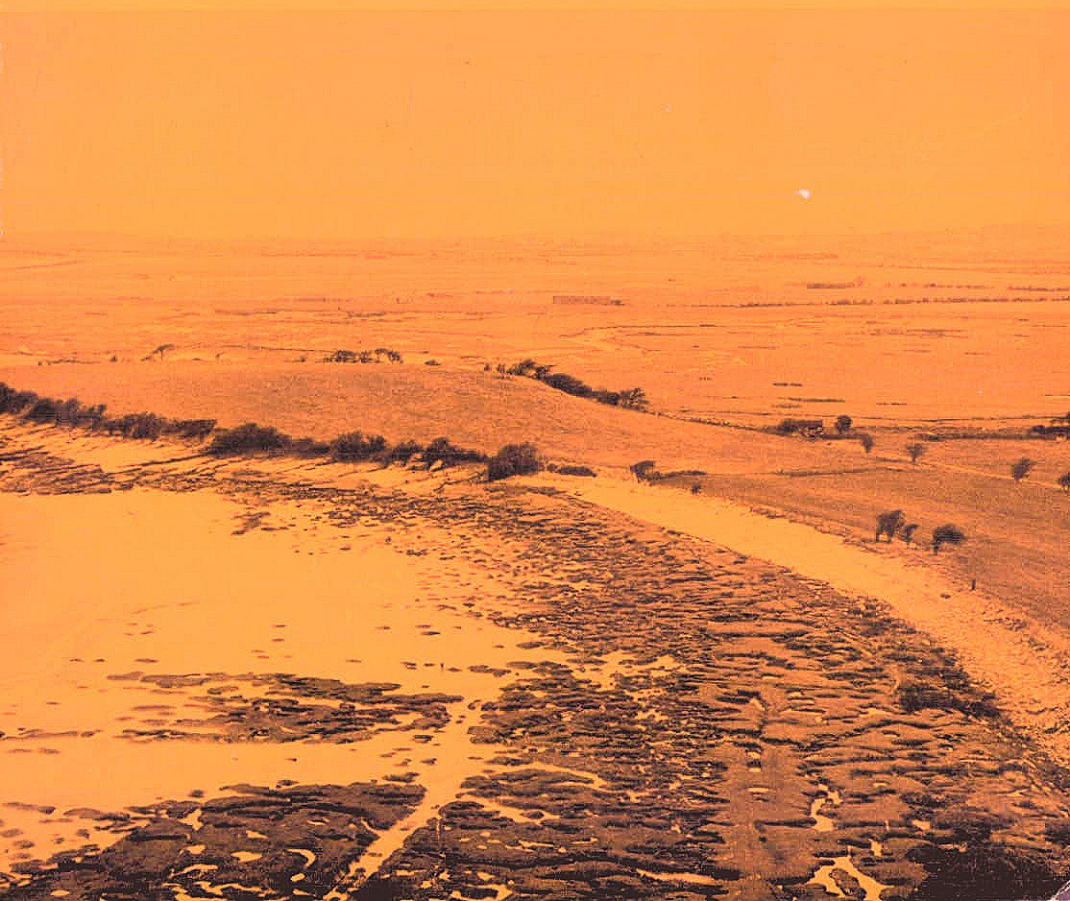
Natural Environment Research Council
(INSTITUTE OF TERRESTRIAL ECOLOGY)

COASTAL ECOLOGY RESEARCH STATION

— NORWICH —

Report for 1969—1972



Natural Environment Research Council
(INSTITUTE OF TERRESTRIAL ECOLOGY)

Coastal Ecology Research Station

Report for 1969—1972

1973
Colney Lane,
Norwich
Norfolk.
Tel: Norwich 54923.

During the period covered by this report, the Coastal Ecology Research Station was a part of the Nature Conservancy, itself a constituent body of the Natural Environment Research Council. With the creation of the Nature Conservancy Council on November 1st 1973, the Coastal Ecology Research Station became part of the Institute of Terrestrial Ecology, a newly created constituent body of the Natural Environment Research Council.

Cover.
View over salt marsh at Morecambe Bay from Humphrey Head.

photograph by R. Scott.

Contents

Staff List

(As at 31st January 1973)

Head of Station: D. S. Ranwell, B.Sc., Ph.D. (London).

Station Secretary: B. W. E. Austen.

Scientific Staff: J. C. E. Hubbard, M.I. Biol.
A. J. Gray, B.A., Ph.D. (Keele).
L. A. Boorman, B.A., D.Phil. (Oxford).
D. G. Hewett, B.Sc. (London), M.Sc. (Wales), M.I. Biol (Outposted to Bangor).
S. McGrorty, B.Sc., Ph.D. (Leeds).
R. M. Fuller, B.Sc. (East Anglia).
R. Scott, B.Sc. (London).
C. J. Reading, B.Sc. (London).
P. G. Ainsworth, A.I.S.T.
Miss J. M. Pizzey.
R. J. Parsell, H.N.C.
Miss D. L. Cheyne.

Administration: Mrs. C. M. Wilcockson.
Miss E. J. Reeve.

WASH RESEARCH TEAM (Officer in Charge—Dr. A. J. Gray).

Scientific Staff: J. D. Goss-Custard, B.Sc. (Bristol), Ph.D. (Aberdeen).
Miss S. M. Coles, B.Sc., Ph.D. (Leicester).
P. F. Randerson, B.Sc., M.Sc. (London).
P. E. Newbery, B.Sc. (Edinburgh).
M. G. Curry.

Administration: Mrs. L. Culyer.

MAPLIN RESEARCH TEAM (Officer in Charge—Dr. L. A. Boorman).

Scientific Staff: K. Charman, B.Sc. (Edinburgh).
N. W. Owens, B.A., Ph.D. (Cambridge).
D. W. Wyer, B.Sc. (Swansea).
D. G. Kay, B.Sc., Ph.D. (London).
Miss J. E. Head, B.Sc. (East Anglia).
R. D. Knights, B.Sc. (Cardiff).
Mrs. J. S. Say, B.Sc. (East Anglia).
Miss R. J. Waters, B.Sc. (London).

Administration: Miss W. E. K. Crump.
Miss M. B. Stimpson.

1 General Report

Introduction

The Coastal Ecology Research Station was opened officially by Professor J. A. Steers on 14th July 1969, after an introduction by Professor A. R. Clapham, F.R.S., at that time Chairman of the Nature Conservancy's Scientific Policy Committee. We were delighted that Professor Steers agreed to open the Station because of his lifelong interest in, knowledge of, and above all enthusiasm for the preservation of the coast. It was especially fitting in view of his extensive researches on the Norfolk coast and long held conviction that a nationally orientated coastal research station should be established in East Anglia.

The Research Station was designed by Mr. David Luckhurst, architect of Messrs. Fielden and Mawson, Norwich and was built by Messers. W. S. Lusher and Son, also of Norwich. It shares a pleasantly landscaped site with other research stations at Colney, close to the University of East Anglia.

The period covered by this report is effectively the four years from 1969 to 1972.

Reasons for establishing the Research Station and siting it in Norwich

Ecologists and coastal physiographers have been aware of the need for a centre for coastal ecology research for many years. Their studies revealed the enormous variety of coastal habitats in the British Isles and the wealth of wildlife they support. They were aware that their knowledge of the complex processes controlling structure and biology of the coast could be put to use, but the value of this knowledge was not widely understood and accepted.

Three events in the present century drew sectors of public attention to the value of the coast. At the turn of the century the Royal Commission on Coast Erosion submitted its report to Parliament. In 1953, 300 people lost their lives and some 160,000 acres of land were inundated by coastal flooding in south east England. The third event was the extensive oil pollution of the Cornish and Brittany coasts when the oil tanker 'Torrey Canyon' went aground in 1967 releasing about 100,000 tons of oil. This happened when more and more people and an increasing number of car owners had the desire and time to get out of the towns and enjoy the country and above all the coast. The widespread publicity given to this disaster focussed everyone's attention on the coast and created the conditions for greater investment of public funds in environmental research. The Coastal Ecology Research Station is a part of this investment.

There were a number of good reasons for establishing the Station and siting it in Norwich. The Nature Conservancy has the job of managing an extensive series of National Nature Reserves and 35 of these include some 60,000 to 70,000 acres of coastal land. Ecological advice is needed for the effective management of this land to protect its wildlife resources. It is also needed to advise other coastal land owners and users who have a direct or indirect interest in coastal wildlife resources. Now these resources, especially on the Scottish coast, are by no means as well known as many people assume. So, in addition to research directed towards management, the Station exists to promote survey and assessment of wildlife resources throughout the coast of Great Britain. It might seem logical to site a coastal research station on the

coast, In fact, Norwich was chosen because it is near to a fine range of coastal sites and a number of Nature Reserves. It also provides excellent opportunities for collaborative research and training in association with the University of East Anglia.

There was one other important consideration. The hard coasts, the cliff coasts of the north and west, were by their nature not so vulnerable to human influence. The soft coastline, the tidal flats, salt marshes and sand dunes of south east England, were especially vulnerable to pollution, human disturbance or reclamation of one sort or another. It was foreseen that information would be needed on the ecology of major coastal systems like the Wash or the Thames estuary where the pace of reclamation and other development was likely to be stepped up. The rate of acceleration at which this pace of development would increase, not only at these sites, but on many other parts of the coast was less evident.

2. Value of the Coastline

Coastal features like sand dunes, salt marshes, and grassed sea embankments help to protect land from erosion by the sea. Wildlife resources of tidal flats and salt marshes can be cropped. The coast is also an ideal environment for both recreation and education. Each of these special values of the coast depends in part on the plants and animals that live there. For example, salt marsh plants like Cord grass *(Spartina anglica)* form a protective apron on mud in front of sea walls and help to reduce wave action. They also help to build new land which can be reclaimed from the sea. Sand dune grasses like Sea Lyme grass *(Elymus arenarius)* or Marram *(Ammophila arenaria)* trap wind-blown sand and raise protective dune barriers. Salt marsh grasses provide extensive pasturage on the west coast which is cropped by stock and wildfowl. The diversity of coastal habitats and their flora and fauna form ideal breeding grounds for new kinds of plants and animals and provide a range of open ground on which these new genetic combinations can survive. It is no accident that many of our crop plants—cabbage, kale, beet—originated on the coast. Tidal flats supply game for the wildfowler, shell-fish, and vital food supplies for birds, and fish.

For those who simply want to relax in a boat or on a beach, the wildlife of the coast forms a living tapestry of colour and sound, a vital background which enhances the quality of a holiday in subtle but rewarding ways.

The research and educational value of the coastline cannot be over-stressed. The changing environment and the plants and animals it supports provide a challenging field of study for research workers and a stimulus to the interest of students of all ages. Awakening interest and study leads to real appreciation of the value of wildlife and a desire to protect it.

3. Threats to Coastal Wildlife

Plants and animals that live on the coast are adjusted to living in less stable conditions than those in an inland woodland or moorland for example. But there are still limits to the amount of disturbance they can tolerate. Changes in the amount of material (physical or biological) put into or taken out of a coastal system can trigger further changes in its wildlife resources. Alterations to water amount change wildlife patterns. Decreases occur in the form of lowered water tables adjoining built-up areas through domestic and industrial extraction. Increases in fresh water flow into estuaries occur

through improved drainage of agricultural areas in the catchment. If the water table of a dune system is lowered through extraction, the varied flora of dune slacks will be threatened. We know this has happened in Holland and we believe it may be responsible for changes at Ainsdale, Lancashire. Increased fresh water flow into estuaries alters salinity gradients and consequently the zonations of estuarine plants and animals.

Increases in sediment through increased cultivation in catchments alters both the rate of accretion on salt marshes and the turbidity of estuarine waters. Discharge of mining waste to the Durham coast is believed to have reduced light supplies for algal growth there. Beach mining in Shetland has destroyed populations of the rare Oyster Plant *(Mertensia maritima)* and quarrying disturbs sea bird populations.

Profound changes in trophic (food) relationships in estuaries and coastal waters can be caused by increases in nutrient and toxin inputs deriving from fertilizers, chemical sprays, industrial and domestic effluents, and oil pollution. These effects are most apparent in southern estuaries like Poole Harbour, Dorset where they appear to favour growth of micro-organisms rather than macro-organisms. This in turn affects the birds that feed on macro-organic resources.

Equally significant changes can be produced by input of plant or animal species in great amounts or numbers. Pine trees or Sea Buckthorn *(Hippophaë rhamnoides)* can dominate dune grasslands and shade out a great variety of species. People in large numbers also reduce the variety of wildlife, as at Camber in Sussex. Trampling had formerly destroyed much of the dune vegetation, but this is now being restored by artificial means. Trampling also has serious effects on cliff top turf, already under stress from drought and salt spray influences.

Cropping and disease exert selective effects on coastal wildlife resources. Colourful plants like the Sea Lavenders *(Limonium* spp.*)* are suppressed by grazing, and resources like Eel grass *(Zostera)*, a vital food plant of Brent Geese, may be destroyed by disease.

Now, although we know, in a general way, the effect of these different factors, we are still a long way from being able to measure them effectively or assess exactly how they are affecting fluctuating wildlife populations. This is especially true of large scale plans to transform coastal systems for human use such as the Maplin Airport plan or Wash Water Storage proposal.

4. Action to Safeguard Coastal Wildlife Resources

A National review of sites of scientific importance has been organized by the Nature Conservancy. The coastal contribution to this based its findings on an estimate of the relative proportions and distributions of individual habitat types in relation to total coastal habitat resources. The value of the best sites was assessed by semi-quantitative criteria such as size, physiographic interest, wildlife populations, species diversity, geographical limits of species and extent of human interference. This has given us a yardstick for comparative assessment of sites and at the same time revealed just how limited our knowledge of coastal wildlife populations is.

Basic survey of coastal sites is carried out by members of the Coastal Ecology Research Station at the request of Regional staff of the Nature Conservancy or in connection with its own research. It is at the Regional level that the case for acquiring a National Nature Reserve or designating a

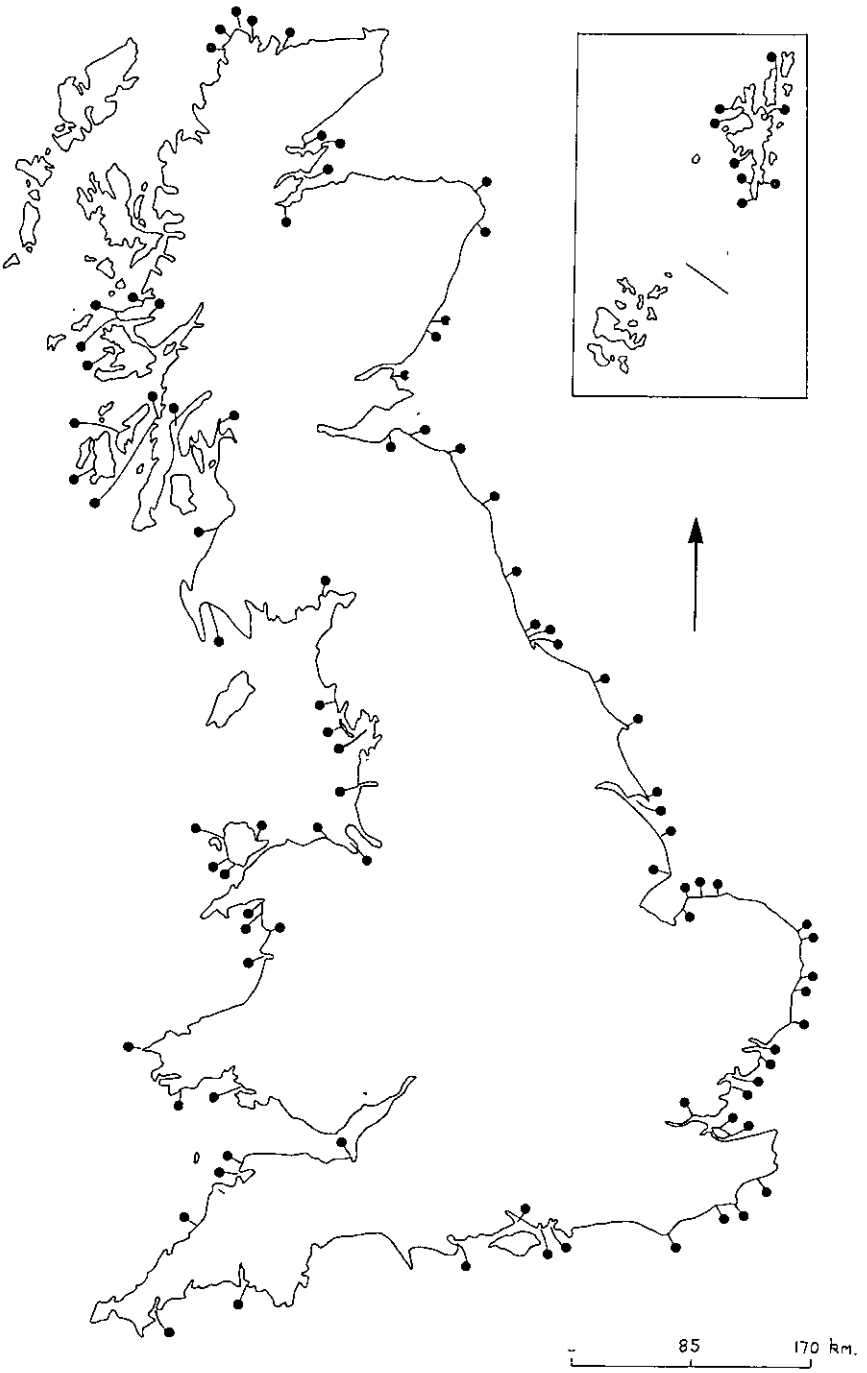


Fig. 1. Some of the sites visited by the Coastal Ecology Research Station staff in connection with advisory work (1969–72

site as of Special Scientific Importance is hammered out. At this level also there is a fertile exchange of ideas and information with Research Station staff on activities affecting coastal sites throughout Great Britain. Work on coastal wildlife problems is expanded through contacts with University Departments and students seeking advice on coastal problems. In 1972 the Coastal Ecology Research Station received about 20 requests for advice on sand dune management alone. In every case advice is tempered with regard to the wildlife resources of the site and owners are frequently in a better position to protect these after consultation.

