour	Hamford Water	Colne	Blackwater	Dengie	Crouch	Foulness	Leigh	Thames
Pintail		1.5								
Shelduck		2	1	1.5	2					1.5
Brent goose	1	1	3.5	2	6.5	2.5	1	16	3	
Oystercatcher								1		
Ringed plover			1.5	1	1			1	1	
Grey plover		2	2.5	1	2	2.5		1.5	1	
Curlew			1.5	1	1	1		1.5		
Black-tailed godwit		1.5	1							
Bar-tailed godwit								2.5		
Redshank	1.5	3	2	2.5	1.5					
Knot								1.5		
Dunlin		1.5	1		1				1	
Sanderling			1.5	1.5		1				
Total Species	2	7	9	7	7	4	1	7	4	1

Table 6. Percentage of European winter populations (1% or more) of bird species recorded at levels of "international importance" (1% or more), in estuaries and tidal flat units of the study area and the number of species in each site with populations in this category.

Species	Orwell	Stour	Hamford Water	Colne	Blackwater	Dengie	Crouch	Roach	Foulness	Leigh	Thames	Total population	% European	% British
Mallard	6.5	13	5.5	12	13	17.5	5	3.5	3	1	20	5015		1.5
Teal	3	2.5	7.5	7.5	11.5	8.5	28.5	6	5.5	3	15.5	2475	1.5	3
Wigeon	11	28	5	1.5	16.5	7	10	1	9.5	10	.5	6865	2	3.5
Pintail	13.5	44	8.5	1	8	5.5	5.5		.5		13.5	1045	2	5
Shoveler	33	6.5	3.5	10.5	14.5	1.5	16.5	3.5	4	4	1.5	150		3
Tufted duck	24.5	2		12.5	17.5			4	2		37	285		
Pochard	5.5		1.5	3	5			.5	1.5		82.5	1260		3
Goldeneye	13	6.5	5.5	37.5	33	3.5						455		4
Long-tailed duck	6.5			25	31	19	6		12.5			16		
Common scoter	2		13	16	2.5	6			60.5			190		
Eider	15		3	24	27.5	9	3		15	3		33		
Red-breasted merganser	3.5		22	33.5	30.5	6.5	.5	1.5	1.5			180		2
Shelduck	11	20.5	10.5	13	20.5	2.5	3	3	4	.5	11.5	8640	7	13
Brent goose	2	2	13.5	6.5	24.5	7	2		33.5	9.5		15830	20	40
Mute swan	29	26	1.5	14.5	12		1	1.5	4.5	1	20	865		5
Coot	53.5	6.5			6.5		4.5	3	19.5		7	1085		

Table 7. Distribution of estuarine wildfowl in Maplin Study Region. Average winter populations of wildfowl species per area as percentage of total average winter population of species for Study Region. Proportions (exceeding 1%) of the latter of British and European populations, are also given.

Species	Orwell	Stour	Hamford Water	Colne	Blackwater	Dengie	Crouch	Roach	Foulness	Leigh	Thames	Total population	% European	% British
Oystercatcher	3.5	3.5	5	5.5	7	13.5			59	2.5		7245	1	3
Lapwing	8	7.5	9.5	9	16	6.5	16	9.5	8.5	6	3.5	7640		
Ringed plover	7	8	21	10	15	2.5	3	2	8	14	9.5	1200	6	12
Grey plover	1.5	10.5	22.5	6.5	16	19.5			11.5	9	2	2575	8.5	32
Golden plover		1	31	11.5	16.5	16	6.5		17			2945		
Turnstone	16	10.5	9.5	15	20	14.5			7	7		1385		14
Common snipe	6.5	3	18	6.5	9	1	6.5	2.5	2	22	23	390		
Curlew	6.5	8	17	12	15	9	4	3	20	6		7480	5	10
Black-tailed godwit		76	23									595	1.5	4
Bar-tailed godwit			2.5		7	8.5			81.5			2110	2.5	3.5
Redshank	13	18.5	14.5	14.5	9.5	3	4.5	5	5	7	5	13765	11	14
Knot	1	4.5	1.5		3.5	27			54	8		11050	2	3
Dunlin	8.5	13	15	9	15	5.5	2	2	9	12	8.5	74165	6	1.5
Sanderling			29	35		8			1			375	4	4.5
Ruff			7.5		5						87.5	40		4

Table 8. Distribution of estuarine waders in Maplin Study Region. Average winter populations of wildfowl species per area as percentage of total average winter population of species for Study Region. Proportions (exceeding 1%) of the latter of British and European populations, are also given.

About 133,000 waders winter in the study area and they represent about 5% of the estimated total for Europe and about 8½% of the British total. Peak numbers of 143,000 have been recorded in the study area. It holds winter populations of 5% or more of the European populations of the redshank (11%), Grey plover (8½%), Ringed plover (6%), dunlin (6%)and curlew (5%) and one percent or more of sanderling, Bar-tailed godwit, Black-tailed godwit, knot and oystercatchers. The proportions of British populations and population percentages found in estuaries and tidal flat units are given in Table 8. Four species of wader breed regularly in the study area: redshank (c. 1,200 pairs), lapwing (c. 320 pairs), Ringed plover (c.275 pairs) and oystercatcher (c. 180 pairs).

The counts show there are at least 30,000 sea birds wintering in the study area and at least half of these are Black-headed gulls. In addition some 4,000 twites (a kind of finch) winter on the saltings, and the beaches support variable numbers of shorelarks and Snow buntings. Totals and proportions of the principal seabird and other species are given in Table 9.

In summer the study region supports breeding populations of Black-headed gulls (c. 8000 pairs), Common terns (c. 220 pairs), Little terns (c. 150 - 200 pairs), Sandwich terns (c. 40 pairs) and herons (c. 100 pairs). The little terns represent up to 11% of the total British breeding population.

One or two of the very rare Marsh harriers feed in the area. Birds of prey in winter include Hen harriers (10 - 20), merlin (10), Short-eared owl (100) and Rough-legged buzzard (11 in 1974 - 75).

BRENT GEESE

Introduction

Reliable records of Dark-bellied brent goose populations have only been kept since about 1960. In the 1930's a disease reduced severely stocks of Zostera on European and North-east American coastlines. The species principally affected in

Europe was Zostera marina and the extent to which one of the main food plants of Brent geese, Zostera noltii was affected is by no means clear. The meagre evidence available from occasional records often years apart, suggested that populations of two species of brent geese declined in both Europe and North America after the disease.

Since the 1930's there has been some recovery of Zostera. It has also become apparent that high frequency of breeding failure as a result of adverse weather conditions on the Arctic breeding grounds is an important factor affecting populations of Dark-bellied brent geese. In addition the birds have been subjected to human predation on their summer breeding ground and to shooting on their winter grounds until recently.

The immediate prohibition of shooting of the Light-bellied brent goose in North America for a number of years after 1930 resulted in a fairly rapid recovery in number. The prohibition of shooting of the Dark-bellied race was more difficult to achieve, since its wintering range encompasses five countries. However, since 1950 all of these countries (except West Germany) have introduced legislation against the shooting of Brent geese. Since the 1950's a gradual increase in Dark-bellied brent geese has taken place and the population was estimated to have reached 25-30,000 in the late 1960's. At that time numbers appeared to be stabilising and it was thought that habitat destruction of the winter feeding grounds might be imposing a limit to further increase. Land reclamation since the war, especially in the Netherlands, has placed increasing pressure on wintering areas for Brent

Species	Orwell	Stour	Hamford Water	Colne	Blackwater	Dengie	Crouch	Roach	Foulness	Leigh	Thames	Total
Great crested grebe	29	15.5	2	9.5	29	9.5	2	1	.5	1	1	105
Little grebe	42	2	15	5.5	7	.5	11	5	11.5	.5		165
Cormorant	18.5	12.5	4	8	20.5	21.5	3	1.5	5	1.5	3	485
Heron	5.5	6.5	5.5	6.5	15	3	8.5	18.5	13	13	5	93
Greater black-backed gull	3.5	8	13	4	9.5	5	1	3.5	4	43	5.5	2040
Lesser black-backed gull	1	.5	19	1	1.5	2	2	2	1	10	60	750
Herring gull	2	2	30	3.5	4	19.5	1.5	4.5	11	10	12	1160
Common gull	3.5	6	10	2	4	44.5	3.5	5	12.5	2	7	2350
Black-headed gull	5.5	4.5	8	5.5	5.5	7	4	3.5	3.5	7	45	17720
Twite	1.5		36	5.5	6	36	6	6	1.5	1.5		4175

Table 9. Distribution of seabirds in Maplin Study Region. Average winter populations of wildfowl species per area as percentage of total average winter population of species for Study Region.

geese. Since 1968 however the world population of Dark-bellied brent geese has more than doubled in size, to about 84,000 birds in 1973. The inter-tidal feeding grounds were apparently insufficient to support this population and substantial numbers of birds fed on agricultural land.

Feeding Ecology of Brent Geese

The aims of the study were to determine the detailed distribution of Brent geese on their winter feeding grounds in the study area, to determine their seasonal choice of food and to relate their energetic requirements to food supply.

This information could then be applied to an assessment of the Maplin food supply for the birds, and the potentiality of substitute sites to support Brent geese displaced by a development at Maplin.

