TRANSACTIONS
OF THE
NATURAL HISTORY SOCIETY
OF
NORTHUMBRIA

Editor:
R. B. CLARK

Assistant Editor:
M. A. PATTERSON

Volume 57

THE NATURAL HISTORY SOCIETY OF NORTHUMBRIA
THE HANCOCK MUSEUM
NEWCASTLE UPON TYNE NE2 4PT
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CONTENTS

PART 4

Corrigendum:

Page 149 4th paragraph (line 33) 'scenarios (a) and (b) above,' should read 'scenarios (a) and (bi) above,'

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Front Cover: *Conus marmoreus* from Gibsone's Conches

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CONTENTS

GEORGE GIBSONE AND HIS CONCHES

L. Jessop

Sunderland Museum (Tyne and Wear Museums), Borough Road, Sunderland, Tyne and Wear.

SUMMARY

George Gibsone was a talented and very prolific amateur artist who was active in Tyneside in the first half of the 19th century. His work is almost unknown but is highly admired by the few people familiar with it.

This paper notes the existence of the two large collections of watercolours of mollusc shells that he produced around the years 1820 to 1840, details their subsequent history, and summarizes what is known of his life.

INTRODUCTION

Just over one hundred years ago a collection of watercolour paintings of mollusc shells was bought by public subscription and presented to the Free Public Library of Newcastle upon Tyne (now Newcastle Central Library). The collection was remarkable not only because of the large number of paintings (7,260) but also because of their consistently high quality. More remarkable still is the fact that there is a second collection, of 4408 shell paintings, by the same artist owned by the Natural History Society of Northumbria.

Despite this tremendous achievement, virtually nothing is known about George Gibsone, the artist of these paintings. Gibsone himself appears to have published nothing malacological, and none of his paintings has been used in any other published work. It is hoped that the present paper will stimulate interest both in the paintings and in their creator.

1888: GIBSONE'S CONCHES ARE OFFERED FOR SALE

A pamphlet was published in 1888 (Anon., 1888) announcing that the Literary and Philosophical Society of Newcastle upon Tyne wanted to buy the collection of 7,260 paintings by subscription and present them "to some Public Institution in or near Newcastle-upon-Tyne". A committee of twenty-three members was formed to raise the necessary £200, with the mayor of Newcastle as leader, Mr T. Hodgkin as treasurer and the Reverends B. W. Gibsone and Thomas Talbot as honorary secretaries.

The pamphlet includes the following description of the collection:

"Some years ago the Collection was valued by *Messrs Children & Gray*, the heads of the Natural History Department of the British Museum, for the Ratcliffe Library, Oxford (then in treaty for them), at £500 sterling; the number of designs was subsequently nearly doubled, and the whole was catalogued according to the genera of Lamarck.

"The administrator is willing, however, to sell the sheets for the fore-named purpose at £200, relinquishing the rest in favour of the locality loved by the artist.

"The latter occupied at least 20 years of his matured experience on these thousands of water-colour paintings, for which his professional duties had well prepared him; they comprise many species not before figured.

PLATE 1

Turbo marmoratus

Nautilus pompilius

PLATE 2

Conus aulicus, C. capitaneus, C. omaria

"No other copies exist of this, his largest collection. The 16 portfolios contain 1965 separate sheets (13¾ in. by 9 in.); each bears one or more coloured full-sized portraitures from nature; in all 7,260 delineations of 3,025 species or varieties of shells, finished with an intelligence likely to make them long unreproducible and unique, whether considered as works of art or natural science.

"The series of paintings is admittedly (1) beautiful and precious: it is also (2) comprehensive: (3) compact and portable: (4) uncostly in its maintenance. These are qualities rarely combined in choice cabinets or expensive musea of *conches* themselves; and yet this series is as useful for identifying or classifying specimens, and more convenient for illustrating lectures on Natural History or Geology. Such considerations make it well suited for the shelves of a reference library."

The committee intended, when the money had been raised, to hold a meeting of all subscibers of one guinea or upwards in order to decide where the paintings would be deposited. All subscribers of one guinea or more were also to receive "as a personal memorial, a (48 p.p.) reference catalogue of this magnificent collection".

THE SUBSCRIPTION IS RAISED

The money was raised within two years. Lists of subscribers were periodically published during the course of the appeal, and Newcastle Central Library holds a copy of the fourth (and last) edition of the list.

It is interesting to see the support given by wealthy local citizens to the arts and sciences in the 19th century. The list of subscribers to *Gibsone's Conches* contains 132 names and includes several prominent local figures such as the Bishop of Durham, who donated £1.1.0., Lord Armstrong (£4.0.0), R. J. Carr-Ellison the High Sheriff of Northumberland (£2.0.0) and the Hon C. A. Parsons (£1.1.0). Many local naturalists also contributed, including Rev. Canon Norman (£1.1.0), T. W. Backhouse (£0.10.0) and Dr C. O. Trechmann (£1.1.0) as well as some national figures like Sir John Lubbock (£2.2.0) and Sir Joseph Hooker (£1.1.0).

The largest sums of money were subscribed by the Free Public Library of Newcastle (£25.0.0) and Rev. B. W. Gibsone (£31.10.0). Mr Gibsone's thirty-guinea contribution is possibly nominal to make the figure up to £200, as he was at that time almost certainly the owner of the collection.

The City Library Report for 1890-1891 noted that "at a meeting of the Selection Committee held at the Literary and Philosophical Society on 4th July, 1890, it was unanimously resolved that the Reference Department of the Newcastle-upon-Tyne Public Library should be the place selected for their final deposit".

A letter from the Rev. E. H. Adamson was published in the report and explains that "It was thought that as the accomplished artist, though not a native of Newcastle, yet spent so long a period of his useful life in the city, or its immediate vicinity, his grandly conceived and elaborately executed work could find no more fitting place than within the walls of your Library, where no doubt it will be carefully preserved, and will always be freely accessible to the public, under proper regulations..... Among the contributions we gratefully acknowledge a donation of £25 from yourselves, as your promised aid, coming at a critical period, encouraged us to proceed in our undertaking".

The Library Committee arranged for the construction of four sloping desk-stands each with sixteen dust-proof frames so that sixty-four paintings could be displayed at one time in the Reference Library. The intention was to change the contents monthly, so that 768 of the paintings could be exhibited annually. It is not known how long that practice continued.

PLATE 3

Hippopus hippopus

THE 48-PAGE CATALOGUE

When subscriptions were being solicited, those who subscribed one guinea or more were promised a 48-page catalogue. No typeset copy of this catalogue has been traced, but Newcastle Central Library holds two copies of a 48-page cyclostyled manuscript catalogue by the Rev. B. W. Gibsone that, judging by its style, had been prepared for publication (Gibsone, 1887).

The manuscript catalogue comprises a brief introduction followed by an index to the paintings. The index includes the Latin binomen of each species as well as an indication by means of abbreviations of the geographical origin of the specimens (when known), the surname of the owner of the specimens (when known) and in some cases additional information indicating juvenile specimen, new species, variety etc.

The collectors listed in the index are J. Adamson, Blossom, Bean, Broderip, Cuming, Champ, Conrad, de Montfort, Deshayes, Ferussac, Fryer, Heiner, Dr Gray, Lamarck, Lea, Mawe, Rev. W. Mark, Sowerby, Say, Salvin, Swain, Trevelyan, Wagner and Wood, plus the collections of the British Museum: a curious mix of local, national and international contacts for an unknown artist.

The range of origin of the specimens is worldwide: as Newcastle is a major seaport it is probable that Gibsone acquired specimens from sailors and travellers as well as from his malacological correpondents.

The size of the collection and the effort involved in its production are staggering. There are 7,260 separate figures of 3,025 species or varieties of mollusc, painted on 1,985 separate sheets of paper. The whole was calculated to have occupied all of Gibsone's daylight hours for at least twenty years.

THE PAINTINGS

The paintings are presently sorted by genus. Each genus is separately housed in a paper folder and the folders are held in a total of sixteen card wallets, probably the original sixteen portfolios of 1888. The paintings are on paper watermarked with a range of dates between 1828 and 1840. Two sheets are watermarked Rose & Turners, the remaining watermarked sheets were all made by J. Whatman.

The uniform style of the paintings shows that Gibsone used a 'method' in executing them. Each shell is drawn with light coming from the upper left, and the shadow cast by the shell is indicated. The shininess and degree of roundness of the shell are shown by the use of white and grey paint respectively. Many specimens are illustrated from more than more than one angle in order to exhibit the whole of the shell. The shells are drawn as dead, 'cabinet' specimens: no attempt is made to portray them as if alive or in their natural habitat. The paintings are arranged simply on the page and not in any geometric pattern.

COLLECTION OWNED BY THE NATURAL HISTORY SOCIETY OF NORTHUMBRIA

A second collection of 4,408 shell paintings by George Gibsone is owned by the Natural History Society of Northumbria. Bound in six volumes, these paintings were presented to the society by the Rev. E. H. Adamson in 1885; Mr Adamson also contributed two guineas towards the purchase of the collection in the Newcastle Central Library. The Society holds a manuscript catalogue of the paintings in its possession.

The quality of the paintings is comparable to those in the Central Library, and the same method is used in portraying the attributes of each shell. The paper is watermarked "J. Whatman, Turkey Mill" and with dates between 1820 and 1828. It

is worth noting that the range of watermark dates in the two collections do not overlap, the Natural History Society's collection being the earlier one.

The Natural History Society of Northumbria also owns a further volume containing thirty-three water-colour paintings of birds, in the front cover of which it is noted: "C. M. Adamson from his father, June 1849. Drawings of birds by Mr George Gibsone, late of Newcastle. Presented by Miss C. Adamson, 1937". The birds, like the shells, are mostly exotic species.

GEORGE GIBSONE

Little is known of the life of George Gibsone. There is a brief biography in *Men of Mark Twixt Tyne and Tweed* (Welford, 1895), from which the following account is mostly taken. A newspaper cutting (Anon. undated) in Gateshead Library indicates that the article in Welford may have been compiled by George's grandson, Rev. B. W. Gibsone of Wolvey, Warwickshire.

George Gibsone's father, also called George, was an architect, who married a Miss Green, possibly the daughter of a shipowner or merchant of Hull. They had three sons: George (the artist), William and John.

George the artist, born in 1762, was trained as an architect and was admitted into partnership with his father. In 1796 he married Elizabeth, daughter of Prebendary Waring and at some time in the 1790s the family moved to Newcastle.

In 1801 the two George Gibsones together with Richard Fishwick erected an iron works at Lemington to the west of Newcastle, a short-lived venture that ended when Surtees's bank stopped payment. Gibsone then became manager of his brother John's colour manufactury on Gateshead's South Shore.

Elizabeth Gibsone opened a school for girls in Forth House, Newcastle in 1812, the school later moving to 5 Saville Row, which is listed in a Newcastle directory of 1827 as a "ladies' day and boarding school". It is not know what part, if any, George Gibsone played in the running of Elizabeth's school, but Welford (1895) speculated that he may have taught drawing.

Retiring in 1831, George and Elizabeth subsequently lived at Belle Vue Cottage in Gateshead Low Fell.

The register of St John's Gateshead Fell records the burial on 5 February, 1846 of Elizabeth Gibsone, age 77. Elizabeth Gibsone's gravestone no longer stands in the graveyard of St John's. Welford (1895) suggested that George Gibsone died in 1846, but no entries have been located in local parish registers and it is possible that he left the district after the death of his wife.

Gibsone was a founder member of the Natural History Society of Northumbria, and served on the committee at least until 1834. He was on the list of parliamentary electors for Gateshead Fell in 1832, 1837 and 1840.

CONCLUSION

There are still several important aspects of the Gibsone paintings to be investigated. For instance, no attempt has been made in the present study to locate the shell specimens that he painted, nor to follow up the taxonomic possibilities offered by his claims of painting undescribed species, nor to trace correspondence between Gibsone and any of the collectors he mentions, nor to establish links between Gibsone and other contemporary artists. It is hoped that the present paper will stimulate further interest and research into the collection.

The merits of Gibsone's paintings as an alternative to a collection of shells were already recognized in the 1880s, albeit as a one-off production: at that time, the cost

of mass-producing colour images of high quality would have been prohibitively high. It is only with recent advances in printing technology that it is possible to bring *Gibsone's Conches* to a mass market.

The plates accompanying this paper comprise the first published facsimiles of Gibsone's paintings since they were finished 150 years ago! There are several obvious uses for the collection, from limited-edition collectors' prints, through fine-quality books on the art of natural history, to malacological textbooks or papers: it would be a great shame if in 100 years' time they are still sitting, half-forgotten and unused, as they have been until now.

ACKNOWLEDGEMENTS

Thanks are due to the Local Studies librarians at Newcastle Central Library and to Hugh and Stella Chambers and David Gardner-Medwin of the Natural History Society of Northumbria for their help in searching out the material in their care. During 1996 a series of limited edition prints of some of the conches was produced by Francobollo Ltd/Natural History Society of Northumbria: I am very grateful for their permission to use four of the prints as figures in this paper.

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FORAGING DISTRIBUTIONS OF TERNS AND PUFFINS IN COASTAL WATERS OFF COQUET ISLAND (NORTHUMBERLAND)

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SUMMARY

Observations were made from the shore and from *RV Bernicia* of foraging activities of arctic terns, common terns, Sandwich terns and puffins in waters adjacent to the breeding colony at Coquet Island (Northumberland). Each species fished up to 20-25km offshore but tended to forage closer to Coquet Island in July, when chicks were fledging, than in June, before fledging occurred. Terns also exploited the littoral zone, taking fish mostly from shallow pools on the receding tide: arctic and common terns tended to feed higher up the shore than Sandwich terns.

INTRODUCTION

While the food and foraging techniques of several species of terns (e.g. Lemmetyinen, 1976; Uttley *et al.*, 1989) and puffins *Fratercula arctica* are well-known, there is relatively little information on either the distances breeding birds may travel from their nests in search of prey or the extent to which they exploit offshore areas. Pearson (1968) estimated maximum foraging ranges from measurement of the times that terns and puffins were away from their nests but, since he took no account of the times birds spent foraging or engaged on other activities, they may be inaccurate. The object of the present study was to make direct observations of foraging activities of puffins and the three commonest terns (arctic tern *Sterna paradisaea*, common tern *S. hirundo* and Sandwich tern *S. sandvicensis* in the area of coastal waters adjacent to Coquet Island in mid-Northumberland during part of the 1991 breeding season. The study area included shallow tidal pools in the littoral zone, as well as waters up to 25km offshore. Coquet Island supports a substantial breeding colony of seabirds, including the most southerly breeding population of eiders *Somateria mollissima* on the east coast of Britain and large numbers of puffins. Four species of tern breed there: the arctic tern, the common tern, small numbers of the roseate tern *S. dougallii*, and the Sandwich tern.

METHODS

There were insufficient sightings of roseate terns to justify their inclusion in the analysis. It is often difficult to distinguish reliably between arctic and common terns in the field, and when identification was uncertain, birds were recorded as 'commic' terns.

Birds foraging offshore

The offshore study area measured 40 x 25km eastwards of the Northumberland coast and included Coquet Island (Fig. 1). *RV Bernicia*, the research vessel of the Dove Marine Laboratory (University of Newcastle upon Tyne), made transects through the area, heading in a northerly route on the outward journey and a southerly one (towards the home port of Blyth) on the return journey. Observers on board kept records of sightings of birds within an estimated 0.4km of the vessel. Records were kept of the sightings of birds 'in flight' or 'fishing' per 10-minute period, together

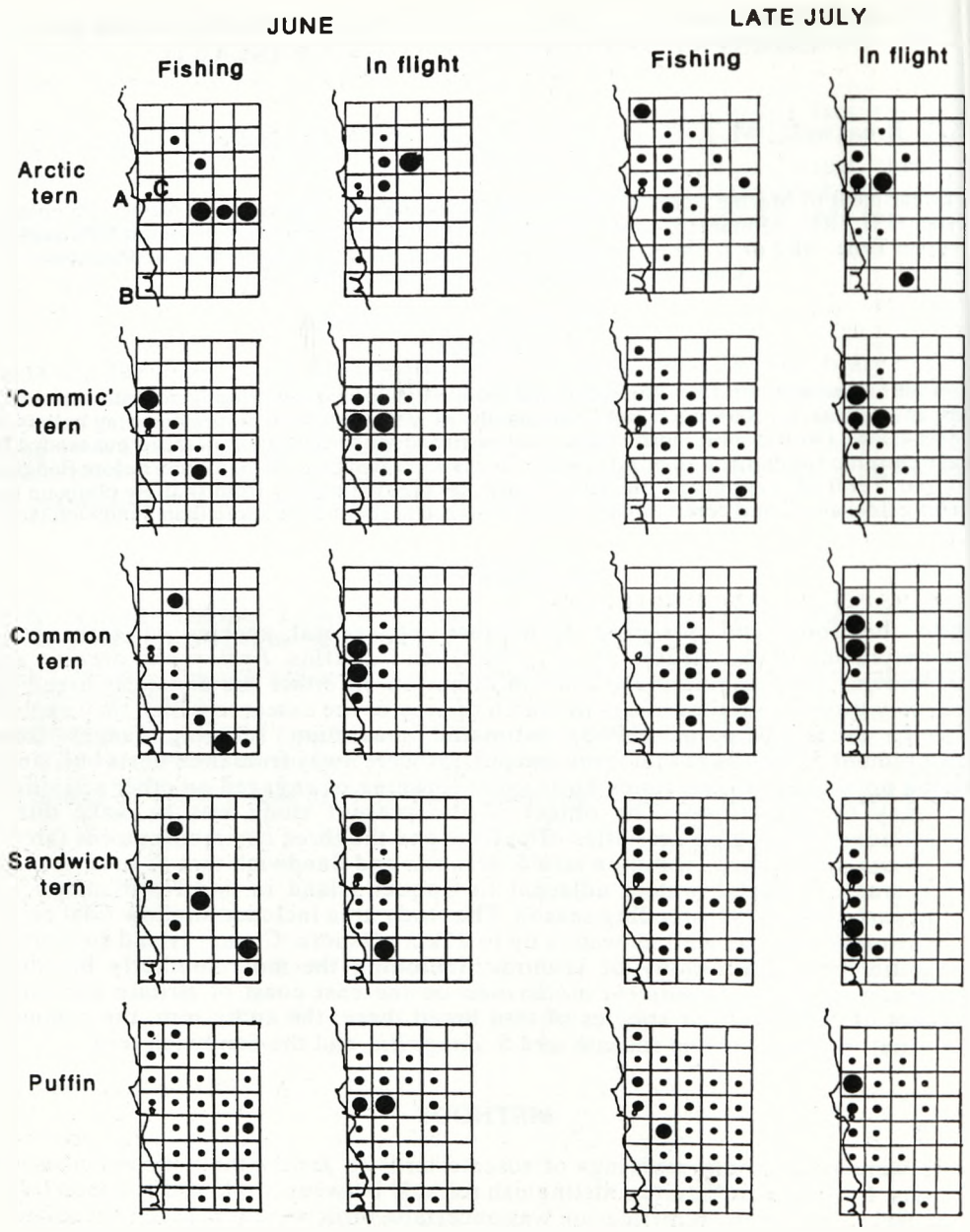

Fig. 1 The distributions of terns and puffins in the study area in June and late July. Data for fishing and flying are presented separately. Percentages are based on the mean numbers of birds sighted per square per survey. The following symbols are used: • less than 5% of the summed total of means; ● 6-10%; ● 11-15%; ● 16-20%; and ● more than 21%. The positions of Amble (A) Blyth (B) and Coquet Island (C) are indicated on the first map.

with the position of the boat at the start and end of each recording period. Terns were regarded as fishing when they were plunge diving or dipping, and puffins, when they were on the surface of the sea at locations where they, or other puffins were diving. There were two observers on board *RV Bernicia* on some cruises. On these occasions, one of them observed to the port side and one to the starboard; mean scores were used in subsequent analyses. Twenty transects were made between 17 June and 22 July, 1991; these were divided into two groups: fourteen transects were between 17 June and 2 July (mean duration = 5.2± 0.8h) and are referred to below as the June period; and six were between 17 and 22 July (mean duration = 5.7± 0.7h) and are referred to as the late July period. To analyse the data, the offshore study area was subdivided into squares 5 x 5km, and the numbers of birds seen during the transect through each square were calculated. The precise routes taken through the study area varied but each 5km square was surveyed at least four times during the June period and at least twice during late July. *RV Bernicia* cruised at a steady speed of eight knots throughout each transect. In the presentation of results (see Fig. 1), the mean number of recordings for each species per visit to each 5km square was calculated and expressed as a percentage of the sum of means for all squares. Comparisons were also made of the proportions of birds close to, and distant from Coquet Island. The area close to the Island was defined as the six 5km squares immediately adjacent to, and including Coquet Island (total area 10 x 15km). The area distant from the island was the remaining part of the study area.

Birds foraging in the littoral zone

The observer (MJD) was positioned approximately 75m from the top of the shore line on the highest available vantage point, a sand dune 14m high, 2.5km from Amble, with Coquet Island about 2km to the north-east. The littoral study area was the adjacent shore and consisted of sand, outcrops of rock near high water and rock pools (see Fig. 2). The entire area, which was covered by water at high tide, measured 1.0 x 0.5km but was subdivided into squares 0.1 x 0.1km, using landmarks as reference points, together with rough estimates of distance. There were ten observation sessions between 26 June and 10 July (mean duration = 6.7± 3.2h). Each session spanned the period of low water so that approximately half of the session occurred as the tide was receding and about half as it was rising. Recordings were made of the numbers of terns in each square at 30 min. intervals through each session.

Means are presented ± their standard errors throughout this paper.

RESULTS

The first sightings of adult terns at Coquet Island in 1991 were in March (Sandwich tern) and April (arctic tern and common tern). Eggs were first recorded in May, and the first chicks hatched in May (Sandwich tern) and June (arctic tern and common tern). The first fledglings were recorded in early July and last ones in early August (Wylie Horn and Jane Brookhouse pers. com.). The June period (17 June to 2 July) coincided therefore with the period during which chicks were in the nest but had not fledged. The late July period (17-22 July) was within the first and last recorded fledging. There are no equivalent data for puffins.