Research is directed towards better understanding of coastal systems and better control of changes within them. We aim to communicate and see our ideas translated into action and, from the results, to improve the quality of our predictions of coastal wildlife changes.

5. Pattern of Research

The research programme grew from initial intensive studies on the dynamic development of salt marshes. This emphasised the need for measurements at boundaries where significant changes occur as a useful approach to the study of biological systems in the field. It also underlined the value of studying common species which by their structure or abundance exert a controlling influence on the nature of the habitat. Wider coverage of coastal problems was developed by expanding studies into other coastal habitats. Greater understanding has been achieved by developing a team approach with scientists representing different disciplines. The team approach is particularly suited to the study of large coastal systems like Morecambe Bay or the Wash.

1968/69

When the Research Station was first occupied in the autumn of 1968, initial research studies on salt marshes in southern England were being completed. Studies on uses of air photography for recording coastal plant population changes were in progress on the shingle beach at Dungeness in conjunction with ground studies of its vegetation. A contribution to the study of the biology of Morecambe Bay in relation to proposals for an estuarine barrage was started.

1969/70

Research strategy was reviewed at a Coastal Habitat Team meeting in Spring 1969 and the vital importance of balancing our programme with studies on coastal invertebrate animals was emphasised. Preliminary studies on invertebrate populations of tidal litter commenced in 1969 and work was promoted on the trophic relations of the newly adapted fauna living in *Spartina* marsh.

Genecological studies on common salt marsh pasture grasses began with studies on the role of phenotypic plasticity in adaptation to habitat gradients, in association with the applied studies on salt marsh at Morecambe Bay. Techniques for the simultaneous survey of plant and animal associates on tidal flats and salt marsh were tried out at Holkham, Norfolk. A working party was set up to report on a national policy for the management of the

invasive shrub Sea Buckthorn on dunes. The year was marked by a great increase in requests for advice on dune management and it was evident that expansion of research on this was needed. After consultation with the Road Research Laboratory a small investigation was started on the significance of winter salting to roadside soil and vegetation.

1970/71

There was expansion of work into management studies on the effects of fire, trampling and mowing on sand dune vegetation, and of fluoride air pollution on cliff vegetation in Anglesey. Work on the fauna of a variety of strandlines was expanded, while studies on shingle beach vegetation continued. This year also saw the completion of the Morecambe Bay study, culminating in a report giving predictions of the type of vegetational changes likely to follow construction of an estuarine barrage. This study was of particular significance, because for the first time biologists were working in close association with engineers on the consequences of a large scale project to alter a part of our coastline. Primary survey was extended to Scottish coastal sites in Argyllshire and to the surprisingly little known Essex coastal marshlands.

1971/72

By 1971 work programmes were established in most of the imprortant coastal habitat types and the recruitment of permanent staff was more or less completed. In the lesser known habitats the emphasis lay on survey. The fauna of tidal flats was studied at Holkham, Norfolk; Dengie, Essex; Poole, Dorset and in the Moray Firth in Scotland. Primary survey of coastal vegetation was extended to further sites in Wales and Scotland and a study group set up to report on cliff vegetation survey techniques.

In better known habitat types emphasis was on experimental management research. Turf cutting, rotavation and herbicide effects on the vegetation were being studied on salt marshes; effects of trampling, mowing, grazing and fertilising on dunes.

1972 saw a dramatic change in emphasis in the pattern of our work with the temporary appointment of two teams of scientists on a contract basis. They are contributing to studies of the ecological implications of proposals to build fresh water impoundments in the Wash and an airport at Maplin Sands, Essex. The emphasis in both these projects is on intensive study of the coastal systems as a whole. Whereas in Morecambe Bay it was possible to establish only broad correlations, the more comprehensive attack on the present problems should result in better insight into the way the systems work and change when altered. This contract work has given us better coverage of disciplines, e.g. ornithology and algology, and much improved collaboration with other coastal workers in related fields of study.

6. Liaison Activities

As a follow up to the assessment of coastal sites in Great Britain, broad recommendations on the management of those considered of national importance were completed as part of a Management Review in January 1972.

We maintain very effective internal liaison through the medium of the Coastal Habitat Team. This brings together representatives of the varied coastal interests within the Nature Conservancy every year or so to discuss

research activities and re-define priorities in the light of current needs. It operates also through Working Parties to get specific priorities dealt with (see Publications—'Report on the Management of Sea Buckthorn' and 'Report of the Sea-Cliff Vegetation Study Group').

The staff of the Coastal Ecology Research Station have the benefit of assistance and advice from Specialist Units and Sections of the Nature Conservancy based elsewhere. We are particularly grateful for the extensive help given by the Soil Chemical Section (Merlewood) and the Library and the Biometrics Section (London). In addition we much appreciate collaborative help given by the Biological Records Centre (Monks Wood), the Pedological Section (Bangor) and other sections like the Geology and Physiography Section (Newbury) with whom we are in consultation from time to time. Last, but by no means least we are especially grateful for the help and guidance of Administrative Sections both at the headquarters of the Nature Conservancy and the Natural Environment Research Council (London) particularly in relation to the complexities of contract work and the recruiting programmes these involve.

Apart from day-to-day informal contacts we communicate on a more formal basis with other government agencies in a variety of ways. These may be written submissions, as in 1968 to the Coastal Preservation and Development Survey published by the National Parks Commission, or through Working Parties or Liaison Committees. We welcomed especially the opportunity to be represented on Working Party II (Near shore ecology) concerned with the development of part of the projected research programme of the Institute of Marine Environmental Research and on the Natural Environment Research Council's Working Party on Estuarine Research. Through liaison committees concerned with drawing up specifications relating to Wash and Maplin projects we developed direct contact with members of the Water Resources Board and of the Department of the Environment's Hydraulic Research Station. This kind of contact can only lead to more effective multi-disciplinary approaches to the problems of the coast. It is particularly rewarding to see engineers, physiographers and ecologists working side by side in such work. We are much indebted to the Royal Air Force and in particular, the Officer Commanding and personnel of R.A.F. Kinloss and to the Commanding Officer and personnel of the Royal Marines Amphibious Training Unit, Hamworthy for special facilities in relation to coastal surveys.

In 1969 the Nature Conservancy organized a most productive seminar with National Trust Agents at Monks Wood Research Station. This led directly to a great increase in requests for advice from National Trust Agents concerned with coastal problems. National Trust coastal land, so effectively increased in recent years by their highly successful 'Operation Neptune' campaign, carries a wealth of wildlife and we welcome the chance to be involved in its management. Much relevant information was brought together and disseminated at the most successful Dune Conservation Study Conference organized jointly by Mr. Frank Tindall (County Planning Officer, East Lothian) and the Nature Conservancy at North Berwick, East Lothian in 1970.

Over 100 lectures, seminars or field demonstrations have been given by staff during the past 4 years. We have, of course, close ties with our neighbours in the University of East Anglia, and contribute a short course of lectures in Coastal Ecology for second year undergraduate students. Apart

from formal links through membership of the Board Committee of the School of Biological Sciences, there is much informal contact through seminars and research.

We are particularly grateful to student members of the University of East Anglia Conservation Corps who assisted in bitterly cold weather in March 1972 in a successful attempt to transplant *Zostera,* an important food plant of Brent geese. Valuable collaborative relations with colleagues in a number of other Universities, here and abroad, are continually developing.

We are keenly aware of the vital contribution that Voluntary Bodies make to the care and protection of coastal wildlife and especially birds. It is a privilege to contribute as a member of the Research Committee of the Royal Society for the Protection of Birds and to have been involved with the very valuable Birds of Estuaries enquiry organized jointly by the British Trust for Ornithology and the Royal Society for the Protection of Birds. It was a pleasant task also to have the opportunity of inaugurating the newly formed Estuarine and Brackish Water Sciences Association in London on October 13th 1971. This independent organization acts as a rallying point for the many varied interests concerned with our estuaries.

Outside Great Britain we were glad to take part in the selection of potential nature reserve sites on the coast of Northern Ireland and to contribute to the Report of the Coastal Group to the Northern Ireland Nature Reserves Committee. A further contribution was given at the conference on 'Physiography, Ecology and use of the North Coast of Northern Ireland', held at Ulster University, Coleraine in 1970. More recently advice was given at the request of the Irish Wildbird Conservancy on rubbish dumping proposals at the North Bull Island Bird Sanctuary, Dublin and to the Island Development Committee, Jersey, Channel Islands, on the development of the Quennevais sand dunes.

7. Reports and Publications

Our work is reported in a variety of ways because we are not only concerned with the advancement of knowledge but also with its application to everyday problems on the coast.

A full list of publications and reports of the Coastal Ecology Section and the Coastal Ecology Research Station is given in Section VII.

A series of papers have been published mainly in the Journal of Ecology on the ecology of *Spartina* salt marshes in southern England and on the shingle beach vegetation of Dungeness. A substantial part of one issue of the Journal of Applied Ecology was devoted to papers on the ecology of Morecambe Bay following contributions to the Study Report on this area in relation to the proposal to build an estuarine barrage.

The Station produces Research and Development papers of work in progress for limited circulation. These are especially concerned with the development of techniques in coastal ecology research.

Two study group reports to which staff have contributed have been completed, the Report of the Sea-cliff Vegetation Study Group and that of the *Hippophaë* Study Group, and a book on the 'Ecology of Salt Marshes and Sand Dunes' has been published.

(D. S. Ranwell)

8. Staff

The Coastal Ecology Section of the Nature Conservancy was based at Furzebrook Research Station, Dorset until the Coastal Ecology Research

Station at Norwich was completed in 1968. At that time the section consisted of Dr. D. S. Ranwell, Mr. J. C. E. Hubbard and Mr. R. E. Stebbings. Mr. Hubbard came in advance of the rest of the Section and thanks to the hospitality of Dr. Martin George (Regional Officer, East Anglia), found temporary accommodation at the Regional Office at Bracondale in Norwich. From there he organized most effectively the transfer of equipment from Furzebrook and helped to supervise the completion of the Coastal Ecology Research Station. We recall also at this time the valuable help we received in our accountancy from Mr. R. H. N. Timson, Executive Officer at the Norwich Regional Office. By the end of 1968, five staff were in post including Miss R. P. Hattey, Clerical Officer in charge of administration matters and Miss S. Porter who assisted in research studies. In the following year seven additional staff arrived and Miss S. Porter resigned to take up a position at the Dereham High School. Miss E. J. Reeve was appointed as Shorthand/Typist and Mr. B. W. E. Austen as Station Secretary. The scientific staff was strengthened by the appointment of Dr. S. McGrorty (invertebrate zoologist) and Mr. R. M. Fuller, Miss J. Pizzey, Mr. R. Scott and Miss J. M. Winn assisting other research studies.

Dr. A. J. Gray was outposted to Merlewood Research Station in 1968 for two years in charge of the Morecambe Bay salt marsh study in which he was assisted by Mr. P. Adams. Dr. Gray returned to Norwich to develop genecological studies in common coastal grasses. We are most grateful to Mr. J. N. R. Jeffers (Director of Merlewood Research Station) for providing accommodation for Dr. Gray and the opportunity for valuable interchange of ideas with other scientists at Merlewood. Mr. D. G. Hewett (botanist) joined the staff and was out-posted to the Headquarters of the Nature Conservancy in Wales at Bangor, where he has developed management studies in Welsh coastal habitats and valuable liaison with Regional staff in Wales. Again our thanks are due to Dr. R. E. Hughes, Director of Nature Conservancy Wales for providing accommodation and facilities. Mr. P. G. Ainsworth was appointed Laboratory Steward and Mr. R. J. Parsell took charge of the Growth Cabinets. After much valuable work in both botanical and zoological fields of coastal ecology, Mr. R. E. Stebbings, who had a lifelong interest in bats, at last achieved his ambition to work full time on them. He left in Autumn 1970 to carry out a Ph.D. study at the University of East Anglia prior to joining Monks Wood Research Station to do research on mammals.

Dr. L. A. Boorman (botanist) joined us in 1971 to work on sand dune ecology and Miss S. S. Anderson to work on invertebrates. Mrs. C. M. Wilcockson replaced Miss R. P. Hattey as Clerical Officer and Miss J. M. Winn left to get married. By the end of 1971 there were 12 Scientific and three Administrative staff, a complement of 15 in all.

By the end of 1972 this number had more than doubled with the addition of 15 extra scientific and three administrative staff appointed on a temporary basis to work on the Wash and Maplin projects. During the year Miss S. S. Anderson transferred to the Institute of Marine Environmental Research, Seals Research Unit, Lowestoft leaving us with a total complement of 32 by the end of the year.

Dr. A. J. Gray was successful in obtaining a Ph.D. (University of Keele) in 1971 with a thesis on 'Variation in *Aster tripolium* L. with particular reference to some British populations'. Mr. J. C. E. Hubbard registered for an M.Phil. degree course at The City University in January 1971

with a study of 'Aerial imagery as an aid to the survey of coastal vegetation', Dr. S. McGrorty successfully obtained a Ph.D. (Leeds University) in 1972 with a thesis on 'Factors affecting the distribution of *Bathyporeia* species (Amphipoda)'. Mr. R. Parsell gained the Higher National Certificate as a result of part time study at Norwich City College.

Dr. S. McGrorty and Miss S. S. Anderson were promoted to Higher Scientific Officer in 1971.

(B. W. E. Austen)

9. Accommodation and Facilities

(a) *Buildings*

The Station was completed sufficiently for occupation in autumn 1968. It consisted of a single storey block with laboratory accommodation, growth cabinet room, library and herbarium room and administrative accommodation. The first greenhouse unit was erected in 1969. A bird and mammal-

A Bird and Mammal—proof plant cage at the Research Station.
photography by R. M. Fuller

proof plant cage for growth trials was set up in 1970. New growth cabinets (two units) were installed in 1971 and a new wing consisting of a conference room, workshop and garage were added to the existing building. The greenhouse was extended by a second unit in the same year.

Accommodation was leased at Wells, close to the Holkham National Nature Reserve an important working site, and converted for use as a field laboratory in 1972. A property close to the Wash was leased from the Royal Society for the Protection of Birds to provide field laboratory and living accommodation for scientists working on the Wash project. An additional detached block, to provide laboratory facilities for the extra staff recruited for the Wash and Maplin projects is now completed.

(b) *Controlled environment facilities*

A pair of Prestcold controlled environment cabinets comprise a major part of these facilities. Each cabinet has a plant growth space 1.4 m × 1.4 m × 1.2 m high. The temperature within the space can be controlled to within 1°C and over a range of 5°C to 35°C. The relative humidity can be controlled (±5%) within a range of 50% to 95%.

Above the growth space are fifty-five 5foot 60w warm white fluorescent tubes arranged in two banks. Four 60w tungsten lamps boost the amount of the red end of the spectrum available. The maximum light intensity at the chamber floor is 40,000 lux. Facilities allow for alternating 'day' and 'night' regimes.

A single glycol cooling system provides cooling for both cabinets. A direct expansion cooling system maintains the lamps at a temperature of 30°C, thus ensuring uniform illumination in time and space. Situated in the same room as the refrigeration equipment is an emergency generator. This is on permanent standby and cuts in immediately a power failure occurs, thus ensuring continuous running of the cabinets and all ancillaries.

Permanent records of temperature, humidity, day-length, light intensity and lamp temperature in both cabinets are provided by a Foster-Cambridge twelve channel chart recorder.

Two 8 l/hr stills provide distilled water both for the humidification equipment within the cabinets and also supply a four hundred litre store of distilled water for use in making up culture solutions and for watering experimental material, where necessary.

Underground tanks are connected to the cabinets so that liquids may be pumped into the cabinets to provide continuous culture conditions or with the aid of time switches, tidal regimes may be simulated.

(c) *Workshop*

The workshop has only recently been completed and has already proved to be a great asset to the research programme. It has been designed with windows on the west and north walls to give the maximum amount of even light. Adjoining the workshop is a garage/storeroom which is used for the storage of timber, metal sections, sheet materials and slotted angle on purpose-built racks. The workshop equipment includes a small metal-turning lathe, a woodworking lathe, circular saw bench and bench drill.

(d) *Darkroom*

The darkroom is equipped with a wet bench on one side consisting of a sink and draining board unit alongside a stainless steel print washer set in the bench. This side is used for the processing of prints and film. On the other side of the room is the dry bench, which is used for exposure work, and is equipped with a 35mm enlarger and a second enlarger for 35mm, $2\frac{1}{4} \times 2\frac{1}{4}''$, 70mm and $5'' \times 4''$ negatives which is fitted with a 'cold-light' source. Other

equipment includes an automatic stabilisation print processor, a 15″ rotary print glazer, a contact printer for use with large negatives up to 10×8″, and a film drying cabinet.

(e) *Field Equipment*

The Station has two dinghies. One is an 8′ fibreglass boat which can be used for crossing creeks and rivers. The second is a 10′ 6″ inflatable rubber dinghy. It can carry four people and equipment and is equipped with a small outboard motor.

Another item of specialised equipment for use in the field is a miniature tractor, powered by a single cylinder air-cooled engine. Power take off points are provided at the front and rear of the vehicle, and a pulley-drive power take off is provided under the mid-point of the vehicle for mid-mounted implements.

The station has surveying equipment including two levels and a theodolite. In association with this equipment we have a pair of portable 2-way radios for communication when surveying over long distances.

(P. G. Ainsworth, R. J. Parsell)

10. Sports and Social Club

The annual Christmas Party continues to be the main social event of the year, attracting an ever increasing number of guests. Also very popular in 1972 was an evening cruise along the River Yare in the motor vessel "Regal Lady". With the licensed bar doing a brisk trade the passengers were soon in the mood to enjoy the music and dancing. Supper was also served on board.

A charity dance held at the Horning Ferry and organized by Mike Curry and Liz Reeve raised over £100 for the Burlingham Children's Home. A fine effort, and many thanks to Liz and to Mike who so kindly brought along his discotheque "Wild Things" for the evening.

Colney United, a combined C.E.R.S./British Sugar Corporation Sunday soccer team was formed at the start of the 1972/73 season. With a squad of some 16/17 players they have a full fixture list and recent results have been very good.

The ladies too are expending a great deal of energy during lunch hour netball sessions. They have combined with the John Innes Institute and are trying to arrange suitable fixtures. Any challenges for either football or netball?

Other activities include tennis, table tennis, squash etc. which are played at the University of East Anglia's fine new sports centre. These facilities are greatly appreciated and the thanks of all players go to the University and in particular the staff of the sports centre.