At the start of the study there was a justifiable assumption that Brent geese fed almost exclusively in the inter-tidal zone. The fact that the study coincided with a doubling in population size and a change in feeding behaviour could not be predicted. Provision was therefore not made to cover inland feeding, and even salt marsh feeding on the scale that it occurred in the unusually mild winters was something of a surprise. However, the very size of the differences in food use in the feeding study (see below) underline the magnitude of these changes in feeding behaviour from traditional patterns (although disturbance was an additional factor that had to be taken into account).

From arrival in September until January, more than half the Brent geese in Essex feed on the Zostera beds at Foulness and Leigh. After this date the majority of birds are to be found in the other estuaries of the study area feeding mainly on Enteromorpha, and to a small extent on salt marsh. In January-February 1973-74 when peak counts of Brent geese in the study area were about double those in 1972-73, over 30% fed on winter cereals and grass pasture landward of the sea wall (Table 10). Feeding on agricultural land had previously only been recorded during the severe winter of 1962-63.

Juvenile birds spend 95% of their time feeding. Initially adults spend only 75% of their time feeding, but this approaches 95% as the amount of food declines through the winter.

Food intake was measured (1) by comparison of food biomass within and outside grazing exclosures (2) from formulae based on energy requirements in relation to body weight and (3) from estimates of the total weight of faeces produced per bird per day and estimates of food intake from the relative ash content of food and faeces.

Estimates of food consumption derived from basal metabolic requirements (287 Kcal per day for an active Brent goose of 1,300 gm live weight) give good agreement with the values derived by other methods.

The values of standing crop of the intertidal foods Zostera and Enteromorpha were divided by the estimates of food consumption and from this, figures for the potential goose days grazing obtained (Table 11). No estimates of the standing crops of salt marshes, pastures, or cereals were obtained. Suggested reasons for the differences between actual use of geese of all available food stocks and estimated potential use of surface intertidal food stocks are summarised in Table 12.

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
				1972-73				
Zostera	66.7	97.5	83.4	88.5	60.4	44.6	33.6	52.4
Enteromorpha	33.3	2.5	16.6	7.9	29.9	38.7	51.4	24.6
Saltmarsh	0.0	0.0	0.0	3.6	9.7	16.7	15.0	23.0
Cereals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rough grazing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				1973-74				
Zostera	100.0	92.6	84.2	52.8	34.9	27.4	19.6	20.8
Enteromorpha	0.0	7.4	15.8	21.0	20.0	31.7	38.5	57.4
Saltmarsh	0.0	0.0	0.0	4.4	10.2	10.4	12.1	4.9
Cereals	0.0	0.0	0.0	11.9	16.8	12.3	8.4	0.0
Rough grazing	0.0	0.0	0.0	9.7	16.1	18.3	21.4	16.8
				1974-75				
Zostera	98.3	91.4	67.5	53.3	33.9	23.1	21.6	91.6
Enteromorpha	1.7	8.6	32.5	28.0	30.7	34.1	40.7	8.1
Saltmarsh	0.0	0.0	0.0	5.9	9.5	12.3	12.9	0.3
Cereals	0.0	0.0	0.0	6.0	12.3	9.5	6.1	0.0
Rough grazing	0.0	0.0	0.0	6.8	13.8	21.0	18.7	0.0

Table 10. The percentage of total population of Brent geese feeding on different food types for each month during the winters from 1972-75.

	Best estimate of potential grazing on intertidal food in thousands of goose days			The actual usage of areas in thousands of goose days		
	1972-3	1973-4	1974-5	1972-3	1973-4	1974-5
Orwell	234	234	243	3.7	57.7	26.5
Stour	323	323	329	41.4	41.5	46.8
Hamford Water	90	90	91	107.6	413.1	322.0
Colne	74	74	74	140.8	214.6	184.6
Blackwater	428	428	432	281.2	796.3	633.4
Dengie	160	160	160	177.3	220.2	262.4
Crouch	186	186	186	-	35.4	49.6
Foulness	692	692	822	766.9	1164.8	817.0
Leigh	157	157	188	208.3	225.9	183.6
Swale	635	635	644	31.6	72.1	47.8
Medway	1671	1671	1677	30.8	165.2	80.9

Table 11. Best estimated potential goose days grazing available of surface intertidal foods (derived from values of standing crops and daily food intake) together with the actual number of goose day grazing used on all food sources in each of 11 areas.

Site	1972-3	1973-4	1974-5
Orwell	Actual less than potential: disturbance	Actual less than potential: disturbance	Actual less than potential: disturbance
Stour	Actual less than potential: disturbance	Actual less than potential: disturbance	Actual less than potential: disturbance
Hamford Water	Actual equal to potential	Actual greater than potential: feeding on rough grazing	Actual greater than potential: feeding on rough grazing
Colne	Actual greater than potential: saltmarsh feeding	Actual greater than potential: feeding on saltmarsh, cereals and rough grazing	Actual greater than potential: feeding on saltmarsh
Blackwater	Actual less than potential: disturbance	Actual greater than potential: feeding on cereals and rough grazing	Actual greater than potential: feeding on cereals and rough grazing
Dengie	Actual equal to potential	Actual greater than potential	Actual greater than potential: disturbance
Crouch		Actual less than potential: disturbance	Actual less than potential: disturbance
Foulness	Actual greater than potential: *Zostera* root feeding	Actual greater than potential: feeding on *Zostera* roots, cereals and rough grazing	Actual equal to potential
Leigh	Actual greater than potential: *Zostera* root feeding	Actual greater than potential: *Zostera* root feeding	Actual equal to potential
Swale	Actual less than potential: disturbance	Actual less than potential: disturbance	Actual less than potential: disturbance
Medway	Actual less than potential: disturbance	Actual less than potential: disturbance	Actual less than potential: disturbance
Average Brent goose winter population	11,600	18,800	16,700

Table 12. Summary of differences between estimated actual use by Brent geese of all available food stocks and estimated potential use by geese of surface intertidal foodstocks in estuaries and tidal flat units of the study area and probable reasons for discrepancies.

It is estimated that the consequences of removal of the large area of Zostera at Maplin, should reclamation take place, would be to place additional demands of about 1,000,000 goose days grazing on the rest of the area. It is predicted that this would result in an earlier and more rapid stepwise progression down the gradient of food preference from Zostera to Enteromorpha to cereals. In consequence it seems likely that loss of Maplin food resources for Dark-bellied brent geese would result in increased goose grazing on agricultural land.

Movements of Brent Geese

Until the present study only 16 individual Dark-bellied brent geese had ever been ringed in the British Isles. The initial aim of this study was to develop techniques for catching and marking substantial numbers of these birds. Subsequent aims were to find the role of Maplin as a holding and dispersal area, their movement to other areas, their fidelity to sites from year to year and to contribute information on flock behaviour.

Catching these wary birds on open mudflats depended very much on capacity to predict accurately where they would alight, and on split-second timing in trapping them.

Cannon nets were designed to overcome the difficult and novel problems of catching the birds on mudflats, but the size of the catch had to be limited to the number of birds that could be processed without risk to operators or birds. When feeding in saltings and agricultural pasture developed, traditional rocket net techniques designed previously by the Wildfowl Trust allowed higher catches to be made. A total of 817 geese (1% of the maximum recorded world population) was caught (Table 13). These were marked with individually coded, coloured tarsal rings and 3,343 re-sightings were made of 578 (71%) of them (Table 14). The presence of family units was detected in 1973-74. One family party of four ringed on Foulness was followed north to the Blackwater and then south to Chichester harbour (where two were seen the following year). One family party travelled at least 500 miles (from Chichester harbour to the Dutch Waddensea) in 24 hours.

A background analysis of local wildfowl counts showed that Maplin was an early winter resort and on average 70% of all British Dark-bellied brent geese were there in October during the period of study (Table 15). Colour marked birds dispersed to other English estuaries from Maplin and along the south coast into France. The spring migration of marked birds from these late winter resorts through the Netherlands and West Germany was also traced (Table 16).

Between 41% and 53% of birds were re-sighted, in the year following capture, in the areas where they had been marked. Further evidence that a high proportion of birds were faithful to particular sites was shown by the fact that some birds even returned to the same particular parts of estuaries. In contrast birds from many different English estuaries were seen gathered together in flocks on spring migration in the Netherlands and Germany.

Increases in the number of birds depend on good breeding years and in only eight of the last fifteen seasons have significant additions been made to the population (Fig 7). No other goose species has such variable breeding success. This leads to unbalanced age class structure in the population likely to affect social behaviour.

In good breeding years (1972 and 1973) adults and juveniles migrated together in autumn. In 1974, when few Brent geese bred, adults migrated in autumn ahead of two year old birds. It is probable that adult experience is important to well-being of survival of juveniles and Maplin may be of special importance, not only as a gathering point from which autumn migrants disperse, but also as a learning site for juveniles on their first winter grounds.