Birds foraging offshore

There were relatively few sightings of terns or puffins during the June transects. Puffins and 'commic terns' were recorded most frequently; Sandwich terns were observed infrequently (Table 1). In each species, most June recordings were of birds in flight, rather than fishing. Foraging birds were seen in most of the offshore study area, including to the southern and eastern boundaries, some 20-25km from Coquet Island (Fig. 1). It is assumed that all birds were from the Coquet Island colony but

Table 1

Numbers of birds recorded fishing in the offshore study site. Statistical comparisons were made of the numbers of birds recorded fishing (Chi-square Test), and the mean numbers fishing per hour (Mann-Whitney U Test) in the early- versus the late-season: * P<0.05; **P<0.01; ***P<0.001.

	Total number observations	Number fishing	Percent fishing	Mean number fishing/hour
June:				
Arctic Tern	71	15	21.1	0.21± 0.01
'Commic' Tern	255	76	29.8	1.04± 0.18
Common Tern	33	12	36.4	0.16± 0.04
Sandwich Tern	74	15	20.3	0.21± 0.04
Puffin	317	104	32.8	1.43± 0.19
Late July:				
Arctic Tern	30	17***	56.7	0.50± 0.11***
'Commic' Tern	221	145***	65.6	4.24± 1.21***
Common Tern	46	31*	67.4	0.91± 0.31***
Sandwich Tern	46	23**	50.0	0.67 ± 0.13***
Puffin	285	191***	67.0	5.58 ± 1.80***

the possibility that some were non-breeders cannot be excluded. The nearest large breeding colony of terns and puffins is on the Farne Islands, 30km to the north of the study area.

Foraging activity changed in two respects in late July. First, there were increases in the numbers of birds sighted compared with the June period, and, for each species, significantly higher proportions were recorded as fishing (Table 1). The mean numbers of each species fishing per hour of observation were also higher in late July than in June. Second, birds tended to forage closer to the breeding colony later in the breeding season. The relative proportions of those doing so in late July were significantly larger than those recorded in June in each species (Table 2). Data for birds recorded as flying show the same trend but numbers flying close to or distant from Coquet Island in June and late July are statistically significant in the cases of 'commic' terns, common terns and puffins only. There are insufficient data to comment in detail on the differences between species in their distributions within the study area, although each species exploited most of the offshore area. However, Sandwich terns were often recorded fishing in the south-west corner of the area, where other species were recorded infrequently (Fig. 1).

Table 2.

The numbers of birds recorded fishing and flying, close to and distant from Coquet Island (see Methods). Comparisons were made of the relative numbers of birds close to and distant from Coquet Island in June versus late July: $P<0.01$;$P<0.001$ (Chi-square Test).

	Arctic Tern	'Commic' Tern	Common Tern	Sandwich Tern	Puffin
			Fishing		
June:					
Close	0**	36***	3***	1***	13***
Distant	15	40	10	14	91
Late July:					
Close	9	138	30	17	131
Distant	8	7	2	6	60
			Flying		
June:					
Close	33	76***	7***	24	104***
Distant	23	103	14	35	109
Late July:					
Close	9	65	13	11	73
Distant	4	11	3	12	21

Birds foraging in the littoral zone

The littoral study area was exploited by terns which fished in the shallow pools left by the receding tide, and sometimes in rock pools. The numbers of birds fishing increased rapidly as the tide receded and then decreased equally rapidly, presumably as available prey was fished out. Sandwich terns were relatively more common (than the other tern species) in the littoral area than they were in the offshore area (see above) but there was considerable variation in the numbers of each species recorded during observation sessions. Mean numbers of individuals recorded per session were: 7.6 ± 2.6 (range 0-10) for arctic terns; 21.6 ± 10.6 (range 0-111) for 'commic' terns; 2.5 ± 1.1 (range 0-8) for common terns; and 26.1 ± 16.8 (range 0-203) for Sandwich terns.

Arctic, 'commic' and common terns tended to fish high up the shore (Fig. 2) and predominantly before low water (Fig. 3); the numbers recorded fishing when the tide was receding were always greater than those recorded after low water (data for arctic, 'commic' and common terns combined; $P< 0.05$; Sign Test). Sandwich terns exploited the lower shore and, since the pools there were not exposed until later in the tidal cycle, they did not forage in the littoral zone until closer to low tide than

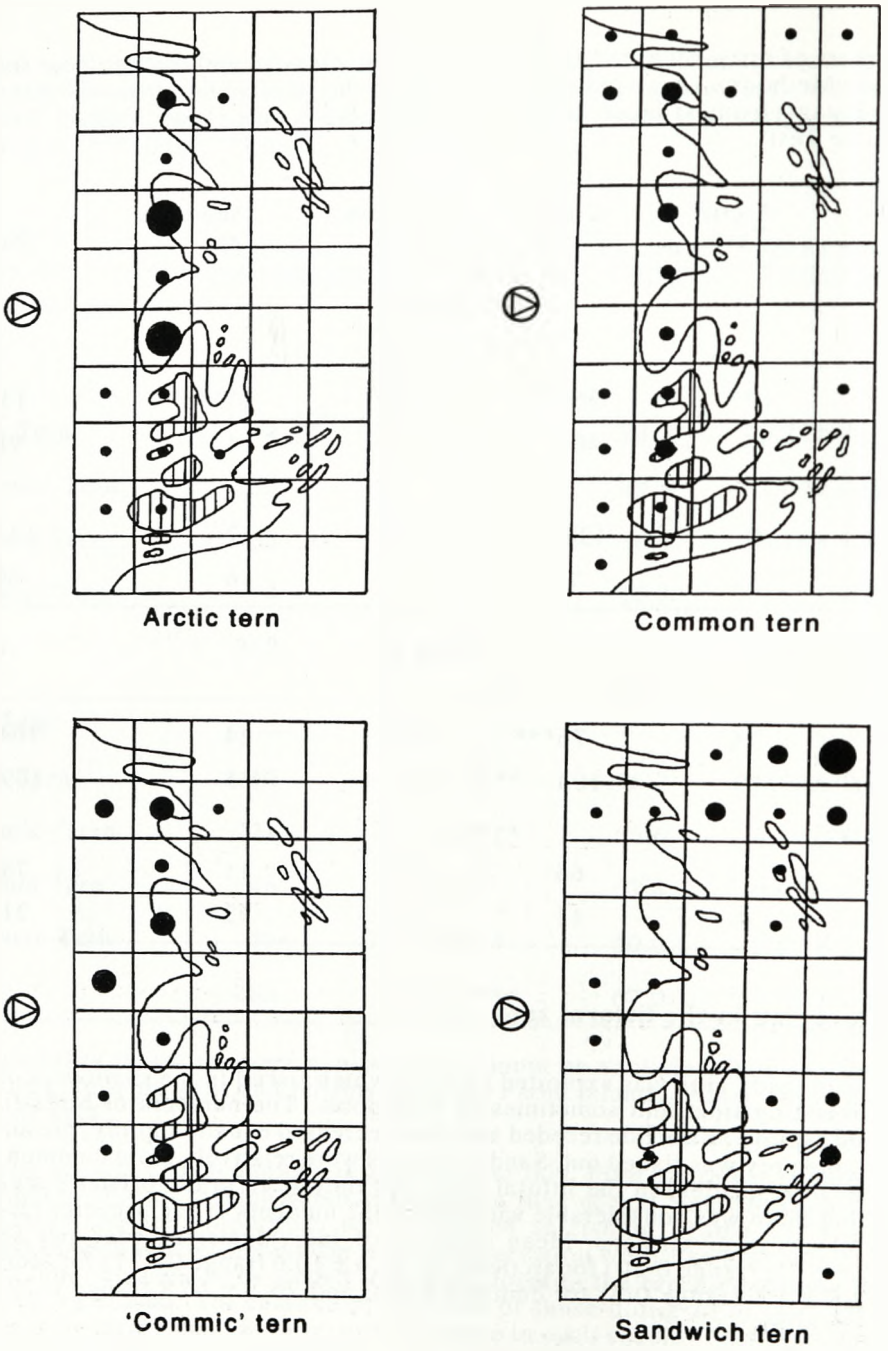

Fig. 2 Distribution of terns in the littoral study area. The area measured approximately 0.5 x 1.0km, and each square measured 0.1 x 0.1km. The position of the observer is marked. The outlines of rocks are shown, together with rock pools (lined). Percentages are based on total numbers of terns recorded throughout the study: • less than 5% of recordings; ●6-10%; ●11-15%; ●16-20%; and ● more than 21%.

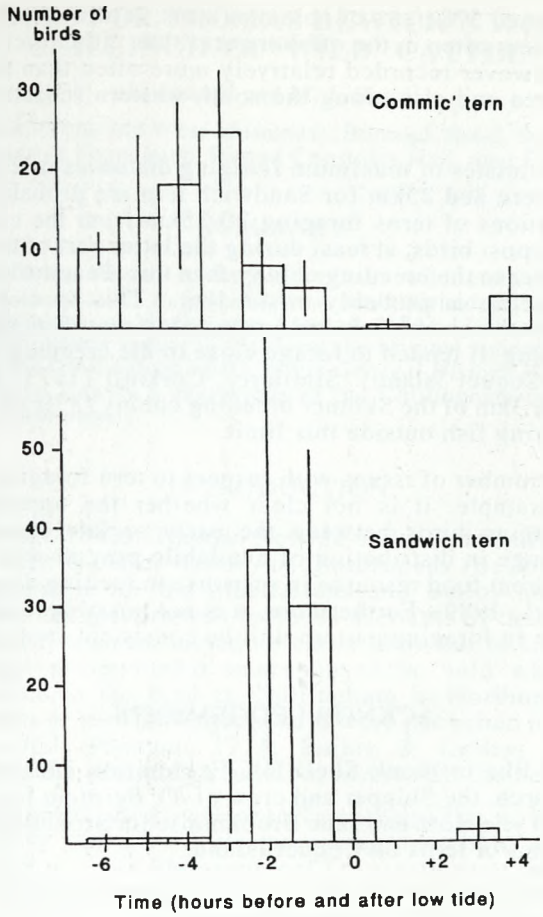

Fig. 3 Mean numbers of 'commic' and Sandwich terns foraging in the littoral study area in relation to low water. Means are shown with their standard errors.

the other terns. Nevertheless, they too foraged in larger numbers before low tide than after it ($P < 0.05$; Sign Test).

DISCUSSION

Common and Sandwich terns are regarded mainly as inshore feeders (Langham, 1968), although they utilize offshore waters to at least some extent (Dunn, 1972). These findings are borne out, and can be extended to arctic terns, as a result of our own observations of terns exploiting littoral pools at low tide, as well as waters up to at least the boundaries of the study area. The littoral zone represents a predictable, though transient food resource for terns. However, since the numbers fishing in rock pools at any one time were small in relation to overall colony size (see below), availability of prey in the littoral zone may be of less importance than that offshore. All three species of terns were observed feeding towards the eastern boundary of the study area, some 20-25km from the coast. Although Sandwich terns were numerically dominant in the colony in 1991 (1736 breeding pairs compared with 439

pairs of arctic terns and 578 pairs of common terns; Jardine *et al.*, 1991), they were recorded relatively less often in the offshore area than either arctic terns or common terns. They were however recorded relatively more often than the other species in the littoral study area and also along the south-western (coastal) boundary of the offshore area.

Pearson's (1968) estimates of maximum foraging distances of 20km for arctic tern, 22km for common tern and 25km for Sandwich tern are probably realistic in view of our own observations of terns foraging 20-25km from the coast. There is little doubt however that most birds, at least during the latter part of the breeding season, normally fished closer to the breeding colony than this. Pearson's estimate of 137km for the range of puffins is probably misleading. This species characteristically returns to the nest with several fish and presumably therefore spends a substantial amount of time fishing. It tended to forage close to the breeding colony (i.e. mostly within 5-10km of Coquet Island). Similarly, Corkhill (1973) found that puffins fished mostly within 3km of the Skomer breeding colony (83% of observations), and none was seen carrying fish outside this limit.

This study raises a number of issues with respect to tern foraging patterns and prey availability. For example, it is not clear whether the apparent change in the distribution of foraging birds between the early or late season survey periods resulted from a change in distribution of availabile prey or whether it represented utilization of a different food resource in response to feeding demands of the chicks (e.g. Monaghan *et al.*, 1989). Furthermore, it is not possible to say, as yet, whether the temporal change in foraging pattern will be consistent from year to year.

ACKNOWLEDGEMENTS

The authors would like to thank Shell UK Exploration and Production for their support of this research, the Skipper and crew of *RV Bernicia* for their help with the transect work, and Wylie Horn and Jane Brookhouse for providing information about the breeding activities of terns on Coquet Island.

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SOME SOURCES FOR THOMAS BEWICK'S WORK ON THE CHILLINGHAM 'WILD' CATTLE

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SUMMARY

Thomas Bewick's published account of the Chillingham 'wild' cattle, and his engravings of them, are discussed in relation to two hitherto unpublished letters from John Bailey (1750-1819) of Chillingham to Marmaduke Tunstall (1743-1790) of Wycliffe in County Durham. These letters together appear to represent the original source of the data published by Bewick regarding the Chillingham cattle, in his *General History of Quadrupeds* of 1790. The similarities between Bewick's engravings of the Chillingham cattle and certain 16th century woodcuts are also noted.

INTRODUCTION

Towards the end of the 1780s, Thomas Bewick and Ralph Beilby were completing the preparation of their *General History of Quadrupeds* (Beilby & Bewick, 1790), Bewick being responsible for the illustrations and Beilby and Bewick working together on the text. The *Quadrupeds* includes accounts of the natural history of a wide range of mammal species, including cattle (*Bos taurus* Linnaeus, 1758), and no less than four pages are devoted to an account of the 'wild' white cattle of Britain, with special reference to the herd at Chillingham in Northumberland. Although several other accounts of the Chillingham herd were published in the late eighteenth century (Wallis, 1769; Pennant, 1774; Bailey & Culley, 1797) that in the *Quadrupeds* received the greatest circulation, and is still the best known.

We know from letters published by George Townshend Fox in 1827 that, during the late 1780s, Marmaduke Tunstall was also preparing an account of 'wild' white cattle, probably for publication in the *Philosophical Transactions of the Royal Society*, but which was never published. Tunstall's own interest was possibly stimulated by his family's one-time ownership, at Burton Constable in East Yorkshire, of a herd that died out in the late 1740s (Boyd, 1996). Marmaduke Tunstall also commissioned Thomas Bewick, in 1788, to produce a large woodcut of a bull from the Chillingham herd, a work of art that remains one of Bewick's most famous single engravings.

Two letters between John Bailey (land agent to Lord Tankerville at Chillingham) and Marmaduke Tunstall have recently come to light in the Humberside County Record Office, and these appear to include the original material from which Bewick and Beilby derived their account of the Chillingham cattle. The letters are also of interest as being early and extensive first-hand accounts of the Chillingham cattle; they provide some additional data on the herd in the 18th century and also suggest a possible artistic influence on Bewick's engravings of the Chillingham cattle.

EXCHANGE OF DATA BETWEEN TUNSTALL AND BEILBY & BEWICK

It is already well known that Tunstall and Beilby & Bewick were aware of each other's work on the Chillingham herd. Fox (1827: pp 23, 24 & 297) published four of the relevant letters from Tunstall to "Messrs Beilby & Bewick".

The second of these letters from Tunstall, dated 11 February 1789, includes the following passage:

> Am also obliged to you for the account of the wild cattle, at Mr Leigh's, of Lyme, have been told they were at Mr Leigh's of High-Leigh, also in Cheshire, but on

> enquiry found it a mistake - The cuts for me beg may be done in the manner you think will have the best effect. Have no objection to what you propose for the plates being made use of in a particular account of them; but as I have collected many anecdotes about them, most of which I have already communicated to you, and hope to be able to procure more, propose making up a small memoir, to send to Sir Joseph Banks, the President of the Royal Society, of which I am a member, which probably may be ready for the next winter, and should be sorry it should be anticipated by the publication you mention; but after that, it is of no importance.

This clearly indicates a two-way exchange of data: Beilby and Bewick had passed information to Tunstall about the cattle at Mr Leigh's in Cheshire (possibly by providing a reference to Leigh, 1700), but Tunstall had given them most of the "many anecdotes" he had collected with respect to 'wild' white cattle and, like researchers before and since, he did not want his own findings to lose priority.

Tunstall's paper on 'wild' white cattle was never published, and probably remained incomplete on his death on 11 October 1790. Beilby & Bewick's *Quadrupeds* was published on 27 April 1790, predating Tunstall's death by five and a half months (Robinson, 1887).

Although Tunstall had not seen the book three months after its publication - he could write on 15 July 1779 "When will your work on quadrupeds be completed?" - it is clear from a letter from Bewick to Beilby in 1791 (cited in Bain, 1981) that by the time of his death he had not only seen a copy of their book but had time to analyse its contents:

> You would be amazed at Mr Tunstals [sic] industry - to skim over only his own remarks wou'd take a much longer time than I can possibly spare - he has not only put down every thing that came under his own observation on the habits and propensities of Animals &c with numberless Anecdotes - but he has also quoted every thing that he thou't curious from other Authors - he has not even forgot Beilby and Bewick's Quads & has discover'd all that we call new in our Book - & has placed the Cuts along with his remarks.

It is tempting to assume that there was a rift between Tunstall and Beilby & Bewick because of the publication of Tunstall's "many anecdotes" in the *Quadrupeds*, but no evidence of an argument survives. Bewick did not hint of one in his letter to Beilby in 1791, and if there was any discord it did not reach such proportions as to cause Tunstall's family to bar Bewick from consulting the library and collection of mounted birds at Wycliffe after Tunstall's death. It is possible that Tunstall accepted the benefits of having his data published in a popular account and abandoned the preparation of his article; it is also possible that the text of the *Quadrupeds* had been typeset by February 1789, when Tunstall wrote that he did not want his publication anticipated, so Beilby and Bewick could not comply with the request not to publish the "anecdotes".

JOHN BAILEY'S LETTERS

These two letters from John Bailey to Marmaduke Tunstall illustrate the extent of the information passed by Tunstall to Beilby & Bewick, and doubtless represent at least some of the "many anecdotes" that Tunstall mentioned in his letter.

The letters, hitherto unpublished, appear to have passed into the possession of Tunstall's half-brother, William Constable (1721-1791) of Burton Constable Hall, after the former's death in 1790. They now form part of the Burton Constable Archive deposited at the Humberside County Record Office in Beverley, where they are housed in HCRO File DDCC 144/11.

Both letters are addressed to Marmaduke Tunstall at Wycliffe, and read:

First Letter

Chillingham Castle 3rd June, 87

Sir,

Herewith I send two Drawings, a Bull and a Cow, of the wild Cattle in Chillingham Park; as you desired they are only rough Tinted-Indian-Ink drawings, but the Animals I hope, are very Accurate, being immediately known, by every Person who saw them, that had ever seen the wild Cattle before, the figure behind the Cow is the general appearance of the Oxen.

Their Colour is constantly the same, being White with red Ears and black Muzzles; Horns white with black Tips and very sharp.- Mr Pennant says the Ears are black, but this mistake may probably have arisen from not being near them.- The Manes mentioned by Boethius are not so conspicuous, only, some of the Bulls, have a thin upright Mane about 1½ or 2 Ins long.

At the first appearance of any Person they set off in full Gallop and at the distance of 200 or 300 yards, wheel round & come boldly up again, tossing their Heads in a menacing manner, untill they get within 40 or 60 yards, where they make a full stop, and look wildly at you; but on the least

[page missing]

killed two years since, and weighed 45 Stone;- the best Graziers all agree, that they are well made for getting soon Fatt,- being light behind, round carcased,- small Boned, and have every essential necessary for quick Feeders.- The Beef is very tender,- finely marbled,- and has a peculiar Flavour superior to any other Beef I ever eat,- and is esteemed so by every person that eats it.

I do not at present recollect any other particular singularity of their Oeconomy or natural history.- shd any arise I will send them,- or if you want any explanations or further enquiries I will with pleasure, give the best information in my power.

I believe these at Chillingham are the only remains in the Kingdom - as I have been told, the Duke of Queensberry has destroyed his, at Drumlanrig.

I am Sir with great respect your obliged

and very humble Servt

John Bailey

P.S. you wish to know if I am at liberty to Survey:- when you have any thing of that kind to do, I shall be glad to serve you. - and have a pleasure in reflecting that my labours will be for a liberal patron of the Arts, who possesses a true and refined Taste.

Second Letter

Chillingham Castle 3rd Oct. 1787

Sir,

I have waited long for an Authentic Acct. of the extirpation of the Wild Cattle at Drumlanrig, from the Steward; as I got a friend to write to him, for that purpose, but not recieving any Ansr suppose he has particularly reasons for being silent - the Gentleman who I got to write, lived in that Country, and says they were sold when he was there; and the report was, "that they were all killed" - but I will try

another way to have this well authenticated; and transmit you when recd. I shall now Ansr your Queries.

1 Qu:- "What number is their [sic] usually at Chillingham"

Ansr: Abt 40

2nd Qu:- "To what age are they usually kept"

Ansr: The oxen to 6 or 7 years old.- Cows are killed at all ages from 4 to 10 or 12 Years.- Bulls 5 or 6 years old.

3rd Qu:- "Some thought, at Burton, that the marbled flesh & fine flavour was in part owing to their Age & having been fatted often over"

Ansr. This is a mistake, as the 4 year old heifers are as ~~fine~~, high flavored and beautifully marbled as the old Ones,- and it is well known to Graziers of observation that this valuable property is entirely owing to the peculiarity of the Breed, not only in horned Cattle, but in Sheep;- it is an easy matter to raise a breed that will not have the least marbling in the texture of their Flesh.

4 Qu: "In what manner are they now killed"?

Ansr. They are usually killed between Martinmass and Christmas - for 2 or 3 mornings the Park=keeper leads out a Sledge load of Hay, to fodder them, and whilst they are eating, he (with a Rifled Gun) shoots from behind the Horse; the Victim never fails of dropping dead, the report of the Gun makes the others Gallop away - he follows with the Sledge and hay, and distributes the remainder to them,- while he is doing this, the Butcher bleeds the dead one, and gets it carried to the Slaughter house before the others have eat their Hay,- this method is easy safe and quiet,- the old method was the Contrary.- but marked with tumultous [sic] Grandeur; and perhaps, the only modern example of the Manliness of Anct Hunting,- On Notice being given, that a wild Bull wd be killed on such a Day,- the Gentlemen in the County [?or Country] came mounted, many armed with Guns,- sometimes to the amount of 100 Horsemen.- and four or five hundred Foot, the Foot stood upon the Park Wall, or got into Trees,- while the horsemen rode off the Bull from the rest of the Herd, and when he stood at Bay, dismounted and Shot,- but he was seldom killed by one ~~shot~~, Firing (as they shot with common Guns).- At some famous huntings 20 Shots have been fired before the ill fated animal was subdued, On such occasions, you may be sure he was desperately furious. from the smarting of his wounds, and the shouts of savage joy that was echoing from every Hill.