(B. W. E. Austen)

II Techniques of Survey and Population Assessment

INTRODUCTION

The purpose of this work is to improve our knowledge of coastal wildlife resources. It also aims to improve and develop techniques for the measurement of coastal habitat resources and assessment of coastal wildlife populations. To meet the needs of those who have to make decisions on land use we must supply quantitative information about the relative importance of different sites and their wildlife populations. To achieve this we need to develop both simple and practical methods to give general orders of size. In the longer term we also need more accurate methods which can be applied in a unified way to the problems of resource assessment.

1. APPLICATION OF REMOTE SENSING TECHNIQUES TO THE STUDY OF COASTAL VEGETATION.

The studies have been aimed at understanding the process of aerial survey with particular reference to the interpretation and mapping of vegetation. They originated from the use of aerial photographs to produce simple maps, quantitative assessments and estimates of change. The work was restricted to two sites in southern England, namely the salt marsh, brackish marsh and mud flats of the Farlington Marshes in Hampshire and the shingle, sand dunes, salt marshes of Dungeness, Kent. The former was used to study vegetation in relation to season and film type using sorties taken at bi-monthly intervals throughout the year. It was carried out in collaboration with Mr. B. Grimes, of the Nature Conservancy. Dungeness has been the site of ecological studies for about 15 years and the vegetation forms an intricate patchwork of irregular shaped areas contrasting with the shingle. It has proved an ideal site for testing interpretation from different scales of photography and also the different seasons.

Aerial photography has been used not only for mapping large areas of vegetation, but also for following the effects of rabbit grazing, using a ground-based frame to produce vertical stereo photography at regular intervals of time over the same area. A major study was started in 1969 to map 1000 acres of shingle at a scale of 1 : 1000 to produce a record of the ridge system as well as the vegetation. It was carried out in collaboration with the staff of City University, London who provided the ground control for the aerial photographic survey. Dungeness has since been used for examining film/filter combinations and types of colour film. Experiments have been carried out on methods of density slicing as aids to interpretation and evaluation has been made of machinery for the rapid assessment of area measurement.

(J. C. E. Hubbard)

2. ASSESSMENT OF COASTAL HABITAT RESOURCES USING AERIAL PHOTOGRAPHY

Aerial photography is a useful tool in survey of coastal areas, especially those where accessibility proves a problem. The conventional techniques of plotting and map production are however often considered too time consuming and too specialised for general ecological purposes. Less sophisticated techniques may be adequate for more general survey.

An aerial photo-mosaic of Holkham National Nature Reserve provided a suitable base onto which to fit a map; over such a flat area the problems of distortion of the mosaic due to relief should be fairly small. A simple

habitat map was drawn from this and the areas of the four representative habitats—sand-dune, salt marsh, reclaimed marsh and flats were estimated using a dot grid.

The dot method was chosen since it is a simple way of measuring area on complex highly dissected patterns. This became of more significance in the second stage of this study when a salt marsh vegetation map with even more complex patterns was constructed. Nine salt marsh vegetation types could be quite readily recognised on the photographs. These were traced together with the adjacent terrestrial habitats and fitted to the base obtained from the photo-mosaic. To check the validity of the interpretation a method of quantitative field verification was developed, measuring presence or absence of species in $100 \times (10\ \text{cm})^2$ squares at 10 sites per "community" (or less if there were less than the 10 sites). This enabled construction of a key based on frequency scores of the three top perennial species of each "community".

It was not possible to assess the total error in area estimates but error estimates were made for each stage as far as possible.

To help evaluate the method an estimate of the time taken to achieve each stage was also made. The habitat map and resource assessment together with simple field checks requires 2–3 working weeks for about 4000 hectares. To produce and measure the 670 hectare vegetation map takes a little longer, 3–4 weeks, and quantitative field verification and data analysis adds a month or more to the task. These times assume perfect working conditions and no problems but such conditions are rarely encountered.

Attention is now being turned to methods of predicting possible locations of rare species believed to be associated with habitat boundaries and vegetation transition zones.

(R. M. Fuller)

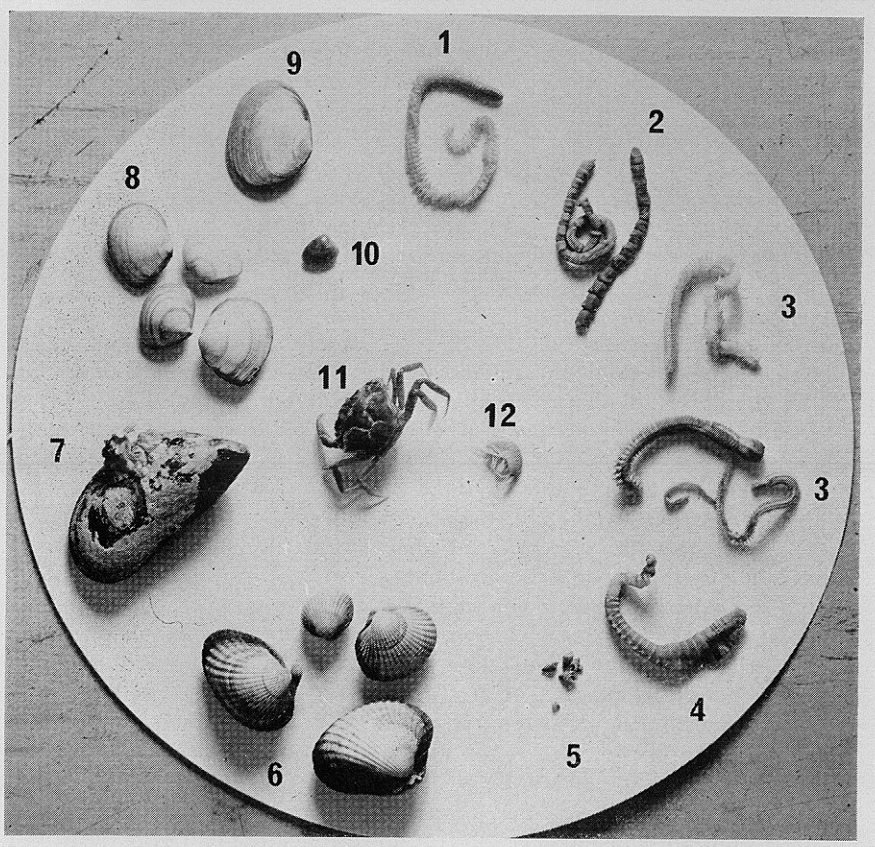
3. Inter-tidal flat invertebrate survey

The invertebrate fauna of a number of British estuaries is well known, particularly those close to Universities and marine biology laboratories, but the fauna of many estuaries and open-coast intertidal flats is poorly known and before Anderson's 1968–9 survey of Morecambe Bay, none of the very large areas of intertidal flats had been surveyed in their entirety. This survey formed part of the Morecambe Bay Barrage Feasibility Study and aimed to assess the invertebrate resources available as potential food for wading birds and wildfowl by systematic sampling on a grid over the entire intertidal area. It also attempted to relate species distributions to physico-chemical soil parameters. This exercise was sufficiently successful to promote requests by the Conservation Branch of the Nature Conservancy for similar surveys to be carried out in many other areas of importance for their over-wintering flocks of waders and wildfowl. In particular those where food resources were very poorly known and where there was an actual or potential threat to the coastal eco-system were given priority.

Surveys have been carried out in the Moray Firth (sampling March/April 1970 and 1971) and at the Caerlaverock National Nature Reserve (March/April 1972), areas in which industrial pollution is a potential threat. Similar surveys have been carried out on the Dengie peninsula (September 1971) and River Blackwater estuary (September 1972), where changes are likely to occur due to the extensive reclamation and airport construction proposed at Foulness, immediately south of these two areas. A systematic sampling scheme was used in these surveys, similar to that used by Anderson (1970)

in Morecambe Bay and aimed to provide data on the present status of the 'undisturbed' invertebrate populations at these sites.

It is often stated in the literature that estuaries are characterised by low species diversity but high productivity. This is probably only true in the upper reaches of estuaries within the oligohalinicium (salinity range 0·5–3·0‰ (Ekman, 1953)). We have identified 82 species from the five areas studied and this does not include for example Barnacles seen on shells and pebbles, but not taken in the core samples, or Nemertina, Nematoda, Anthazoa and Oligochaeta, which have not been identified. Of course, many of these species (52) were found in only one or two areas and in low densities but 11 species, *Nereis diversicolor**, *Arenicola marina**, *Pygospio elegans**, *Cerastoderma* (=*Cardium*) *edule**, *Macoma balthica**, *Mya arenaria*, *Hydrobia ulvae**, *Mytilus edulis*, *Corophium volutator**, *Crangon vulgaris* and *Carcinas maenas* were present in all the five areas studied and those asterisked were considered to be common species in three or more of the five areas and undoubtedly contain the most important bird food species:



Intertidal invertebrates of food value to waders and wildfowl.

1. COMMON RAGWORM (Nereis diversicolor)
2. BAMBOO WORM (Clymene torquata)
3. WHITE RAGWORMS (Nephthys species)
4. LUGWORM (Arenicola marina)
5. Hydrobia ulvae
6. COCKLE (Cerastoderma(=Cardium) edule)
7. MUSSEL (Mytilus edulis)
8. BALTIC TELLIN (Macoma balthica)
9. Scrobicularia plana
10. Nucula turgida
11. COMMON SHORE CRAB (Carcinus maenas)
12. 'SAND HOPPER'—AMPHIPOD (Ampelisca brevicornis)

photography by R. M. Fuller

a further 18 species were found in at least three of the areas and of these 3 *Nephthys* species, Oligochaete species, *Scrobicularia plana* and *Scoloplos arminger* were the most abundant.

The Caerverock N.N.R. sand flats and Morecambe Bay are very similar and show a clear pattern of high level medium-coarse sand poor in carbon, nitrogen and phosphorous. Not surpisingly the fauna and species abundance at the two sites were very similar; *Macoma, Corophium, Nereis* and *Nephthys* species were probably the most important bird food items common to both. Absolute values of the soil chemical parameters were also very similar, but organic nitrogen was consistently lower at Caerlaverock indicating a poorer micro-organism content and this may reflect the relative mobility of the sands. This is also probably the reason why a large proportion of the *Corophium* at Caerlaverock were the species *arenarium* which appears to prefer 'clearner' sands than *volutator.*

The Moray Firth was very different from Morecambe Bay and Caerlaverock. There was no clear pattern of sediment or fauna distribution either within bays or between the bays. Indeed the sediment 'pattern' was one of very poor sorting, showing a very wide range of types but generally low in organic carbon and calcium, but with high organic nitrogen content. This was reflected in the fauna which had a greatly increased number and diversity of species, but lower densities e.g. *Macoma balthica*—maximum density in Moray Firth 1000/m^2—in Caerlaverock and Morecambe 5,000/m^2.

The Essex sites varied considerably in substratum type from the previous sites with a fine grey clay (London Clay series) overlain in the upper R. Blackwater estuary and the lower level Dengie flats by varying depths of silt and fine sand respectively. The striking faunal difference compared with northern sites is the paucity of Crustacea, in particular an almost total absence of *Corophium.* Though a number of species were present in small numbers, only the tube building isopod *Cyathura carinata,* not recorded from the more northerly sites, could be classed as common within a small area of the River Blackwater estuary around Osea Island. The recently immigrant species of bamboo worm, *Clymene torquata* was found on Dengie occupying low level sandy areas together with the native *Lanice conchilega.* The number and range of species found in the River Blackwater estuary and on the Dengie flats was very similar, the only differences were probably related to shelter. Biomass per unit area was greater in the inner estuary around Osea Island and for example *Cerastoderma* (=*Cardium*) *edule* grew faster, bigger, and lived longer than on the more exposed Dengie flats.

One further survey is being carried out under contract by Mr. J. B. Arnold and Dr. H. G. Stubbings and aims to describe the intertidal invertebrate fauna of Poole Harbour in Dorset. The mollusc and annelid populations of this natural harbour have been harvested for a very long period but in recent years fears have been voiced that eutrophication and bait-digging might be reducing the fauna of certain areas. A preliminary semi-quantitative survey in September 1971 showed that in some intensively dug areas the predominantly mud, shingle and clay substratum stratification had been destroyed, and resulted in almost totally anaerobic conditions. Other less disturbed areas however carried large populations, in particular of *Nereis diversicolor* and *Nereis virens* and there was considerable evidence of a very diverse fauna. In June and July 1972 a systematic sampling survey was carried out with the help of Royal Marines personnel in transporting samples from the more difficult areas. As yet these samples have not been fully analysed, but it is

expected that the data will allow estimation of the present status of the invertebrate populations and the mapping of their distributions.

(S. McGrorty)

References

ANDERSON, S. S. (1970). *J. Appl. Ecol.* **9**, 161–178.
EKMAN (1953). quoted by Remane & Schieper 1958
Die Biologie des Brackwassers. Die Binnengewässer. *Bd. XXII Stuttgart.*

4. TIDAL LITTER INVERTEBRATE STUDIES

Each tide deposits at its upper limit quantities of litter commonly referred to as flotsam and jetsam. The resulting litter lines commonly contain the remains of dead plants and animals of marine and terrestrial origin and also man-made artificial products such as polythene bags and polystyrene packing material. There have been few studies of this tidal litter habitat and the associated faunas, and these have been restricted to the wrack beds of N.E. England and the Baltic, where marine algae (*Fucus* and *Enteromorpha* spp., cast ashore by the autumn Spring Tides, forms large, deep, permanent structures, which decompose readily to form ultimately a peat-like material in the deepest layers. The faunas of these wrack beds are dominated by species of dipteran flies, adapted to specific niches within the decomposing wrack or by talitrid amphipods. There were several obvious differences between these wrack beds and the litter lines in S.E. England. Litter quantities are generally low throughout the year. Wrack is sometimes absent and is never present in sufficient quantities to form a wrack bed, but nevertheless is usually one of the dominant litter components. These studies aimed to describe the variation within the tidal litter habitat in S.E. England and the associated faunas occurring in the upper beach zone between High-Water Neap Tides and Extreme High-Water Spring Tides.

(a) *Survey of Litter Lines in South-East England*

A survey was carried out from Burnham Deepdale in Norfolk to Hurst Beach in Hampshire in August 1972 to describe the variation present in the strand zone. 70 sites were visited where the 10 Km. Ordnance Survey grid lines cut the coast. At each site 10 categories of information were recorded:—Substratum type, 'hinterland', quantity of litter (in cu. ft. of fresh litter per 10 m), percentage of a kilometre section of beach with litter, percentage composition of litter, permanence, live vegetation, animal groups, pollutants present and public pressure. The three main substratum types encountered were shingle, sand and stones, and 'marsh' with earth or stone embankments, but a wide range of other substrata were also recorded. Litter quantities were generally very small, 53% of sites had less than 1 cu ft. of litter/10m. and only 10% had 10 cu. ft./10 m. These litter lines can only be described as 'strings' or 'flakes' in Backlund's terminology. There was a distinct trend of increased litter quantity with shelter as indicated by substrate type; bare rocks and shingle had least litter, sand and marsh sites had greater litter deposits. Unlike the wrack beds previously studied the most commonly occurring items of litter were man-made products such as plastic, nylon, polystyrene, metal cans, and oil, found on 90% of the beaches examined. *Fucus* and *Enteromorpha* species however formed the greatest proportion of the fresh litter, but this was only approximately 40% by volume. Wood and wood products (15–20% each by volume), salt marsh vegetation (10%), and grass straw (10%) were other common constituents. Only 6% of the litter lines examined could be considered permanent structures and showed signs

of advanced decomposition in the deeper layers; these were generally salt marsh sites. A further 37% of the litter lines were clearly old structures, but they showed few signs of litter breakdown; the remaining 57% of sites had litter lines which were considered to be ephemeral.

The fauna of these strand-lines like the wrack beds was however still dominated by Diptera and Talitrids (found at 81 and 67% of the sites respectively) with Coleoptera (43%), Areneida (40%), Acarina and Nematoda (26%) and Isopoda (woodlice) (21%) also common. Coleoptera, Isopoda, Diplopoda, Chilopoda, Areneida, Acarina, Nematoda and non-dipterous insects occurred most commonly in permanent, decomposing litter lines; Talitrids and Oligochaetes occurred most commonly in old non-decomposing litter lines; Diptera were the commonest group found in ephemeral litter lines.

In addition to the general paucity of litter, over 60% of the litter lines visited showed evidence of moderate to extensive human disturbance. It is hoped that when the results of this survey are fully analysed, it will be possible to modify the questionnaire to make it suitable for a national survey.

(b) *Seasonal Variation in Litter*

Seasonal variation in litter quantity and content was followed by monthly sampling at spring tides at three Norfolk beaches from October 1970 to September 1971. Litter quantities increased with decreased exposure, as shown by substratum type (Table I).

TABLE I. *Tidal litter accumulation and invertebrates found on different types of shore in Norfolk during the period October 1970 to September 1971*

Site	1. Cley to Blakeney	2. Winterton	3. Wells to Stiffkey
Substratum	Bare shingle	Bare sand	Salt marsh, silt
Mean dry weight of litter (g/m^2)	7*	770	4000
Animal species			
Talitrid Amphipoda		+	
Isopoda		±	
Diptera		+	
Coleoptera		+	
Hymenoptera		+	
Areneida		+	
Opilionides		±	
Diplopoda		±	
Chilopoda		±	
Nematoda		±	
Oligoacheta		±	+
Acarina	−	±	+
Collembola	−	−	±

+ =common ± =occasional − =very infrequently taken or absent
* 340g/50 m of litter line)

There appeared to be a trend in the data for all three beaches of greater accumulation of litter during the spring and autumn equinoctial tides, but these trends were not statistically significant. Up to 80% of the marsh litter was composed of local marsh vegetation, but this was present in negligible quantities only on the other two beaches, where up to 90% of the litter consisted of hard animal remains e.g. crab casts, polyzoan skeletons and feathers. The algal content of the litter generally varied between 10 and 15% at each site.

(c) *Species Diversity*

It is perhaps to be expected in such a variable habitat that a wide range of litter fauna species would be found. The greatest taxonomic difficulties however arose with the large number of immature stages found, for which there are no adequate keys of identification. To avoid a heavy commitment to taxonomic work only the Talitrid populations at the three Norfolk sites have been analysed in detail, other species have been grouped according to Phyla or Class (Except insects, where certain orders e.g. Diptera, because of their abundance have been separated out).