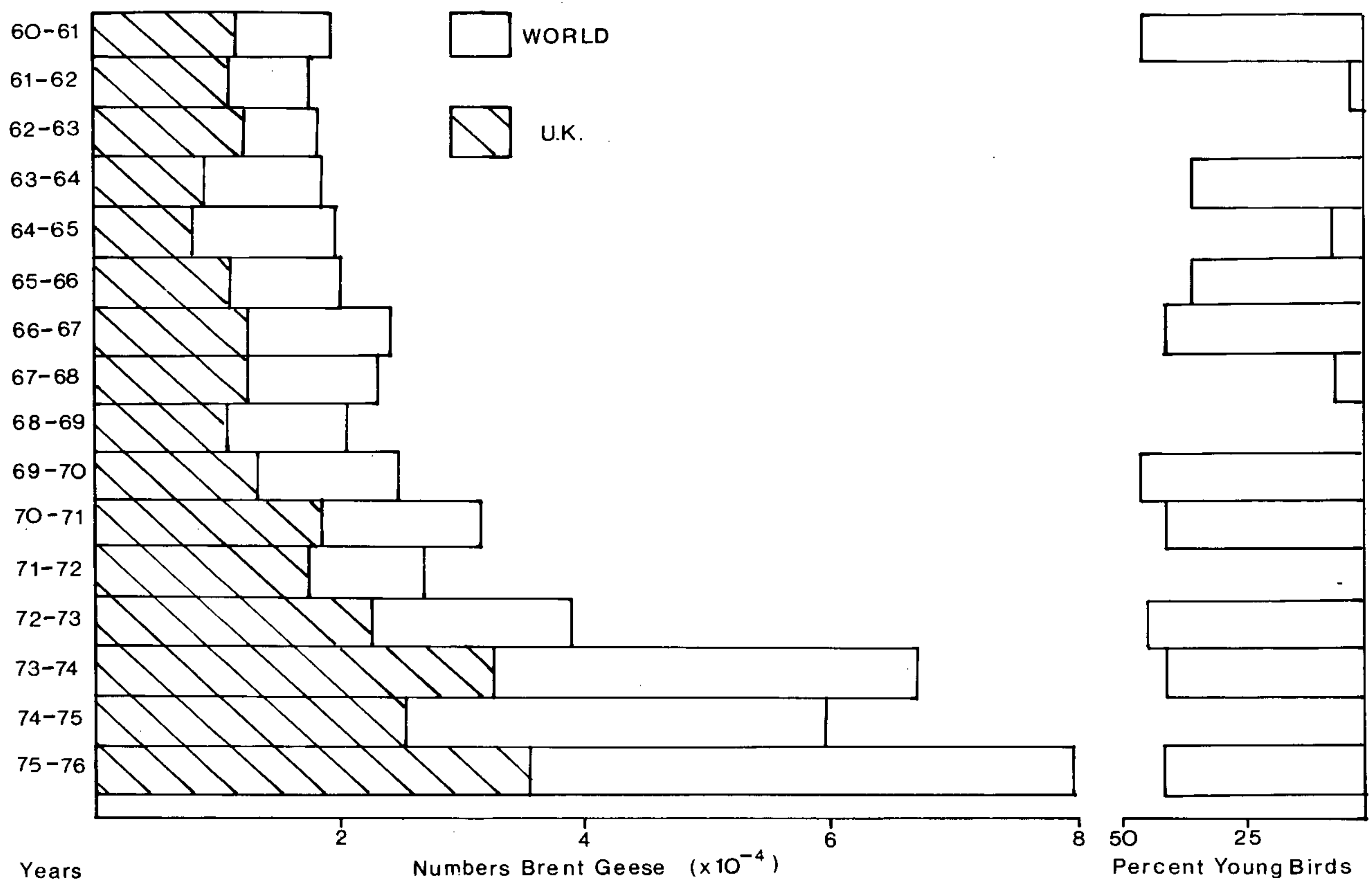


Fig. 7 Population Changes in Dark-bellied Brent Geese 1960-1975

	1972-3			1973-4					1974-5			Total catch for each site
	Jan	Feb	Mar	Nov	Dec	Jan	Feb	Mar	Nov	Dec	Feb	
Foulness	29	4	2	93	49				41	40		258
Crouch		24					12				89	125
Blackwater				6	10	10	80				57	163
Hamford								130				130
North Norfolk							57					57
Wash								84				84
Total		59				531				227		817

Table 13. Catches of Dark-bellied brent geese for each month in each site.

Area	1972-3	1973-4	1974-5	Total for each area
	Years			
Foulness	59	363	860	1282
Germany	0	57	782	839
Blackwater	0	116	251	367
Hamford Water	0	5	264	269
Netherlands	0	73	160	233
North Norfolk	0	10	100	110
Leigh	2	11	44	57
Chichester Harbour	0	51	20	71
Crouch	2	20	18	40
Langstone Harbour	8	20	10	38
Colne	0	13	1	14
Orwell	0	2	5	7
Swale	0	5	1	6
Medway	0	2	2	4
Dengie	0	3	1	4
Pagham	0	2	0	2
Total for each year	71	753	2519	3343

Table 14. The number of sightings of marked Brent geese by years for each area.

Area	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
South coast + Wales							
Burry Inlet	0	0	42	57	62	35	1
Exe	0	425	625	650	205	93	25
Poole Harbour	0	0	101	190	146	52	0
Isle of Wight	0	41	237	335	209	310	9
Solent	0	0	100	320	321	202	1
Portsmouth Harbour	0	0	200	320	(200)	180	nc
Langstone Harbour	54	(2000)	6075	5500	4513	2407	652
Chichester Harbour	105	425	6070	6850	7390	5215	420
Pagham Harbour	0	0	300	500	(500)	635	65
Total	159	(2891)	13750	14722	(13546)	9129	1173
Essex - Kent							
Swale	26	343	923	320	349	448	8
Medway	20	250	565	766	568	200	160
Leigh, Canvey	800	3300	1650	425	604	428	202
Foulness	9782	12868	6707	3576	2100	1451	695
Crouch, Roach	0	7	420	640	1226	3	1
Dengie	900	400	580	935	1040	1650	475
Blackwater	297	2900	6117	4518	4850	4838	2939
Colne	6	98	1150	2033	1754	1785	289
Hamford Water	278	405	2200	3000	3360	3130	1170
Stour	138	310	360	188	79	219	66
Orwell	0	290	540	650	400	132	0
Total	12247	21171	21212	17051	16330	14284	6005
North Norfolk - Wash							
North Norfolk	(14)	(296)	2000	2284	3855	(628)	(231)
The Wash	3252	4323	4224	3765	3998	3917	2918
Total	(3266)	(4619)	6224	6049	7853	(4545)	(3149)
British Total	(15672)	(28681)	41186	37822	(37729)	(27958)	(10327)

0 = no geese   nc = no count   ( ) = incomplete coverage.

Jersey 1150; France 31700; Netherlands (Friesland Isles) 1682; Netherlands (Mainland) 5426; Germany (3000); Denmark 257.

World Total = (84401)

Table 15. 1973-74 The monthly total of Dark-bellied Brent geese at each of their regular wintering sites in Britain. Below the main table are the December figures from the remainder of the wintering range. The sum of these and the British figures are the World Total.

	Peak population (to nearest 100)	No. of observation days		No. of marked birds identified	
	1974-5	1973-4	1974-5	1973-4	1974-5
Foulness	8600	65	63	108	208
Langstone	5600	5	6	7	6
Chichester	5200	11	7	18	14
Blackwater	4600	36	52	53	105
Hamford Water	3500	2	18	4	83
Leigh/Canvey	3100	5	7	7	25
North Norfolk	2600	3	11	9	46
Colne	1900	4	2	8	1
Dengie	1800	2	1	3	1
Crouch	800	6	2	9	12
Swale	700	2	2	2	1
Medway	700	2	2	1	1
Pagham	700	2	0	1	0
Orwell	400	1	2	2	5
	Total Gt. Britain	146	175	232	508
Fohr	3500	3	30	31	86
Langeness	4000	1	44	2	88
Rest of Germany		3	2	13	1
Texel	5000	12	10	15	15
Schiermonnikoog	3000	13	43	14	30
Rest of Netherlands		2	23	7	14
	Total Continental sites visited	34	152	82	234
	Total all sites visited	180	327	314	742

Table 16. Dark-bellied Brent goose populations in British and Continental sites and numbers of marked birds seen in relation to observation frequencies 1973-75.

The approximate age composition of the British population of Dark-bellied brent geese was calculated for 1973-74. The total was estimated at 41,000, with about 15,400 first-winter birds, 7,600 breeding adults and 18,000 full grown birds without young (from the estimated mean brood size of 4.0 and the estimated percentage of first-winter birds as 37.5). The full grown birds without young were probably mostly in their second winter, for Brent geese do not usually breed until their third or fourth summer.

Behaviour of Brent Geese

It was clear from the results of the marking studies that Brent geese, in common with other geese, have a well-marked social structure based on the family unit. Social behaviour of higher organisms like geese must be taken fully into account in interpreting distributional relationships. Interaction between flocks and individuals also modifies their reactions to disturbance factors.

The objectives here were to determine the main causes of disturbance to Brent geese in the study area, their frequency and effectiveness in disturbing geese, the plasticity of response to disturbance, and the amount of feeding time lost through disturbance.

Six sites (Colne, Goldhanger and St. Lawrence Bay - Blackwater, Dengie, Leigh and Maplin) were selected for study to include a range from little disturbed sites (Maplin) to very disturbed sites (Leigh). Together these supported about two thirds of the British population of Dark-bellied brent geese. Data on geese and disturbance factors were recorded in over 10,000 watching-time units of 1 minute each. Feeding time lost by disturbance was estimated by comparing the percentage of time spent feeding during undisturbed and disturbed periods. The effect of flock size or susceptibility to disturbance was measured by standard approaches on foot.