5th Qu: How are the Calves castrated?

Ansr. The Cows hide the Calves for some days while Young, among the Rushes, Brakes &c - the Park=keeper marks the Place, and when the Herd are at a distance, takes an Assistant with him on horseback,- they tye a handkerchief around the Calves Mouth, to prevent its roaring,- and then perform the operation in the usual way, with as much expedition as possible.-

6th Qu: Are those at Chillingham kept in the Park?- and what dimensions is it.-

Ansr. They are kept in the Park, inclosed by a high Wall, the quantity about 150 Acres:- the old Park [word missing] about 500 Acres, and inclosed a very large Wood [word missing] remarkable high heathy Mountain, called Ross= [word missing]. Note. the Top of this hill has been strongly fortified.- You know Ross is the Brittish for Hill or Mountain. from which I take it to have been a Brittish Camp.

A Circumstance occurs to me that I believe was not attended to in my former letter. When any Individual of the Herd is wounded, or Ill thro' sickness or misfortune, the rest of the herd set on it, and gore it to death,- another proof of their native wildness.-

If I recollect any other peculiarities, I will send you them. at present nothing more strikes me - abt a month since I sent you the two Drawings and a Black Cock, which I hope came safe - and am Your humble Servt. Jn Bailey

Note. The Ears are Red, on the Inside, and about <u>one third</u> down the <u>outside</u> from the Tip - as is shewn in the drawing of the one laying which I introduced for the purpose.-

I did not know this peculiarity, when I made the first drawings.- The Park=keeper says he has seen one or two with <u>black Ears</u>,- but always killed them on the Idea they wd. spoil the breed.

P.S. You seem to insist on knowing what you are indebted to me for the drawings.- I did intend them as offerings of respect,- but as you probably will not accept them,- I shall observe that each drawing cost me 2 days, from which I think they will deserve a Guinea each.

It is worth comparing Bailey's account with that in the *Quadrupeds*

Bailey's first letter:

Their Colour is constantly the same, being White with <u>red</u> Ears and black Muzzles; Horns white with black Tips and very sharp. Mr Pennant says the Ears are black, but this mistake may probably have arisen from not being near them. The Manes mentioned by Boethius are not so conpicuous, only, <u>some</u> of the <u>Bulls</u>, have a thin upright Mane about 1½ or 2 Ins long.

Quadrupeds:

Their colour is invariably white; muzzles black; the whole of the inside of the ear, and about one third of the outside, from the tip downwards, red; horns white, with black tips, very fine and bent upwards: some of the bulls have a thin upright mane, about an inch and a half, or two inches long.

Note in second letter:

The Ears are Red, on the Inside, and about <u>one third</u> down the <u>outside</u> from the Tip

At the first appearance of any Person they set off in full Gallop and at the distance of 200 or 300 yards, wheel round & come boldly up again, tossing their Heads in a menacing manner, untill they get within 40 or 60 yards, where they make a full stop, and look wildly at you; but on the least [page missing]

At the first appearance of any person, they set off in full gallop, and, at the distance of two or three hundred yards, make a wheel round, and come up boldly again, tossing their heads in a menacing manner: on a sudden they make a full stop, at the distance of forty or fifty yards, looking wildly at the object of their surprise; but upon the least motion being made.....

Bailey's Second letter (4th Query)

[after describing the modern method of killing the cattle with a rifle] the old method was the Contrary.- but marked with tumultous [*sic*] Grandeur; and perhaps, the only modern example of the Manliness of Anct Hunting,- On Notice being given, that a wild Bull wd be killed on such a Day,- the Gentlemen in the County [?or Country] came mounted, many armed with Guns,- sometimes to the amount of 100 Horsemen.- and four or five hundred Foot, the Foot stood upon the Park Wall, or got into Trees,- while the horsemen rode off the Bull from the rest of the Herd, and when he stood at Bay, dismounted and Shot,- but he was seldom killed by one ~~shot~~ Firing (as they shot with common Guns).- At some famous huntings 20 Shots have been fired before the ill fated animal was subdued, On such occasions, you may be sure he was desperately furious, from the smarting of his wounds, and the shouts of savage joy that was echoing from every Hill.

Quadrupeds

The mode of killing them was, perhaps, the only modern remains of the grandeur of ancient hunting. On notice being given that a wild Bull would be killed on a certain day, the inhabitants of the neighbourhood came mounted, and armed with guns, &c. sometimes to the amount of an hundred horse, and four or five hundred foot, who stood upon walls, or got into trees, while the horsemen rode off the Bull from the rest of the herd, until he stood at bay; when a marksman dismounted and shot. At some of these huntings twenty or thirty shots have been fired before he was subdued. On such occasions, the bleeding victim grew desperately furious, from the smarting of his wounds, and the shouts of savage joy that were echoing from every side: but, from the number of accidents that happened, this dangerous mode has been little practised of late years; the park-keeper alone generally shooting them with a rifled gun, at one shot.

After 6th Query:

A Circumstance occurs to me that I believe was not attended to in my former letter. When any Individual of the Herd is wounded, or Ill thro' sickness or misfortune, the rest of the herd set on it, and gore it to death,- another proof of their native wildness.

When any one happens to be wounded, or is grown weak and feeble through age or sickness, the rest of the herd set upon it, and gore it to death.

There is sufficient coincidental material in Beilby & Bewick's account on the one hand and Bailey's letters on the other to conclude that the former is simply a paraphrase of the contents of the latter. Although Bailey and Bewick are known to have been acquainted - Bailey is described as "my kind old friend" in Bewick's *Memoir* - there is no need to postulate direct exchange of information between the them; it would be unlikely for Bailey to have written separately to Bewick expressing his information in such a similar way.

Ironically, Bailey's own published account of the Chillingham herd (Bailey & Culley, 1797) is a copy of that in the *Quadrupeds*, preserving Bewick & Beilby's paraphrasing of his own original letters.

NEW INFORMATION IN BAILEY'S LETTERS

So far as is known, no outside blood has ever been introduced to the Chillingham herd, although there is a tradition that the whole herd of 'wild' white cattle once present at Drumlanrig Castle (Dumfries & Galloway) was, around the year 1780,

sold and driven off to Chillingham (Whitehead, 1953: pp 45, 115, 116). Bailey's letters seem to refute this tradition. His enquiries failed to resolve the question of what happened to the Drumlanrig herd, other than a suggestion that they had all been killed. Placed as he was at Chillingham, if the herd had been moved there he would surely have been able to acquire some information about it.

Bailey's second letter includes details of the management of the herd hitherto unpublished: on the age at which they were slaughtered, on the distribution of hay to the animals before they were slaughtered, on the castration of calves and on the size of the walled enclosure. There is also a figure for the size of the herd (about 40), which agrees with that given in Pennant's *A tour in Scotland* (Whitehead, 1953).

ENGRAVINGS OF CHILLINGHAM CATTLE

Bewick published three engravings of Chillingham cattle, two small ones (a bull and a cow) in the *Quadrupeds* and the single large woodcut of the bull which was commissioned in 1788 by Marmaduke Tunstall for a fee of seven guineas.

The single, large, woodcut (Fig. 1)

Letters published by Fox (1827) provide some background to the origin of Bewick's single large woodcut, and the account of its preparation and the fate of the block are described in his own *Memoir* ([Bewick], 1979).

In the *Memoir* Bewick describes how he visited Chillingham in Easter 1789 where "we took up abode with my kind old friend John Bailey". He says of his sketch:

> I could make no drawing of the bull .... I was therefore obliged to see one which had been conquered by his Rival & driven to seek shelter alone in the quarry holes & in the woods. I was under the necessity of creeping on my hands and knees to leward & out of his sight - and I thus got my sketch or memorandum, from which I made my drawing on the wood. I am sorry my figure was made from one before he got furnished out with his curled or shaggy neck and mane

The *Memoir* also includes Bewick's, curiously vague, reminiscence that the woodcut of the bull was done for "Marmaduke Tunstal [sic] ... or my friend George Allan Esqr..." It is difficult to account for the fact that Bewick seems to have forgotten whether it was Tunstall or Allen who commissioned this, one of his most famous engravings.

On 6 November 1788 Tunstall had written to Beilby and Bewick (*teste* Fox, 1827):

> I approve of your idea of putting the Chillingham bull and cow into one plate, and that a copper one. I should like to have about sixty impressions taken off and sent me with the plate, when finished, together with your account, which I will immediately discharge the amount of....The sooner you can compleat and send me the plate and impressions, the more you will oblige.

And on 11 February 1789 (*teste* Fox, 1827)

> The cuts for me beg may be done in the manner you think will have the best effect.

We know the date of completion of the work, as Tunstall wrote on 15 July 1789 (*teste* Fox, 1827)

> I duly received the six impressions of the Chillingham bull, on vellum, they were rather relaxed and a little rumpled in the coming; the figure is well engraved, and has much expression; would have, I think, fifty impressions taken off, half with and half without the border, all on strong good paper; should be glad to have printed

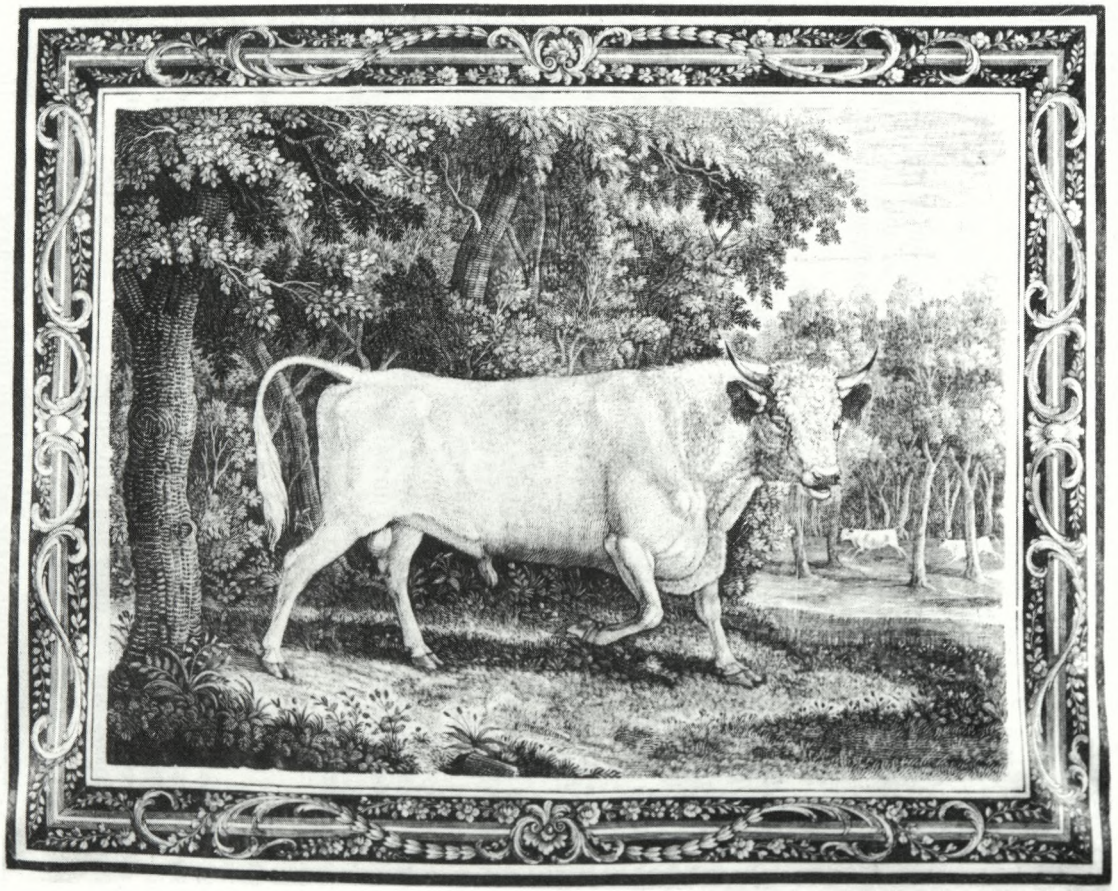

Fig. 1 First printing (1789) of the single, large, woodcut of the Chillingham Bull commissioned from Thomas Bewick by Marmaduke Tunstall in 1788.

under them, *Bull of the ancient Caledonian breed, now at Chillingham Castle, Northumberland.* I understood by your last, that both bull and cow were to be in one plate, which would have made the expense much less; can say nothing about the cow, till I know the price of this engraving, which I desire you will send me, as also of the specimens taken off, both on vellum and paper, which I will then send a note for the payment of.

When will your work on quadrupeds be completed? On again looking at the engraving, I think the shading of the muzzle rather too faint, and there seems to be a white straight line down from the mouth; but this last may probably have happened in the taking off, though observable in all; can it be meant to show the foam?

The six impressions of the woodcut on vellum appear to have been re-acquired by Bewick shortly after Tunstall's death (Boyd, 1886, following Thomson, 1882). A second edition of the woodcut was indeed prepared by Bewick; it is dated 1789 and bears the legend suggested by Tunstall.

Figures in the Quadrupeds (Fig. 2)

The *General History of Quadrupeds* includes two engravings, of a bull and a cow, the bull being similar to that in the single, large, woodcut commissioned by Tunstall, but differing slightly in stance. Although first published in book form in April 1790, at least one of the plates (the cow) is known to have been engraved before April 1788, as an advertisement bearing the figure was then issued (the advertisement is reproduced in Bain, 1979).

There is a slight anomaly in the sequence of events. We know that Tunstall and Bewick were discussing the possibility of putting "the Chillingham bull and cow into one plate" in November 1788, and that an engraving of, at least, the cow was ready by April 1788, yet it was not until Easter of the following year that Bewick visited Chillingham to make his "sketch or memorandum". Making the assumption that Bewick had not previously visited Chillingham to draw the cattle (and, if he had, why visit again in Easter 1789?), then what sources were available to him?

We know that two drawings, of a bull and a cow, were sent from Bailey to Tunstall on 3 June 1787. Were these the figures that Tunstall suggested being put "into one plate" and of which he said, in February 1789, that he had "no objection to what you propose for the plates being made use of in a particular account of them"?

Bailey was an artist of some training: his published works include drawings and engravings in Brand's *History and Antiquities of Newcastle*, in Hutchinson's histories of the counties of Northumberland and Durham, and in his own agricultural works (Hall, 1982; Welford, 1895). In his *General View of the Agriculture of the County of Northumberland* (Bailey & Culley, 1797) there is an engraving by Neele of a sketch of two cows and a bull at Chillingham that Bailey drew in 1794 (Fig. 3). The similarity of the style of the most prominent cow in this engraving and that in the *Quadrupeds* is striking, although the bull does not particularly resemble either of Bewick's works.

Unfortunately, neither Bailey's drawings nor Bewick's "sketch or memorandum" appear to have survived.

GESSNER'S WOODCUTS AND BEWICK'S ENGRAVINGS

The only published figures likely to have been used as inspiration by Bewick when preparing the large woodcut of the Chillingham Bull commissioned by Marmaduke Tunstall were already almost 250 years old. These were the woodcuts in Gessner's *Historia Animalium* (Figs 4, 5 & 6). Although this book is by no means obscure, its

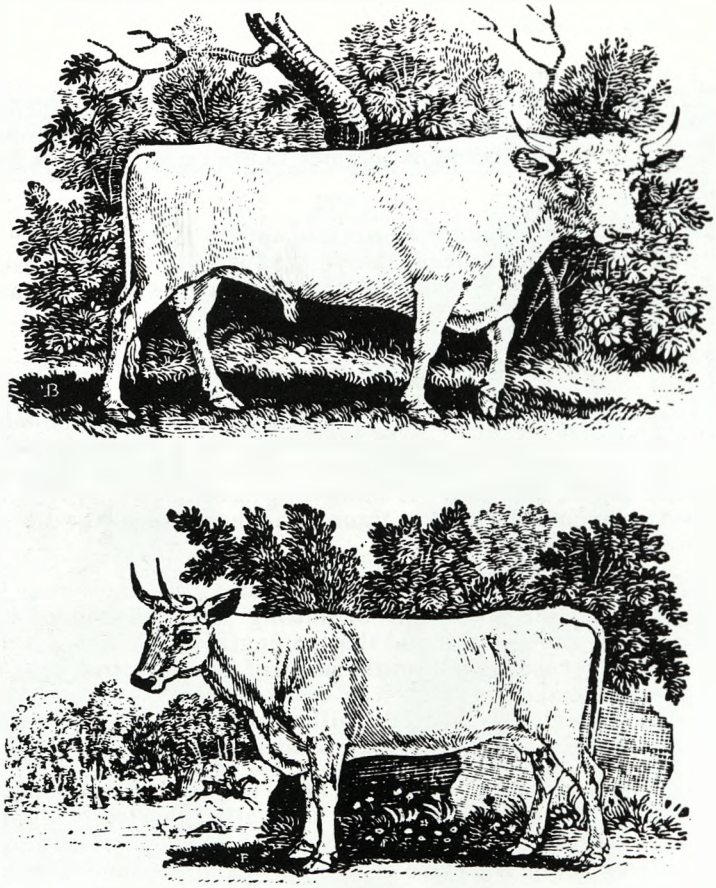

Fig. 2 Thomas Bewick's illustration of Chillingham bull and cow, published in Beilby & Bewick's *General History of Quadrupeds* (1790).

probable influence on Bewick's work seems to have been missed by subsequent historians.

The stance of the Bull in Bewick's large woodcut is too close to that of the figure of the *Bisone albo scotico* first published in the appendix to Gessner's *Historia* volume II (Gessner, 1554) for the resemblance to be coincidental. We know that Bewick had access to a copy of 'Gessner' when preparing the *History of British Birds*, as Bewick noted in his memoir that "Mr Rotheram gave me Gesner's Natural History". It is not known to which edition he had access: an original in Latin or, for instance, Topsell's English translation of 1607/1658.

The illustrations of the *Bisone albo scotico* in Gessner (1554), were derived from woodcuts printed in Vienna in 1552 for Baron Sigismund von Heberstain (Pyle,

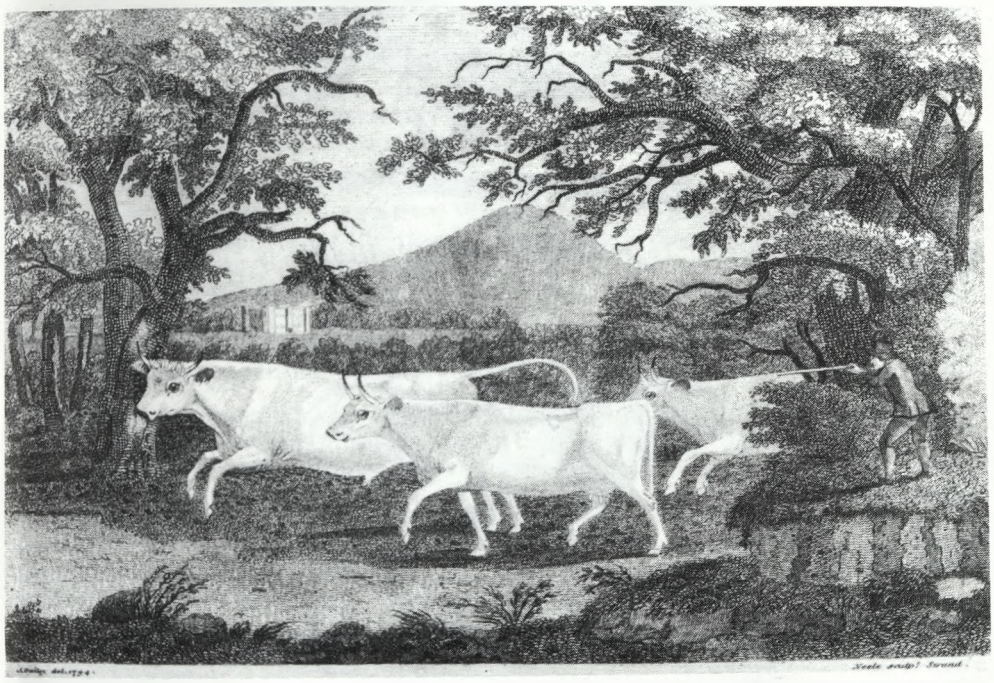

Fig. 3 John Bailey's (1794) drawings of Chillingham cattle, published in Bailey & Culley's *General View of the Agriculture of the County of Northumberland... (1797).*

1994). A similar stance was used to portray three 'types' of bovids, called in English by Topsell the *Bison, White Scotian Bison* and *Bull*: one fore-leg being raised, as if ready to paw the ground. In the Bull and White Scotian Bison one of the hind legs is placed ahead of the other, the tail is swishing and the head is raised but in the Bison both hind legs stand together, the tail hangs limp and the head appears lowered.

Although Bewick may have derived the posture of the Bull in his large woodcut from these earlier illustrations, his was not a simple copy. Not only are his lines much finer, as one would expect from a workman of his abilities, but the proportions of the animal are changed: the Chillingham Bull in Bewick's large woodcut is almost precisely the same length as the White Scotian Bison in Gessner's illustration, but about three-quarters the height. This is due to an overall reduction in height, maintaining the proportion of the length of the legs to the depth of the body. In fact, Bewick's figure is much nearer to the true shape of the animal depicted, and Gessner's figure stands about 30% too high.

There are also minor alterations in posture. In none of Gessner's illustrations is the tail raised, and the angle of the last joint of the raised fore-leg in Bewick's engraving makes the Bull appear as if running, rather than standing and pawing the ground.