Diligent searching throughout the year on any beach would probably provide occasional specimens of any terrestrial invertebrate group; Table I however lists only those groups found commonly at one or more of the three Norfolk sites. The salt marsh litter line undoubtedly supported the greatest variety of species and the greatest microfaunal element; the shingle beach had the poorest fauna. The greatest biomass at all three sites was recorded in late spring and early summer and there was a minor autumn peak.

(d) *Talitrid Biology*

Orchestia gammarella occurred in low densities on the shingle beach and high densities in the salt marsh litter. The maximum densities recorded were 120 individuals (≡6·12 g dry weight) per 50m length of litter line on the shingle beach in September and 1470 individuals (≡23·78g dry weight) per m^2 of salt marsh litter in June. The breeding cycle appeared to be identical in the two populations and was based on two generations per year. Females with ova or embryos in the brood pouch were found between April and September, with peaks within the female population in May and August. The spring generation matured in three months and their progeny overwintered.

Talitrus saltator was found on the sandy beach, but was active in the litter only during the March–November period, reaching a maximum recorded density of 650 individuals (≡4·120 g dry weight per m^2) in July. During the winter months this species burrows into the sand above the spring tide litter line to 'hibernate'. The breeding cycle is based on only one generation per year; the overwintering generation begins breeding shortly after emergence in spring and breeding ends in September. The progeny breed the following summer.

(e) *Seasonal movements of fauna*

Bi-monthly samples were taken on neap tides from a series of four litter lines at a site on the East Hills area of the Holkham National Nature Reserve between January and November 1971, to detect any seasonal movement of animals into or within the litter. The litter lines included:—

1. The 'fresh' Neap-tide litter consisting mainly of fragments of algae and marsh vegetation on bare sand.
2. The Spring-tide litter line; a twisted 'rope' of grass straw on bare sand.
3. } Old straw and timber storm tide lines resting on a short grass turf,
4. } with occasional marram clumps.

A number of animal groups had a restricted range within these four strandlines, which they occupied throughout the year. *Talitrus saltator* only occurred in strandlines (1) and (2), and the dipterous flies, though found in all four litter lines, occurred predominantly in (1) and (2) with the Talitrids.

Chilopoda and Isopoda (woodlice) were found in (2), (3) or (4) but never in (1). Areneida, Collembola and Coleoptera species could be found in all four litter lines throughout the year.

Some species however only occurred in the litter at certain times of the year. Opilionidae were only found in July and September and the common earwig, *Forficula auricularia* between November and March. The ladybird, *Coccinellia 11-punctata* appeared in strandline (3) in September and by January had reached densities of up to 1000 individuals/m² in litter lines (2), (3) and (4). This species left the litter in March. A millipede, *Cylindroiulus* sp. was found throughout the year in the two storm-tide litter lines (3) and (4), but in September specimens were found in the spring tide line (2) and throughout the winter, until the beginning of March, successive downshore migrations resulted in densities of up to 500 individuals m² in the neap tide litter line (1) and 90–95% mortality of these individuals.

(S. McGrorty)

5. Ground survey of maritime vegetation

(a) *Flats*

Ground and air survey techniques have been employed for the location of beds of *Zostera* and filamentous, green, macro-algae in southern England. Really extensive beds of *Zostera* can be easily located in late summer and autumn by the presence of large quantities of leaves and shoots in tidal litter at high water mark. The general distribution of *Zostera* in Essex was recorded in this way on shore walks at high water mark. The size of areas in which *Zostera* occurred was recorded by paced transects along and (where feasible) perpendicular to the shore. Green algae are ubiquitous on these shorelines and therefore tidal litter observations are of little value in studying their distribution. Binocular observations from a height of 6 ft. above these flat shores gave little valid information about the extent of algae or *Zostera* where the mudflats were too soft to walk on.

Better results were obtained by observation from a light aeroplane together with hand held 35 mm air oblique colour photography in late summer. This was particularly useful for locating extensive beds of green algae which are bright green and readily visible in good light. *Zostera* however is dark green, shows poor contrast on mudflats, and is not easily visible from the air.

Vertical black and white, colour, or infra-red colour reversal air photography will show up beds of *Zostera* and green algae, but Mr. Hubbard's work in Langstone Harbour, Hampshire showed they cannot be reliably distinguished from one another using air photographs alone.

Dr. S. Coles (Wash Project) and Mr. D. Wyer (Maplin Project) are following up this preliminary work with extensive resource surveys and setting up transects for more detailed studies of seasonal changes in populations of algae and *Zostera*.

(D. S. Ranwell)

(b) *Saltmarsh*

The production of a taxonomy of the set of objects in which one is interested is a prerequisite of any attempt to sort, order, evaluate or interfere with those objects. Thus answers to questions about the rarity of a particular salt marsh type, its relationship with other types, or about ways in which it should be managed, rely heavily on the characterisation and quantification of salt marshes in general. This in turn depends on accurate, repeatable survey.

The development of survey techniques which minimise the practical effort needed to sample vegetation, whilst retaining a sufficient level of accuracy for classification, is seen as a prime research objective.

A variety of approaches to the survey of salt marsh vegetation and the description of plant communities has been used and in a number of locations. In Morecambe Bay, in 1968, species lists were collected from 2×2 m. quadrats laid out along transect lines spaced around the study area. The inclusion of the transition habitat near the landward limit of tidal inundation albeit compressed and truncated by reclamation banks and sea walls, is generally very revealing. Samples of communities of this type, often rich in species, are particularly useful in identifying regional variations in marsh type. At the analysis stage samples from such areas are quickly separated from other salt marsh communities (e.g. in techniques such as association-analysis, because of the occurrence of a large number of species of limited distribution).

The remaining communities, that is the vegetation occurring to seaward of the normal spring tide level down to the line of high neap tides, belong arguably to one plant community because most of the species can survive at almost any part of the zone. This wide ecological amplitude of individual species is one of a number of problems which make more difficult the production of a logical and objective classification based on simple standardised field methods. Others include the paucity of species, their ecotypic differentiation and the imposition on the habitat of strong pattern elements related to tidal factors which produce local small-scale gradients and mosaics. One method is to make use of the variability of the soil data and to add this to the data obtained from the floristic survey in a multiple-correlation approach. The total array of variation may then be simplified and subdivided, using methods such as cluster analysis, to produce subunits based on closely correlated soil and floristic variables. (see for example the Morecambe Bay results in Gray and Bunce (1972)). Whilst this method provides an insight into the causal ecology of salt marshes, particularly when supported by experiments into species response and interaction, the need to sample and analyse soils makes it less suitable for rapid survey.

Among the methods which utilise floristic data alone association-analysis has been tried on data from Morecambe Bay and from a survey of Essex salt marshes carried out in 1971. Although apparently good results were obtained from Morecambe Bay it became clear with the Essex work that the technique lacked sensitivity where characteristic vegetation types occur along a continuum and can only be defined by differences in the proportion of the various species. Following the Morecambe Bay survey, which used only presence or absence data for the vegetation part of the analysis, subsequent collections of field data have been made on quantitative basis using a 1 m. square quadrat and recording species presence in the 100 10×10 cm. squares of the quadrat. This percentage frequency record is economical of time and no corrections are necessary to put the data in a form suitable for arithmetical analyses (unlike subjective estimates of cover such as the Domin scale for example). We have found the data generated from such a sampling technique to be suitable for the extraction of characteristic plant assemblages in the manner of Continental phytosociology. A preliminary phytosociological account of the Essex marshes has been produced by our co-worker P. Adam (Botany School, Cambridge University). Future research is examining the effect of quadrat size and use of numerical methods of analysis of a polythetic, agglomerative type such as information analysis.

Whilst working towards a greater degree of standardisation of technique particularly at the recording stage where valid comparisions of the results of contemporary work will be possible, the need to gear sampling techniques to the objectives of individual surveys should be recognised. In this context two current projects deserve reference here. The first is the monitoring of colonisation patterns of Holkham National Nature Reserve where we are examining the effectiveness of different techniques in recording the changes observed in developing vegetation stands. The second is the salt marsh survey of the Wash where the production of a classification of the Wash salt marshes is one of a number of shared objectives, an important one of which is the development of a predictive model for examining the effect of the proposed water storage scheme on salt marsh development. For this reason the survey has been designed to include, as well as vegetation analysis, measures of sediment type, tidal inundation, accretion rate and vegetation standing crop. *(A. J. Gray, R. Scott)*

Reference

GRAY, A. J. and BUNCE, R. G. H. (1972). *J. Appl. Ecol.* 9, 221;234.

(c) *Sand Dune*

The flowering plant and fern flora of over 50 sand dune sites in Great Britain has been listed from recent published reports, Biological Records Centre records, and reconnaissance visits (e.g. to little known sites in Scotland). This reveals that more than 1000 species of flowering plants and ferns (more than half the British flora) occur on sand dunes and it underlines the problem of assessing these floristic resources. Results are being analysed in the form of association-analysis on the Southampton University computer.

In addition records have been made of the floristic composition of visibly distinct plant communities on many sites visited. This information, together with the analysis can be used to develop a provisional synoptic classification of British dune vegetation. The validity of the system can then be checked by completely objective random sampling. This approach seems justified in view of the complexity of dune vegetation types, the considerable amount of subjective information available at present, and the excessive amount of sampling that would be needed if a wholly objective approach were used to start with. *(D. S. Ranwell)*

(d) *Shingle beach*

The shingle vegetation of Denge Beach, Dungeness, Kent, has been the object of much study. Of particular interest is the colonisation of new shingle (which is being added at the rate of about three metres per year on the eastern shore) and the plant succession on the beach. To study this, transects have been taken along the eastern and southern shores, a 50m permanent quadrat site has been established and $10 \times (2\ m)^2$ permanent photographic plots have been positioned on areas representing different parts of the succession.

Arrhenatherum elatius seems to be the most abundant of the colonisers and is accompanied by *Glaucium flavum, Rumex crispus* and a fine population of *Crambe maritima*. As the plant cover increases, and so the humus builds up in the shingle, the vegetation composition changes to include species of acid heathland. *Festuca tenuifolia, Cladonia impexa* and *Dicranum scoparium* make up the majority of the cover with herbs such as *Cochlearia danica* and *Rumex acetosella* scattered throughout.

The prostrate form of *Sarothamnus scoparius* appears very important in the cycle of vegetation changes on the shingle. It grows on areas already colonised but overhangs bare areas. Its death then liberates humus to the bare areas providing new ground for plant colonisation. Death of the plant starts at its centre and spreads radially outwards, and species such as *Anthoxanthum odoratum* soon colonise the open space. In this way plant cover can spread down from the shingle ridges into the lows which consist of coarser shingle and are the last areas to become colonised.

The Open pits, a group of primary hydroseres exhibit a range of freshwater marsh from reedswamp to *Salix cinerea* ssp. *atrocinerea* carr and fen. The rich flora of 130 species has been likened to that of the Norfolk Broads.

A holly wood on Holmstone beach, to the west of Denge beach is thought to mark the climax of the shingle vegetation transition and has been the subject of intensive study (Peterken and Hubbard 1972). This is reported in a separate section.

(J. C. E. Hubbard, R. M. Fuller)

Reference

PETERKEN, G. F. and HUBBARD, J. C. E. (1972). *J. Ecol.* **60**, 547–572.

(e) *Cliffs*

The period covered by the report marks a great increase in interest in coastal cliffs, possibly as a result of the Nature Conservancy's "Nature Conservation Review".

In 1970, Dr. D. S. Ranwell devised a scheme for primary survey based on the structure of cliff vegetation. The units conform with those used in the 'Biological Sites Recording Scheme'. A sketch map was drawn and the various vegetation structural units were indicated upon it by numbers. In the example given about three miles of cliff were surveyed. It was also suggested that species lists for the cliff depicted should be made. A survey from St. Catherine's Point to the Needles, Isle of Wight using this method was made by the Hampshire and Isle of Wight Naturalists' Trust.

Late in the following year, the Coastal Habitat Team set up a Sea Cliff Vegetation Study Group to report on techniques for survey of cliff vegetation. The Study Group consisted of:

Mr. D. G. Hewett *(Chairman)*
M. E. Ball
Mr. S. B. Evans
Mr. E. T. Idle
Mr. D. A. White.
Dr. A. J. Malloch *(Cambridge University)*
Mr. E. M. Matthew
Mr. P. Rothery
Mr. M. G. Watkins

The report presented to the Habitat Team Meeting in September 1972, covered the working definition of a sea cliff indicating the forms it may take, a technique for collecting data from cliffs and techniques of classifying vegetation from that data. Four appendices covered field aspects of cliff survey, and extracts from 'Conservation of the Coast' (Countryside Commission, 1969) and 'A Nature Conservation Review' (Nature Conservancy 1972) plus a useful review of published studies on maritime cliff vegetation by Dr. Malloch.

The report provoked lengthy discussion at the Habitat Team meeting and it was decided to distribute it widely throughout the Nature Conservancy for comment. A limited trial of the technique will be undertaken.

Also during 1972 the Regional staff in North and South Wales had been carrying out pilot coastal surveys for conservation purposes. In North Wales, the Lleyn peninsula, Caernarvonshire was the subject of survey using traditional techniques on sites selected from random co-ordinates. A proforma was used to ensure a uniform standard of information. While in Gower, Glamorganshire survey along the lines in the Study Group Report has been tried. Elsewhere in England and Scotland reconnaissance surveys of cliff vegetation have been carried out at a number of sites.

(D. G. Hewett)

III Trophic Relations

The object of studies on trophic or food relationships is to understand how coastal plants derive their nourishment in an environment dominated by salt and how they in turn, alter the nutritional status of the environment. The studies also seek to find how coastal animals derive nourishment from plants and each other, altering the system as they do so. Only by helping to unravel these complex interactions can we begin to understand the significance of additional nutrients and toxins derived from human sources reaching the coastal zone and recommend corrective action to protect wildlife resources.

1. Salt tolerance and mineral nutrition studies

(a) *Salt Marsh Soils*

The changes in the soils of salt marshes which occur during their accretion and development, and the interaction between these changes and the vegetation produce a mosaic of soil types. Studies of the variation in physical and chemical soil factors particularly in relation to vegetation were carried out in Morecambe Bay in 1969 and 1970. There was found to be a high degree of intercorrelation between the variables associated with soil maturity, variables such as total nitrogen, percentage clay, loss of ignition and potassium content having high values in mature marsh soils and contrasting with calcium content the high values of which occurred in the less well-developed pioneer soils.

The soils of salt marshes at Holkham have also been subjected to physical and chemical analysis and similar methods of multivariate statistical analysis are being used to examine the correlations between soil type and vegetation. In addition the relationship between organic and ionic status of the various soils and the 'salt tolerance' of *Puccinellia maritima* biotypes occurring naturally in them is being examined.

Dr. D. Ball and his colleagues (Pedology Section, Nature Conservancy, Bangor) have measured small space variability of selected physical and chemical properties of salt marsh soils beneath selected plant species using intensive sampling methods at Holkham, Norfolk.

(b) *Salt Marsh Vegetation*

Salt marsh plants, especially those of the pioneer zones occur in soils which are often water-logged and highly saline. Research is in progress to examine the mechanism of salt tolerance in selected species, the interaction between water-logging and salinity, and the comparative tolerance of different biotypes of the same species *(Puccinellia maritima)* from different habitats.

The majority of these experiments have been carried out in the controlled environment cabinets and both hydroponic and inert medium (perlite) culture conditions have been used. Preliminary trials have been undertaken with a range of culture solutions. The experiments are at a preliminary stage.

Early results from the *Puccinellia* salt tolerance experiments indicated that all populations so far screened show a significant depression of growth in solutions to which 18 gm/litre of Sodium Chloride have been added (but not in some biotypes in solutions with up to 9 gm/litre of added salt). Growth is measured as either root length, root number, tiller number or leaf number which are highly correlated parameters (root length v root number $r=0{\cdot}92$, root number v leaf number $r=0{\cdot}72$ (99 degrees of freedom)).

However, the tolerance index, measured as:

$$\frac{\text{Performance in 18 gm/litre NaCl} \times 100}{\text{Performance in basic solutions}}$$ of individual

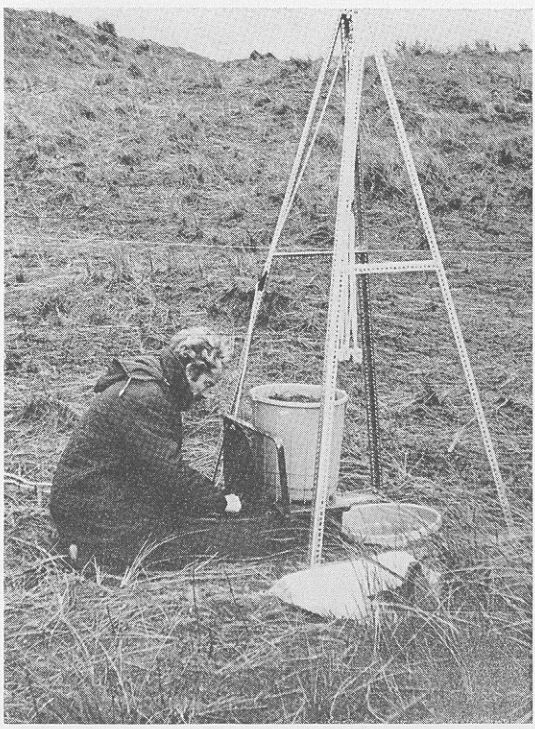
biotypes can be related to the organic and ionic level of the soil from which the biotypes were collected, those from soils of a high ionic status having a high index of tolerance. Among the populations being screened for their index of salt tolerance are a range of coastal grass species as well as commercially bred varieties of grasses which might be used on coastal reclamation banks.

Early experiments in controlled environments have been concerned with a further aspect of salt tolerance in coastal grasses, namely the ability to absorb and utilise the essential nutrient potassium in the presence of large quantities of the chemically similar sodium ion. The sodium and potassium contents in roots and shoots of both adapted and non-tolerant (glycophytic) grasses is being examined following growth in a range of solutions containing different concentrations of the two cations.