The main causes of disturbance were people on the shore or sea wall and propellor driven small aircraft. These together accounted for 75% of all disturbance recorded (Table 17). People on the ground were found to put to flight 48% of geese; aircraft put to flight 39%; the remaining 13% were put to flight by loud noises (boats, gun shots etc.). Brent geese were found to be particularly susceptible to disturbance from aircraft, and any aeroplane below about 500 m and up to $1\frac{1}{2}$ km away could put them to flight. They were very slow to become habituated to aircraft, though at Leigh Marsh they did cease responding by January and February to transport aeroplanes taking off regularly from Southend airport. About 30% of people approaching within 100 m put birds to flight in the November to December period; only 12% of people did so at this distance in the January to March period. Brent geese learned the dangers associated with particular places and became more wary in areas where they had previously been threatened. For example in February geese could not be approached within 500 m on the Colne saltings which were much used by wildfowlers, while in contrast the same birds could be approached to within 150 m on the Colne mudflats which were less disturbed. Experimental approaches to flocks of between 6 and 400 geese on Norfolk salt marshes in February and March showed there was a tendency for larger flocks to take flight at greater distances.

Taking all areas into account, disturbance prevented geese from feeding for an average of 3.5 per cent of their time. The greatest losses of feeding time were recorded at weekends at Leigh and Goldhanger (Table 18). Brent geese spend most of their time feeding in inter-tidal areas when food is available to them because the tide limits food availability allowed. Using a nightscope it was established that Brent geese fed at night throughout the winter, sometimes in cloudy weather, and in some cases on quite sparse Enteromorpha. Geese appeared

				Nature and number of disturbances										
				People on the ground			Aircraft				Loud noises			
Place	Time of year	Total time watched (mins)	Mean time between disturbances (mins)	On shore or seawall	Wildfowlers	Baitdiggers	Propeller driven small aircraft	Propeller driven large aircraft	Jets	Helicopters	Boats with outboard engines	Army explosions	Gun shots	Total
Colne	Jan - Mar	1179	147	1	1		1					4	1	8
Goldhanger	Nov - Dec	1439	60	10	1	1	7			2			3	24
Goldhanger	Feb - Mar	1428	179	2	1	1	4							8
Goldhanger	Jan - Feb (weekends)	452	75	5									1	6
St. Lawrence Bay	Feb - Mar Nov	611	76	4			1	1	1		1			8
Dengie	Nov - Mar	1958	218	2		3	4							9
Foulness	Oct	581	290									2		2
Leigh	Nov - Dec	862	32	14			4	6			3			27
Leigh	Jan - Mar	947	118	1		2	4				1			8
Leigh	Oct - Nov (weekends)	600	25	7		3	10	4						24
Total		167h 37m		46	3	10	35	11	1	2	5	6	5	124

Table 17. The nature and frequency of disturbances that put some or all of the Brent geese being watched to flight.

Place	Months	Year	% Time feeding no disturbance (A)	% Time feeding overall (B)	% Time disturbance prevented feeding (A-B)	Time watched mins.
Colne, mudflats	Feb - Mar	1973	41.8	41.1	0.7	235
Colne, Geedon saltings	Feb - Mar	1973	91.1	90.3	0.8	209
Goldhanger	Nov - Dec	1973	64.3	61.2	3.1	519
Goldhanger	Feb - Mar	1974	50.0	48.0	2.0	581
Goldhanger	Jan - Feb (weekends)	1974	51.9	44.8	7.1	295
St. Lawrence Bay	Feb - Mar - Nov	1973	67.8	63.3	4.5	501
Dengie	Mar. Nov. Dec. Jan.-Feb.	1973 1974	59.3	57.3	2.0	435
Foulness	Oct	1973	82.4	80.5	1.9	581
Leigh	Nov - Dec	1973	79.3	74.4	4.9	862
Leigh	Jan - Mar	1974	62.7	62.9	-0.2	697
Leigh	Oct - Nov (weekends)	1974	53.3	41.6	11.7	600

Table 18. The feeding time lost by Brent geese as a result of disturbance.

not to feed so intensely at night as during the day, and mostly fed at mid-tide as the water lifted the food off the mud and made it easier to eat.

Brent were shown to lose a mean of 9% body weight from November-December to January-February in 1974, a mild winter when the world population was at a maximum. No such loss in weight was found when measurements were made in Denmark in 1963-65 when the world population was less than one third of the 1974 value. Evidence from White-fronted geese in the 1962-63 cold winter showed that birds that had died of starvation were 42 per cent lighter than the average for normal winters. Even a 9 per cent loss in body weight could result in reduced breeding performance.

MANAGEMENT

The final objective of the scientific programme was to undertake trials for the purpose of providing guidance for the future management of substitute sites to increase their wildlife potential.

Practical management consists of either improving conditions favourable to a desired aim or reducing conditions that are detrimental to it. It was apparent at the start of the study that certain basic ecological information was essential to plan any detailed management activities. It was equally clear that trials relating to the feasibility of management activities were desirable in three main areas of study. These were (a) provision of additional food resources for particular species, (b) reduction in competition from other species and (c) reduction in disturbance and pollution in substitute sites.

Until the basic ecological information had been collected, and from this possible substitute sites identified, management trials could not be planned comprehensively and it was anticipated that they would have formed an important part of continuing studies in the event of a major development at Maplin going ahead. Since such studies take several seasons to complete some input on management trials seemed desirable and contributions have therefore been made on the feasibility of transplanting Zostera, the potential of existing mudflat areas for additional Zostera growth, and the significance of competition between Brent geese and wigeon which share common food plants.

Zostera noltii turfs were transplanted on a pilot trial scale on sheltered estuarine mudflats at Breydon Water, Norfolk in March 1972. All of the 20 turfs planted survived to the end of the first year, 35 per cent after 2 years, and 5 per cent after $3\frac{1}{2}$ years. Some transplants flowered and seeded in each year after planting.

A field scale trial, approaching 1 ha in size was set up at a cost of £1,000 in 1973 using about 2,000 Zostera noltii turfs. There was 3 per cent survival after 1 year and 0.2 per cent after 2 years.

The facts that some turfs in both trials showed an 8 to 10-fold increase in area during the first summer after transplanting and at least some turfs flowered and seeded and persisted for over 3 years, demonstrate that Zostera noltii planting is feasible, though the site used was clearly unsuitable for long term growth. Three lines of evidence support this conclusion. First, measurements of changes in the mud surface levels revealed that while survival did occur in areas where the level changed $\pm$ 7 cm per year (or up to $\pm$ 3 cm per week), the overall trend on the mudflat over a 3 year period was one of erosion. Second, there was a very rapid natural colonization of the transplant area during the trials by Zostera marina var. angustifolia, a species favouring marginally lower-lying and wetter areas than Zostera noltii. Third, map evidence of the natural distribution of Zostera noltii (a newcomer to the site and which spread in the course of the trials), shows that it favours slightly higher creek bank sites which drain more freely than the planting trial sites.

While we have not yet seen a copy of the Hydraulics Research Station's final report on hydraulic limitations and potential mudflat areas for Zostera growth, interim reports suggest that few, if any, extensive mudflat areas suitable for creating new Zostera beds exist at present in the study area. The possibility remains of creating suitable areas by engineering activities.

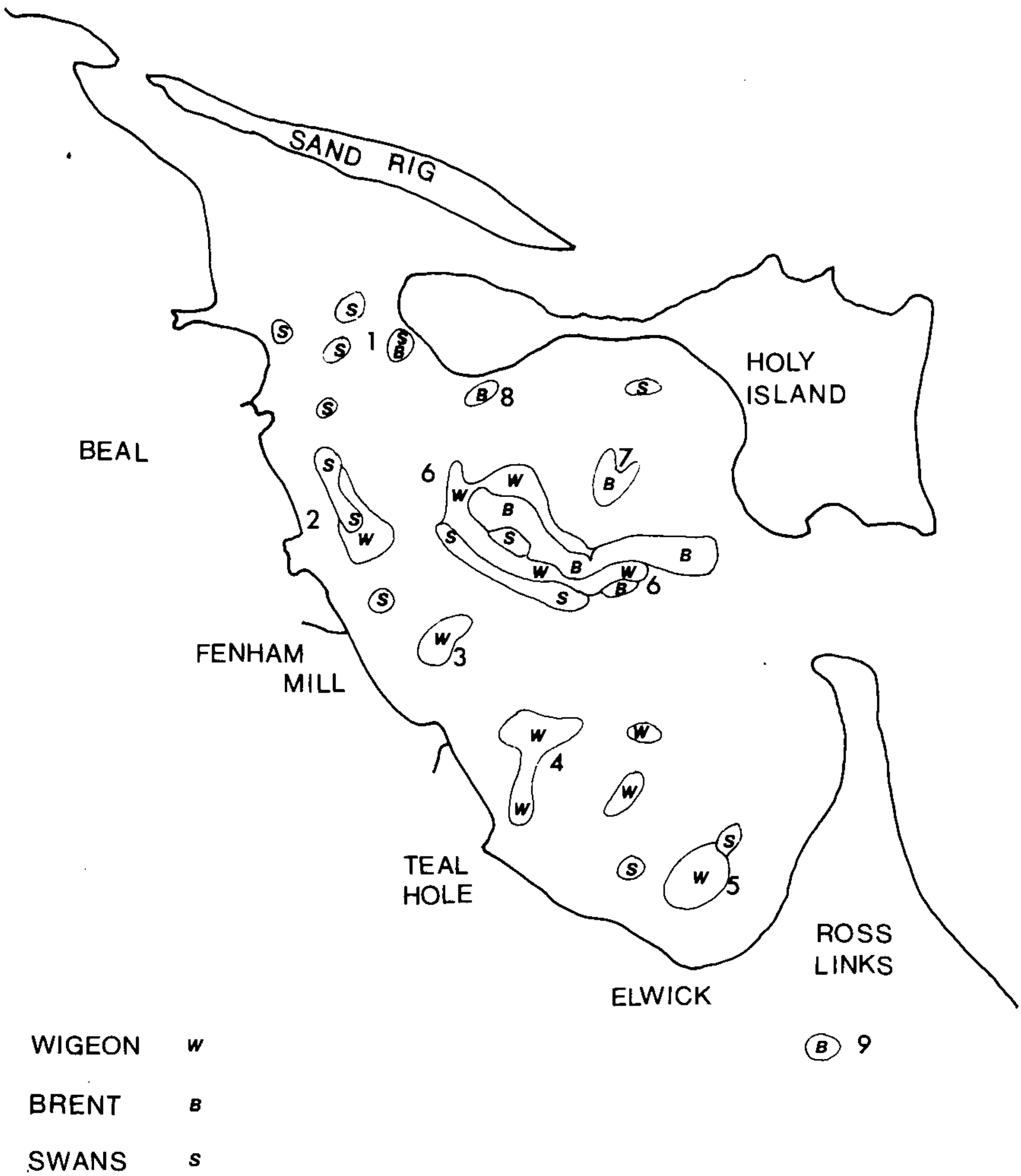
One possible strategy would be to encourage geese to feed on agricultural land and compensate farmers for any damage done to crops.