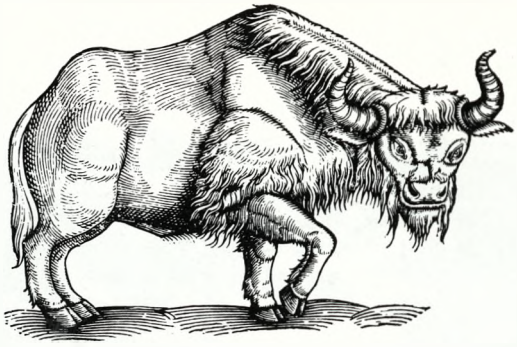

Fig. 4 Gessner's 'Bison', reproduced in Topsell's *History of Four-footed Beasts (ex 1658 edition).*

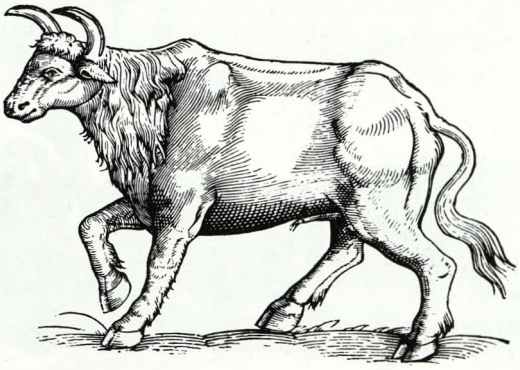

Fig. 5 Gessner's 'White Scotian Bison', reproduced in Topsell's *History of Four-footed Beasts (ex 1658 edition).*

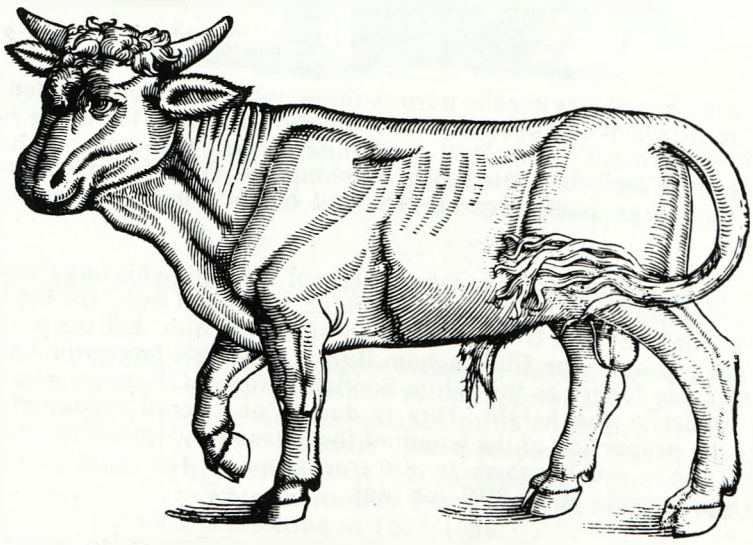

Fig. 6 Gessner's 'Bull', reproduced in Topsell's *History of Four-footed Beasts (ex 1658 edition).*

DISCUSSION

The present authors are only too aware of the way in which supposition in historical research can become 'fact' (Jessop, 1989), and it should be stressed that the evidence for Bailey's influence on Bewick's published work, via the letters presented here, is, strictly speaking, circumstantial. For the written account of the Chillingham Cattle in the *Quadrupeds* there is, nonetheless, an almost incontrovertible case for supposing that Beilby and Bewick paraphrased information taken from these letters - the words used and the order in which they are presented, taken together with the fact that Tunstall is known to have passed "many anecdotes" relating to 'wild' white cattle on to Bewick and Beilby, constitute very strong evidence indeed.

So far as the illustrations in the *Quadrupeds* are concerned, the evidence is less conclusive but still strongly suggestive. We know that Bailey sent drawings of a bull and a cow to Tunstall during the period immediately prior to the preparation of Bewick's two small engravings of a Chillingham bull and cow for that work, but we do not know what Bailey's drawings looked like; the evidence we have from his published work is not dissimilar to the work of Bewick but could have been influenced by Bewick's work itself. We do, however, know that Bewick in other instances copied or modified the work of other illustrators (Davis & Holmes, 1993).

With respect to the single large woodcut of the Chillingham bull, it is probably not unreasonable to assume the following sequence of events: that Tunstall sent Bailey's drawings to Bewick, who decided to make use of them in the *Quadrupeds*. Tunstall then asked Bewick to engrave the figures onto one (copper) plate, but Bewick could not justify charging seven guineas merely for copying Bailey's drawings; he therefore visited Chillingham to make his own drawings. Failing to draw a cow but making a sketch of a bull, he produced his famous large woodcut by elaborating his earlier illustration in the light of his new, personal, observations.

Although Bailey's influence on the figures in the *Quadrupeds* may be disputed, the influence of Gessner's published woodcuts on Bewick's cattle illustrations is more conclusive. The posture of the Chillingham bull figured in the Quadrupeds may be merely suggestive of that of Gessner's bovids, but the similarity of that in the single, large, woodcut produced for Marmaduke Tunstall to those in Gessner's figures is too close to be coincidental.

Bewick's work has, quite rightly, generated much admiration over the last two centuries, but in some cases, for instance the works of Boyd (1886) and Thompson (1882), this has expanded to a form of unthinking veneration. The present generation of historians may believe that it is their purpose to 'debunk' previous notions, but we would be disappointed if this paper was seen as part of that trend: it is intended as an exploration of Bewick's influences and not as a criticism of his methods.

ACKNOWLEDGEMENTS

Our thanks are due first to Dr David Connell, Curator of Burton Constable, for his permission to publish the two letters from John Bailey to Marmaduke Tunstall. We are also indebted to the staff of the Humberside County Record Office, at Beverley, for their kind assistance.

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February 1929: an insight into the climatology of Northumbrian cold spells

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SUMMARY

Climate is an inherently variable part of our natural environment and will present us with periods of unusually cold and warm weather. This paper examines the peculiarly cold spell of weather that prevailed in the Northumbrian region during much of February 1929 and in doing so emphasizes those climatic elements which determine the character of all such cold outbreaks. Our region is fortunate is having two meteorological stations, Durham University and Sunderland, with records back to the middle of the last century and confident statistical comparisons are made with other periods of cold weather. Climatic variations within the region are also studied together with the local factors that control them.

INTRODUCTION

At a time when our preoccupation is with the apparent trend towards warmer winters (Cannell & Pitcairn, 1993) it is interesting, if not informative, to look back to what is now an 'endangered climatic species': spells of exceptionally cold winter weather. That of 1947 was notable for its abiding coldness and its prolonged duration and can be recalled by many in the region today. The shorter, though more intense, cold spell of February 1929 will however be a memory for only the oldest residents. The present writer was alerted to its passage by a request from the *Northern Echo* for information on the weather of that month following its discovery of a contemporary photograph of a spectacularly frozen High Force (Fig. 1). The information that was unearthed as a result of this request, both the purely climatological as well as the more anecdotal, threw into sharp focus the factors that determine cold spells in the Northumbrian region.

CLIMATIC BACKGROUND

January and February are the coldest months of the year in our region (Table 1), though the general temperature levels will vary across the region, being warmer in coastal districts but cooler inland away from the tempering influence of the North Sea, and colder again on the exposed high ground of the Pennines. The delay of the coldest month until after the winter solstice is a characteristic which the region shares with other mid-latitude maritime climates both in Britain and elsewhere. But in north-east England and south-east Scotland that characteristic may be intensified by the consequences of a commonly occuring synoptic condition when, during the late winter season, the cold anticyclone that usually dominates Scandinavia may combine with the larger Siberian 'high' that governs the winter weather of continental Asia. It is under those conditions that our region is most likely to experience the chilling effects of polar continental air of Siberian origin as it is drawn westwards by the circulation of air along the southern margins of the now extensive Eurasian anticyclone. The arrival of such air serves merely to intensify the already cool conditions of the season. Both pressure systems are purely seasonal and a result of the intense cooling of the land surface that takes place at that latitude during winter. Hence as the year advances into spring both the Scandinavian and the Siberian anticyclones weaken and disappear in the face of increased air temperatures and such outbreaks become less probable and less effective.

In the wider climatic setting, it should not be forgotten that the distribution of winds over the British Isles is dominated by westerlies and south-westerlies from the

Fig. 1 A photograph of the frozen River Tees at High Force taken in mid-February 1929. At the time it was the first such complete freezing since 1869. Comparisons with the propensity of the present day Tees to freeze over are difficult because of its controlled flow following completion of the Cow Green reservoir. Photograph by courtesy of the Northern Echo.

Atlantic. These prevail for approximately 70% of the time bringing frequently mild and often cloudy weather. The Northumbrian region is for the most part sheltered from these air streams which, while remaining mild have often lost a good deal of their moisture in negotiating the high ground to the west, the Lake District and the High Pennines in particular. Table 2 shows the annual frequency of wind and associated rainfall from different directions for Sunderland; these data are however typical for most sites in the eastern half of our region. The table shows how our exposure to easterly weather is expressed in the frequency with which such winds produce rain when the data are manipulated to give a standard 1000 hours of wind from each direction. Winds from a generally easterly direction provide, hour for hour, between three and four times as much rain as those from the west. Table 3 develops this theme and shows how the frequency of wind directions vary from month to month. The relative abundance of easterlies in February is noteworthy and a clear expression of the contribution of the late winter anticyclones to the region's weather in that month. Though not seen in these data, it is equally important to observe that easterly weather in February is, paradoxically, not wet and for most weather stations in Northumbria it is the driest month of the year. This dryness is a result of the anticyclonic character of the February easterlies which inhibit rain-making processes and vertical mixing of the atmosphere. Any precipitation which falls is usually in the form of snow. Occasionally, however, such snowfalls can be very heavy in north-east England and southern Scotland if associated with a low-pressure system crossing eastwards over southern England. This was the case in February 1941 when one of the region's heaviest snowfalls of the century occurred (Wheeler, 1991).

CLIMATE OF FEBRUARY 1929

Although the cold spell in February 1929 embraced the whole of the country, it was well-developed in the Northumbrian region. At its most intense, between 11th and 17th (Fig. 2), it was officially reported in the Meteorological Office's *Monthly Weather Report* to have been the coldest such period since that of February 1895. The degree of intensity of cold varied through the month, largely in response to the changing synoptic patterns. In fact the month started relatively mild and damp. Temperatures began to fall during the first week and by 11th a strongly developed anticyclone over Scandinavia had extended to embrace a large part of Britain. For the following week its grip, especially in eastern districts, was unrelenting. Milder conditions became general around 21st with the temporary return of 'westerly' weather and a weakening of the high pressure system. But the month concluded with the return of easterly winds and the resurgence of the anticyclone, though not with the same vigour as it had enjoyed earlier in the month. Although the subsequent cold weather persisted into early March it quickly moderated thereafter.

The averages for the month were well below normal. The Meteorological Office calculated that the north-east's regional mean was 3.6°C below normal, quite remarkable anomaly. Table 4 summarizes the data for some of the official Meteorological Office stations then operating; unfortunately none of them was on high ground and are unable therefore to indicate the greater degree of coldness likely to have been encountered in those areas. Under the prevailing conditions these would probably have been the coldest in England at that time. The source of the cold air was continental Europe and Russia where even more extreme conditions were widespread, extending as far as North Africa. The city of Budapest, for example, recorded on one occasion over 40 degrees of frost, which equates to -22°C. And, as if to provide a scene reminiscent of Agatha Christie's *Murder on the Orient Express,* the Simplon Express was held snowbound in eastern Thrace for a week. The Polish city of Krakow recorded a minimum of -34.4°F and news came from Sofia of nine people being attacked and killed by wolves starved of their usual food supplies.

Table 1

Mean monthly temperatures (°C) for the period 1980 to 1989 for sites in Northumbria. The sub-regional mean, based on the stations cited, is also given.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Newcastle	4.0	4.1	5.4	7.6	10.3	13.2	15.7	15.4	13.6	10.3	7.1	5.3
Durham	3.0	3.2	5.1	7.7	10.0	12.9	15.4	14.9	13.0	9.5	6.3	4.4
Sunderland	4.2	4.2	5.5	7.4	9.9	13.0	15.5	15.3	13.6	10.4	7.6	5.3
Low Etherley	2.3	2.2	4.3	6.5	9.4	12.3	14.9	14.2	12.2	8.7	5.5	3.8
Sub-region	3.38	3.43	5.08	7.30	9.90	12.85	15.38	14.95	13.10	9.73	6.65	4.70

Table 2

Table showing percentage of time for which winds of different directions prevail over Sunderland, the average rainfall yielded by those winds and the average rainfall standardised over a 1000 hour period of wind from each direction. Averages based on the observations between 1983 and 1989.

	north	north-east	east	south-east	south	south-west	west	north-west	calm
%time	9.7	3.6	6.1	10.0	8.4	23.8	21.8	5.7	10.9
Rainfall (mm)	90.1	37.3	49.6	98.5	54.0	81.0	53.1	50.8	40.9
Rainfall in 1000 hrs	105.9	118.8	93.0	111.7	73.2	38.7	27.8	102.0	42.6

Table 3

Mean percentage time for which winds prevail over Sunderland. The monthly averages are based on the period 1983 to 1989.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
N	3.8	7.1	8.8	16.0	24.1	17.3	9.7	9.7	6.6	3.2	7.9	2.0
NE	3.5	3.6	3.2	5.7	4.8	7.9	3.7	2.8	2.6	0.1	2.7	2.1
E	7.5	11.4	6.7	9.2	7.7	5.2	6.5	6.1	1.9	2.9	5.7	2.4
SE	5.5	8.2	9.6	13.0	13.4	18.1	12.2	9.9	5.8	9.0	7.5	8.0
S	10.6	10.2	9.9	6.3	5.1	2.0	3.2	6.8	8.7	13.8	12.3	12.2
SW	28.7	21.9	23.5	19.1	16.1	12.4	22.8	26.4	26.9	34.6	22.6	31.9
W	25.7	24.2	21.7	11.6	11.8	16.2	25.3	22.9	32.2	21.6	22.8	26.9
NW	6.5	5.7	7.7	5.2	5.2	6.7	4.9	5.1	4.9	3.0	6.9	3.6
Calm	8.2	7.7	8.9	13.9	11.8	14.2	11.7	10.3	10.4	11.8	11.6	10.9

Table 4

Mean and absolute maximum and minimum temperatures for sites in Northumbria during February 1929. Dates of the extreme temperatures are also given.

Station	mean maximum	mean minimum	daily mean	absolute maximum	absolute minimum	max/min dates
Berwick	2.9	-1.6	0.6	10.0	-9.4	4/14
Bellingham	2.2	-4.3	-1.1	8.9	-13.3	22/16
Cockle Park	2.5	-2.8	-0.2	8.3	-14.4	4/16
Tynemouth	2.9	-0.2	1.3	9.4	-11.7	4/14
Chopwellwood	3.0	-3.9	-0.4	9.4	-15.0	4/16
Durham	2.6	-3.3	-0.4	8.9	-12.2	4/14
Houghall	2.5	-3.8	-0.6	10.0	-18.3	4/17
Ushaw College	1.7	-3.1	-0.7	9.4	-11.1	4/16
Sunderland	2.9	-1.6	0.6	10.0	- 8.9	2/16

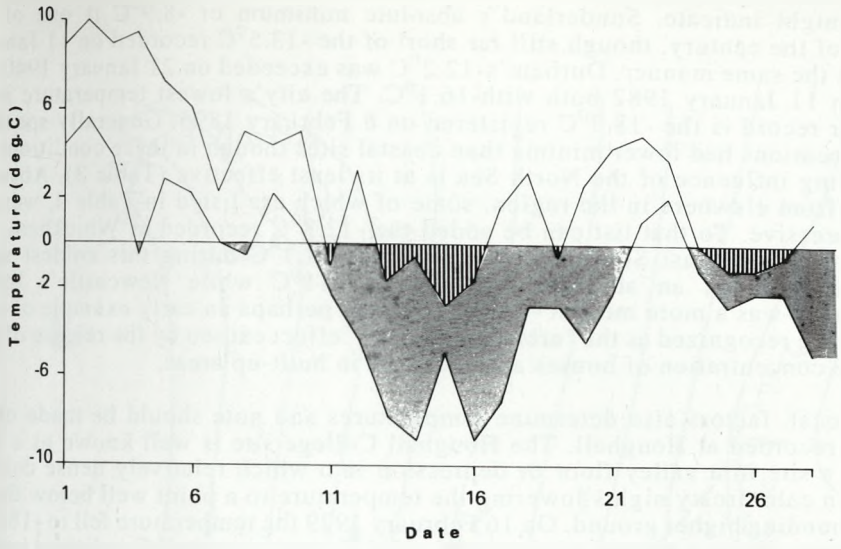

Fig. 2 Graph of maximum and minimum temperatures for February 1929 recorded in Sunderland by the Public Health Department at its Mowbray Park site close to the city centre.

There were also reports of the Siwa Oasis in Egypt freezing over towards the middle of the month.

Such exotic reports notwithstanding, the conditions in the Northumbrian region were themselves exceptional. By good fortune, two of the stations listed in Table 4, Durham and Sunderland, have sufficiently long periods of record to enable some statistical perspective to be given to the events of February 1929. Looking firstly at Durham, February 1929 was the coldest of any month hitherto in the century. It remained the coldest February until that of 1947 when a daily mean of -1.1°C was recorded. Subsequently the Februarys of 1963 and 1986 have also been cooler with means of -1.2° and -0.6°C respectively. Otherwise only the month of January has provided lower daily means, in 1940 (-1.5°C), 1941 (-0.5°C) and 1979 (-0.6°C). Night-time frosts were a particular feature of this spell and the mean minimum was to be later exceeded only by that of February 1963, with -3.9°C. The mean daytime maximum on the other hand, though cool, was not correspondingly anomalous and the mean maxima of five later months were lower; February 1947 (0.6°C), 1963 (1.5°C) and 1986 (1.8°C) and the Januarys of 1940 (1.6°C) and 1941 (1.7°C). All those months were again characterized by outbreaks of cold Siberian air.

A similar picture emerges for Sunderland, where once again February 1929 was the coldest of the century up to that time but since then, the means of January 1940 (-0.3°C), January 1941 (0.4°C), February 1947 (-0.2° C) and February 1963 (0.5°C) have all been cooler. The Sunderland weather station was temporarily out of operation in January 1979 but it seems likely that that month too may be added to the list of those that were cooler.

Figure 3 shows the distribution of pressure across the British Isles on 19 February 1929 and is generally typical of this and other late winter cold spells. The westwards limit of the European anticyclone is clearly seen and on this day cold air was being drawn westwards across the mainland before turning northwards. Conditions were milder in more western districts away from the influence of the Siberian airstream. During this coldest part of the month temperatures fell to levels far lower than the

means might indicate. Sunderland's absolute minimum of -8.9°C is one of the coldest of the century, though still far short of the -13.5°C recorded on 11 January 1982. In the same manner, Durham's-12.2°C was exceeded on 21 January 1940 and again on 11 January 1982 both with-16.1°C. The city's lowest temperature in its 140-year record is the -18.3°C registered on 8 February 1895. Generally speaking inland locations had lower minima than coastal sites though in these conditions the moderating influence of the North Sea is at its least effective (Table 3). Absolute minima from elswhere in the region, some of which are listed in Table 4, were no less impressive. To that list can be added the -12.8°C recorded at Whickham, and although on the coast South Shields recorded -11.1°C during this coldest spell. Gosforth recorded an absolute minimum of -11°C while Newcastle's lowest temperature was a more modest -9.4°C, which is perhaps an early example of what has become recognized as the 'urban heat island' effect caused by the release of heat from the concentration of houses and factories in built-up areas.

Other, local, factors also determine temperatures and note should be made of the minima recorded at Houghall. The Houghall College site is well known as a frost hollow, a site in a valley floor or depression into which relatively dense cold air settles on calm frosty nights lowering the temperature to a point well below that of the surrounding higher ground. On 16 February 1929 the temperature fell to -18.3°C. On the same night, a ground minimum of -20.6°C was recorded. Conditions on that night were perfect for the necessary 'cold air drainage' with mainly clear skies and calm conditions. Even these however were not records and Houghall recorded -21.1°C air minimum on 5 January 1941 (Houghall ceased meteorological readings in 1979 and no data are available for the remarkable cold spell of January 1982). To put these latter figures into a wider perspective, the UK record minimum is -27.2°C registered at Braemar (also a frost hollow in the Dee valley) in January 1982.

Some of the daytime maxima of this cold spell were also unusually low. A day on which the maximum temperature fails to rise above freezing point is known as an 'ice day'. Over the past two decades such days have occurred in Sunderland with an average frequency of once every three years (though they are more frequent further inland). Yet in February 1929 there were nine such days in Sunderland where the lowest of the maxima was -2.8°C, recorded on 14th. These were the lowest maxima of the century at that time and such figures were matched only by those of the cold spells that characterized Sunderland's weather in the 1870s and 1880s. Houghall recorded fifteen ice days in the month, the coldest being -8.1°C (on 14th). This extraordinary maximum was probably the result of stagnant cold air remaining in the valley floor throughout the day, the calm conditions being unable to agitate the atmosphere sufficiently to disperse the pool of chilled air that had gathered there. At Durham University's Observatory site, the lowest maximum of this spell was a warmer -3.9°C (on 12th). Such a figure was nevertheless notable by local standards and the then observer, Mr. Frank Sargent, reported that this low maximum had been 'bettered' only twice before since 1850, in December 1883 and December 1891.

Sargent made several informative observations on the last previous cold spell, which prevailed from 5 to 15 February 1895. Comparing the latter with the period 11-19 February 1929 he found the two mean maxima to be -0.7 (in 1895) and -1.6°C (in 1929). The two corresponding mean minima were -10.7 and -7.3°C. Overall, the 1895 period was slightly the cooler. The warmer days and colder nights of the 1895 spell reflect the differing degrees of sunshine and cloud cover. The latter enjoyed clearer skies with four hours a day of sunshine. Whilst the consequent direct solar radiation may warm the air during the day those same clear skies allow intense night-time radiant heat loss and rapid lowering of temperatures close to the ground. In 1929 conditions were often more cloudy, witness the average of only one hour a day of sunshine. Hence the daytime maximum failed to rise to levels of 1895. On the other hand the same cloud cover limited night-time heat loss.