(A. J. Gray, R. Scott, R. J. Parsell)

(c) *Sand Dunes*

A set of 12 lysimeters was set up in the dunes at Holkham N.N.R. as part of a study of the water and mineral relationships of the dune eco-systems. Four types were used, undrained vegetated, undrained bare, vegetated pumped of water, and free drained vegetated. The weight and thus water content of the lysimeters was measured with a platform weighing machine using a small hoist. In addition rainfall was measured at a number of stations



Weighing the Lysimeters at Holkham. *photography by R. M. Fuller*

in the area. After the figures for one year had been obtained it became apparent that there was a need to be able to get information on short term changes in water content. It was decided to make various modifications to enable frequent direct readings to be taken using hydraulic load cells. The study so far has been on the water relations only. It is planned to extend the work to include measurements of the mineral content of the various components of the system and to work out the overall nutrient circulation and balance.

As part of the proposed nutrient studies it was decided to investigate the general mineral status of the area by nutrient addition plots. The aim of these was to see which nutrients were limiting plant growth and controlling the floristic composition of the site. The basic layout was similar to that used by Willis (1963) in Braunton Burrows. The mineral combinations used were (1) complete with nitrogen, phosphate and potassium; (2) complete less nitrogen; (3) complete less phosphate, and (4) nitrogen only. A randomised Latin square layout was used, individual plots were 2 m×2 m. Fertilizer was applied three times a year in spring, summer and autumn. In addition a further set of plots was set up in 1972 using the slow release fertilizer 'Enmag' applied at three different rates, primarily to see whether it could be used to increase the resistance of the sward to trampling without seriously affecting the floristic richness of the area.

Studies were also made of the comparative productivity of different stages in dune zonation by measuring the standing crop. This was done in September 1971; while in 1972 an assessment was made of the changes in the standing crop during the growing season. The most striking features of the changes in standing crop through the dune zonation from seaward to landward was the rapid build-up of standing-dead material, mostly the leaves and leaf-bases of *Ammophila arenaria*.

Standing dead *Ammophila* could amount to nearly a kilogram per square metre, compared with a level of dry matter of living *Ammophila* of 180 gms per square metre. Examination of the plant remains indicated that a proportion of the dead *Ammophila* persisted for three years. These values were obtained from the calcareous dune system at Holkham. Figures from the acid dune system at Winterton were similar but rather lower. The measurements made the following season showed that the changes during the season were relatively small and that one season's growth remained green and functional until replaced by the new season's growth. The figures confirmed those of the previous year regarding the high level of standing dead plant material. It was considered that the minerals locked up in the standing dead inhibited further changes in the succession and indeed the growth of *Ammophila* itself. The very vigorous growth that occurred after an area of *Ammophila* at Holkham had been accidently burnt in 1970 supported this hypothesis, and both of these observations were supported by earlier nutrition studies on *Ammophila* (Willis, 1965).

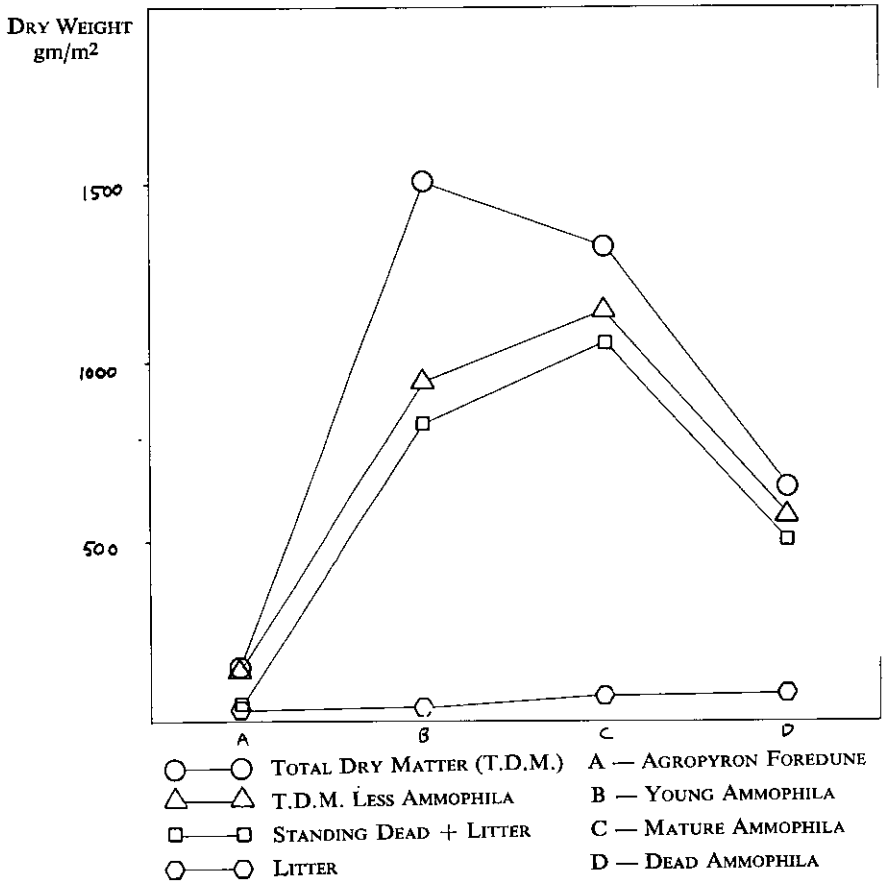
In conjunction with Dr. D. Ball and his colleagues (Pedology Section, Nature Conservancy, Bangor) a study of the broad zonation of vegetation and soil types was carried out at Holkham, Norfolk. Intensive soil sampling at specific loci was used to compare small space variability with that found in salt marsh soils.

(L. A. Boorman, R. M. Fuller)

References

WILLIS, A. J. (1963). *J. Ecol.* **51**, 353–374.
WILLIS, A. J. (1965). *J. Ecol.* **53**, 735–745.

Fig. 2—DUNE STANDING CROP—HOLKHAM N.N.R. 1971



Results based on five 0·25m × 0·25m plots at each site

(d) *Roadside verges*

A study in conjunction with the Soil Chemical Section, Merlewood Research Station on the effects of road salting on roadside verge soil and vegetation has been completed. This gives evidence suggesting that sodium is accumulating in roadside soils from year to year. Sodium values in surface soils within 1 m of the road edge on main highways may exceed those in embryo sand dune soils and approach values found at the extreme upper limits of salt marsh or in the spray zone of coastal cliffs. The flora of the verge within 1 m of the road edge is either destroyed or reduced to a group of species commonly found in the spray zone of coastal cliffs. The salt effect is significant up to 9 m from the road edge. Owing to the accumulation of

salt in long-lived perennials like trees, susceptible species such as Beech in roadside tree plantations are likely to be suffering sub-lethal effects which might kill them within a decade or two, and further study of these effects is highly desirable.

(D. S. Ranwell)

2. Trophic Relations of Consumers

(a) *Invertebrates*

We have not made any specific studies of invertebrate trophic relations but while assessing the use of traps in strandline studies, data was collected which possibly indicates the food preferences of certain species. Traps only sample the active fauna and underestimate the number of breeding females in Talitrid populations. Using unbaited traps (plastic cups) Talitrids were found to be active only on 'dark' rainy days and at night, with *Talitrus saltator* on sandy beaches reaching an activity peak around midnight and *Orchestia gammarella* on shingle and marsh beaches, most active at dawn and dusk. Baited traps were used during these active periods. The number of escapes from unbaited traps were negligible but when bait was present animals entered and left the traps with equal ease and it can be assumed that the numbers of animals remaining in the traps after a period of activity reflects their preference for the various baits.

Baits were obtained from the litter lines. Unbaited traps because animals could not escape, always caught more Talitrids than baited traps and both species showed the same bait preference, that is:—
Unbaited > 'old' *Fucus* > *Enteromorpha*/'fresh' *Fucus* > fresh *Fucus*/grass straw > grass straw/wood > wood/*Halimione*/*Spartina* litter. (where > indicates a significant difference between means at the 1 % level of probability in the analysis of variance and studentized range tests.)

It is possible that the first three items, old *Fucus* (already partly decomposed by nematodes, oligochaetes, etc), *Enteromorpha* and fresh *Fucus* are the most important food items, while all provide shelter.

Many species were caught other than Talitrids, but only the beetle *Phalaria cadaverina* occurred in sufficient numbers to allow analysis and it only occurred on the sandy beach with *Talitrus saltator*. It is of particular note that this species showed a strong positive attraction for old *Fucus*. Three and a half times as many were caught in these traps as in unbaited traps and only very occasional specimens were taken in other baits.

(S. McGrorty)

(b) *Waders and Wildfowl*

Dr. J. Goss-Custard has started work on behavioural aspects of wader feeding (especially Knot) as part of the Wash study. This work involves long hours of observation in the field in winter and development of new techniques for estimating size class and amounts of prey taken at some distance away from the site. The first questions to be answered are whether or not food supplies become limiting for birds and if so under what environmental and behavioural conditions.

Mr. K. Charman is carrying out a study of the feeding pattern, and Dr. N. Owens the behavioural patterns of Brent Geese in relation to disturbance, in south east England as part of the Maplin Project.

(D. S. Ranwell)

(c) *Rabbits*—Sand dune

Rabbits form an important part of the dune ecosystem at Holkham. While the sparse vegetation is partly the result of low mineral and moisture status, rabbit grazing is undoubtedly an important factor. Accordingly three (4 m)^2 rabbit exclosure plots were set up in 1971. There was little difference between inside and outside the plots in the first year, as the moisture levels in the soil in June (when the plots were set up), were rather low for significant plant growth. However some grasses and herbs flowered for the first time inside the exclosures. *Erodium cicutarium* and *Galium verum* both flowered profusely from plants that had previously been kept down by rabbit grazing and *Agrostis stolonifera, Holcus lanatus* and *Arrhenatherum elatius* flowered inside the exclosures but not in the control plots outside. Bryophytes also increased within the exclosures probably as a result of the reduction in surface disturbance. The plants were recorded in detail in 1972 and the results are presently being analysed. Apart from the very marked growth inside the plots in 1972 the most striking feature are the scrapes round the outside of the plots as rabbits attempted to burrow under the fence to get at the lush growth. No rabbits succeeded in getting in as the fence was buried 15 cm down and 15 cm out to exclude this happening. The preliminary results were in line with those obtained at Blakeney (White 1961). From observation during 1971 and 1972 it became clear that the numbers of rabbits varied greatly and so it is hoped to estimate the rabbit population size by dropping counts in 1973, this to be accompanied by time lapse photographic studies of their feeding behaviour.

(L. A. Boorman, R. M. Fuller)

Reference

WHITE, D. J. B. (1961). *J. Ecol.* **49**, 113–118.

(d) *Rabbits*—2. Shingle Vegetation

The shingle heathland of Denge Beach, Kent, remained virtually ungrazed by rabbits from 1954 when myxomatosis eradicated the populations, and few rabbits were seen until 1969. However, their return in 1969 resulted in a vast increase in the grazing pressure on the vegetation and produced dramatic changes. Palatable species such as *Festuca rubra* and *Anthoxanthum odoratum* are almost completely grazed out of the sward, and are replaced by mosses and lichens, in particular *Dicranum scoparium* and *Cladonia impexa*. *Sarothamnus scoparius* is grazed to a flat plate appressed to the ground, and even gorse is trimmed to a very tight mound.

In December 1969 two rabbit exclosures were erected on a heavily grazed area of heathland. Changes within these were monitored by stereo photography of 1m plots. The vegetation within soon started to show recovery and began to take on some of the characteristics of the former ungrazed sward Grasses were able to flower and *Sarothamnus scoparius* grew to a much taller bush. Mosses and lichens gradually lost ground to previously grazed species, and the number of different species within the exclosures increased.

(J. C. E. Hubbard, R. M. Fuller)

(e) *Ungulates*

In the past, grazing by domestic animals has been widespread on coastal habitats, particularly in the west of Britain. For the maintanence of nature reserves it may be necessary to continue grazing after it becomes uneconomic for farmers to do so. Many salt marshes and dune systems are grazed by one

or all of the domestic animals, sheep, cattle, and ponies. The study of grazing situations has become especially important in relation to dune systems following the reduction in numbers of rabbits through myxomatosis.

Some studies on the grazing of *Spartina* by sheep were carried out at Bridgwater Bay National Nature Reserve prior to the establishment of the Research Station (Ranwell, 1961). An investigation of stock grazing was started at Whiteford National Nature Reserve in October 1971.

Grazing on the reserve is principally by ponies owned by members of the Gower Commoners Association, but there are also sheep and cattle present on the salt marshes of the Burry river. The first task was to establish the numbers of ponies and any other animals that were frequenting the area, and the parts of the area visited. The warden has visited the reserve

Ponies grazing the Sand dune vegetation at Whiteford. *photography by I. Jones*

as often as possible during 1972 to record the presence of animals. These observations were augmented by an intensive study during six weeks in the summer by a student (Mr. P. Glynn), from the University College, London, M.Sc. Course. All parts of the reserve are visited by the ponies and all vegetation types grazed, even the mobile dunes with *Agropyron junceiforme* and *Ammophila arenaria*. The numbers of ponies present on the study area varies between four and seventy. It is clear the ponies are ranging widely on the salt marshes and the study area is but part of their home range. Features of special importance to the ponies, such as springs and places of shelter, have been located. Channels in the salt marsh are not obstacles to the ponies as was at first thought. Ponies cut off by the tide, stand still waiting for the water to recede. Occasionally they are forced to swim for the shore. On emerging from the sea, ponies have been observed to roll in bare sand. These areas often contain sea-weed and other detritus, so the behaviour appears to have a drying and cleansing function. Of the various habitats in

the reserve, Mr. Glyn has produced quantitative data which suggests that the transition zone between sand dune and salt marsh is the most favoured area.

During 1973, it is hoped to erect a fence to exclude the animals from an area comprising salt marsh, transition zone, sand dune and pine plantation, in order to measure effects of the absence of stock grazing.

(D. G. Hewett)

Reference

RANWELL, D. S. (1961). *J. Ecol.* **49**, 325–340.

IV Species Biology and Genecology

INTRODUCTION

The purpose of these studies is to learn more about the potentialities for human use of selected coastal species, to learn facts relevant to the control of populations of those that become too abundant and threaten the existence of others, and to study the requirements of threatened species so that the right environments can be provided for their continued existence. While it is unlikely that new *species* of use to man will be found on the British coast, it is highly probable that new *varities* of coastal grasses will be discovered which will be of use in the increasing areas of man-made habitats in the coastal zone or even inland, on salted roadside verges for example.

1.. VARIATION IN SALT MARSH SPECIES WITH WIDE ECOLOGICAL AMPLITUDES;

(a) *Adaptation of Plants to Environment—Puccinellia maritima*

Puccinellia maritima is the most widespread grass species on British and N. European salt marshes and is often the predominant plant over many thousands of hectares. Within the coastal zone the species has a wide ecological amplitude, commonly occurring as a pioneer on mobile sediments, in both grazed and ungrazed closed swards and in herb-rich areas of the middle salt marsh, on high-level brackish marsh, and in seepage areas behind sea walls. Despite this apparently important ecological role, little is known of the biology of the species or of the ways in which it has become adapted to the range of habitats in which it occurs.

Genecological research on the species began in 1970 with some preliminary sampling in the Morecambe Bay area, and in the spring and summer of 1971 a collection of the species was made on a national scale, some 150 accessions being added to those already in cultivation at the Station. In 1972 sampling on a local scale was carried out at Holkham National Nature Reserve, 30 genotypes being collected from a wide range of soil and habitat types to determine the local pattern of population differentiation.

A single-tiller trial of a subsample of 57 accessions in the national collection began in September 1971 using the basic technique of collateral cultivation (in a plant 'cage' which protects the plants from birds and mammals). All the original samples were of vegetative material and all genotypes are represented in trials by a number of ramets derived from the original 2–3 tiller clone. A single-tiller trial of the Holkham collection was begun in November 1972.

A large range of characters is being examined in these trials—thus far the national sample trial material has been measured for plant height, plant spread, monthly tillering rate, stolon production, leaf length, leaf width, dry weight at harvest, date of ear emergence, date of anthesis, inflorescence height at anthesis, length of flowering stem, tiller survival at flowering, inflorescence number and seed weight. Correlations are being examined between these characters and with a number of environmental variables, including, in the case of the Holkham collection, a range of chemical and physical soil variables.

The trials are being supported by a series of experiments aimed at investigating the breeding system, reproductive biology and germination, the response of the species to waterlogging, salinity, and competition, (see earlier section) and by taxonomic and chromosome studies.

In addition the establishment and colonisation patterns are being studied by the monitoring of four permanent 10 × 10 m quadrats set out in an accreting salt marsh at Holkham. Transplant studies, aimed at investigating the physical factors controlling establishment of this and other salt marsh species, were undertaken at Holkham in 1972 and are planned for a site in the Wash in 1973.

A range of chromosome numbers has been reported for British material from 2n=14, 49, 56, 63 and 77.