However, there is considerable potential for improving existing salt marsh and reclaimed marsh vegetation to improve food resources for Brent geese. But it must be borne in mind that such feeding areas will only be fully available in relatively mild winters. The saline mudflat feeding grounds washed daily by the sea remain available and ice free in all but the severest winter periods. Formerly most of the salt marshes in the study area were grazed by sheep and this encourages a type of sward more suitable for goose grazing than the present ungrazed swards. The general principles of manipulating salt marsh swards are moderately well known from farming practice and recent experimental management studies. Feasibility trials would be necessary to relate this knowledge to the marshes in the study area.

Wigeon also feed on Zostera and Enteromorpha and therefore could compete with Brent geese for these foods. Had an airport been built at Maplin, Brent geese might have been faced with such competition in other Essex sites, and from known numbers of wigeon present this could have been an important factor. The present distribution of Brent geese and wigeon in the study area does not appear to bring these birds into direct competition for food. The presence of Light-bellied brent geese and wigeon, both in substantial numbers at Lindisfarne, Northumberland suggested this would be a suitable area for study although a different race of Brent goose was involved. The feeding ecology and behaviour of Light-bellied brent geese at Lindisfarne, Northumberland was found to be basically similar to that of Dark-bellied brent geese in Essex. Study of the distribution of Light-bellied brent geese and wigeon (and also Whooper swans) at Lindisfarne showed that they generally occupied separate (though sometimes adjoining) feeding areas in 1973-4 (Fig 8). Overlap tended to occur when the tide restricted the availability of feeding areas and it seems likely that severe weather conditions might have a similar effect. The few interspecific encounters recorded among Light-bellied brent geese and wigeon occurred when the tide restricted access to feeding grounds.

Proposals relating to future management and improvement of substitute sites are discussed at the end of the interpretation section.

Fig.8 Main Feeding Locations of Herbivorous Wildfowl – Lindesfarne



PART III

INTERPRETATION AND PROPOSALS

INTRODUCTION

The state of knowledge at the start of the study and the specific practical requirements relating to the proposed airport development controlled the pattern of the work and to some extent therefore conditioned the results. So it seems important here to start with an overview of certain general relationships affecting the study area which help us to understand the changing nature of this coastline in relation to the results of the study. The next section of this part of the report deals with the core of the study, the predicted effects of human developments at Maplin, and features of possible substitute sites in relation to Maplin. The final section deals with proposals for future action arising from the study.

The coastline of the study area is the product of centuries of human management imposed on a natural system left as a legacy from the end of the last glaciation some 10,000 years ago. Many papers in local journals, in historical documents and in imprints on the ground surface visible in air photographs, testify to the impact of man on mud flats and marshes since the arrival of the first Neolithic settlers over 5,000 years ago.

Mud (for brick making), salt, samphire, wildfowl, shell fish, stock grazing and reclaimed land have all been won from this coast and modified its contours. Sea defence activities have been of paramount importance on this coast which has a long history of subsidence. Most of the marshlands outside the sea wall were grazed by stock between the wars; most of the reclaimed land enclosed inside sea walls was pasture. Labour costs made shepherding of open range stock uneconomic and the development of building associated with recreation near the coast between the wars increased disturbance to birds and stock from people and dogs. The rising prices of agricultural land and new techniques of drainage have led to extensive ploughing of reclaimed pasture for arable in the last twenty years.

OVERVIEW OF THE STUDY AREA

This short term study of three years provides a picture which is effectively a cross section in time of the study area. A perspective must take into account long term temporal changes in isostatic balance (land and sea level changes), and climatic fluctuations. In addition the human historical influences which modified and helped to create this coastal landscape interact with the long term trends and may sometimes obscure them.

Isostatic balance

Several lines of evidence draw attention to the delicate balance between accretion and erosion that is a special feature of this coast and there are important consequences following from this for the plants and animals that live on it.

It is evident from current proposals for a tidal barrage in the upper Thames estuary and the evidence on the need for this, that there is a trend towards submergence on this coast of the order of size of 30 cm per century. Recent unpublished studies on the Medway confirm that submergence features characterise that site also. Physiographic studies on the Dengie and Foulness coast confirm a close balance between accretion and erosion at the salt marsh seaward edge, where it seems that salt marsh increase in level is approximately balanced by submergence due to isostatic adjustments.

Studies from the Hydraulics Research Station on potential Zostera-planting areas suggest that Zostera flats at Maplin are in a state of dynamic equilibrium , with erosional losses of material just counterbalanced by accretion. Measurements associated with Zostera transplant studies further north at Breydon, Norfolk confirm that Zostera survives on mudflats with a low amplitude of surface oscillation ($< \pm 7$ cm/annum). The mudflat level records in the transplant site at Breydon show nett erosion over the period of study. This might be a very local effect, but it might be part of the general trend towards submergence mentioned above. In addition the presence of species only capable of tolerating low levels of accretion, such as Spartina maritima and Salicornia perennis in the pioneer salt marsh zone at Maplin and certain marshes as far north as the Stour, confirms the close balance between erosion and accretion at the seaward margin of these marshes.

It would seem that the abundance of Zostera found in this part of the British coast could depend on this fine balance between accretion and erosion.

Climatic influences

The whole study was conducted during a period of exceptionally mild winters at a time when general climatic trends in the Northern Hemisphere are towards year-round cooler weather. In severe winter conditions some of the winter food resources for Brent geese reported in this study (salt marsh, reclaimed marsh pasture and cereals) would be frozen and not available, and even in less severe conditions they would be less available, so birds would be likely to come under stress through lack of food. The remarkable upsurge in the population of Brent geese in 1973-74 in the middle of the period of study possibly also reflects the interaction of climate with breeding success on the breeding grounds, about which very little is known. Any prediction of effects of a major development at Maplin has to make allowances for very different climatic conditions than those operating in the period of study. There is also the possibility that bad breeding conditions in summer may chance to occur in conjunction with severe winters. The same general arguments apply to other wildfowl and waders.

Population fluctuations due to disease

We are at this time witnessing marked reduction in the population of elm trees due to disease and in the 1930's myxomatosis severely reduced the rabbit population. Both were indirectly mediated by human imports and both became beyond control. In the 1930's a fungal disease wiped out huge areas of Zostera on coasts either side of the Atlantic in circumstances which are still obscure. Violent fluctuations in wildlife populations are a fact of life. Zostera disease re-appeared (in Zostera marina var. angustifolia) after many years without any record of it, at Lindisfarne, Northumberland during the study period.

The earlier literature refers persistently to Zostera marina as a main food of Brent geese. It is now apparent that this species or its var. angustifolia is either rarely available (as its leaves are shed in early autumn) or for some reason now rarely eaten. This study confirms this and it must be emphasised that Zostera noltii was effectively the only species of Zostera recorded as eaten by Dark-bellied Brent geese during the present study. Any proposals for large scale transplants would need to be carefully screened to minimise the risk of inducing an epidemic.

The human element

Historical human influences have affected this coastline in three main ways 1) by altering the proportions of semi-natural habitats, 2) by altering their nutritional status and 3) by adding an element of disturbance which affects wildlife and particularly bird behaviour.

Sea defence embankments have been built since Roman times to protect existing agricultural land and to take in new land in the form of salt marshes ripe for reclamation. No less than three hundred of the four hundred miles of Essex coastline is modified in this way. As a result scarcely any natural transitions between salt marsh and the hinterland coast survive, except on very short lengths of coast, for example on part of Harty marshes, Sheppey. This has truncated the upper limits of salt marsh and obliterated the natural habitat of many species, though some of them (like Trifolium squamosum on sea embankments and Scirpus maritimus in drainage ditches) have found a new home in man-made habitats. Apart from alterations in the nature of the coastal boundary, embankment changes the proportions of coastal habitats.