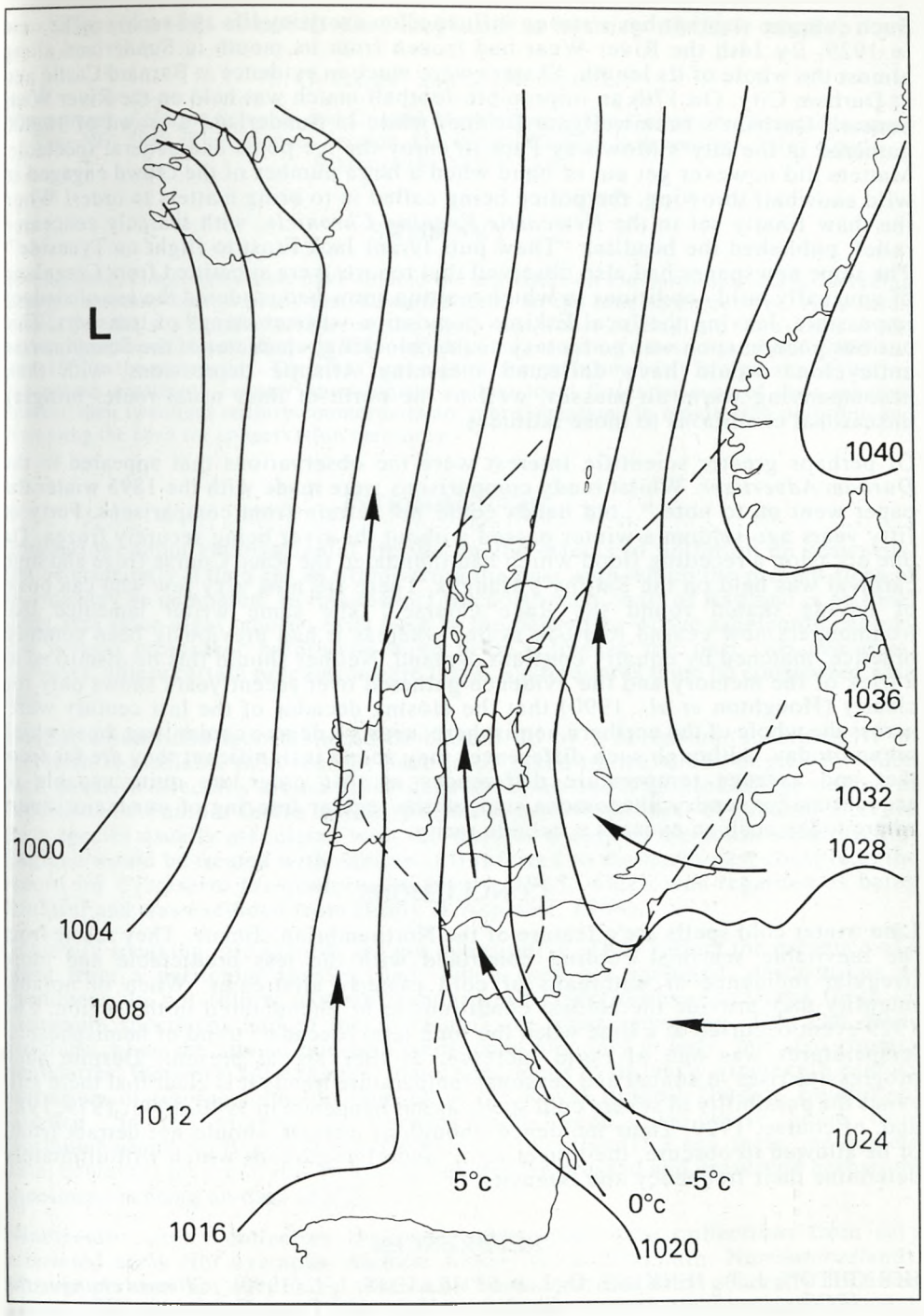

Fig. 3 Synoptic chart for 19 February 1929 showing the disposition of pressure systems. The air flow around the anticyclone centred over Scandinavia is shown by the arrows. Isotherms over the British Isles have also been included to reveal the pattern of temperature variations.

Such extreme weather has a strong influence on everyday life and such was the case in 1929. By 14th the River Wear had frozen from its mouth in Sunderland along almost the whole of its length. Skaters were much in evidence at Barnard Castle and at Durham City. On 17th an impromptu football match was held on the River Wear beneath Durham's Framwellgate Bridge, while in Sunderland a crowd of 10,000 gathered in the city's Mowbray Park to enjoy the ice pools and general spectacle. Matters did however get out of hand when a large number of the crowd engaged in wild snowball throwing, the police being called in to bring matters to order! When the thaw finally set in the *Newcastle Evening Chronicle,* with scarecly concealed relief, published the headline "Thaw puts tyrant Jack Frost to flight on Tyneside". The same newspaper had also observed that reports were submitted from Greenland of unusually mild conditions in which melting snow had rendered the use of sledges impossible, leaving the local Eskimo population without means of transport. This curious phenomenon was no fantasy as the 'blocking' character of the Scandinavian anticyclone would have deflected incoming Atlantic depressions, with their accompanying warm air masses, well to the north of their usual routes bringing unseasonal conditions to those latitudes.

Of perhaps greater scientific interest were the observations that appeared in the *Durham Advertiser.* Whilst ready comparisons were made with the 1895 winter the paper went on to note "...old hands could not refrain from comparisons. Forty or fifty years ago seldom a winter passed without the river being securely frozen. On one occasion a receding flood which had inundated the Race Course froze and high carnival was held on the Smithy's Haughs. There are now very few who can boast of having skated round the Race Course." The same writer lamented that ironmongers now ceased to stock skates whereas it had previously been common practice, matched by equally constant demand. Neither should this be dismissed as a trick of the memory and the evidence gathered over recent years shows only too clearly (Houghton *et al.,* 1990) that the closing decades of the last century were, across the whole of the northern hemisphere, nearly a degree cooler than those which prevail today. Although such differences may sound insignificant they are far from that and average temperature differences of that order are quite capable of accounting for sundry phenomena such as the regular freezing of our major rivers where today such an event is a notable rarity.

CONCLUSIONS

Late winter cold spells are a feature of the Northumbrian climate. They result from the inevitable seasonal cooling combined with the less predictable and more irregular incidence of outbreaks of cold easterly airstreams. When of notable intensity they provide the coldest conditions to be encountered in the region. The 1929 event occurred at a time when the long term (decadal) trend of hemispherical temperatures was one of rapid increase, as they are at present. Despite such progressive rises in annual and seasonal temperature trends it is clear that there still exists the possibility of severe cold spells as has happened in 1940, 1941, 1979, 1982 and, of course, 1929. Their incidence, though of interest, should not detract from, or be allowed to obscure, the longer term, underlying trends which will ultimately determine their frequency and intensity.

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The seaweeds of north-east England: a history of their study.

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SUMMARY

Several famous local naturalists have studied the seaweeds on the north-east coast, including George Johnston, George Brady and Edward Batters in the nineteenth century. As a result records for the marine macroalgae on the north-east coast of England date back to the beginning of the nineteenth century. The most detailed recording dates from 1829 to 1889 and from 1952 to the present day. There has been a great change in emphasis in algal studies during this period: nineteenth century phycologists studied local floras because of their inherent interest; their twentieth century counterparts are more interested in monitoring pollution and discussing the need for conservation measures.

INTRODUCTION

Conclusions about environmental change, or the effects of pollution on seaweeds, can be made only if data are available from the past with which the present flora of an area may be compared. In this respect the north-east coast of England is an ideal study area since algal records exist back to the beginning of the nineteenth century and several prominent naturalists have been active in the past two centuries. However, unless certain precautions are taken, such records must be considered with care.

Ideally, a published record should be backed up by a herbarium specimen: if no specimen is available then records have to be taken on trust. The degree to which such unverified records are accepted depends upon one's opinion of the degree of expertise of the author and/or the rarity of the species involved. For example a record for a species usually associated with the warmer waters of the south-west coast of England would be treated with caution if it referred to the north-east coast (e.g. the record for *Cystoseria foeniculacea* in Hardy, 1985, which was regarded as being doubtful and was excluded from Hardy & Aspinall, 1988).

Generally speaking, old records are not quantitative. They reflect the presence of a plant from a particular locality and, when they are included, descriptions of abundance do not follow modern standardized conventions. Localities (both on herbarium specimens and in the literature) are often imprecise. This can cause problems when the site in question transcends not only county, but also country boundaries: there are, for example, many specimens in the early nineteenth century herbarium of George Johnston (housed at the Royal Botanic Garden, Edinburgh) labelled "in the vicinity of Berwick-upon-Tweed". Do these come from Northumberland or Berwickshire (England or Scotland)? Even these incomplete data, however, are preferable to having beautifully pressed and preserved herbarium specimens bearing no data at all.

Nineteenth century collectors frequently only made their collections from very restricted areas (for example, Andrew Amory from Alnmouth, Northumberland). This is perhaps not surprising when one considers that they generally followed professions other than botany, and that they did not have the travel facilities which are now so easily taken for granted.

The record of a species being present at a locality is obviously important. However, the lack of a record may not necessarily indicate its absence. The apparent lack of a species at a location may reflect the difficulty of finding a single plant of a very

small species in a large area or it may be a reflection of the sampling techniques that have been used. This may, for example, explain why *Fucus vesiculosus* was not recorded from the Gateshead area of the River Tyne in a 1970-1971 survey (Edwards, 1972) when it was unquestionably present at that time in that part of the river (F. G. Hardy, personal observation). Because, unlike flowering plants, seaweeds do not have a large popular following, maps which show the distribution of marine algae in the country show a strong correlation between the distribution of individual species and the distribution of marine laboratories and Universities which employ, or have employed, marine phycologists. Victorian naturalists (not just phycologists) had a tendency to collect anything and everything that they found. Sadly, as a result, if a plant was found that was particularly interesting or rare, the chances are that it would not survive its discovery.

Taxonomists need to be up to date, and to know which Victorian taxa are no longer regarded as valid, otherwise it is not possible to make any conclusions about any reduction (or addition) in the number of species over a period of time. This may go part way to explaining why some authors have recorded considerable decreases in the algal population of an area as a result of pollution which have been rapidly refuted by others (for example the claim made by Bellamy *et al.,* 1967 refuted by Moss & Frankton, 1969).

This paper is an overview of the literature of the marine macroalgae of the north-east coast of England. References have been gathered from a variety of sources but draw heavily upon the bibliographies published in the *British Phycological Journal* (Dixon *et al.*, 1966; Price, 1967, 1984; Price & Tittley, 1970, 1975), and the checklists of Hardy (1985, 1987b). Nomenclature follows that used by Parke & Dixon (1976).

NORTHUMBERLAND AND DURHAM

A very detailed knowledge of the seaweeds of Northumberland and Durham has been accumulated over the past two centuries. Studies fall into three categories: studies of the entire area, those of particular localities, and those of individual species. In addition to a large published literature, there are extensive herbarium collections (particularly nineteenth century) to which reference can be made.

In the early nineteenth century botanists' interests tended to encompass the entire plant world rather than, for example, just the algae or just the flowering plants. As a result floras which deal largely with the angiosperms can often include details of interesting algae. Two such works are those of Dawson Turner (1775-1858) and Lewis Weston Dillwyn (1778-1855) (Turner & Dillwyn, 1805), for England and Wales, and of Winch *et al.* (1807) for Northumberland and Durham. The herbarium of Nathaniel John Winch (1768-1883) is now in the Hancock Museum, Newcastle upon Tyne, along with that of his contemporary William Robertson (died 1846). The north of Northumberland, around Berwick upon Tweed, commanded the attention of Dr J. V. Thompson (1779-1847), Surgeon to His Majesty's 37th Regiment, whose *Catalogue of Plants growing in the Vicinity of Berwick upon Tweed* lists the seaweeds found in Berwickshire and Northumberland (north of the river Aln) (Thompson, 1807) and, slightly later, of George Johnston (1797-1855). Johnston is famed as the founder of the Berwickshire Naturalists' Club in 1831, and his natural history studies include works on sponges as well as on botany (Johnston, 1842). His phycological herbarium is now at the Royal Botanic Garden, Edinburgh, and the specimens are cross-referenced to his flora (Johnston, 1831) and a supplementary list (Anon., 1834). Sadly most of the specimens are recorded from rather imprecise localities: only one plant has a definite site, a drift specimen of *Plocamium cartilagineum* ("*Ulva defracta*") from Coldingham in Berwickshire (outside the area of this study). Johnston continued his botanical forays along the coast of the eastern border counties, and published a second flora twenty-two years later (Johnston,

1853). This was to be the first volume of a natural history of the Eastern Borders, a project which remained uncompleted at his death.

By the mid-nineteenth century, algae had begun to be studied as a group of plants in their own right and subsequent floras of the area, such as those of Baker & Tate (1868) and Swan (1993), include only vascular plants, an exception to this trend being the new flora of County Durham (Graham, 1988) which includes bryophytes.

In the 1860s the whole of the Northumberland and Durham coast came under the scrutiny of George Stewardson Brady (1832-1921) whose *Catalogue* (Brady, 1861a) is a milestone in local phycological history. This was followed up by several papers including later records for the area (Brady, 1861b, 1862, 1863a, 1863b) and was the source for the algal records for County Durham in Potter's account for the *Victoria History of the Counties of England* (Potter, 1905). Brady was a graduate of the Newcastle College of Medicine, but spent most of his professional life as a zoologist. In 1876 he was made Professor of Natural History (i.e. Zoology) at the College of Physical Science, Newcastle upon Tyne, a post he held until his retirement in 1906. (A separate Chair of Botany was established in 1892 and its first occupant - until 1925 - was Michael Cressé Potter who wrote the account of the Botany of County Durham referred to above.) Brady's herbarium is now in the Hancock Museum, Newcastle upon Tyne. The specimens it contains originate mainly from the southern part of Northumberland and from County Durham (with very few specimens from Yorkshire). He obviously had several friends with phycological interests: some of their collections are incorporated with his own, others are in bound volumes, stored separately at that museum. The algal herbarium of the Hancock Museum also incorporates specimens formerly at Ushaw College, Durham and at the Department of Biological Sciences, University of Durham, making it the most important collection of Northumbrian seaweeds in the country.

In addition to these county-wide surveys, there are three localities which have received particular attention. The algae of Berwick-upon-Tweed (from Holy Island in Northumberland to Eyemouth in Berwickshire) were studied in great detail by Edward Batters (1860-1907) in the 1880s (Batters, 1882, 1883, 1884, 1888) culminating in a considerable check list (Batters, 1889) and a few later records (Batters, 1897, 1900). Batters went on to study the marine algae of the whole of the British Isles, and published a check-list of them (Batters, 1902) which is an invaluable guide to the nomenclature of the period.

Further south in Northumberland, the marine algae of Alnmouth were studied in detail by Andrew Amory (1841-1921) in the 1880s (Amory, 1884, 1885, 1887). Amory was, by profession, a wood-carver and he ultimately became keeper of the pictures and works of art belonging to the Duke of Northumberland at Alnwick Castle (Hodgson, 1921). The records published in his papers are all supported by fully documented herbarium specimens which were found in the attic of one of his descendants in Alnwick in the 1980s and are now in the Hancock Museum, Newcastle upon Tyne (Hardy, 1992). Following the discovery of his herbarium the algae of Alnmouth were studied by the Marine Conservation Society (Foster-Smith & Hardy, 1987; Hardy, 1987a, 1989).

In County Durham, the seaweeds of Sunderland were studied by Edward Backhouse (1808-1879) and his herbarium, a bound volume of 170 specimens, is now in the Sunderland Museum (Hardy, 1992).

During the second half of the twentieth century there has been considerable interest in the marine macroalgae of the Northumbrian coast. The British Phycological Society visited several locations in north Northumberland in 1959 (Jones, 1960a, b) and revisited Berwick-upon-Tweed in 1972 (Norton, 1976). A few records have also resulted from field meetings of the Northern Naturalists' Union: at Budle Bay and Ross Links (NNU, 1969), St Mary's Island (NNU, 1970) and Whitburn Steel (NNU, 1981). Blackhalls Rocks in County Durham were the site of natural history

observations by Preston (1915, 1923). Ecological studies have been carried out by John (1968), Rands (1986) and Seshappa (1948, 1956, 1961). Short notes record the finding of interesting individual species in the county (Blackburn, 1938; Lacey & Robertson, 1953; Morgan, 1953). In addition a short paper on the natural history of the local seaweeds was published during the First World War, when one might have expected people's minds to be otherwise engaged (Young, 1917). An interest in the effects of pollution has resulted in a number of papers relating to changes in the algal flora of County Durham (Bellamy *et al.*, 1967; Edwards, 1975; Malachtari, 1973; Moss & Frankton, 1969).

The seaweeds found at Berwick-upon-Tweed during the present century were summarized in a short paper which demonstrated the richness of the flora (Hardy, 1984). A total of 141 species has been recorded from Berwick during the twentieth century, which is comparable with the diversity found there by Johnston and Batters in the early and late parts of the nineteenth century respectively. This compares with sixty-four species recorded from Newton Haven by Foster-Smith (1984) and 266 species recorded from Northumberland and Durham in the twentieth century (Hardy & Aspinall, 1988).

The Farne Islands are an area of considerable importance and it is no surprise, therefore, that their macroalgae have been a topic of interest. Moss visited Inner Farne in the 1950s and her findings are summarized in a paper on that island (Moss, 1959). The outer Farnes were one of the sites visited by the British Phycological Society in 1959 (Jones, 1960a, b). A few years later the islands were the subject of a more wide-ranging biological survey (Thompson *et al.*, 1966) and, indeed they were among the first places visited following the launching of the Nature Conservancy Council's Marine Nature Conservation Review (MNCR) in the late 1980s. Conservation interests have resulted in several marine biological surveys being carried out in Northumberland in recent years, including the areas from Berwick to Beadnell (Connor, 1989) from Beadnell to Dunstanburgh Castle (Foster-Smith & Foster-Smith, 1987; Hodgson, 1984), Newton-by-the-Sea (Foster-Smith, 1983, 1984) and Cresswell to Newbiggin (McAllister, 1973). The literature for the east coast, from Orkney to Yorkshire, has been reviewed by the Nature Conservancy Council (Bennett, 1991), and the results of the most recent surveys carried out by the MNCR will, when completed, give a comprehensive view of the marine ecology of the area (Brazier *et al*, in prep.; Davies, 1994; Holt, 1994).

Several individual species have been the subject of scrutiny in recent years. The green seaweed *Codium fragile* subsp. *atlanticum* was first recorded from Northumberland in October 1949 (Moss, 1957) and during the succeeding few years spread southwards as far as St Mary's Island (Hardy, 1981). It then seemed to go into a decline and was not recorded at any sites in the region after 1980. However, the Joint Nature Conservation Committee's MNCR survey team recorded the species from Newton in 1992 and from St Mary's Island in 1993. The closely related *Codium fragile* subsp. *tomentosoides* spread rapidly along the coast of the neighbouring county of Berwickshire in the late 1980s (Hardy, 1990). The two subspecies of *C. fragile* found in Britain were described by Silva (1955): they have little in common and differ considerably in a number of anatomical characters, life history, and shore position (Burrows, 1991).

Fucoid algae have been the subject of much research at the University of Newcastle upon Tyne in the past forty-five years, since Betty Moss took up a lectureship there in 1949. Work which contributed to our knowledge of the local algal flora included detailed studies of the autecology of *Halidrys siliquosa* (Lacey, 1955) and on factors affecting the distribution of *Himanthalia elongata* (Mercer, 1976; Moss *et al.*, 1973). This large brown seaweed has large zygotes (*ca* 250µm) which require a firm substratum for settlement and light for germination. A combination of soft, easily erodable, magnesian limestone rocks and silt deposits which reduce light intensity, accounts for the species' absence from the coast of County Durham. It has recently

been demonstrated that naturally-occurring hybrids between *Fucus spiralis* and *Fucus vesiculosus* may be found at several sites in Northumberland (Mulyadi, 1995).

In 1910 a new species of alga was reported from St Mary's Island, and named *Chantransia sanctae-mariae* (Darbishire, 1910). It occurs as an endophyte in the reproductive fronds ('thongs') of *Himanthalia elongata.* Its affinities seem to have been uncertain at one time, but it is now regarded as a species of filamentous red alga and bears the name *Audouinella sanctae-mariae* (Dixon & Irvine, 1977a). The plant has not been recorded since its original finding and remains endemic to its initial location. Because it differs in many respects from other species of the genus *Audouinella* it has been retained in the latest flora (Dixon & Irvine, 1977b) despite obvious suspicions as to the status of a taxon known only from a single collection, particularly when the present location of this is unknown.

The coralline red algae have generally been under-studied because of the great difficulties encountered in their identification. However, the recent publication of the relevant section of the new seaweed flora (Irvine & Chamberlain, 1994) might result in this position being redressed. In Northumberland, the population biology of the encrusting coralline red alga *Lithophyllum incrustans* has been studied at two sites: Berwick-upon-Tweed and Hauxley (Ford *et al.*, 1983).

All records for seaweeds from Northumberland and Durham for the twentieth century have been summarized in two detailed check-lists (Hardy, 1985, 1987b) and their distribution has been plotted on a 1km square basis on 266 computer drawn maps (Hardy & Aspinall, 1988).

YORKSHIRE

During the closing decades of the nineteenth century and the early years of the twentieth century the Hull, Yorkshire, and Essex Naturalists' societies visited a number of sites on the Yorkshire coast; Scarborough (Anon, 1888; Anon, 1905; Holmes, 1883; Irving, 1918; Petty, 1901); Robin Hood's Bay (Bingham, 1933), Flamborough (Hey, 1888; Robinson, 1896, 1909); and Filey (Roebuck, 1883). These visits appear to have involved the collection and identification of specimens from a wide range of taxa (animal and plant), and the excursion accounts published in the journals of the various societies include lists of the macroalgae encountered. In addition, some information about the occurrence and distribution of the commoner (or at least more commonly identified) species is provided by the various tourist-type guides which have been published: Filey (Cole, 1828; Lewis, 1983; Shaw, 1867); Redcar (Ferguson, 1860); Scarborough (Hulme, 1842; Lewis, 1987; Massee, 1882; Theakston, 1861); Yorkshire (Inchbald & Baker, 1907; Inchbald *et al.*, 1922); Tees-mouth (Jones, 1966); United Kingdom (Turner & Dillwyn, 1805), east coast of United Kingdom (Walcott, 1861).

Such was the popular interest in seaweeds during the Victorian period during the 1880s, there was a marine algae collector called F. J. Holderness at Milton Street, Saltburn-by-the-Sea. His trade card announced "2s., 4s., and 5s 6d. per dozen specimens (150 varieties)" and proudly proclaimed "Foreign Specimens Procured".