The counts made so far at the Station are shown in Fig. 3. These are all of the octoploid level with chromosomes apparently missing from some cells (the existence of aneuploid individuals might be expected in a species

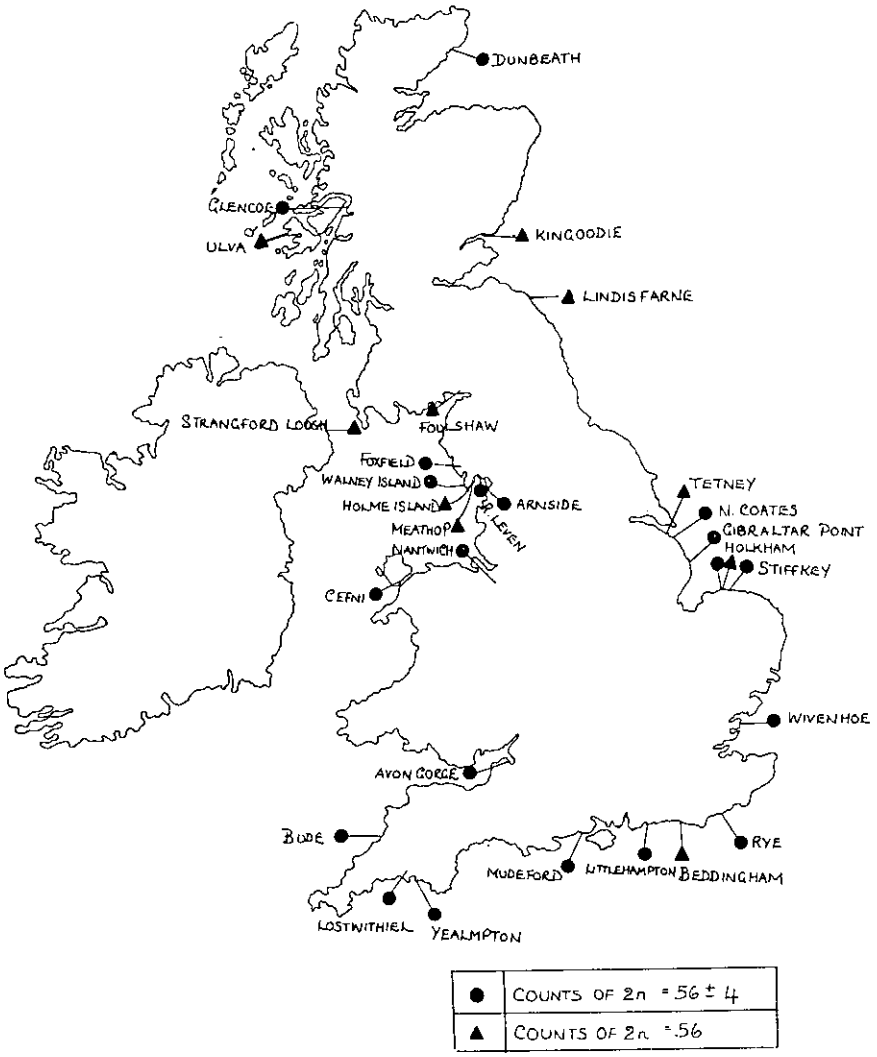


Fig. 3 Map showing origins of *Puccinellia maritima* used in chromosome counts

with a high level of vegetative reproduction.) We thus far have no evidence to support the original assumption that British populations of *P. maritima* contain a number of ploidy levels.

The somatic chromosome of *P. maritima* are shown in the photomicrograph. The technique of preparation and staining has been described by

Photomicrograph of *Puccinellia maritima* chromosomes *photography by R. Scott*

Scott (1972). Karyotype analysis is being carried out on a selected range of material.

A preliminary analysis of the collateral cultivation trials reveals a wide range of variation within the species. Extreme types include erect, caespitose forms with large open panicles as well as prostrate forms with a few small hardly-branched panicles. Initial correlations with environmental variables suggest widespread ecotypic differentiation within the species, the pattern and extent of which is being elucidated using multivariate methods.

(b) *Adaptation of Plants to Environment—Other Puccinellia species*

In contrast to the generally stoloniferous sward-forming *Puccinellia maritima* the other representatives of this genus in Britain (with the possible exception of *P. capillaris*) are short-lived species of disturbed and often ephemeral habitats. A small collection, principally from sites in S.E. England, has been made of *P. fasciculata, P. distans* and *P. rupestris*. Preliminary examination of the pattern of variation in the flowering stages supports the conclusion (Jones and Newton 1970) that *P. pseudodistans* is conspecific with *P. fasciculata*. Whilst there is sometimes difficulty in separating *P. distans* and *P. fasciculata* in the stages prior to the full deflexing of the panicle branches in the former species (we found the most reliable character to be the extension of the middle nerve to the apex of the lemma in *P. fasciculata*) the species found in coastal sites in lowland Britain can readily be distinguished on the basis of the morphology of the panicles and the size of their floral parts.

Studies on the biology of *P. distans, P. fasciculata* and *P. rupestris* are continuing and material of *P. capillaris* from north Scotland which was acquired in the autumn of 1972 is also in cultivation. The ephemeral nature of the habitat occupied by the three southern species (cart tracks, bare mud areas, edges of drainage fleets and so on—generally landward of the sea wall) presents an interesting problem in conservation management. Unless areas are constantly provided by the clearing of ditches and so on, these habitats are rapidly colonised by sward-forming and tall-growing species and the *Puccinellia* species are soon excluded.

(A. J. Gray, R. Scott)

References

JONES, B. M. G. and NEWTON, L. E. (1970). *Watsonia* **8**, 17–26.
SCOTT, R. (1972). *Coastal Ecology Research Paper No.* 2.

2. BIOLOGICAL INVESTIGATIONS OF INDIVIDUAL SPECIES

(a) *Cakile maritima*

A study of *Cakile maritima* was undertaken because it is a typical plant of the strandline flora thought to be under much threat at this time from increased human disturbance and pollution, and because there is little information about the biology of the species, which occupies a well defined habitat in sandy situations at the level of the highest spring tides. It belongs to a family which shows great capability for a range of genetic expression and the fact that *Cakile* populations are renewed from small numbers of a large initial stock gives it great potential to show rapid evolutionary responses should selection pressure be exerted on it.

Some aspects of the morphology of geographically distinct populations from the coast of Europe have been studied in standard conditions to elucidate patterns of variation and to attempt some correlation with climatic factors. Plants from coasts suffering spring droughts show a greater degree of leaf dissection than those from Western oceanic sites, but there is a great deal of variability within populations and even within individuals when the conditions of growth are altered. Fruit morphology shows an interesting cline from distinct horned Eastern Mediterranean forms to the more barrel-shaped North Atlantic type. Again there is great variability within populations and to a certain extent within individuals.

The plants are salt tolerant, but in a small greenhouse experiment there was greater seedling mortality in high salt levels compared with lower concentrations. The seeds have a low initial germination rate of about 15% after they have dried and ripened, and the dormancy factor resides in the testa. Upper seeds of the dimorphic fruit germinate less readily than lower ones, but can be stimulated by treatment in salt water which seems to prevent decay of the fruit and decreases mortality from microbial attack. A progressive increase in germination rate is observed after each year of storage.

In Britain the species is strictly annual and depends for its survival on the successful dispersal of seed. A number of factors militate against its establishment on the same site in the following season, most obvious of which is that if the area has remained stable or continued to accumulate sand then grass dune species will have colonised it. The effect is to inhibit greatly the growth and reproductive capacity of *Cakile,* though relict populations do survive in grassy foredunes, Rate of colonisation by the grasses, led by

Agropyron junceiforme, can be rapid, and on one site studied an area occupied only two years previously by a large *Cakile* stand is now mainly *Ammophila*, and the level has risen by up to 1 metre. Another reason for the elimination of *Cakile* is the build-up of residual populations of predatory insects, notably a flea beetle, *Psylloides marcida*, which has mining grubs and whose adults also eat stems, leaves and fruits, particularly of young plants. Mortality from human disturbance in *Cakile* appears to be insignificant, though coastal defence works sometimes eliminate stretches of beach at the optimal level for it.

Counts have been made along defined stretches of beach to assess population fluctuations of the plant and survival of seedlings. Fully developed plants can produce up to 2000 fruits, the dry weight of which almost equals the rest of the plant at maturity. The presence of emerging seedlings is reasonable evidence in itself that a beach is accreting. Emergence is optimal in soil depths from 5–10 cm., and work is continuing on germination preferences in respect of temperature and soil factors. A combination of circumstances ensures that the fruits (especially upper portions) when dispersed by autumn tides are eventually deposited in accreting situations in a mulch of organic litter. This is of undoubted assistance to the seeds, especially when buried and compacted below a sand layer. The root systems which develop have long lateral branches running horizontally along the litter layer, and a relatively minor vertical tap root.

The work so far has revealed patterns of occurrence of this conspicuous strandline species. An abundance of arthropods is attracted to the plant for food possibly because of its high fresh to dry weight ratio compared with the other more xeromorphic plants of the habitat, and it is likely that it provides the basis of the food web for a considerable animal population, as well as supporting numerous insects visiting the flowers. It is a precursor of dune accretion, and a useful indicator of the erosion/accretion balance of a beach.

(R. Scott)

(b) *Elymus arenarius*

We have been exploring the use of *Elymus arenarius* (Sea Lyme grass) as a primary sand stabiliser in coastal dune formation. This plant is capable of building low profile dunes and of spreading further seaward than *Ammophila arenaria* (Marram grass) once growth is established. *Ammophila* is extensively used as a sand stabilising grass but its growth tends to develop high dunes that remain unstable and lead to erosion under intensive trampling.

Our primary investigations have been designed to find seed treatments which result in rapid germination and field sowing techniques that result in the establishment of a dense plant cover with the minimum of seed wastage.

It was found that *Elymus arenarius* seeds may be stored air dry at room temperature (approximately 20°C) for a year and probably longer, without losing viability. All the seeds in our trials were harvested from a robust population on the east coast of England in the autumn of 1970.

Maximum germination, under laboratory conditions, was found to occur in seeds that had been soaked for seven days in distilled water at +5°C., with the water changed daily. This soaking treatment was designed to remove any water soluble germination inhibitors present in the seed coat and the washing also helped to reduce the incidence of infection in newly emerged seedlings. In laboratory trials it was found that germination of these pre-treated seeds occurred most freely when the seeds were kept under fully

saturated moisture conditions within a temperature range of 20°C —25°C. Germination of 80% or more was regularly achieved by this method. Germination in untreated seed is very sporadic.

Field trials were carried out at Brancaster, Norfolk to investigate the establishment of *Elymus arenarius* plants from seed. Pre-treated (wet stored for seven days at +5°C) and untreated, (dry stored at 20°C) seeds were sown in varying densities on a newly constructed dune ridge. The pre-treated seeds were observed to germinate earlier than the untreated seeds. It was also found that a sowing density of 100 pre-treated seeds/m ^{2} resulted in a dense cover of seedlings with few mortalities as the plants matured. When seeds were sown in a density greater than 100 pre-treated seeds/m^2 many seedlings failed to establish sturdy vegetative growth and died, probably due to intra-specific competition.

Further field trials are being carried out at Caister, Norfolk using 1 month old greenhouse reared seedlings and offsets. The seedlings and offsets were planted out in a domino-five pattern at the High Water mark of Spring Equinoctial Tides on the beach during May 1972. Caister beach is used intensively during the summer months as a recreation area, and because of the resulting trampling, little vegetation can survive and wind blown sand threatens buildings above the shoreline. In view of this tourist pressure we were very interested to find that even a simple wood-post fence and two strands of wire around the plantings and a notice explaining the activities was sufficient to keep the majority of holidaymakers off the site. Plantings in a nearby unfenced site were completely destroyed by trampling.

In Autumn 1972, four months after planting at Caister, it was observed that most seedlings and plants were still surviving and had produced vegetative growth, but were not yet big enough to trap sand.

(J. M. Pizzey, D. S. Ranwell)

(c) *Hippophaë rhamnoides*

A Study Group was set up in 1969 to enquire into the current status of Sea Buckthorn *(Hippophaë rhamnoides)* on selected sand dunes in Great Britain and to report on its management. Under the Chairmanship of Mr. R. Goodier, the Group consisted of Mr. D. G. Hewett, Dr. D. S. Ranwell, Mr. N. A. Robinson, Dr. L. K. Ward, and Mr. D. White.

Sea Buckthorn has increased in abundance on many dune systems since myxomatosis reduced rabbit grazing. It is a shrub which can form dense thickets and shade out much of the diverse flora of dune grasslands. It has been used to stabilize mobile dunes. Ultimately it may act as a nurse crop in which more varied dune shrub communities, can develop.

The survey was carried out using specially designed record cards and the Study Group is much indebted to all those who helped complete these for the 43 dune sites recorded. Sections on the current status of Sea Buckthorn in the British flora, its ecological limits and effects, its fauna, use, and control were brought together with recommendations on management and a bibliography in the Report of the Study Group.
(Ranwell (ed). 1972).

The significance of this work is that for the first time a national management policy for a species which can dominate some coastal environments has been worked out against a background of comprehensive ecological

knowledge. It paves the way, therefore, towards thinking about coastal habitat management generally on a national scale.

(D. S. Ranwell)

Reference

RANWELL, D. S. (ed.) (1972). The management of Sea Buckthorn, *Nature Conservancy, London.*

(d) *Rhododendron ponticum*

Rhododendron was noted as an invading species at Winterton Dunes National Nature Reserve and a small scale study programme was initiated. A distribution map of the extent of the species was made as well as measurements of the height and spread of individual bushes. To investigate the effectiveness of cutting as a control measure and to determine the rate of spread, plots were set up and the precise distribution of individuals and the age structure of the stands recorded. The pattern of spread seemed to be one of sudden advances as the plants on the periphery reached seed producing age. A crop of seedlings would then spread out some 10 yards from the old edge and these would form seed parents for further expansion in about five years time. In the cut plots, where regrowth was to be measured, detailed age information is being obtained from the cut stems. It was hoped to tie in the rate and extent of growth with the age of the stand.

(L. A. Boorman)

(e) *Ilex aquifolium*

Holmestone Beach, Dungeness supports a fine holly *(Ilex aquifolium)* wood. Thought to be over 400 years old, the wood consisted of about 400 thickets until shingle excavation commenced in 1968. It is not known whether the original trees were planted but its local distribution suggests that this might have been so.

Individual thickets may consist of several trees forming a wind sculptured wedge. The branches grow as a flat plate flush with the shingle and upright branches from this give the bush its characteristic shape.

Associated with the thickets are *Sambucus nigra, Rubus fruticosus, Lonicera periclymenum,* and *Solanum dulcamara.*

Rabbits graze the lower leaves to give vertical sides to the bush up to a foot or so from the ground.

A comprehensive study of the Holly wood has been published by Peterken and Hubbard (1972).

(J. C. E. Hubbard)

Reference

PETERTEN, G. F. and HUBBARD, J. C. E. (1972). *J. Ecol.* **60**, 547–572.

(f) *Macoma balthica*

A stratified random sampling programme was begun in April 1972 at Wolferton on the east coast of the Wash and aims by monthly sampling on the lowest Spring Tides to study the life cycle, population dynamics and seasonal movements of the macro-invertebrate populations present, over at least a two year period. Initially the study will concentrate on the mollusc *Macoma balthica* as this species has received little attention in Britain, (although it is known to be a very important food item of wading birds and certain wildfowl) and as the presence of growth rings allows the animals to be aged relatively easily. However, since the sampling scheme samples equally well all the other species present (except the largest polychaete and lamellibranch species) these are also recorded. Detailed studies of other species will be carried out when time becomes available.

Pairs of randomly placed cores (1/100 $m^2 \times 10$ cm) are taken from each of 32, 100 m squares placed 150 m apart along two transects extending from the marsh edge to the low water channel, and sieved through a 0·5 mm mesh sieve. Only eight monthly samples have been analysed to date but a number of interesting trends have emerged.

Macoma balthica has been found in all but the highest and lowest level sites, but reaches its maximum densities in the mid-shore (4,700 individuals/m^2). Within this broad zone however there appears to be a partial separation of age groups with the spat occurring at the highest levels and the oldest adults at the lowest levels. Maximum densities of *Macoma* occurred in May and June when the main spat fall occurred, but small numbers of spat have been found each month.

There appears to be a vertical movement down into the sand of *Macoma* with the onset of cold weather. Only 4% of the total population were found below 5 cm in August, but this had increased to 15% in October—a further breakdown of these figures however shows that the 15% includes only 2% of the spat, 30% 2nd year, 40% 3rd year, and 60% 4th year and 100% of the 5th year or older animals in the population. It is possible that the younger animals cannot burrow as deeply as the older age groups because of their relative siphon lengths and that a more detailed study of depth distribution would show that the younger animals also made significant vertical migrations.

Forty-five species other than *Macoma* have been taken so far, of which the following are the commonest and probably include the most important bird food items: *Cardium edule, Hydrobia ulvae, Corophium volutator, Nephthys cirrosa, Scoloplos armiger, Eteone longa, Phyllodoce maculata, Pygospio elegans* and *Spio filicornis.*

Two species of *Corophium* occur in the muddy, upper third of the flats. *C. arenarium* occurs at a lower density than *C. volutator,* 12,000 and 90,000 individuals m^2 respectively at the peak breeding period in August and September, and also occupies a narrower zone entirely within the *C. volutator* zone. These two species are described in the literature as having distinct habitat requirements and it seems likely that this overlap of distribution is possible only because of the ridge and runnel topography of the upper shore—it is expected that when substratum analyses are complete they will show that the ridges are composed of fine grained, organic rich mud and the runnels contain, 'cleaner', coarser sediments.

Prior to July there were very few cockles on the transect, but the July samples contained high densities of cockles, up to 1,000 individuals/m^2; many of these cockles were very small size spat, probably the recent progeny of the large cockle populations found on some of the offshore banks, but there was also a proportion of larger animals indicating a migration into the low shore flats on the eastern Wash.

Many other species e.g. *Spio filicornis, Capitella capitata, Manayunkia aestuarina, Retusa obtusa,* Tanaid and Oligochaete species normally taken only in very low numbers, have been taken in very high densities for one or two months, indicating either the existence of very local, highly aggregated populations or possibly migration into and out of the transect area. It will be interesting as this study continues to see if population migrations can be substantiated and what effect they might have on food availability for birds.

(C. J. Reading, S. McGrorty)

V Experimental Management of Coastal Habitats

These studies are designed to investigate ways in which the balance between species populations can be altered in coastal habitats by different forms of interference such as grazing, mowing, fertilizing, flooding, or the direct introduction or elimination of particular species. Knowledge so gained enables us to manipulate wildlife resources in a planned way so that we can retain or improve the plant and animal populations for which nature reserves are declared and advise other land users on the management of coastal habitats.

1. Management of salt marshes

Experimental studies carried out prior to the move to Norwich investigated the effects of sheep grazing on *Spartina* marsh (Ranwell 1961), the production of palatable silage from *Spartina* marsh (Hubbard and Ranwell 1969) and the use of herbicides in the control of *Spartina* marsh (Ranwell and Downing 1960). Results of this earlier work were summarized in relation to present problems of salt marsh management in two more general papers entitled 'World resources and economic use of *Spartina* marshland' (Ranwell 1967) and 'Coastal marshes in perspective' (Ranwell 1968).

A more recent experiment tackled the problem of improving reclaimed marshland overgrown with *Juncus maritimus* (Sea rush) and *Agropyron pungens* (Sea Couch grass), species which are unpalatable for stock or wildfowl. It was found that rotavation of this type of marshland successfully controlled these two species and that a natural regrowth of palatable grasses could be produced. However, although *Juncus maritimus* could not regenerate, small amounts of *Juncus effusus* (Soft rush) invaded in spite of cutting treatments used to simulate grazing. This problem could be overcome by spot treatments of *Juncus effusus* with herbicides. This work was carried out at Poole Harbour, Dorset.