If we assume that the 16,900 ha of farmland flooded on the Essex coast in 1953 is a rough measure of the salt marsh areas reclaimed since Roman times and compare this with the 5,000 ha of salt marsh currently remaining we have some indication of order of size of changes brought about by man. It may be argued that reclamation stimulates salt marsh development (from evidence in the Wash). This may have been so in the past, but from the evidence we have at present salt marsh advance is very limited on this coast at the present time.

The interim report of the Hydraulic Research Station noted that there appeared to be a foreshortening and steepening of the intertidal mudflat zone in estuaries within the study area, so that there was simply not room for further Zostera growth. It seems possible that while salt marsh accretion continues, erosional features will dominate the mudflats and contribute to over-steepening of shorelines and reduction of intertidal mudflat habitat. In other words the pace of reclamation may not only have truncated the upper limits of marsh, but also the lower limits where Zostera could grow as well.

It has not proved possible to assemble data on long term nutrient and disturbance changes within the study area. However it is evident from existing river nutrient analyses that enhanced levels of major nutrients (e.g. such as nitrogen in the Stour) exist in some of the estuaries and domestic and industrial effluents and fertiliser run-off from agricultural land are likely to be responsible. Human disturbance may in the past have been much more widespread on the marshes and mudflats with a larger agrarian population and a more intensive use of marshlands than there is today. Within the past one hundred years the trend has been to denser aggregations of people in towns and recreational areas resulting in locally high, but not necessarily widespread disturbance activity. The proportion of coast actually built on (developed) to undeveloped in Essex is in the ratio of 1:4.5. However even at Southend/Leigh while the landward side of the coastline is completely built on, the seaward intertidal zone carries thriving communities of Zostera, intertidal invertebrates, Brent geese and waders.

It is concluded that the primary human influences on this coast are those resulting in big changes in habitat type and proportion and that influences such as altered nutrition and increased disturbance are of secondary importance.

EFFECTS OF HUMAN DEVELOPMENTS AT MAPLIN

Although the original remit was concerned with assessment on the effects of the proposed airport development at Maplin (Stage I) and projected post-airport development (Stage II - Fig 9), the study was planned, not only to assess these effects, but to contribute to a knowledge of the effects of development generally on the Essex coast and in the Maplin area in particular.

Having found out what plant and animal populations are at Maplin and its environs, and to some extent how they relate to each other we are now in a position to assess direct and indirect effects of human development at Maplin and in the study area as a whole.

Direct effects of reclamation at Maplin

The direct effects of reclamation for airport development are likely to be similar to the effects of reclamation for any other purpose as the part ripe for reclamation is likely to be the same in each area. The various configurations for the runways suggest that direct loss would be mainly in the intertidal zone. If they were on the mudflats seaward of the Zostera beds, the direct loss of mudflat habitat would be 3,200 ha (Stage I Airport development) or 6,200 ha (Stage I and II projected post-airport developments). These values represent 30% and 60% of the total Maplin mudflat area respectively or 0.5% and 1% of the estimated total British acreage of intertidal flat area. On a crude area to bird population ratio Stage I airport development would obliterate habitat for some 7,500 wading birds i.e. one third of the average winter population using the Maplin flats. In the case of the additional Stage II developments, 15,000 wading birds of two thirds of the average wintering population at Maplin would lose habitat. In addition to direct area to bird population ratio effect, there is the likelihood that significant losses would occur in certain species for which Maplin has international status (as defined previously). Up to 3% of the European population of Bar-tailed godwit, 2% of Grey plover and knot and around 1% of curlew, oystercatcher and Ringed plover could be put at risk by either Stage I alone or Stage I and II developments together.

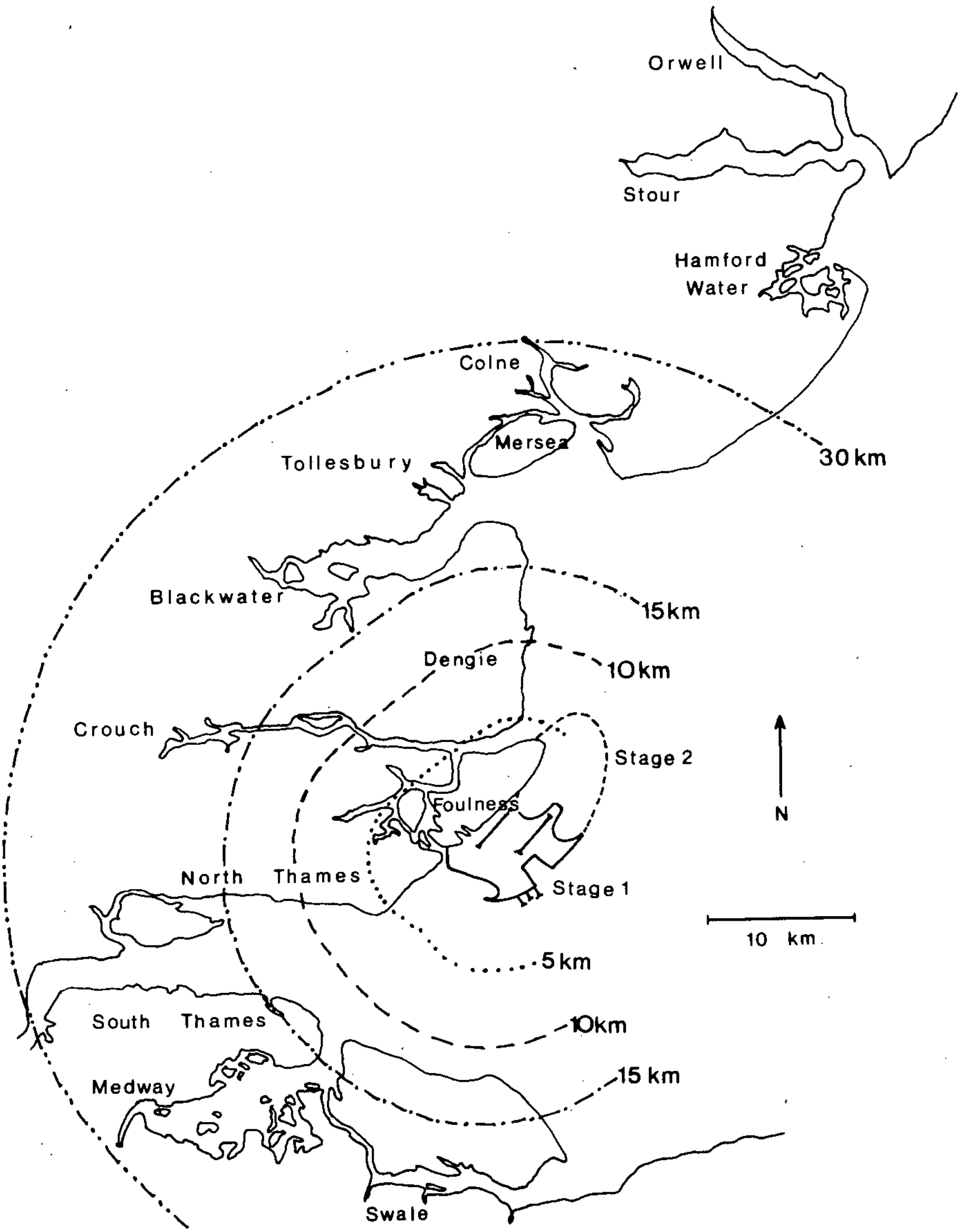
The airport proposal or any extensive reclamation adjoining the south east shore of Foulness Island would result in the loss of at least 80% of the Zostera noltii bed at Maplin which in turn represents 40% of the entire Zostera noltii resources of the study area. The amount of Zostera noltii lost could support 4,500 Dark-bellied brent geese or about 13% of the total wintering British population of this bird. The airport proposal or reclamation of the Foulness shore would also result in the loss of the only surviving viable population of Spartina maritima in its pioneer situation in Britain and a loss of a substantial part of the British population of this species as a whole.

Indirect effects of airport development at Maplin

The principal indirect effects of airport development at Maplin concern birds and not their food resources. Perhaps the simplest approach to assessment is to consider the first three zones eg. at 5, 10, and 15 km from the perimeter of the airport reclamation (Stage I), see Fig 9.

The perimeter and 5 km zone includes the whole of Maplin intertidal flats, Foulness, Potton, Havengore and Wallasea islands and most of the Roach estuary and the lower Crouch. Within this zone average winter populations of 27,000 waders and 4,000 duck and peak values of 180,000 gulls, and 14,000 Dark-bellied brent geese (20% of the world population) have been recorded in winter and up to 100 pairs of Little tern (6% of the British population) breed in summer at

Fig.9 Impact Zones Maplin Development Stage I



Foulness point. Heavy birds like the Brent geese and ducks, birds forming large dense flocks like knot and dunlin waders and those positioned at the end of runways like the Little terns at Foulness point would all tend to be discouraged in the area for aircraft safety reasons let alone by the noise and disturbance of building and operating a new major international airport. Approaching a quarter of a million birds would be especially at risk in the airport perimeter and 5 km zone.