More detailed (but localized) information regarding the ecology and distribution of the macroalgae is provided studies such as those of Massee (1885) and Perkins (1953) (although the dating of Perkins' study should be accepted with care as a number of the distributions she describes were in fact described by Massee in his 1885 paper) which describe the distributions of the algal communities of the Scarborough district. More recently, and in accord with current interest in the use of marine algae as indicators of pollution, Bird (1991, 1993) and Bird & Morris (1992) have described the effect of a short fall sewage outlet (and the effect if its closure) on the seaweeds of Jackson's Bay in the Scarborough district. Emery (1968), Philip (1934), George *et al.* (1988), Tittley (1988) and Wood (1988) provide

descriptions of the seaweeds of the chalk shores of the Flamborough Headland. Flamborough Head, together with Filey Brigg and Scarborough South Bay, were studied during a seaweed identification course run by the British Phycological Society in July 1994 (Hardy & Scott, 1994). A total number of ninety species was recorded: particular interest was expressed in populations of the dwarf form of *Fucus spiralis* var. *nanus* high on the chalk cliffs at Flamborough and on Filey Brigg.

The remainder of the work concerning the marine macroalgae that has involved the Yorkshire coast region is limited to the use of locally collected specimens for taxonomic studies, which are often the only records for species from the area. These have included the Nemaliales and Gigartinales (Dixon & Irvine, 1977a,b); the genus *Callithamnion* (Dixon & Price, 1981); the *Lithothamnia* (Foslie & Printz, 1929); the genus *Rhodymenia* (Guiry, 1977); *Ptilota plumosa* (Holmes, 1914); the Cryptonemiales, Palmariales and Rhodymeniales (Irvine, 1983; Irvine & Dixon, 1982; Irvine and Guiry, 1983); Johnston's (1842) account of the lithophytes of Britain; *Laminaria hyperborea* (Kain, 1971); the genus *Stictyosiphon* (Naylor, 1958); the *Sphacelariaceae* (Prud'Homme van Reine, 1982a, b); the *Phaeophyta* (Tittley & Tyler, 1983); the genus *Fucus* (Turner, 1802), and studies of the ecology of individual species such as *Callithamnion hookeri* (Edwards, 1979); *Ralfsia spongiocarpa* (Fletcher, 1981); and *Porphyra umbilicalis* (Grubb, 1924).

ESTUARIES

Certain species of marine algae penetrate estuaries, although there are few species which can tolerate great reductions in salinity. Generally speaking, red algae are the least tolerant and die out first, followed by the brown algae; some green algae are able to penetrate up into freshwater. The brown alga *Fucus ceranoides* is adapted to estuarine, low-salinity, conditions where it frequently replaces *Fucus vesiculosus*: it is present in the rivers Tweed, Wear, and Esk, and has not been recorded from either the Tyne or Tees (Suryono, 1996). However, the distribution of species in estuaries is also affected by pollution and the rivers Tyne, Wear and Tees have received the most attention in this respect. A survey carried out between 1929 and 1933 (Alexander *et al.*, 1935) showed the River Tees to have a varied and interesting flora, including delicate red species such as *Delesseria sanguinea*. By 1970-71, when the next algal survey was carried out, the river was severely polluted, largely as a result of the industrial developments on its banks (Edwards, 1972). The River Wear was polluted by domestic sewage at its estuarine end in the early 1970s, but was otherwise relatively clean (Edwards, 1972; Wilkinson, 1973). The River Tyne's main problem in the 1970s (when the first algal survey was performed) was domestic sewage (Edwards, 1972). In recent years a considerable effort has been made to clean up these rivers, resulting in a slightly more diverse flora found during a survey of 1991 (Hardy *et al.*, 1993), and a decrease in the nitrophilous species such as *Prasiola stipitata* that flourish in sewage polluted conditions.

The River Wansbeck has been the subject of a study by Vasisht (1965) and, more recently, Edyvean & Bailey (1984) used *Enteromorpha* and *Fucus* as biological indicators to monitor the levels of heavy metal accumulation in the estuaries of the rivers Wansbeck and Blyth. *Enteromorpha* had higher levels of copper, but lower levels of zinc, than *Fucus*. The two genera accumulated similar amounts of lead. Mean levels of metals in algae collected from the River Blyth between March and November 1983 were 21ppm copper, 27ppm lead and 389ppm zinc in *Fucus* stipes, and 51ppm copper, 35ppm lead and 94ppm zinc in *Enteromorpha*. Lower levels were recorded from coastal sites.

Between July and September 1992 the Marine Nature Conservation Review surveyed the estuaries between the Tweed and the Esk (Brazier & Murray, 1994). Their report records a total of 234 taxa (animals and plants) from the eleven estuaries studied,

and analysis of their data revealed twenty-three biotopes ranging from bedrock and sand biotopes to very distinct muddy and cobbly estuarine biotopes.

CONCLUSION

The various works referred to in this paper illustrate the interest that has existed and continues to exist in the seaweeds of north-east England. However, they also serve to illustrate a great change of emphasis which has occurred in algal studies during the past two centuries: whilst twentieth century phycologists are interested in monitoring pollution and discussing the need for conservation measures, their nineteenth century counterparts studied local floras because of their inherent interest.

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DISCUSSION ON PAPER BY MITCHELL ET AL. (1994) ENTITLED 'THE FLORA AND VEGETATION OF MAGNESIAN LIMESTONE SEA CLIFFS, COUNTY DURHAM' (*Trans nat. Hist. Soc. Northumb, 56, 153-175*)

Comments by D B Smith

I welcome the comprehensive record and analysis by Mitchell *et al.* (1994) of the flora of the coastal cliffs of County Durham, but I am concerned by the implied close link between most of the flora and the Magnesian Limestone. Although the authors note that the upper part of the cliffs is composed of glacial drift, it is not made clear that it is on this drift, and not on the Magnesian Limestone, that most of the plants grow. Only those relatively few species that have colonized the near-vertical rock face at the base of the cliffs can be directly related to the Magnesian Limestone; the connection between the underlying rock and most of the flora becomes increasingly indirect and tenuous in successively higher parts of the cliffs.

The distribution of the drift deposits of the Durham coast is documented in a complete cover of published 1:10,560 scale Geological Survey maps, which show that the drift of the cliffs commonly makes up more than half of their total height and is generally more than 15m thick; this drift is widely divisible into relatively uniform lower and upper boulder clay sheets and a more varied median deposit of sand, silt and (uncommonly) gravel (Fig. 1). The inherent instability of cliffs formed by this undercut and over-steepened drift sequence has led to mixing of the components through downslope creep, landslips and mudflows, but this is a one-way gravity-driven system and it is difficult to see how floras evolving high on the cliffs and on the cliff-tops could be directly influenced by the presence of underlying Magnesian Limestone. Given these relationships, is it not misleading to refer to these plant assemblages as floras of the Magnesian Limestone cliffs?

If, in answer to this question, it were argued that the drifts of the Durham coastal cliffs comprise debris from the underlying rock, then these drifts do indeed contain much detritus from the Magnesian Limestone. More than half of the small clasts in the lower boulder clay of the coastal belt are of Magnesian Limestone (Beaumont, 1967), but many of these clasts are of dedolomite (i.e. non-magnesic limestone) rather than dolomite; furthermore, this lower clay is generally less than 8m thick and, in the coastal cliffs, is the lowest and steepest unit of the drift and is only slightly less remote from the high-cliff and cliff-top floral assemblages than the Magnesian Limestone itself. With the Magnesian Limestone largely covered by the lower boulder clay, and therefore not available to contribute to younger drift deposits except by erosion of the lower boulder clay and from places where the latter was absent, it is not surprising that the median sands and the upper boulder clay contain relatively fewer Magnesian Limestone clasts (many of them dedolomite) than the lower boulder clay (Beaumont, 1967). Yet it is on these higher drift deposits, with their relatively lower Magnesian Limestone content, that most of the flora of the Durham coastal platform and cliffs has become established. The well-known chair-shaped damp hollows in the middle of the cliffs south of Blackhalls Rocks are a special case; they owe their origin to instability and headward sapping caused by water issuing at the contact between the wet median sands and the relatively impervious lower boulder clay.

It is not in question that soils and plant assemblages developed on these various drift deposits must be influenced by their Magnesian Limestone content, but it remains to be proved that this influence was generally dominant. Pending the advent of such proof, might it not be prudent to avoid using the term 'Magnesian Limestone' in connection with floras unless the two are closely juxtaposed?

Acknowledgement: Dr G. A. L. Johnson is warmly thanked for his helpful comments on an early version of this contribution.

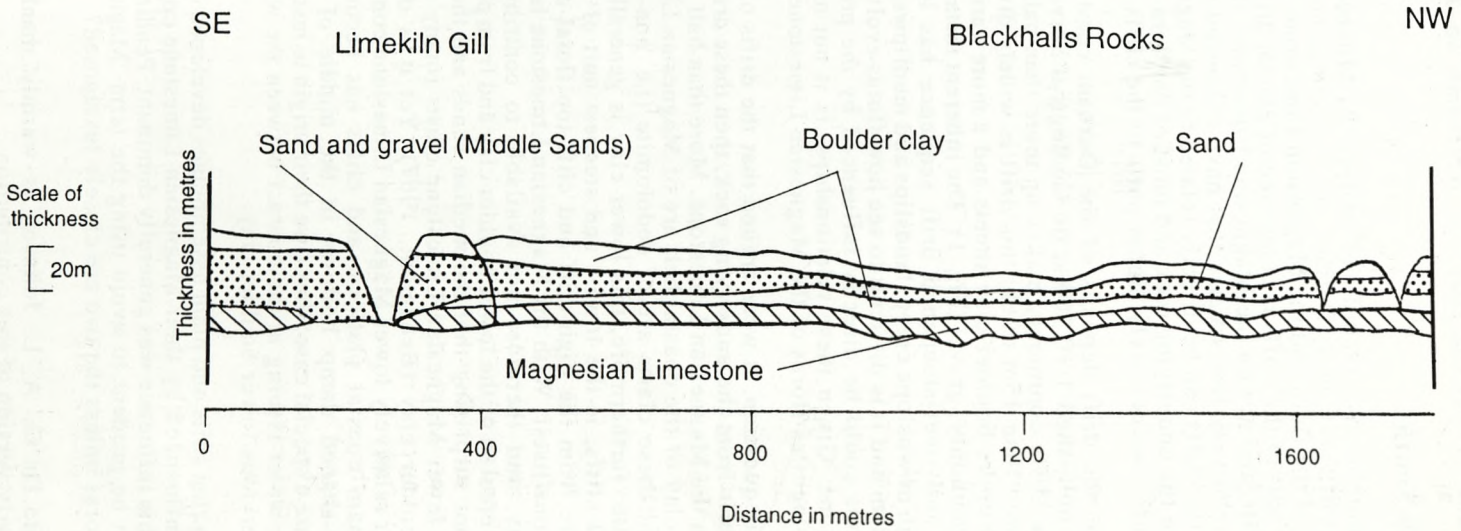

Fig. 1 The coastal cliffs at and near Blackhalls Rocks, showing the thick sequence of glacial drifts overlying Magnesian Limestone. Based on Smith, D. B. (1994) *Geological Conservation Review Series; Marine Permian,* fig. 3.55, by permission of the Joint Nature Conservation Committee.

Reply by D. N. Mitchell, A. W. Davison and J. A. Cooke

We are grateful for the opportunity to respond to Denys Smith's comments regarding our recent paper. He appears to express concern over two interrelated points that we will deal with in turn. These are: (i) It is not made clear in the paper whether the plants grow on the glacial drift or the Magnesian Limestone bedrock, and consequently there is a misleading implication that most of the flora and the Magnesian Limestone are closely linked; (ii) Most of the flora has developed on boulder clays with a relatively low Magnesian Limestone content, such that any link between the underlying rock and most of the flora becomes increasingly indirect in successively higher parts of the cliffs. Regarding the first point, it is made clear in the second sentence of the introduction (p153) that the Magnesian Limestone forms "... sea cliffs which are capped with dry banks and damp hollows of calcareous glacial drift ...". This point is re-emphasised in the site description (p155), where it is stated that "The cliffs and sea banks are capped with Pleistocene clays, sands and gravels resulting in a complex pattern of dry banks and damp hollows and variable soils ...". Once this sequence has been defined it is clear that the vegetation must grow on the drift and not on the underlying Magnesian Limestone bedrock. The paper, therefore, does not imply a misleading close link between the flora and the bedrock and such a link is never discussed at any point in the text. Instead, a range of other factors which may directly or indirectly influence the flora and vegetation is discussed, including the effects of sea spray and the moderating influence of the sea on the local climate (p161), flushed substrates with low nutrient levels (p163), leaching of agricultural fertilisers (p164) and the slippage of glacial materials with associated hydrological changes (p164).

We are in agreement with the second point. Although calcicolous grassland is undoubtedly the dominant type of vegetation growing on the glacial drifts, it is apparent in Tables 1 and 2 of our paper (pp157-158) that mesotrophic grassland and associated species represent a significant component of the vegetation and flora. This, together with the occasional occurrence of predominantly calcifugous species (listed in Appendix 1 of our paper) such as *Calluna vulgaris* (Heather), *Potentilla erecta* (Tormentil) and *Eriophorum angustifolium* (Common Cottongrass), suggests that some of the drifts contain little or no Magnesian Limestone. We agree with Denys Smith's observations in that such taxa tended to occur on the deeper drifts towards the higher parts of the cliffs, where they are furthest removed from the direct influence of the bedrock. Indeed, we have conducted further research into these observations by classifying the vegetation mosaics on the glacial deposits according to the new British National Vegetation Classification (NVC) (Rodwell, 1991a; 1991b; 1992; 1995) and relating these to habitat variables measured in the field. The results obtained have allowed us to propose a simple model to describe the general vegetation-habitat heterogeneity of the area (Fig. 2). A number of communities have been identified, ranging from unusual dune slack and calcicolous mire assemblages at the base of the cliff slopes to rank calcicolous and mesotrophic grasslands on the thicker drifts towards the higher parts of the cliffs. Many of these communities grade into each other imperceptibly to form complex transitional communities and vegetation mosaics over the various glacial deposits. We suggest that further research into these relationships is required and welcome Denys Smith's useful contribution to this subject.

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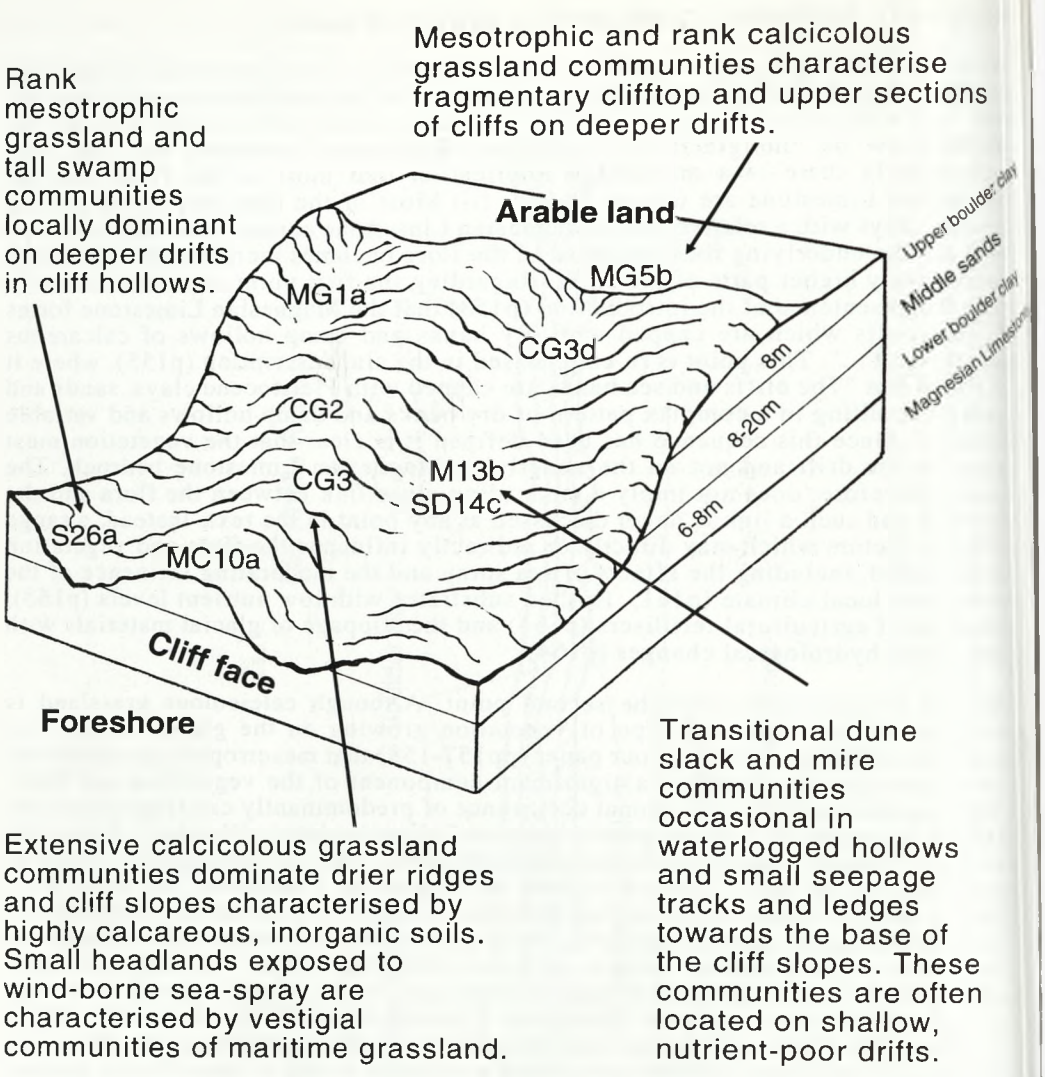

Fig. 2 Simplified model showing suggested distribution of NVC communities on the drift-covered sea cliffs on the Durham coast.

Key to NVC codes: *Phragmites australis-Urtica dioica* Swamp. *Filipendula ulmaria* sub-community (S26a). *Arrhenatherum elatius* Grassland, *Festuca rubra* sub-community (MG1a). *Cynosurus cristatus-Centaurea nigra* Grassland, *Galium verum* sub-community (MG5b). *Bromus erectus* Grassland, *Festuca rubra-Festuca arundinacea* sub-community (CG3d). *Bromus erectus* Grassland (CG3). *Festuca rubra-Avenula pratensis* grassland (CG2). *Festuca rubra-Plantago maritima* Maritime grassland, *Armeria maritima* sub-community (MC10a). *Salix repens-Campylium stellatum* Dune slack, *Bryum pseudotriquetrum-Aneura pinguis* sub-community (SD14c). *Schoenus nigricans-Juncus subnodulosus* Mire, *Briza media-Pinguicula vulgaris* sub-community (M13b).

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STAFF:

Mrs P Hammock, Mrs J Jones, Mrs M A Patterson, Mrs R Wolland (retired)

GOSFORTH PARK NATURE RESERVE

Warden: P Drummond

THE HANCOCK MUSEUM

Principal Keeper: A Coles

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR ENDED 31 JULY 1996

This year the Society has been saddened by the untimely death of its President, His Grace the 11th Duke of Northumberland, in October 1995. Mr Derek Shannon, the Chairman of Council, spoke in appreciation of the Duke at the next meeting of the Society and a shortened version of his remarks appears at the end of this report.

Shortly afterwards, at the annual meeting, Mr Shannon announced that both he and the Honorary Treasurer, Mr Edwin Slack, would be retiring. Together they had led the Society for more than a decade with tireless vigilance, wisdom and skill. Happily they both remain members of Council, but it will not be easy to maintain the standards that they set.

These events and many others have been set out later in this report by many contributers to whom as the new Chairman of Council I am very grateful, but my special thanks are due to Mr David Noble Rollin whose annual task it is to write the report which appears above my name. The Council then scrutinises and suggests changes in the text with great care, so that it is truly the report of the Council. We hope members will read it with interest and will be stimulated by the wide variety of our activities to take an even more active part in our affairs. Some points deserve to be highlighted in this introduction.

The finances of the Society are in a healthy state. Mr Edwin Slack achieved remarkable improvements during his fifteen years as Honorary Treasurer and his successor Mr Richard Slack is clearly a chip off the old block. But the museum's finances, by a series of agreements, lie separately in the hands of the University of Newcastle and we are much indebted to Professor Ben Farmer and to Professor Richard Bailey, who took over from him as Chairman of the Museum Management Committee during the year, for their fair minded and energetic championing of the museum's cause, an undoubted expense for the University in very difficult times for University finances. Members will have been impressed by the transformations wrought by Mr Alec Coles and his colleagues in the last three years but running a museum in competition with all the other attractions of modern life is uphill work and we depend also on you as members to use the museum, to spread news of its exhibitions to friends and to make sure that attendance numbers are increased. The visitor numbers for the splendid (and expensive) Pterosaurs exhibition were frankly disappointing, though I wonder if only paleontologists and children really knew what pterosaurs were and whether the outmoded term pterodactyls might have attracted larger crowds.

The report contains news of our plans to build a fine modern extension to the rear of the museum. This will be architecturally exciting yet in sympathy with the much loved (and Grade II* listed) Hancock building. It will make space for conservation, storage and study of the ever increasing collections, as well as a new gallery for temporary exhibitions and, very importantly, a new lecture theatre. This can be achieved only if we succeed in our bid for a very large grant from the National Heritage Lottery Fund, and for matching funds from elsewhere. Please help with this if you can, even if only by spreading enthusiasm for the plan. Mr Coles deserves high praise for his masterly production of the Society's bid to the Lottery Fund.

Finally and most importantly for the primary purposes of our Society, a word about the Society's role in the study of natural history. The report includes some impressive information on ornithological research by the ringing group in Gosforth Park, on the Farnes and on Coquet Island. The Society has a fine record of active research over the last 167 years. As Chairman, I hope that in the next few years increasing numbers of members will collaborate in research projects in all fields of local natural history, using the resources of the library and the museum for reference and drawing on the enthusiasm and experience of the many expert naturalists amongst us, submitting their work for publication in the Society's *Transactions*, and together building an increasingly rich fund of reliable knowledge of our natural surroundings.