At the Bridgwater Bay National Nature Reserve, Somerset, a salting pasture formed by intensive sheep grazing of high level *Spartina* marsh was threatened by invasion of *Agropyron pungens*. Spot treatments with herbicides gave some control, but it was found that regular mowing successfully checked the growth of the *Agropyron*. Currently an experiment is in progress to determine the effect of turf cutting on high level salting pasture. Parts of this pasture were overgrown with coarse growths of *Festuca rubra* (Red Fescue) and these were avoided by sheep and wildfowl. Exclosure experiments had demonstrated that in the absence of grazing the more palatable component of these pastures, *Puccinellia maritima* (Sea Poa) was ousted by *Festuca rubra* within 10 years. Turf cutting in such areas in addition to producing a crop of saleable turf might help to encourage the growth of *Puccinellia* by throwing the succession back to an earlier stage. Initial results indicate that *Puccinellia* is regenerating in the turf cut areas of the experiment at Bridgwater Bay.

The invasion of *Spartina* has transformed much of our marshland in southern Britain and though the grass is palatable to sheep, it reduces wader and wildfowl feeding habitats. The presence of this grass in as yet small quantities in Morecambe Bay, Lancashire, the Solway Firth and Moray Firth in Scotland and in many Welsh estuaries threatens much needed bird feeding and roosting grounds. It is difficult to persuade people of the need

for prompt action to control *Spartina* where it is not required, especially as it has obvious value in coastal protection and reclamation in other areas. An experiment in positive management is in progress at Breydon Water, Norfolk. Here with the aid of members of the Breydon Water Nature Reserve Committee, we have mapped the total distribution of *Spartina,* effectively eradicated 70% of it with a substituted area type herbicide, smothering techniques, and direct digging out, and at the same time carried out a successful trial plantation of *Zostera* on mudflats threatened by *Spartina* invasion. The exact costs of this operation in terms of men, materials and time are being recorded. Trials on the use of herbicides and other eradication techniques are also in progress in Northern Ireland, Wales and on the Somerset coast.

On the Cefni estuary in Anglesey, 2, 4- Dichlorophenoxyacetic acid (Dalapon) herbicide has proved more effective in killing *Spartina anglica* than a granular formulation of 3 phenyl- 1, 1- dimethyl urea (Fenuron). Small isolates surviving herbicide treatment can be dealt with by digging out.

(D. S. Ranwell)

References

HUBBARD, J. C. E. and RANWELL, D. S. (1969). *J. Brit. Grassland Soc.* **21,** 214–217.
RANWELL, D. S. (1961). *J. Ecol.* **49,** 325–340.
RANWELL, D. S. (1967). *J. Appl. Ecol.* **4,** 239–259.
RANWELL, D. S. (1968). Regional Studies Group Bulletin No. 9, *Strathclyde* 1–26.
RANWELL, D. S. and DOWNING, B. M. (1960). *Weeds,* **8,** 78–88.

2. SELECTION AND SCREENING OF ECOTYPES

One of the long-term objectives of the projects described in section III concerning *Puccinellia* species is the production of suitable biotypes for use in management. *Puccinellia maritima* is an important stabilizer of loosely consolidated intertidal mudflats and a favoured food of overwintering wildfowl (White-fronted Geese, Barnacle Geese, Pinkfeet, Brent, and Wigeon). The possibility that this species might be introduced by transplanting or sowing into suitable areas of mudflats is one which has not yet been explored. Whilst there are immense practical problems involved, the need to quickly replace areas of salt marsh lost to reclamation schemes, barrages and other major constructions within estuaries may become of increasing importance.

Such major reconstructions of estuaries will produce new habitat types, such as earth embankments and dredged deposits, which are subject to dessication and to greater salinities than most current reclamation banks for example. Plant species other than those commercially available at present may be required to provide a surface of vegetation.

Preliminary trials, with *Puccinellia maritima* on accreting mudflats and other species on an experimental bank, are being undertaken in the Wash.

(A. J. Gray, R. Scott)

3. EXPERIMENTAL MANAGEMENT OF SAND DUNES

(a) *Trampling and Fertilizing*

The dune sward is relatively easily damaged by heavy trampling, and once the sward is destroyed there is the possibility of rapid erosion.

A study of a blow-out in the fore-dunes at the Morfa Duffryn National Nature Reserve is being made in collaboration with Mr. P. Hope Jones. Five line transects, running parallel with the strandline, cover the area. They have been recorded in September 1970 and 1971. A feature of the

records for 1971 was a considerable growth of strandline species, notably *Salsola kali*. This species is avoided by bare-foot holiday-makers so it may enable other species to become established. The main changes are the continued recession of the blow-out northwards and the maintained vigour of the *Ammophila* in the bottom of the blow-out.

One reason for the susceptibility of the dune sward is the low mineral status combined with the low rate of regrowth of a damaged sward. In addition to a determination of the damage produced by varying levels of trampling an experiment was planned to see how far the damage produced could be reduced by the addition of fertilizer. At Winterton (Norfolk) a plot was set up where two levels of trampling were applied in parallel lines and two different fertilizers applied in strips at right angles to the trampling. The vegetation is a dense *Carex/Festuca* sward more resistent than many other dune swards. Even the low level of trampling of 10 passes applied once a month produced a noticeable track of worn grass. As yet the effect of the fertilizer has been small, being visible as a general greening rather than a significant difference in growth. Near this plot is a well worn path used by people on foot and on horseback and an experiment has been set up with the slow release fertilizer to see if it could be effective in reducing the damage produced by the heavy wear. A classification of all paths in the area, based on their wear and levels of use, is planned for 1973.

At Camber (Sussex) pedestrian and vehicular damage between 1939 and 1967 had destroyed the majority of the dune vegetation so threatening the sea defences for the hinterland, and inundating coastal developments with blown sand. A comprehensive programme of restoration involving

Aerial oblique photograph of Camber Sand dunes showing erosion caused by vegetation damage. *copyright East Sussex County Council*

The Coast road at Camber, inundated by wind blown sand.
photography by J. C. E. Hubbard

hydraulic seeding and fertilisation, coupled with protective fencing was carried out between 1968 and 1971, following advice given by the Coastal Ecology Research Station. The changes in vegetation cover have been monitored by Station Staff and this has shown the development of a stable cover on the dunes with a consequent reduction in the amount of blown sand.

(b) *Mowing*

In areas of old dune grassland there is a tendency for certain grass species to become dominant and form a mat of litter, excluding other often very interesting species. Species diversity in dune grassland is dependant on such areas being kept open by grazing from sheep, cattle, ponies or rabbits. However, grazing is a difficult management tool to apply as it requires there to be fencing and constant supervision. Mowing appears to be a more easily applied substitute, but its effects are not fully known. Accordingly mowing plots were set up at Holkham, (Norfolk), Winterton, (Norfolk), and Newborough Warren, (Anglesey). The mowing exxperiments, based on a 5×5 Latin Square design, were established in Spring 1971. The treatments are:— A. no mowing; B. mow once (in May); C. mow twice (in May and July); D. mow three times (in May, July and September); E. mow five times (in May, June, July, August and September).

At Holkham the *Ammophila arenaria* fore-dune was mown, at Winterton an area of *Festuca rubra* dune and another of *Calluna vulgaris*. Generally the effect of the mowing was to open up the sward and to allow various species that had previously been largely smothered by the grass to thrive; this was particularly true of dune annuals such as *Cerastium semidecandrum* and *Myosotis ramosissima*. After these early changes the rate of change is much

slower and it seems likely to take several years before a stable sward is reached. It is probable that single mowing early or late will be the most effective in maintaining diversity, as it is quite sufficient to keep the sward open.

At Newborough Warren, Anglesey, one experiment is on *Festuca rubra* grassland which contains *Hydrocotyle vulgaris* in the moister parts. The second experiment is on grassland covered by *Arrhenatherum elatius* with some *Festuca rubra* in the lower parts.

Mowing during the first season produced vast quantities of litter as the dead and living material was broken up by the mower. This was most marked on the *Arrhenatherum* plots where tussocks were cut lower at each mowing. The existing vegetation was opened up, by litter suppressing growth and the death of grass tussocks. Mole activity has exposed bare sand and so enabled new plant species to colonise. The plots are also used by Canada Geese *(Branta canadensis)* and Hares *(Lepus europaeus)*.

The vegetation was sampled after one season when analysis of variance on the number of species per plot did not reveal any significant differences. Changes are taking place in the frequency of species in relation to the mowing regimes, e.g. *Arrenatherum* has decreased on the plots mown five times, while *Galium verum* has increased. The plots with *Arrhenatherum* mown once are indistinguishable from the unmown plots by the end of the growing season.

While it may be possible to maintain the *Festuca* grassland by two mowings per season, it is only the plots which are mown five times that the *Arrhenatherum* is effectively controlled. However a steady state has not yet been reached, and the dune annuals which have been recorded in Norfolk have not yet invaded the plots in Anglesey.

(c) *Effect of Cutting Different Aged Stands of Hippophaë rhamnoides*

Experimental plots 5 × 5 meters square were set up at Ainsdale, Lancashire in Autumn 1972. Five replicated plots of young, middle-aged and old stands of *Hippophae* were cleared. The age of the plants is determined by tree ring counts and the amount of re-growth, if any, is to be recorded. A similar method is to be used in Saltfleetby (Lincolnshire) to assess management feasibility.

(L. A. Boorman, D. G. Hewett, R. M. Fuller, J. M. Pizzey)

VI The Ecological Impacts of Major Constructional Developments on the Coast

The purpose of this work is to assess coastal wildlife resources in relation to the impact that proposed major changes, on the coast will have on them. By bringing to bear multi-disciplinary environmental studies on whole coastal systems it should be possible to improve our predictions of the type and extent of ecological change likely to occur. In this way it may be possible to suggest acceptable modifications to the proposals which will do least harm to coastal plant and animal populations. In addition, it may be possible within the scale of such extensive operations to create new habitats of positive benefit to wildlife. These studies are designed to explore such possibilities and are challenging to imaginatively minded ecologists.

1. Contributions to Desk Studies

In formulating and negotiating the contracts for the Wash and Maplin projects, a very considerable amount of time was devoted to desk studies.

Once the general field of action is identified it is absolutely essential for the ecologist to define in simple terms the questions that need to be answered, the means of doing so, and the approximate cost of the operation, in a way that can be understood and accepted by the funding agency. This is a two way process and the rewards are high because not only does it ensure that very careful thought and planning goes into biological projects, but it also injects environmental thinking into those responsible for major planning decisions.

(D. S. Ranwell)

2. Water storage schemes in estuaries

In addition to contributions made to desk studies, the staff of the Research Station have been involved in two major projects concerned with water storage in estuaries. The possibility that fresh water might be stored in Morecambe Bay was investigated by the Water Resources Board to the extent of a full-scale Feasibility Study, the results of which were reported in 1970. This study included a programme of biological investigations in which the Nature Conservancy was involved in the field from 1968. More recently a Feasibility Study was begun in the Wash and in 1972 a team of five temporary staff was recruited to work from the Coastal Ecology Research Station on aspects of the ecological implications of the Wash scheme.

(a) *Morecambe Bay*

A full account of the ecology of Morecambe Bay, including aspects other than those which were the responsibility of Nature Conservancy staff has been produced (Corlett (ed.) 1970) and the Water Resources Board drew on this for their account of the ecology of the area and the possible effects on it of the various schemes for water storage. Apart from their assessment of the general ecology of the Bay the main contribution of the Nature Conservancy consisted of research on the intertidal invertebrate populations and on the salt marshes.

The most dominant and widespread invertebrate species in the bay, and a major source of food for the large populations of over-wintering waders, is *Macoma balthica* which reaches its maximum densities above 6 ft. O.D. Other species restricted to the high level flats (i.e. above 6′ O.D.) and often

occurring in high densities are *Hydrobia ulvae* and *Corophium volutator*. Some species, including *Arenicola marina, Nereis diversicolor, Cardium edule* and *Bathyporeia pilosa,* are wide-ranging with respect to tidal level but reach a maximum density around Mean High Water Neap Tides, whilst a third group of species such as *Tellina tenuis* and *Nephthys hombergi* are restricted to the low level flats. The full results of the survey, together with a discussion of the likely effects of the proposed impoundment schemes are reported by Anderson (1970).

The salt marshes of the bay can be divided into four types, differing in plant composition and soil type. These are mature marshes, high-level saltings, low-level saltings and pioneer zones. A total of 1485 ha of salt marsh are confined to the upper 2·5 m of a 9·5 m tidal range, the pioneer zones extending down to about 3·9 m O.D. The marshes are characterised by close-grazed swards dominated by perennial grasses, the most commonly occurring of which are *Puccinellia maritima, Festuca rubra* and *Agrostis stolonifera.* Other features of the marshes include the highly unstable lower zones, the presence of terraces, the removal of turf for sale, and the existence of small-scale point-to-point variation in vegetation related to local variation in elevation and soil type. The methods used during the study have been referred to in other sections of this report and a full account is given in two papers (Gray 1972, Gray and Bunce 1972). The first of these papers discusses the problem of predicting the effects of the proposed reservoir on the vegetation of the bay.

(b) *The Wash*

Two projects begun in 1972 are being directed from the Research Station as part of the Wash Feasibility Study. They are (1) Wader and wildfowl survey and population food studies and (2) intertidal vegetation survey and process studies. Both projects contain three elements—(1) basic survey (pattern studies); (2) correlation of biological phenomena with environmental variation and the study of species interaction (process studies), and (3) the attempt to assess the impact of the water storage schemes on the ecology (prediction studies).

A diagram, indicating the main activities included in the study is shown in Fig. 4.

Much of the survey of waders, wildfowl and other birds is being undertaken by the members of the Ornithological Working Group, a group composed of the various voluntary bodies (e.g. the Royal Society for the Protection of Birds, Lincolnshire Trust for Nature Conservation, Lincolnshire Naturalists' Union, Norfolk Ornithologists Association, British Trust for Ornithology, Wash Barrage Wildfowlers' Committee and the Wildfowl Trust). The picture which they produce of the numbers and distribution of waders, together with the survey of the mudflat invertebrates being undertaken by the Institute for Marine Environmental Research, will provide an indication of the broad correlations between birds and their food and reveal to what extent the birds are exploiting their resources. In addition a two-year programme of research, which focuses closely on the relationship between waders and their food resources is being carried out by Dr. J. D. Goss-Custard assisted by Mr. P. E. Newbery and Mr. R. Jones. The work involves describing in detail the diet of the twelve most common waders and wildfowl species. The birds are observed on their feeding grounds in as many conditions of

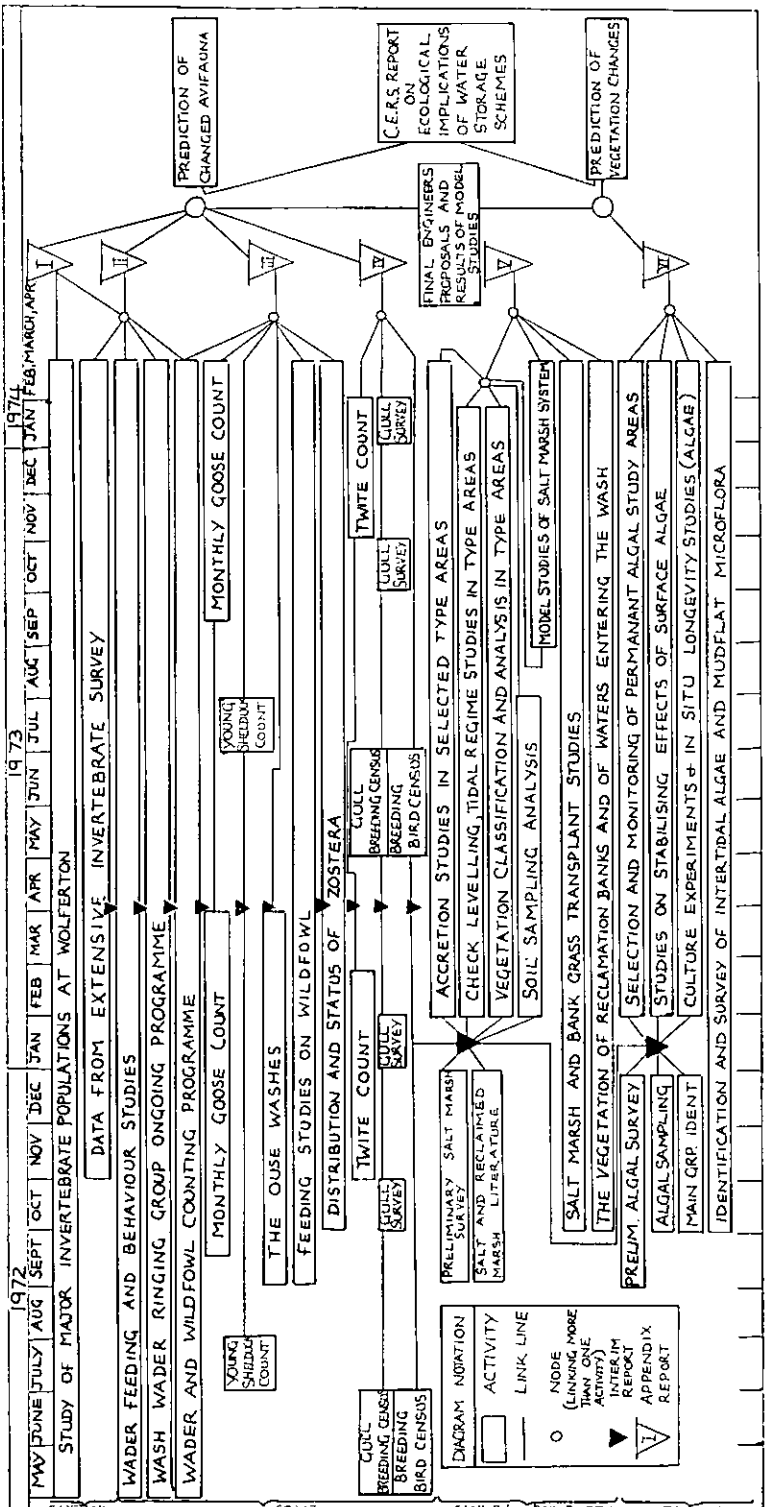


Fig. 4 Flow diagram indicating the main activities included in the biological aspects of the Wash Feasibility Study

temperature, tide and food availability as possible so that the range of adaptability in the diet of each species can be assessed. The extent to which birds at any time or in any particular zone are near to the limit of the resources needs to be investigated. In this way one may judge the extent to which removal of further resources will exacerbate the birds' difficulties.