This 5 to 10 km zone includes the Southend shore, all of the Crouch and the southern half of Dengie. This area provides winter habitat for an additional average winter population of 7,500 waders and 2,000 duck and an additional peak value of 3,700 Dark-bellied brent geese (a further 5% of the total world population). Such birds would be subject to increased disturbance but without detailed knowledge of flight paths, such as the Ministry of Agriculture Fisheries and Food Bird Strike Studies team would have produced, it is not possible to predict the effects on their behaviour. However, at least 13,200 birds could be affected in this zone.

The 10 to 15 km zone brings in the north part of the North Kent marsh, Leigh marsh in the Thames estuary and the rest of the Dengie peninsula. This would add a further average winter population of 18,000 waders and 4,700 duck plus an unknown but comparatively large population of duck in particular on the North Kent marshes and peak values of up to 10,000 gulls and 4,700 Dark-bellied brent geese. At this distance from the airport development, disturbance would certainly be minimal, but with a population of 37,400 birds in this area there could be problems relating to safety of aircraft operation.

In total therefore, some 275,000 birds could be affected within a 15 km radius of the proposed airport perimeter.

Indirect effects of a major development at Maplin on the study area as a whole

The nett effect of eliminating Maplin from the coastal habitat series in Britain would be to displace bird populations in the orders of size given above which might or might not be accommodated in suitable sites within the study area or further afield.

It is highly significant that during the period of the study it chanced that population numbers of Dark-bellied brent geese doubled in size and that feeding observations and marking studies demonstrated that coastal sites had already reached carrying capacity limits so that birds were dispersed to new untraditional inland feeding grounds. This seems a clear demonstration that birds of this type displaced from one feeding habitat may adapt rapidly by changing their behaviour.

One consequence therefore of eliminating Maplin for wildlife by development would be to put additional pressure of wildlife use on adjoining coastal and possibly inland agricultural and reservoir shore habitats. Coastal waders have recently become adapted to feeding on Abberton reservoir for example.

The evidence from marking studies in Dark-bellied brent geese emphasised the significance of Maplin as a dispersal point for these birds in Britain and as a sanctuary for juveniles developing novel feeding habits. Just how novel these techniques of winter feeding must be for juveniles is underlined by the fact that brent are observed to subsist initially on mosses and lichens among rocks on their Arctic Tundra feeding grounds.

Coastal plants tend to migrate along the tidal litter line and a study of their distribution makes it clear that industrialized inlets or rocky promontories may act as barriers to dispersal. A sterile species like Spartina maritima which can only reproduce vegetatively may well be prevented from re-establishing pioneer populations north or south of Maplin (if this shore were developed) should conditions favour its spread in the future.

POSSIBLE SUBSTITUTE SITES

The special features revealed by the study at Maplin include its exceptional size, unusually large high protein Zostera food resources and its carrying capacity for one fifth of the world population of Dark-bellied brent geese. It also has a special role as transit and dispersal point for about one third of the British population and importance as a little disturbed nursery ground for their juveniles. It has a large resource of wader food and wader population holding capacity and is on a main migration line for European migratory birds. It is the only site in the study area where an internationally important population ($2\frac{1}{2}$% of the European population) of Bar-tailed godwits overwinter. It has special physiographic features favouring the largest population of pioneer Spartina maritima in Britain and the largest shell bank in Britain which supports 6% of the breeding population of rare Little terns.

These features cannot be matched in the study area, and indeed in this combination, nowhere else in Europe. We conclude therefore that no alternative site to Maplin exists. The best that can be considered therefore is to provide evidence from which sites could be chosen that might partially substitute for losses incurred by development at Maplin.

The following assessment of site areas (Fig 9) takes into account all the factors investigated and attempts to provide integrated information on which a choice of substitute sites, as they stand at present, could be made. The site areas are given in what would appear to be overall priority order, but subsequent consideration will be given to special cases and the possibilities of management for improving certain sites. Within each site the features are dealt with in order of importance.

Blackwater

The Blackwater has the largest mudflat area of all sites outside Maplin, but this is only just over a quarter of the size of Maplin. It has greater macro-invertebrate species diversity than Maplin, but only about half the standing crop biomass of macro-invertebrates per unit area. However, these food resources support nearly half as many waders as at Maplin. These include internationally important populations of Grey plover, redshank, dunlin, Ringed plover and curlew. The Blackwater has only one tenth of the standing crop of Zostera noltii compared to Maplin, but six times as much Enteromorpha. Consequently it is able to support an average population of Brent geese nearly 75% of that found at Maplin. This is in agreement with the calculation given earlier that at capacity a similar proportion of goose days grazing is in fact utilised on the Blackwater. This site also has the highest number of species of regularly wintering wildfowl, waders and seabirds of any site (including Maplin). The Blackwater contains twice as much salt marsh as Maplin (including notable populations of rare species such as Inula crithmoides, Spartina maritima, and Suaeda fruticosa) and seven times as much undeveloped reclaimed marsh with a third more species of flowering plants than at Maplin.

Medway

The Medway has one third the area and biomass of Enteromorpha found in the whole study area and about fourteen times that at Maplin, but negligible Zostera noltii. It is outstanding for its salt marsh area which is about twice that at Maplin. These marshes carry a notable population of the rare species Inula crithmoides. This site carries one sixth of the total undeveloped reclaimed marsh in the study area and about ten times that at Maplin. It is also 50% richer in reclaimed marsh plant species than Maplin. Besides the intrinsic interest of the Medway marshes they provide a source of food for herbivorous wildfowl and it is not surprising to find they carry about one third of the total wildfowl (excluding Brent geese) of the whole study area and about five times as many as at Maplin. The Medway supports internationally important populations of wigeon, pintail, shelduck, and teal.

Hamford Water

The salt marshes of Hamford Water are only surpassed in area by those of the Medway and form about one eighth the total in the study area. Notable populations of local species such as Inula crithmoides and Limonium humile on salt marsh, Peucedanum officinale in reclaimed marsh and Eryngium maritimum on sand bars occur here and Inula reaches its northern limit on the east coast in this area. Although mud flat area and invertebrate food resources are relatively low, this site carries regular winter wader populations as high as 80% of those at Maplin, though actual peak numbers are less than half, which perhaps reflects the importance of Maplin as a transit area. No less than seven internationally important populations of wader species overwinter: Grey plover, redshank, Ringed plover, curlew, Black-tailed godwit, dunlin and sanderling. Although neither Zostera nor Enteromorpha occur in quantity in Hamford Water, salt marsh and reclaimed marsh are capable of supporting in mild winters as many as 40% the number of Brent geese found at Maplin. This is one of the least disturbed sites in the study area and significantly carries two populations of breeding Little terns (The Naze and Dovercourt) which together approach in size that at Maplin. However, poor breeding success indicates that local disturbance does affect the Hamford Water colonies.

Colne

Although one of the smaller sites in the study area, the Colne is one of the richest in variety of both plant and bird species and the least disturbed (as a result of Nature Reserve wardening and Military range restrictions on access). It has the fourth largest area of reclaimed marsh consisting of one ninth the total in the study area. The Colne is especially notable for plant species diversity which may well reflect the long history of human activity (dating back to Neolithic times) in this area. It has the greatest number of both salt marsh and of reclaimed marsh plant species of any site in the study area. It has notable populations of Spartina maritima and of most of the local reclaimed marsh species. Although only 4% of the area of Maplin, its relatively undisturbed mudflats support an average winter population of waders nearly a half that at Maplin. Moreover no less than five wader species with populations of international importance are found in this relatively small area: redshank, sanderling, curlew, Grey plover and Ringed plover. Nearly one fifth the number of Brent geese and almost twice as many wildfowl occur on the Colne as at Maplin. The Colne also supports a breeding population of Little terns half the size of that at Maplin.

Stour

The Stour mudflats are one sixth the size of those at Maplin and they are second only to the Blackwater in numbers of macro-invertebrate species and comparable to the numbers at Maplin. The biomass of macro-invertebrates per unit area is second only to that on the Orwell and more than one and a half times that at Maplin. Although the mud flats of the Stour are only one sixth the size of those at Maplin they carry no less than 70% of the wader populations found at Maplin, whether measured as peak populations or as average winter populations. Four populations of wader species of international importance occur on the Stour: redshank, Grey plover, Black-tailed godwit (75% of the population in the whole study area) and dunlin. The Stour carries one twelfth of the standing crop fresh weight of Zostera noltii in the study area (one sixth of the amount at Maplin). These food resources support more than twice as many wildfowl as at Maplin and populations of international importance of wigeon and shelduck (the latter dependent especially on the herbivorous molluscs, Hydrobia sp. generally abundant on Enteromorpha in these estuaries). The numbers of Brent geese however are surprisingly low in view of the food resources and this is attributed largely to bank and channel disturbance on this comparatively narrow estuary.

Swale

The Swale area contains half the total unimproved reclaimed marsh in the study area and about thirty times that at Maplin. It has the greatest diversity of reclaimed marsh plant species of any site in the study area and substantial populations of most of the local species in this habitat. Moreover it contains rare natural transitions to unimproved terrestrial habitats and a variety of brackish to freshwater transitions. Over 10% of the total acreage and standing crop fresh weight of Enteromorpha in the whole study area occurs on the Swale mud flats, that is five times as much as at Maplin. These plant food resources support wildfowl populations (other than Brent geese) second only to those of the Medway and more than four times the numbers found at Maplin. The site also supports an internationally important population of wigeon.