MEMBERSHIP

The total membership (with 1995 figures in brackets) on 31 July 1996 was 884 (921). This was made up of 7 (6) honorary members, 42 (43) life members, 529 (582) members who receive *Transactions*, 269 (259) members who do not receive *Transactions*, 28 (22) associate members, 2 (1) school and 7 (8) complimentary members. Several people make payments under long-standing bankers' orders ranging from £1 to £12, made when these sums were the current subscription rates, and they are regarded as donors and not members.

The Council reports with much regret the death of five members, The Duke of Northumberland (1989), Professor G S Rushbrooke (1965), Dr J P Hurley (1955), Mr A M Bankier (1980) and Emeritus Professor T S Westoll (donor). The dates in brackets are the years in which they joined the Society.

COUNCIL

This year has seen a number of important changes in the membership of the Society's Council. At the annual meeting in November 1995 the Chairman, Mr Derek Shannon, officially announced that Mr Eddie Slack would be retiring as Honorary Treasurer after fifteen years. The previous year Mr Slack had indicated that he wished to retire from this post. He had guided the Society's finances over the last fifteen years with great ability and expertise and he had nurtured the Society's investments to such an extent that their value has increased many times. His close eye on the day-to-day running of the Society has meant that it can claim to be both financially sound and extremely efficient in its management. He supported the Chairman throughout the various traumas of the last nine years, adding his financial acumen and attention to detail to the team that worked on the problems. On behalf of Council Mr Shannon proposed that Mr Slack be made a vice president of the Society and this motion was carried unanimously. Although the Society will have a new treasurer, Mr Slack's commitment will still be evident with his presence on Council as a vice president, and as a trustee, a member of the Hancock Museum Management Committee and chairman of the Gosforth Park Management Committee.

At the same meeting Mr Richard Slack was elected as Honorary Treasurer. He had been working with his father since June to ensure a smooth takeover. Richard is a qualified Chartered Accountant who lectures in finance at the University of Northumbria, and the Society is very lucky to have a young and active accountant of his calibre in charge of its finances.

Mr H H Chambers and Mr A Creedy were also elected to Council as representatives of the members and Mrs S Chambers, Mrs J Holmes and Dr T G Walker retired by rotation.

Mr Hugh Chambers has been a member of the society since 1957 and has been on Council before. He works tirelessly for the Society's library and was recently made Chairman of the Library Committee. Mr Allen Creedy is the Countryside Officer for the Planning Department of Newcastle City Council; he organises most of the work that is done in the nature reserve and is on the Gosforth Park Management Committee.

At the January Council meeting Mr Derek Shannon opened the meeting by saying that he wished to retire as Chairman, a position that he had been honoured to hold for the last ten years. He announced that Dr David Gardner-Medwin had agreed to become the Society's next Chairman and with great relief of Council elected him unanimously.

Mr Shannon took over as Chairman from Sir James Steel in 1986 and has steered the Society through many difficult times. Firstly the death of Grace Hickling was a major blow and the Society's recovery and onward progress owes much to the very hard work that he undertook during the ensuing years. Following rapidly on from this blow was the announcement by the University of Newcastle that they were going to mothball the Hancock Museum unless there was a reduction in their financial commitment to its running. This problem continued for over three years of extremely difficult negotiations in which Mr Shannon played an important role. The successful outcome, with Tyne & Wear Museums taking over and increasing the Hancock's popularity and profile within the local community, owed its success in no small part to his work, which often proved difficult and very time consuming for him. At the same

time the Society was fighting a battle with High Gosforth Park Racecourse over their plans for large developments within Gosforth Park.

Although his time was taken up with these major issues, Mr Shannon also bore in mind the importance of the production of the' Flora of Northumberland' and was constantly urging the staff to complete the project. We wish him every happiness in his retirement both from the chairmanship of the Society and his position in the University, but hope he will be present on Council in his capacity as a vice president for many years to come.

PUBLICATIONS

During the beginning of this financial year 'Robson's Geology of North East England' was published and sent out to those members who receive the *Transactions*. Although another major issue is almost ready it has not been possible to complete it within this year, due to pressure of work in the Society office.

Other publications produced were 'Birds on the Farne Islands in 1995' and the 1995 annual report, both now part of the *Transactions*. The office has also been involved in the production of the *Fossil Vertebrate Catalogue* which is being printed by the museum.

STAFF AND MANAGEMENT

The Society is run by a mixture of paid staff and volunteers. The success of the office in coping with the work of looking after the membership and producing bulletins and publications depends on a successful team effort from everyone involved. The following members of staff and volunteers have made it possible for the Society to complete most of its commitments during the current year: Mrs Rita Wolland, who has been working in the Society office for many years, intimated that she would like to leave so that now her husband had retired they could pursue their hobbies without her weekly commitment to the office. Rita, who looked after the day-to-day accounts and the ringing returns from the Farne Islands, stayed on until Mrs Joyce Jones had been able to learn the basics of the work. The Society would like to thank her for the dedication that she has shown to her work and the amount of voluntary time that she put in at home on the ringing returns. This was greatly appreciated and Council wishes her success in her well earned retirement.

Ms Tricia Hammock is responsible for the covenants, bankers orders and exchange of periodicals with other organisations around the world, and she also puts in many hours of voluntary work above her office duties.

Mrs Margaret Patterson continues her secretarial work and is assistant editor of the *Transactions*. A great deal of her time this year has been spent in the preparation of material for volume 57 part 1 of the *Transactions*, due out shortly, and the Society is particularly indebted to her for her work on editing 'Birds on the Farne Islands in 1995' and the annual report.

Mrs Joan Holding has continued to illustrate the bulletin, helped the Secretary to prepare identification posters for the Scout Camp in Gosforth Park and undertaken other graphic tasks that have required her special skills.

Mrs Janet Angel continues to assist in analyzing the logbooks from Gosforth Park. She comes into the Society's office periodically to collect the information and a month or two later returns with detailed lists of species seen etc.

Mrs Anna Newson has worked diligently on upgrading the catalogue of papers in the *Transactions* which should eventually become both a subject and author database and a catalogue which will be printed in the *Transactions* for the use of members. She has also collected and listed all the papers on the Chillingham Wild Cattle that could be found and a number of researchers have already come to the library to use the information.

Mrs June Holmes is now mainly occupied in producing the catalogue of the manuscripts held within the museum. This will make it possible for researchers to locate more easily the enormous amount of original material that is held in the archives.

Mrs Sheila Mullan has begun the mammoth task of transcribing the letters and documents in the Society's archives which will assist Mrs Holmes in her work and will also help preserve documents as researchers will be able to read transcriptions before they decide if they need to see the original.

Mrs Joyce Jones joined the staff in June 1996 and is taking over from Mrs Wolland. She will be responsible for the day-to-day finance in the office and will help in general secretarial duties.

Without the support and help of this dedicated team of volunteers and staff the Society would not be able to undertake so many commitments, and Council would like to thank them all for their contribution throughout the year.

HANCOCK MUSEUM

The past year has been very much a 'curate's egg' with significant successes being mixed with disappointments. Whilst the visitor figures for the last financial year were disappointing at just over 118,000, there were a number of exciting developments. There is no doubt that the forthcoming year is little less than 'make-or-break' time as far as the museum is concerned, depending on the fate of the museum's application to the Heritage Lottery Fund.

Living Planet Probably the most significant achievement of the year has been the opening of the new 'Living Planet' display on February 2, by the Lord Mayor of Newcastle upon Tyne, Councillor Barney Rice. This gallery is important for many reasons: in the first place it shows the important environmental mission of the museum - something of which most Society members are aware, but casual visitors less so. Secondly, the gallery provides a large number of interactive exhibits, ranging from simple magnetic jig-saws to computers and video-microscopes. Museum staff have been at pains to combine the new technology with a wide range of natural history specimens, and this approach has been greatly appreciated by visitors. Finally, the gallery represents a fruitful collaboration between the Hancock and a number of commercial sponsors. Support has been received from the Environment Agency (through one of its precursors, the National Rivers Authority), Northern Electric, Northumbrian Water Group Plc, and Procter & Gamble. All these companies contributed expertise through their collaboration as well as cash. Their cash contribution was matched with awards from the Government's Pairing Scheme, and a variety of charitable trusts. The total value of these contributions was in the region of £36,000. Great credit is due to Ms Sheila Chapman, the Sponsorship and Development Officer of the North of England Museums Service (NEMS) who secured the majority of these funds.

Museum Development A large amount of time has been spent this year preparing development plans for the future five years and beyond. The reasons for this have been two-fold: in the first place to establish where the museum is going. In the second place, to prepare a bid to the Heritage Lottery Fund (HLF). To this end, a bid to the HLF has been submitted for a grant of approximately £5.2million, as part of an overall scheme costing £6.6 million. The plan includes an extension to the rear of the building which will include: a purpose-built gallery of 380m^2 to accommodate large touring exhibitions; 400m^2 of new storage areas for the collections; office, conservation and laboratory facilities for staff, Society members and visiting researchers; a fully-equipped education area suitable for teaching up to 60 children; a high-quality lecture theatre for up to 150 people, with both internal and external entrances, so that it can be used outside museum opening hours; a new cafeteria for visitors, with associated WCs; lift access to all three floors.

In addition, the plan seeks to address the future of the existing building, in particular the refurbishment of the roof, the replacement of the antiquated heating system with full air-conditioning and a programme of gallery renewal.

A number of applications have been prepared for other funding bodies and charitable trusts, with a view to raising the additional money required, should the application to the Heritage

Lottery Fund be successful. Special thanks are due to Ms Jane Goddard, who, until recently was Development Officer for Tyne & Wear Museums and who worked tirelessly on these applications. In addition, thanks are due to Mr Peter Howe of Pearce, Howe, Murray (architects), Messrs Fred Cosgrove and Peter Carruthers of Hall & Partners (quantity surveyors), and the staff of T G Armstrong, all of whom have donated significant amounts of time and expertise in the development of the bid. The project team was brought together with the assistance of Mr Stan Henderson, the University's Director of Estates.

Major Temporary Exhibitions The undoubted success of 'Living Planet' has not been matched by that of the year's major temporary exhibitions. The 'Megabugs' exhibition performed less well than expected. It was possibly a victim of the unusually good summer weather in 1995. This was unfortunate because the exhibition was unquestionably one of the most impressive seen in this country: not only for its giant animated model insects but also for a spectacular 3-D slide-show. We are extremely grateful for support of the exhibition from Eldon Square Shopping Centre, Tyne Tees Television, Ingersoll Rand, and Tyne & Wear PTE.

The other 'blockbuster' exhibition of the year was the 'Pterosaurs - Rulers of Jurassic Skies'. Whilst the modelling of the animals was extremely good, the animatronics proved unreliable, and this exhibition also failed to live up to visitor expectations. It has been necessary for the museum to reclaim liquidated damages in respect of the poor performance of the creatures during the early part of the exhibition. We would like to record our sincere thanks to Century Radio for their support of the exhibition; as first-time sponsors their support received awards from the Governments Pairing Scheme and the Sponsors Club (see below). We would also like to thank the students from Cleveland College of Art and Design who produced the back-drops, and Tyne & Wear PTE who again provided marketing assistance. On 15 January the exhibition was featured on BBC's Blue Peter Programme. This gives the Hancock the distinction of featuring on Blue Peter twice in a year!

Other temporary exhibitions For the first time, a number of smaller exhibitions have been organised to complement the main temporary exhibitions. Several of these were extremely successful and created a great deal of interest amongst press and public alike:

'Messel Fossils' was a small travelling exhibition from Germany featuring high quality specimens and photographs.

'Water for Wildlife' was an exhibition of children's work for an annual competition sponsored by North East Water and organised by the Northumberland Wildlife Trust.

'The Travelling Discovery Centre' is a 'hands-on' natural science exhibition toured by the Natural History Museum. It was opened on 7 September by Mr Peter Gates, the Manager of Marks and Spencers' Metro Centre Branch (M&S sponsor the tour). The exhibition ran until October and was booked especially to coincide with the British Association for the Advancement of Science Week in the University of Newcastle upon Tyne. Also organised to coincide with the BAAS festival was an exhibition of superb minerals and agates organised by the Russell Society's North Eastern Branch.

'Behind the Scenes' (1 March-31 May) was an interesting exhibition of prints based on the Hancock's collections, stores, and work, by Anti Hachler following a short residency.

'Birds and Flowers of the Castle of Balmoral' (3 June-12 July) was a superb exhibition of the beautiful paintings produced by Newcastle artist Mr James Alder for his new volume in honour of Her Majesty the Queen. It created a good deal of press interest in Scotland.

'After Chernobyl - Cornelia Hesse-Honegger' (15 July-8 September) turned out to be the 'press coup of the year' for the museum. It represents the first British showing of this important exhibition featuring dramatic images of insects and marine animals mutated by the effects of radiation. It has been featured far and wide, both on radio and in the press.

Educational Work As usual there has been a full programme of formal and informal education activities to support the museum's exhibitions and displays. The Time Travellers living history activities again dominated the schools work, with sessions organised in the autumn and spring terms as usual, and for the first time, summer term , also. In all cases the

original dates had to be extended to cope with the increasing demand from schools for this type of activity. This year the Time Travellers activities won a BT North East Museum of the Year Award for 'Best Educational Initiative', which was recognition, not only of the Hancock's delivery of the activities, but of the quality of the activities themselves as developed by Mr Jon Price of the Time Travellers Company.

The popularity of the 'Year of the Bug' activities with schools contributed to the large number of school and further education students visiting the Hancock in the financial year 1995-6: the total was 31,312, an increase of over 6,000 on last year's figures. This represents nearly one third of students visiting all Tyne & Wear Museums - a significant achievement given that the Hancock is the only museum of the twelve that charges admission, and a testimony, once more, to the tireless efforts of Ms Gillian Mason.

The museum ran two weekends of 'Family Fun' events on the theme of 'Flight' for the BAAS Science Week (SET 7) in March. These tied in with the 'Pterosaurs.' exhibition and included an illustrated talk on evolution of pterosaurs by Dr David Unwin of the University of Bristol, 'Pterosaur Tales' for younger children, and an exploration of 'human flight' with an early aviator (played by an actress!). Staff were also involved in the three-day science event at the University and ran activities for 12-15 year olds, focusing on fossil evidence for pterosaurs and dinosaurs. Other Family Fun activities taking place during the year included a Spider Weekend (with Mr Michael Mann), environmental activities to tie in with the 'Living Planet', an Easter Prints workshop with Anti Hachler, the ever-popular Behind the Scenes Tours and the intriguingly named 'Shadows of the Pterosaurs' and 'Family Fern Day'.

Visitor Surveys and Access In order to try to find out why people came to the museum, and what they thought of it, a programme of market research was carried out. It appeared that price was not a major factor in deciding whether or not to visit. The socio-economic position of visitors showed an improved spread, with 41% from socio-economic groups C2, D and E. Given the requirement for the Hancock to levy charges, this improvement is most welcome.

Twenty-two per cent of visitors had not visited before. The main 'like' , and indeed the main reason for visiting was always the temporary exhibition. The main 'dislike' was the front access for visitors with mobility difficulties (6%). This confirms the importance of eliminating this barrier in the development plan for the museum.

The remaining access problems seem to be the main reason for the museum failing to win the Gulbenkian Award for provision for disabled visitors, despite reaching the final short-list of four. A number of further objectives of the museum's Access Strategy have been achieved: an Intellectual Access Audit has been carried out , looking in particular at the effectiveness of new gallery developments in reaching ordinary visitors, and those with learning disabilities. The audit has been carried out by two organisations: Percy Hedley School and Skills for People. The work has received generous funding from the Museums and Galleries Commission (67%). In addition audio-guides have been produced for the Living Planet Gallery and are available to all visitors, but are particularly useful to those with visual impairment.

Claws! on Tour It should be remembered that the Hancock is no longer responsible for educating only within its four walls! The 'Claws!' exhibition, built at the Hancock in association with Redman Design Associates, has been 'on tour' ever since. This year it visited Sunderland Museum and Art Gallery, Oldham, Dundee and Gloucester Museums. It broke attendance records in the first three of these venues, and did exceptionally well in the fourth.

Collections Management and Research Possibly the main development in collections management has been the agreement with the University of Newcastle to acquire the mineralogical collections of the University, together with an important collection of botanical illustrations, on long loan. Although the mineral collection is both extremely important, and was under severe risk, the Principal Keeper was reluctant to acquire the material *on loan* unless a satisfactory agreement could be secured (there would have been a danger of devoting space and resources to a collection that could have been recalled by the University at any time). Happily, the University was persuaded to agree to a 63-year loan, terminating in the year 2058. This is when the University must decide whether or not to renew its management agreement

with the Natural History Society, at which point the ultimate fate of the collections can be determined.

A further factor in favour of acquisition was a grant of £6,800 to provide cataloguers and equipment to care for the collections from the Higher Education Funding Council for England. A further grant of £5,500 has been made in respect of the conservation/storage of the collections for the current year. The collections also came with their own storage furniture.

Cataloguing of the mineral collections was completed by three contract cataloguers, Mr Darren Hudson, Miss Louise Hollingsworth and Miss Sarah Studd (the former two staying well beyond their paid contracts to complete the task voluntarily), whilst cataloguing of the botanical illustrations was carried out by Miss Alison Evans, a student on the University's Museums Studies course.

Significant progress has been made on re-storing and cataloguing the museum's collections of bird mounts and skins. This represents a combination of the continued transfer of items from the attic, and the rationalisation of storage areas behind Abel's Ark. The work has led to possible the 'discovery of the decade' by Mr Les Jessop, who tracked down and identified no less than thirty two mounted birds figured by Thomas Bewick, as reported in the Society's *Transactions*. Whilst these historic specimens have been consigned to a special secure area in the stores, a new specimen has been thrust into the limelight, namely a dodo reconstructed by Mr Eric Morton according to the latest theories.

Further re-storage of geology collections has been possible, in part due to the dismantling of the 'Yesterday's World' gallery. An extension to the type and figured store has been made, and this is providing a home for a large number of palaeontological specimens. The long-awaited publication, of the 'Catalogue of Type and Figured Palaeontological Specimens in the Hancock Museum' is now imminent. Mr Steve McLean has spent a good deal of time preparing the catalogue (initiated by Mr Andrew Newman some years ago), and the final product looks impressive indeed. Special thanks are due to Mr Noble-Rollin and Ms Tricia Hammock in the Society's office who prepared the camera-ready copy for publication.

Mrs June Holmes is progressing well with the Pilgrim Trust-funded work on the archive collections held in the museum and the Society's library, office and council room. A catalogue is to be produced and it is hoped that this will form a special volume of the *Transactions*.

It should be remembered that the care and conservation of collections is just as relevant to their display as to their storage. It is pleasing, therefore, to report that the Visual Arts Year exhibitions have provided the stimulus to install protective screening against ultra-violet light in key display areas. This will obviously increase the range of exhibitions and sensitive material that can be shown in these galleries in the future.

Aquisitions The majority of aquisitions this year have been of carcasses of birds and mammals. In addition to the long-loan collections noted above, notable items received as gifts include: a fossil of *Pitys primaeva*, collected at its type-locality at King Water Burn by Mr Anthony Tynan and an historic specimen of an armadillo from Brazil, from M. Raquel Medeira Marques.

Internet Connections One exciting extra-mural development has been the creation of an interactive 'home-page' for the Hancock Museum on the World Wide Web. This allows anyone with access to the Web to find out about the museum, its facilities, its current exhibitions and exhibitions for hire. The page (in actuality a number of linked pages) was created by Mr Kevin Hughes and is certainly one of the better museum pages that we have seen. It is the intention that collections data will be added to the information available at the earliest opportunity.

Awards and Grants The museum has been lucky enough to receive a number of awards this year:

BT North East Museum of the Year Awards: reference has been made to the success of the Time Travellers activities, and it was with much satisfaction that the BT North East

Museum of the Year Award for Best Educational Initiative was received at the awards ceremony at the Hancock on 9 January. In addition the museum received a commendation for 'The Most Innovative Display' for the Monster Creepy Crawlies exhibition, and a member of the public received a runners-up prize for their nomination of the Hancock as Best Children's Visit.

'Pairing Scheme'(National Heritage Arts Sponsorship Scheme): Century Radio (for 'Pterosaurs-Rulers of Jurassic Skies') and Procter & Gamble, North East Water and Northern Electric (for 'The Living Planet') all received awards under the above scheme which has meant an injection of £14,750 towards the marketing of the two projects.

Sponsors Club: the sponsorship by Century Radio was also supplemented by an award of a further £4,000 from the Sponsors Club in addition to the 'Pairing Scheme' figure mentioned above.

In the light of the awards noted above, it was entirely fitting that the museum should play host to the Association for Business Sponsorship of the Arts, as they held their Northern Regional Awards Ceremony for companies and museums/arts organisations in receipt of rewards under the 'Pairing Scheme'. The awards were presented by Lord Inglewood.

As in previous years, the Hancock has benefited greatly from grants awarded by the North of England Museums Service (NEMS). A total of £12,500 has been provided for a variety of schemes including the installation of ultra-violet light screening in a number of galleries, construction of a new geology store, display cases for the Earthworks gallery, Visual Arts exhibitions, and a subsidy towards the costs of staging another series of Time Travellers activities.

Staff The current staffing complement is as follows:

Alec Coles (Principal Keeper, Natural Sciences)

Steve McLean (Keeper of Geology)

Les Jessop (Keeper of Biology)*

Helen Fothergill (Assistant Keeper, Geology)*

Eric Morton (Assistant Keeper, Biology)

Kirsty Ramshaw (Biology Assistant)

Gillian Mason (Assistant Education Officer)

Fiona Fenwick (Secretary)

Kevin Hughes (Environmental Recording and Cataloguing Assistant)

John Pratt (Chief Attendant)

Anne Aspery (Senior Attendant)

John Connell (Full-time attendant)

Scott Appleby (Part-time attendant)

Susan Davison (Part-time attendant)

Angus Thompson (Part-time attendant)

Lillian Livingston (Cleaner)

Post vacant (Cleaner)

*Based at Sunderland Museum

Volunteers As in previous years, the contribution by Hancock volunteers has been truly impressive. There is no question but that the museum could not function efficiently without their efforts. The Society, and the museum's staff owe a collective debt of gratitude for all of them for their outstanding efforts. The following list is of those who have contributed regularly over the last year:

Derek Briggs Geology

Ron Cook Botany/Oology Curation

Paddy Cottam Osteology Curation

Caroline Gettinby Vertebrate Zoology

Julie Gowland Administration/Education

Will Higgs Vertebrate Zoology and Observation Beehive

Louise Hollingworth Geology

Darren Hudson Geology

Melissa Murphy Education materials

Roger Stobbart Entomology Curation

Matthew Wasserman Biological Recording

Victoria Wilson Vertebtrate Zoology

MUSEUM MANAGEMENT COMMITTEE

The Committee met on two occasions during the year and discussed the matters that are covered in the museum report.