The studies of vegetation include work on the higher plants of the salt marshes and the algae, particularly those of the mudflats. This work is being undertaken by Dr. A. J. Gray and Mr. P. F. Randerson (salt marshes), and Dr. S. M. Coles and Mr. M. G. Curry (algae). In addition to survey, the salt marsh studies are aimed at generating a predictive model of the salt marsh ecosystem, major components of which include vegetation type, elevation, standing crop, physical and chemical soil variables, and accretion rate. These parameters are being measured in 10×10 m study areas along levelled transects distributed around the Wash. The algal studies, which include a survey of the macro and microalgae of the Wash and a study of their role in sediment stabilisation and salt marsh development, are also associated with these study areas, where investigations of the seasonal changes in the density and composition of the intertidal algae are carried out.

(A. J. Gray)

References

ANDERSON, S. S. (1970). *J. Appl. Ecol.* **9**, 161–178.
CORLETT, J. (ed.) (1970). Morecambe Bay Barrage Feasibility Study. Biological Report, *NERC, London.*
GRAY, A. J. (1972). *J. Appl. Ecol.* **9**, 207–220.
GRAY, A. J. and BUNCE, R. G. H. (1972). *J. Appl. Ecol.* **9**, 221–234.

3. THIRD LONDON AIRPORT—MAPLIN

In the spring of 1972 the Department of the Environment accepted in principle the proposals made for a study of the biological implications of the building of the Third London Airport at Maplin. There followed a period of detailed planning. In September we interviewed candidates for the posts involved and in October and November the eight new scientific staff arrived.

The aim of the Maplin study is to provide information on the natural fauna and flora of the coastal habitats in the area likely to be affected and to enable a detailed evaluation to be made of the effects of the construction and operation of the airport at Maplin on coastal wildlife. The final report to the Department of the Environment will include recommendations and proposals for future action concerning wildlife in the area.

The Maplin team comprises two ornithologists, an invertebrate zoologist and assistant, an algologist and an assistant, an aerial survey worker, and a salt marsh ecologist. Mr. K. Charman is studying the feeding of Brent Geese, particularly seasonal changes in the feeding pattern and their relation to the available food resources. Dr. N. W. Owens is studying the effect of disturbance on Brent Geese. The aim of the study is to determine whether disturbance can limit the utilization of existing and potential feeding areas. Mr. D. W. Wyer and Miss R. J. Waters are making a detailed study of *Enteromorpha* and *Zostera*, food plants of Brent Geese, looking at seasonal changes and the extent to which environmental factors limit the distribution of these plants. Dr. D. G. Kay and Mr. R. D. Knights are surveying the macro-invertebrate fauna of the intertidal flats with particular reference to the food resources available to waders. The extent of the total wildlife resources from the R. Orwell to North Kent will be estimated from aerial

survey being organised by Miss J. E. Head, and Mrs. J. S. Say will map and analyse the plant communities of the salt marshes in detail. These eight workers only deal with part of the Maplin biological studies and there is a considerable amount of work being done by various outside bodies under contract. There is for example the survey of the waders, wildfowl and seabirds of the Essex estuaries being carried out by a consortium of the Royal Society for the Protection of Birds, the British Trust for Ornithology and the Wildfowl Trust. Mr. A. St. Joseph, working through the Widlfowl Trust, is Trapping Officer. He is responsible for catching, ringing and colour marking Brent to study their movements between their various feeding grounds. Mr. R. Blindell working through the British Trust for Ornithology is Ground Counts Organiser. He is co-ordinating the counting of waders and wildfowl being done by amateur bird watchers in the area. Studies on the creation of new bird feeding grounds are being made in conjunction with Hydraulics Research Station and on the control of pollution by the Water Pollution Research Laboratory. In addition there is close liaison with other bodies concerned with the Third London Airport Project such as the Bird Strike Research being carried out by the Ministry of Agriculture, Fisheries and Food. In December a meeting of all biologists interested in the Maplin area was held at the Research Station; some forty people attended and a helpful exchange of views resulted; in February a meeting in Southend enabled the amateur naturalists of the area to be kept in touch and useful contacts were made.

(L. A. Boorman)

4. ANGLESEY ALUMINIUM SMELTER

The Coastal Ecology Research Station is participating in the studies being made on the effects of the aluminium smelter which has been established near Holyhead, Anglesey.

The work consists of a study of the vascular flora of selected coastal sites near the smelter. The sampling sites were established in 1971, when the works became operative. Sites furthest to the south-west of the smelter are likely to be far enough away to be unaffected by fall-out from the smelter. A floristic survey is made annually at each site and samples of vegetation collected for analysis.

The data collected have not revealed any changes in the flora of the plots to date, but lichen populations are being killed in the neighbourhood of the smelter and locally, leaves of daffodils show symptoms similar to those produced by fluoride poisoning.

(D. G. Hewett)

VII Staff Reprints List

ANDERSON Sheila S. (1970). The Ecology of Morecambe Bay. II Intertidal invertebrates and factors affecting their distribution. *J. App. Ecol. 9*, 161–178.

BIRD, E. C. & RANWELL, D. S. (1964). *Spartina* salt marshes in Southern England IV. The physiography of Poole Harbour, Dorset. *J. Ecol. 52*, 355–366.

BOORMAN, L. A. (1966). Experimental Studies in the genus *Limonium*. *D. Phil. Thesis, University of Oxford.*

BOORMAN, L. A. & WOODELL, S. R. J. (1966). The topograph, an instrument for measuring microtopography. *Ecol. 47* (5), 869–70.

BOORMAN, L. A. (1967). Biological Flora of the British Isles No. 106 *Limonium vulgare* Mill & *L. humile* Mill. *J. Ecol. 55*, 221–232.

BOORMAN, L. A. (1968). Some aspects of the reproductive biology of *Limonium vulgare* Mill, and *L. humile* Mill. *Ann. Bot. 32* (128), 803–824.

BOORMAN, L. A. (1971). Studies in salt marsh ecology with special reference to the genus *Limonium*. *J. Ecol. 59*, 103–120.

FULLER, R. M. (1972). The assessment of coastal habitat resources from aerial photography: 1. A quick and easy method for assessment of the major habitat resources. *Coastal Ecology Research Paper No.* 1.

FULLER, R. M. (1972). The assessment of coastal habitat resources from aerial photography: 2. Mapping and assessment of salt marsh vegetation resources. *Coastal Ecology Research Paper No.* 3.

GOSS-CUSTARD, J. D. (1966). The feeding ecology of the redshank, *Tringa totanus*, L., in winter, on the Ythan Estuary, Aberdeenshire. *PhD. Thesis, University of Aberdeen.*

GOSS-CUSTARD, J. D. (1969). The winter feeding ecology of the redshank, *Tringa totanus*. *Ibus. 111*: 338–356.

GOSS-CUSTARD, J. D. (1970). The responses of redshank, *Tringa totanus* to spatial variations in the density of their prey. *J. Animal Ecol. 39*, 91–113.

GOSS-CUSTARD, J. D. (1970). Factors affecting the diet and the feeding rate of the redshank *Tringa totanus* In: *Animal populations in relations to their food resources. Ed. A. Watson. Blackwell, Oxford. pp.* 101–110.

GOSS-CUSTARD, J. D. (1970). Feeding dispersion in some overwintering wading birds. In: *Social behaviour in birds and mammals. Ed. J. H. Crook. Academic Press. London. pp.* 3–35.

GOSS-CUSTARD, J. D., WILKINS, P., & KEAR, J. (1971). Rearing wading birds in captivity. *Avic. Mag. 77*, 16–19.

CROOK, J. H. & GOSS-CUSTARD, J. D. (1972). Social Ethology. *A. Rev. Psychology, 23*, 277–312.

GRAY, A. J. (1970). The colonisation of estuaries following barrage building. In: *The flora of a changing Britain. Ed. F. H. Perring*, 63–72, *Hampton (Mddx)., E. W. Classey (Botanical Society of the British Isles Conference reports, No.* 11.).

GRAY, A. J. (1971). Variation in *Aster tripolium* L. with particular reference to some British populations. *PhD. Thesis. University of Keele.*

GRAY, A. J. (1972). The Ecology of Morecambe Bay V. The salt marshes of Morecambe Bay. *J. App. Ecol. 9*, 207–220.

GRAY, A. J. & BUNCE, R. G. H. (1972). The Ecology of Morecambe Bay. VI. Soils and vegetation of the salt marshes: a multivariate approach. *J. App. Ecol. 9*, 222–234.

GRAY, A. J. & ADAM, P. (1973). The reclamation history of Morecambe Bay. *Nature in Lancs. Vol.* 4. *(In Press).*

GREENWOOD, J. J. D. & GOSS-CUSTARD, J. D. (1970). The relative digestibility of the prey of redshank, *Tringa totanus, Ibis. 112*, 543–544.

GRIMES, B. H. & HUBBARD, J. C. E. (1969). The use of Aerial photography in the Nature Conservancy .*Photogrp. J., 109.* 264–267.

GRIMES, B. H. & HUBBARD, J. C. E. (1971). A comparison of film type and the importance of season for interpretation of coastal marshland vegetation. *Photogrammetric Record. 7*, (38) 213–222.

GRIMES, B. H. & HUBBARD, J. C. E. (1972). Aerial survey of natural resources. *Endeavour, XXXI (No.* 114*).* 103–134.

HEWETT, D. G. & HARDCASTLE, P. J. (1969). An automatic recording climatological station. *Weather, London, 24*, 265–270.

HEWETT, D. G. (1970). The colonization of sand dunes after stabilization with Marram grass *(Ammophila arenaria). J. Ecol. 58*, 653–668.

HEWETT, D. G. (1970). The effects of the cold winter of 1962/3 on *Juncus acutus* at Braunton-Burrows, Devon. *Rep. Trans. Devon. Ass. Advmt. Sci. Lit. Art. 102*, 193–201.

HUBBARD, J. C. E. (1965). The earliest record of *Spartina maritima* in Britain. *Proc. Bot. Soc. Br. Isl. 6*, 119.

HUBBARD, J. C. E. (1965). *Spartina* marshes in Southern England. VI. Pattern of invasion in Poole Harbour. *J. Ecol. 53.*

HUBBARD, J. C. E. & RANWELL, D. S. (1966). Cropping *Spartina* salt marsh for silage. *J. Br. Grassld. Soc. 21*, 214–217.

HUBBARD, J. C. E. (1967). Cleistogamy in *Spartina. Watsonia 6*, 290–291.

HUBBARD, J. C. E. & STEBBINGS, R. E. (1967). Distribution, dates of origin and acreage of *Spartina townsendii* (S.L.) marshes in Great Britain. *Proc. Bot. Soc. Br. Isl. 7*, 1–7.

HUBBARD, J. C. E. & STEBBINGS, R. E. (1968). *Spartina* marshes in Southern England. VII Stratigraphy of the Keysworth Marsh, Poole Harbour. *J. Ecol. 56*, 707–722.

HUBBARD, J. C. E. (1969). Light in relation to tidal immersion and the growth of *Spartina townsendii* (S.L.) *J. Ecol. 57*, 795–804.

HUBBARD, J. C. E. (1970). Effects of cutting and seed production in *Spartina anglica. J. Ecol. 58.* 329–334.

HUBBARD, J. C. E. (1970). The shingle vegetation of Southern England: A general survey of Dungeness, Kent and Sussex. *J. Ecol. 58*, 713–722.

HUBBARD, J. C. E. (1971). The use of aerial photography in the survey of coastal features. Re-printed from: The Application of Aerial Photography to the work of the Nature Conservancy. *Proc. of the Nature Conservancy staff seminar held in Edinburgh* 14–15 *October,* 1970. *Edited by R. Goodier.* 36–42.

HUBBARD, J. C. E. & GRIMES, B. H. (1972). The analysis of coastal vegetation through the medium of aerial photography. *Medical and Biological Illustration 22 (No. 3)*, 182–190.

HUBBARD, J. C. E. (1972). A bibliography of *Spartina townsendii (sensu lato)*. H. & J. Grovos, European *Spartina alterniflora* Lois and British *Spartina maritima* (Curt) Fernald.

MCGRORTY, S. (1971). Salinity as a factor affecting the distribution of *Bathyporeia* sp. (Crustacea: Amphipoda) *Vie et Milieu supplement No. 22*, 119–133.

PETERKEN, G. F. & HUBBARD, J. C. E. (1972). The shingle vegetation of Southern England: The holly wood on Holmstone Beach, Dungeness. *J. Ecol. (In Press).*

RANWELL, D. S. (1958). Movement of vegetated sand dunes at Newborough Warren, Anglesey. *J. Ecol. 46*, 83–100.

RANWELL, D. S. (1959). Newborough Warren, Anglesey. I. The dune system and dune slack habitat. *J. Ecol. 47.* 571–601.

RANWELL, D. S. & DOWNING, B. M. (1959). Brent Goose *(Branta barnicla* L.*)* winter feeding pattern and *Zostera* resources at Scolt Head Island, Norfolk. *Anim. Behav. 7,* 42–56.

RANWELL, D. S. (1960). Newborough Warren, Anglesey. II. Plant associes and succession cycles of the sand dune and dune slack vegetation. *J. Ecol. 48*, 117–41.

RANWELL, D. S. (1960). Newborough Warren, Anglesey. III. Changes in the vegetation on parts of the dune system after the loss of rabbits by myxomatosis. *J. Ecol. 48*, 385–95.

RANWELL, D. S. & DOWNING, B. M. (1960). The use of Dalapon and Substituted Urea herbicides for control of seed bearing *Spartina* (Cord grass) in intertidal zones of estuarine marsh. *Weed, 8*, 78–88.

RANWELL, D. S. (1961). Field meeting at Lyndhurst (Lichens). *Lichenologist, 1*, 275–76.

RANWELL, D. S. (1961). Spartina salt marshes in Southern England. I. The effects of sheep grazing at the upper limit of *Spartina* marsh in Bridgwater Bay. *J. Ecol. 49.* 325–40.

RANWELL, D. S. (1963). Field meeting at Wareham (Lichens) *Lichenologist. 2*, 197–200.

RANWELL, D. S. (1964). Conservation and management of estuarine marsh in relation to *Spartina* marsh in the Biritsh Isles. *Proc. MAR Conf.* 1962. *IUCN Pubns. NS. No.* 3 *Part 1/C*, 281–87

RANWELL, D. S. (1964). The criteria for the conservation of wetland invertebrates. *Proc. MAR conf.* 1962 *IUCN Pubns. N.S. No.* 3 *Part 1/A*, 130–32.

RANWELL, D. S. & HEWETT, D. G. (1964). Oil pollution in Poole Harbour and its effects on birds. *Bird Notes 31*, 192–7.

RANWELL, D. S. (1964). *Spartina* Salt Marshes in Southern England. II. Rate and seasonal pattern of sediment accretion. *J. Ecol. 52*, 79–94.

RANWELL, D. S. (1964). *Spartina* salt marshes in Southern England. III. Rates of establishment, succession and nutrient supply at Bridgwater Bay, Somerset. *J. Ecol. 52*, 95–105.

RANWELL, D. S., BIRD, E. C. F., HUBBARD, J. C. E. & STEBBINGS, R. E. (1964). *Spartina* salt marshes in Southern England. V. Tidal submergence and chlorinity in Poole Harbour. *J. Ecol. 52*, 627–41.

RANWELL, D. S. (ed) (1966). British Ecological Society. A sub-committee report on Landscape improvement advice and research. *J. Anim. Ecol. 36*, 1–8.

RANWELL, D. S. (1966). The lichen flora of Bryher, Isles of Scilly, and its geographical components. *Lichenologist. 3*, 224–32.

RANWELL, D. S. & JAMES, P. W. (1966). Lichens from the Ile-du-Levant (Iles d' Hyeres). *Revue Bryol. et Lichen. 3-4*, 836–40.

RANWELL, D. S. (1967). Introduced aquatic, fresh-water and salt marsh plants—case histories and ecological effects. *IUCN 10th Tech. Meeting Lucerne* 1966. *IUCN Pubns. N.S. No. 9*, 27–37.

RANWELL, D. S. (1967). World resources of *Spartina townsendii sensu lato*, and economic use of Spartina marshland. *J. App. Ecol. 4*, 239–56.

RANWELL, D. S. (1968). Coastal marshes in perspective. *Reg. Stud. Grp. Bull. No. 9*, 1–26.

RANWELL, D. S. (1968). Extent of damage to coastal habitats due to the 'Torrey-Canyon' incident. *Fld. Stud.* 2. *(Suppl.)* 39–47.

RANWELL, D. S. (1968). Lichen mortality due to 'Torrey-Canyon' oil and decontamination measures. *Lichenologist. 4*, 55–56.

RANWELL, D. S. (1970). Losses and gains in the wetland and coastal flora of Dorset. *Proc. Dorset. Nat. Hist. and Archaeol. Soc. 91*, 134–46.

RANWELL, D. S. (1970). Coastal habitats of Northern Ireland in relation to sites of national importance in Great Britain. Study Conference on the physiography, ecology and use of the North Coast of Northern Ireland. *University of Ulster*, 2–9.

RANWELL, D. S. (1970). The dune environment. Dune Conservation 1970. North Berwick Study Group Report. *East Lothian County Planning Office, North Berwick. Pubn. pp* 5.

RANWELL, D. S. (ed.) (1972). The management of Sea Buckthorn *(Hippophaë rahmnoides* L.*)* on selected sites in Great Britain. Rep. of the *Hippophaë* Study Group. *Nature Conservancy. London. pp.* 55.

RANWELL, D. S. (1972). The ecology of salt marshes and sand dunes. *Chapman & Hall. London. pp.* 251.

SCOTT, R. (1972). Variation in coastal plant species: 1. A method for studying the somatic chromosomes of plants using a Feulgen staining technique. *Coastal Ecology Research Paper No.* 2.

WOODELL, S. R. J. & BOORMAN, L. A. (1966). A light, sturdy, inexpensive point quadrat frame. *Ecol. 47*, (5), 870–871.