Dengie

Dengie contains about one fifth the mud flat area at Maplin, but this supports a macro-invertebrate biomass per unit area comparable to Maplin and one third the peak numbers of waders and one half the average winter population of waders compared with Maplin. There are internationally important populations of Grey plover, sanderling and curlew. Dengie is the least disturbed site in the whole study area and is of particular importance as a transit site for passage waders and wildfowl. Its position on an open coast exposed to dominant north easterly winds is thought to prevent growth of Zostera and to limit that of Enteromorpha. However it acts as a refuge for Brent geese disturbed by military activities at Maplin and supports up to 3.5% of the world population of these birds. Dengie contains the largest continuous block of salt marsh and 8% of the whole in the study area. Its drainage pattern is a relatively simple one facilitating access for management. It contains notable populations of local species such as Limonium humile, Salicornia perennis and Spartina maritima.

Leigh

Leigh has 25% of the total fresh standing crop weight of Zostera noltii in the study area (i.e. half the crop at Maplin), in an area only 13% of the total (a phenomenon that merits investigation in relation to the nutrient status of this site). This supports just over a quarter of the winter population of Brent geese found at Maplin, and amounts to about 3% of the world population. Like Dengie, Leigh contains about one fifth the mud flat area at Maplin, a macro-invertebrate biomass per unit area comparable to Maplin and similar wader population levels to those at Dengie. The site also supports internationally important populations of Ringed plover, Grey plover and dunlin.

PROPOSALS FOR FUTURE ACTION

Expediency demands short term intensive studies of the kind completed for the Maplin study, but it is evident that long term studies are essential for an effective understanding of complex biological systems. Much has been learned in the present study, but the rapid fluctuations in the populations and changes in feeding responses of Brent geese even over a period of only three years makes it clear that we still have a great deal to learn. "Before and after" studies associated with a major development may be relatively meaningless if the types of change during the development trigger off unexpected responses. It follows that the better basic understanding we have of behavioural responses and the closer we can track population changes, the better we shall be able to predict the consequences of large scale disturbances.

The proposals made fall into two groups. The first group is concerned with management and improvement of substitute sites. The second group is concerned with more basic studies on the factors limiting establishment, growth and survival of key species.

Management of substitute sites

Since Maplin contains more than half the total Zostera noltii in the whole study area, there is no possibility that Maplin Brent geese could be accommodated even if the rest of the Zostera in the study area were preserved for them. It has been demonstrated that Zostera noltii can be transplanted on mudflats but that extensive suitable sites for its establishment do not exist at the present time within the study area. Some preservation of existing stocks could be undertaken by controlling the growth of plants like Spartina anglica which can replace Zostera, but this is only likely to be successful on a very limited scale in isolated estuaries (like Breydon Water, Norfolk) where an attempt is being made to exterminate Spartina. To create potential Zostera beds or augment high level tidal flats suitable for macro-invertebrates on which birds feed it would be necessary to use engineering works. These would be prohibitively expensive for this purpose alone, but suitable habitat for this purpose might be created in association with reservoir schemes such as those being investigated in the Wash.

The creation of new salt marsh area to offset loss by reclamation is much more practicable than creating Zostera beds. It should be possible to create salt marsh in association with dredge spoil islands and this has been done successfully in America (e.g. Cape Fear estuary, North Carolina). A possible site for such activity would be the Outer Thames estuary, as an artificial extension of the natural deltaic formation of islands that is found there already. Again there are possibilities of such salt marsh design in association with proposed fresh water impoundments in the Wash.

To attract geese away from arable crops it would be necessary to change the structure and vegetation composition of existing ungrazed salt marshes within the study area. One of the most promising sites for this would be at Dengie which is relatively free of deep creeks thus facilitating the use of grass-cutting machinery and grazing of stock. There is no experimental information on the restoration of a salting pasture from dwarf shrub (Halimione) dominated ungrazed salt marsh (as at Dengie), but there seems no reason why this should not be achieved by mowing and grazing within five to ten years in suitable sites. Available evidence suggests that no alternative food matches Zostera noltii for availability in cold winters and protein richness, nevertheless salt marsh pasture grasses such as Puccinellia maritima are more nutrious than Enteromorpha and more freely available in cold winters (because of salt depression of the freezing point), than inland pasture or arable crops.

Although geese in other parts of Britain co-exist with agriculture, hitherto the Dark-bellied brent goose has been notable for feeding exclusively on vegetation in the inter-tidal zone. The question of whether or not they should be encouraged to feed inland has political implications beyond the remit of this study, but this clearly needs to be considered.

The remarkable diversity and abundance of plant and bird life of the Colne estuary is believed to be the product of natural habitat diversity, gradual changes in land use over a long period of time, and current control of human disturbance. Disturbance is related to the shape of sites, and long narrow estuaries like the Stour with a high proportion of disturbed edge (embankment and river channel) to area, might hold greater wildlife populations if human disturbance could be reduced by management.

The right combinations of damp pasture, ditches and fleets and even controlled flooding can produce exceptionally rich habitat for feeding and breeding wildfowl and breeding grounds for rare wading birds (as in the Ouse washes for example). Opportunities for the application of such management exist on the Dengie peninsula and are already in practice, or under consideration in the Medway, Swale and Colne areas. A great variety of management is applied to sea embankments, including mowing, grazing and burning with little understanding of effects on their sea defence properties and the wildlife they support. In fact, apart from their primary role in sea defence, they carry not only great diversity of plant species, but also are one of the few locations where substantial populations of insects (e.g. butterflies) can breed in coastal marshes.

Background research

Good liaison was developed with loose boundary hydraulic engineers from the Hydraulics Research Station on the special conditions required for Zostera growth, and by inference the special conditions that the presence of Zostera growth indicates. This inter-disciplinary area of study would repay follow-up both for the biologist concerned with food resources and the engineer concerned with stability. We are particularly ignorant about the long term persistence of Zostera beds, thresholds of stability required for their establishment and their response to small scale accretion/erosion phenomena. The special conditions which favour Spartina maritima at Maplin deserve study in relation to this also.

It is perhaps worth drawing to the attention of coastal engineers that transplants indicate the state of erosion/accretion balance in an integrated way and could give useful information in uncertain situations about surface stability in the inter-tidal zone.

Zostera species are exacting in their growth requirements, but pioneer salt marsh plants like Salicornia species, Puccinellia maritima and Spartina anglica are almost universally present on hundreds of thousands of acres of high level mud flats wherever conditions are sufficiently stable for salt marsh growths on European coasts. Because such areas are flat, salt marsh colonisation is peculiarly susceptible to very small changes in land or sea level. The possibility needs to be examined that the state of salt marsh seaward edges round our coast may be an advance indicator of gradual, long term isostatic changes. There are implications here for sea defence maintenance.

The study appears to indicate significant relationships between such birds as Brent geese and their food resources, their flexibility in feeding behaviour and their vulnerability in relation to breeding in harsh climates. Brent geese hitherto have been one of the last remaining wild geese species in Europe to survive on natural vegetation and so have rarely come into direct conflict with agricultural interests. Now that it is definitely known that they can adapt to feeding on agricultural land it becomes necessary to investigate more closely means of population control. In particular study will need to be made of their feeding behavioural responses under cold winter conditions such as were not experienced in the present study.

Specific proposals

a) Management

1. A trial should be undertaken to see if it is possible to establish a viable *Zostera noltii* bed in association with engineering works on mud flats (e.g. in the Wash).

2. The use of the dredge spoil should be considered for the possible formation of additional salt marsh in the study area. Parts of the Medway estuary salt marshes might be restored in this way.

3. Field experiments should be undertaken to discover the right combination of cutting and mowing to create salting pasture suitable for wildfowl and stock in ungrazed salt marshes such as Dengie.

4. Field experiments should be carried out on methods of managing reclaimed marshes, and their ditches and embankments to improve these habitats for local plant species, and breeding, feeding and roosting birds (e.g. in the Swale area). Study is particularly needed of the type and management of the vegetation of sea embankments in relation to sea defence.

b) Background research

5. Improvement of instrumentation for measurements of hydraulic forces affecting *Zostera* beds and studies on the biology of *Zostera* and *Spartina maritima* directed towards prediction of their growth requirements.

6. Study of the relationship between salt marsh formation and erosion in relation to isostatic change on the British coast.

7. Feeding responses of Dark-bellied brent geese under cold winter conditions and factors affecting their population control.

Implementation of proposals

The final objective of the Maplin study states that "The work should lead to recommendations and proposals for future action, including methods for implementing these proposals, and a final comprehensive report".

Zostera transplants might be attempted in the Wash by agreement with the Central Water Planning Unit if suitable sites can be found in more stable situations created by fresh-water impoundment engineering works.

Port authorities in the Thames/Medway area might be approached for co-operation in creation of dredge spoil islands for experiments on the development of salt marsh. Salt marsh pasture management and reclaimed marsh pasture management experiments are clearly within the interests of the Nature Conservancy Council. Vegetational aspects of both proposals are within the competence of salt marsh management specialists at ITE, Colney.

Study of type and management of sea embankment vegetation could be undertaken in association with the Anglian Water Authority.

Biology of *Zostera* and *Spartina maritima* is clearly a university type post-graduate study ideally supervised jointly by a biologist and a sedimentologist.

The status of salt marsh colonisation on British coasts in relation to isostatic trends might be best achieved on a contract basis supervised by appropriate NERC Institutes such as IOS and ITE.

Brent goose behavioural studies in cold winter conditions and population control would best be tackled by grant-aided studies supervised by the Wildfowl Trust.