FINANCE

The surplus for the year after appropriating £3,000 to the Gosforth Park Nature Reserve Restoration Fund is £5,124 (1995 deficit £4,783).

Taking the two years results together gives a small surplus of £341. The principal changes giving rise to the surplus for 1996 are shown below:

	£
Increase in subscriptions	2,340
Surplus on holiday field trip	1,348
Increase in investment income	4,149
Decrease in expenditure on *Transactions*	3,924
Less:	
Increase in salaries, pension contributions and National Insurance	(1,821)
Increase in depreciation	(624)
	9,316
Add surplus on other headings of income and expenditure	591
Movement from deficit to surplus (£5,124 + £4,783)	9,907

The subscription rates were increased with effect from 1 August 1995 and the Society has benefited from an overall increase of £2,340. This increase was necessary to allow for an increase in appropriations to the Gosforth Park Nature Reserve Restoration Fund and to help finance future expenditure of the Society. There was no increase in the subscription rates from 1 August 1996 and none is forecast for 1 August 1997.

The increase in investment income is largely attributable to one-off special dividend payments from Northern Electric plc and on the disposal of Forte plc. These will not be repeated in the next financial year when investment income is expected to be *ca* £28,000. The investment portfolio continues to be managed by Wise Speke and the trustees of the Society. During the year some changes were made which resulted in gains to the various funds as shown below:

	£
General Fund	24
T B Short Memorial Fund	9,738
Grace Hickling Memorial Fund	1,100

Due to the changes in investments there has been an increase in the cash balances of the Society which is to be reduced in the current year by additional investments being made. These will produce a dividend stream that will increase future investment income. In accordance with the general directions of the Charities Commissioners the investments are shown at market value in the financial statements. This has resulted in any difference between cost and market value being shown as an Investment Revaluation Reserve.

During the year 'Robson's Geology of North East England' was published, the cost of which was fully provided for at 31 July 1995. Apart from the annual report and 'Birds on the Farne Islands in 1995', no other *Transactions* have been published. Provision has been made in the financial statements to cover the costs of volume 57 of the *Transactions.*

Significant capital additions were made to the office equipment (£4,757) being the purchase of a new computer and printer. These should facilitate in-house publication and so reduce future print setting expenses. The other major capital addition (£881) was the ringing hut at

Gosforth Park Nature Reserve. As a result of these capital additions there has been an increase in depreciation charged in the current year.

In December 1995 the Society received £7,500 from the Sir James and Lady Steel Charitable Trust. This money is a donation towards the future rejuvenation of Gosforth Park Nature Reserve. The Society is very grateful for this and the other donations received during the year.

INDEPENDENT REVIEW

The financial statements to 31 July 1996, independently reviewed by Price Waterhouse, were approved by Council on 4 October 1996. Council gave its approval for an independent review at its meeting on 12 April 1996.

LIBRARY

After nine years as the Society's librarian and chairman of the library committee, Dr David Gardner-Medwin resigned when he became chairman of the Society, feeling that there might be a conflict of interests if he held both posts. In April Mr Hugh Chambers was elected by the library committee to be their new chairman and Dr David Gardner-Medwin agreed to continue as a member. The committee members are: Mr Hugh Chambers (chairman), Mrs Paddy Cottam (mammals), Mr Peter Davis (marine biology), Dr David Gardner-Medwin (history of natural history), Mr Les Jessop (entomology), Mr David Noble-Rollin (ornithology), Mrs Joyce Parvin (secretary), Dr Alick Walker (geology) and Dr Trevor Walker (botany).

Mrs Helen Dalrymple has settled extremely well into her voluntary work of looking after the binding of publications and the recording of incoming items and exchanges - this section of the library is in capable hands. The library has been open to members on Wednesdays throughout the year in the care of Hugh and Stella Chambers and for an hour before the Friday evening lectures, with this duty being shared by the library committee. Mrs Helen Roscoe has continued to help with the cataloguing of offprints and separates and Mr Trevor Hardy has started sorting geological separates (during the winter months). Without the dedication of the committee and the volunteers the library would be just a collection of old books and not the living, up-to-date entity that it is. The Society thanks them all for their efforts.

To satisfy our insurance company and allow the library to be insured for an amount that would at least cover restoration, an assessment of the value of the library was attempted. This was achieved and we are still satisfactorily insured.

During the year Francobollo Ltd of Hexham has made use of the library's collection of watercolour paintings of shells by George Gibsone to produce a set of eight prints which it is hoped will be financially beneficial to the Society.

The library evening on 15 December was devoted to the newly rediscovered specimens of stuffed birds from the museum attic by Mr Les Jessop. These had been used by Thomas Bewick and it was possible to see the specimens alongside Bewick's original watercolours and the finished woodcuts. The evening was a great success and was appreciated by members of the Bewick Society who had been invited to view the 'finds' and other items of the Society's collection of Bewick 'originals'.

During the winter there was a certain amount of panic when water was streaming down the library walls adjacent to two of the cupboards housing some of the Society's 'treasures'. Fortunately the lining of the cupboards prevented any damage to the contents but there had to be some rehousing of precious material. This was followed in June by a foot through the ceiling with no damage to the books other than dust.

The library has been used by an increasing number of members and, during term time, by a number of hard working students. In fact on some Wednesday mornings chairs in the library have been at a premium.

On relinquishing his library post Dr David Gardner-Medwin made a presentation in recognition of his feelings for the library. It is a run of the first twenty-five volumes of the

History of the Berwickshire Naturalists' Club bound in twenty-three volumes. The first two have the bookplate of George Johnston, founder of that society, and the next eleven volumes have the bookplate of his daughter. This generous gift will be housed in the Tully bookcase in the council room.

This year sixty-two books, twenty-one offprints and two runs of journals have been added to the library. Sixteen of the books were donated; these included Mr James Alder's *Birds and Flowers of the Castle of Mey* which was formally presented to the Society at the Council meeting on 5 July by Mr Alder on his 76th birthday. A facsimile of parts I, II and III of Turner's *Herball* was donated by Mr Frank McCombie, who was involved in its production. A fine set of the six volumes of *A History of British Birds* (1895) by the Rev F O Morris and of the same date his *A History of British Butterflies* was presented by Miss Jean Pinkney. J Duncan's *Birds of the British Isles* (1898) was donated by Mr Peter Davis and Professor Swan gave the 1936 *Geology of the Country around Rothbury, Amble and Ashington*. Other books and journals were given by Mr John Robinson, Durham County Council, Northumbrian Water and Mr D S Ranner. We gratefully received donations of their own published papers from Mr Peter Davis, Miss Barbara Harbottle, Dr Angus Lunn and Dr Denys Smith. Mr Les Jessop presented his booklet on dung beetles from the Royal Entomological Society's *Handbook for the Identification of British Insects*. We thank them all. The Society continued the purchase of notable major books that are being published in multiple volumes over long periods. This year Volume 3 of *The Handbook of Australian, New Zealand and Antarctic Birds*, Volume 3 of *The Handbook of Birds of the World* and Volume 4 of *British Plant Communities* have been bought. Other acquisitions included *Birdwing Butterflies of the World* by B D'Abrera and *The internal structure of fossil vegetables found in Great Britain* by H T M Witham.

ACTIVITIES

Ornithology section On 6 October Dr Peter Garson spoke under the title 'A Happy Himalayan Saga'. Peter is chairman of the Pheasant Specialist Group of the Species Survival Commission, which has world wide cover under the International Union for the Conservation of Nature. In his lecture he told how he had participated in advising the government authorities on suitable locations and the establishment of large nature reserves in the foothills. It was most pleasing to hear that the recommendations were enthusiastically adopted and that the reserves are a success.

On 3 November Mr Mike Mockler gave the Pybus Memorial Lecture and his topic was 'African Birds, Mammals and Conservation'. His talk ranged over the areas that he has visited most frequently in Africa and the conservation projects that he has become involved with since he started to lead African safaris. This talk was followed on 1 December by Dr Mike Harris with 'Requiem for Shags'. During his talk he outlined his research into the recent high death toll of guillemots and shags along the north-east coast and pointed out that, although it appeared as if it was guillemots that were suffering, in fact it was near the normal annual mortality for this species. However the shag populations had been decimated. On 5 January Mr Ian Douglas brought us up to date with the Northumberland Wildlife Trust's 'East Chevington Reedbed Project' and the progress in trying to create a large wetland habitat in central Northumberland; the talk was followed up in the summer by the botanists having a field meeting to the site. On 26 February Mr Rob Lidstone-Scott took us to warmer climes to relate his adventures while 'Wardening in the Seychelles'. It would appear that 'paradise' can have more than one side and living for long periods in a primitive way can have drawbacks. However, he left a distinct feeling that it has to be one of the better wardening posts available.

Dr Matthew Ridley completed the ornithological section's winter programme with a talk on 2 February on 'Modern Farming and Birds.' He discussed the advantages and disadvantages of set-aside and showed that farming interests and conservation can, with forethought, run side by side.

The year's field meetings began with the 'Pelagic Cruise' on 2 September, a joint venture with the North Northumberland Bird Club. It was a beautiful evening and we went out beyond the Longstone and put out our 'chum' and waited. Unfortunately the birds were not in the area

and we had a few views of skuas but no good sightings of shearwaters. The programme continued with better success on 21 October with the section's annual visit to Holy Island. Many of the usual birds were seen and towards the end of the day members had excellent views of merlins hunting over the causeway area. In January the ornithologists went to Musselburgh and Aberlady Bay; the weather was an improvement on the previous year and there were good numbers of velvet scoter and both grebes and divers at reasonable distances. The winter programme concluded with a visit on 17 February to Loch Ken and Murray's Monument. This trip will probably be remembered for its views of birds of prey as well as the geese. We saw peregrine, kestrel, sparrowhawk, over twenty-five buzzards, two merlins and had two superb views of male hen harriers, one at Caerlaverock and the other at the church at Loch Ken.

The summer programme began with a Northumberland coastal trip on 27 April. The weather was excellent but not very suitable for migrants. The group started at Cresswell and saw garganey at Druridge Bay and with hard work members produced a respectable list by the end of the day. On 18 May the Society visited Leighton Moss. Although bitterns were heard they remained invisible but other birds seen included spoonbill, little egret, bearded tit, little owl and green woodpecker.

On 8 June we visited College Valley which proved popular with over thirty members having to get into eight cars to go up the valley. The group had excellent views of both ring ouzel and peregrine and it was such a clear day that from the bottom of the Bizzle we could see the Scottish hills. The next outing should have been the 'Roseate Tern Day' on 23 June, a trip around Coquet Island, but unfortunately this was cancelled due to bad weather.

Mammal section On 27 October the section held its first evening meeting with Miss Abby Halstead talking about the 'Campaign against the illegal poisoning of wildlife'. She outlined the main causes of both accidental and intended poisoning of wildlife and showed members the type of signs to look for and the basic procedures when encountering this sort of problem. Although the subject could be considered distressing, those members who attended felt that after the lecture they would know more about the best course of action if they come across poisoning of wildlife.

On 23 February Mr Duncan Glen gave an excellent talk on 'Improving river bank habitats for fish and wildlife on the Tweed'. His usual enthusiasm remembered by members from his work with otters came through in his new position with The Tweed Foundation in improving the river Tweed.

Mr John Steele came to talk on 1 March on one of his favourite subjects, 'Signs of wildlife'. He had his audience guessing who had made a particular foot print or mark and he provided a very entertaining evening which had many members out looking for tracks and signs the following weekend.

The mammal field meetings began on 5 August with a walk in Gosforth Park with Mr Steele to look for signs of mammals and to check the Longworth small mammal traps that had been set earlier. Twenty members looked at skulls and feeding signs such as chewed nuts etc. and then found wood mice, three bank voles and a field vole in the traps. The group then used a bat detector to identify the species in the area, with possibly a whiskered bat over the woods and noctules over the reedbeds.

In the spring Mr Bob Wilkin and Mr Paul Drummond took a number of members on badger watches which produced excellent sightings of both adults and young and some saw a family of foxes as well. It was very unusual to have both badgers and fox cubs playing within sight of each other.

Geology section There were six lectures during the winter beginning in October with Professor Maurice Tucker of Durham University who is a well known and appreciated lecturer to the Society. His talk was on 'Life in the Swamp' and dealt specifically with the Carboniferous animals. Using slides and a lively discourse he explained about the evolution of amphibians related to the newt family which inhabited coastal lakes, rivers and swamps. He referred to the footprints and other fossil evidence which this area provides in some

abundance. The audience, who numbered forty-four, responded with many questions at the end.

During November Mr Steve McLean lectured on 'Fossil Fakes and Forgeries'. He had an audience of over fifty and explained, using examples from the Hancock and elsewhere, how it was possible to fool a lot of people for in some cases quite a long time before new evidence or a more careful examination revealed that a specimen was not quite what it appeared to be at first sight. We have had many examples from Piltdown Man to *Archaeopteryx* which have been re-examined and declared fakes, sometimes, as with the first example, proving beyond doubt that it was not genuine. We in the Society can remember Dr Alan Charig when he came to prove *Archaeopteryx* was authentic. Steve gave a most interesting lecture and stimulated quite a few members to be less gullible in the future.

Professor Newson, who was unable to lecture in December, sent a very reliable colleague to deputise for him. This was Ms Cath Padmore, a PhD research student in the Geography Department of Newcastle University. An audience of fifty heard how rivers could have their sections classified and the processes at work could then be understood and conserved. She chose examples of local rivers on which the University team had been working and showed how successful man was becoming in understanding and improving river environments. The talk was well illustrated and members realised that there is now a strong scientific basis for optimism for the future of what had been considered hopelessly polluted north-east rivers. There is little doubt that Ms Padmore will be deeply involved in future river conservation.

Dr Howard Armstrong joined us in January 1996 with a talk on 'The Geophysiology of the end-Ordovician Glaciation'. He has frequently been with us in the past, usually talking about fossils and microfossils. At first sight his lecture to a relatively small group of thirty-six seemed to be quite a different line of research. However the audience soon realised that fossils, mostly in the form of Graptolites, had a significant part to play in our understanding of world climatic changes in the late Ordovician. He looked at different parts of the Ordovician world for evidence but confessed that we have on our doorstep a major area where details were available to show that glacial epochs occurred at that time. The area was at Dob's Linn, now a World SSSI. His lecture was well illustrated and questions at the end proved that he had convinced the audience of the significance of these early glaciations on faunal sequences in the rocks when the geography and continental dispositions were quite different from the present.

Professor Girdler of the Geophysics Department, who has lectured to us before, joined us in February to deliver a lecture on 'Extra Terrestrial Impacts'. It was interesting to see a link with the previous lecture as he explained the various sites and occasions during earth history when it is believed large bodies have collided with the earth causing considerable disruption to the planetary ecosystem. He quoted examples of extinctions of species and in some cases vast biomass loss, the development of diamonds from impacts and gave some indication of why such frequent impacts occur. He quoted examples of famous sites and the ease of discovery of meteorites in the Antarctic including possible meteorites originating from a Martian and lunar surface. The audience of over fifty-five gave him a lively reception at the end with several searching questions.

The last lecture was on 8 March by Dr Stafford Linsley of the Continuing Education Department at Newcastle University who dealt with 'The Archaeology of the Coal Trade' in the north-east of England. It was virtually an update of the famous paper produced in 1852 on the Great Northern Coalfield. His lecture was well illustrated and constructed and showed how our region was pivotal in the industrial revolution where mineral extraction and invention worked hand in hand to produce the vast industrial conurbation of Tyneside which led the world in coal production, steel, shipbuilding and railway development. An audience of about fifty enjoyed his lively lecture.

The outdoor meetings of the geology section began with a visit to Holy Island with Dr Mick Jones who led a group of twenty-two to examine the north shore to see the sedimentary succession and collect fossils from the limestones and shales in the Middle Carboniferous Limestone Group. The group then examined the south shore where the whin dyke is exposed forming Steel End and the castle rock. The group visited St Cuthbert's Isle to see the structures

developed in the upper surface of the dyke providing evidence of the movement of magma during dyke injection. Dr Jones related the dyke system to the Whin Sill and explained the reasoning behind the echelon formation of these dykes which was related to the structure of the Cheviot Hills. The weather was kind and the group enjoyed a stimulating day.

The last of the 1995 excursions was to the Seaton Sluice-Tynemouth shore section, this time led by Dr Brian Turner of Durham University. He had been involved with a study of the sedimentary cycles during the coal measure times. He had prepared an excellent handout to go with his visit which was much appreciated by the group of over twenty. His work is linked to the recent Yorkshire Geology Society publication on Northumbrian Rocks and Landscape which many members have read. His interpretation was quite different to what more traditionalist geologists might have followed and this reflects the modern approach from sedimentology.

The outdoor meeting in May 1996 was with Dr Mick Jones who took a group of nineteen members over a well-trodden path - the Beadnell shore. Dr Jones has produced a fairly complete geological column of strata along this section of which copies were issued at the start. The group then proceeded to follow the strata northwards down through the section. With some guidance from the leader most were able to follow the sequence easily and understand something of the reasons for the frequent changes in the Yoredale cyclothems. Dr Jones explained the unique qualities of this section being a part of the carboniferous limestone sequence where there was no injection of the whin sill. Everywhere else in northern England this particular sequence was disturbed by sill intrusion and metamorphism. He accounted for this by referring to the significance of the Cheviot massif providing some protection for igneous intrusion. The only igneous event that was seen during the day occurred long after the Carboniferous with the injection of the Beadnell dyke in the Tertiary.

Unfortunately the June meeting was cancelled due to lack of support. However seventeen members made their way up to Moffat in July to see the Dob's Linn Section where Dr Howard Armstrong demonstrated full proof in support of his lecture given during January. This proved to be a warm day, rare for the Southern Uplands, and after a quick look at the Grey Mare's Tail and the cottage where Lapworth stayed, the party proceeded to examine the section in Dob's Linn. Dr Armstrong started at the oldest part of the geological record and then moved up, the sequence. He issued an excellent field paper with maps and sketches which were compared with the section. He was able to demonstrate that not only had the fossils disappeared but the colour of the rocks changed to a light grey when climatic changes occurred. Fossil dark shales and intervening grey shales could be found within a time scale which related to the Milankovitch cycle. The Silurian boundary was noted as being of World Significance in the upper part of the stream section. The group made their way back home via St Mary's Loch, stopping to visit some other sections in the Silurian.

Entomology section The policy of the entomology section, as in previous years, has been to balance general talks on broad subjects with more specialised topics.

The first meeting of the winter season, on 29 September, was addressed by Mr Dean Heward, a project officer with the BTCV in Darlington and an amateur entomologist with a keen interest in dragonflies and damselflies. His talk on Odonata covered the natural history of this group and described the species found in our region, and was illustrated with some exceptional slides.

On 19 January the section leader, Mr Les Jessop, who is keeper of biology of Tyne & Wear Museums, gave a talk on 'Dung Beetles'. Although feeding on a limited range of foodstuffs (i.e. mainly dung), dung beetles are a speciose group and some genera contain more than 1500 species. The lecture described the morphological range of Scarabaeidae before going on to discuss how the ecology of dung beetles operates in such a way as to allow diversity. This somewhat technical topic was illustrated by a sort of computerised overhead projector that generated almost as much interest as the talk itself.

The final meeting, on 22 March, was entertained by Dr Martin Luff, senior lecturer at Newcastle University and a world authority on ground beetles (Carabidae) and their ecology. Some ground-active species of beetles are very careful about where they live, and they can be

used as indicators of the environmental conditions at a particular site. Samples taken over a period of time have been used to monitor changes in habitats. Dr Luff's talk stimulated a long discussion covering a broad range of ecological topics.

Botany Section The winter lecture programme began with Dr John Richards' account of his expedition 'In the footsteps of Forrest: yomping in Yunnan', a botanical hotspot which is the source of many of our garden plants. Subsequently Dr Veronica Howard described the vegetation of another mountainous country in her 'Woodlands in Scotland'.

Coming home, Dr Angus Lunn analyzed George Swan's *Flora of Northumberland,* in terms of the distribution of the native flora according to habitat, life-form, survival strategy, geographical element, rarity etc. Finally Dr Gates discussed the distribution shifts, extinctions and immigrations of our flora which global warming might bring about in 'The natural history of climate change'.

The summer field trips, all in July, were blessed by fine weather.The first was to another botanical hotspot, High Cup Nick and the Maize Beck, led by Drs Richard and Lunn. A long walk from Dufton was rewarded by alpine cinquefoil and alpine meadow grass. The following week Professor Swan led a party onto the MoD Otterburn ranges in upper Coquetdale (having checked the firing schedules) in order to see among other plants the national Red Data Book species Jacob's ladder. Finally Mr Ian Douglas, the Northumberland Wildlife Trust's Habitats Manager, showed us the splendidly mature Hauxley nature reserve (where plants are beginning to outshine the birds) and the still raw East Chevington reedbed reserve. A relict meadow there had lesser butterfly-orchid, and we later visited the marsh helleborine site on the dunes.

Ornithological holiday tour Members who went on the Society's holiday to south-west Spain spent two weeks watching the autumn migration of birds to Africa. We stayed at Zahara de la Atunes on the Atlantic side of the Straits of Gibraltar and visited the best bird sites south of the Guadalquivir river. The first week was mainly spent studying the enormous passage of birds of prey with large numbers of short-toed, booted and Bonelli's eagles. Also the resident populations of red kites and griffon vultures kept us entertained while waiting for migrants. The group had one rather close encounter with 'Grif', a vulture that had a problem. He flew into the hotel and landed on the flat roof in front of the rooms of two members of the party. He appeared ill and starved. We fed him on chicken from the kitchen and removed a piece of string that was tied around his leg, and after a few days the police took him away to the Coto Doñana to be rehabilitated back to the wild. He left us with memories of how large vultures are and the Secretary personally with an interesting collection of feather lice which were brought back to the museum pickled in gin (the only alcohol available).

The group also found a very desiccated tern which was identified as an arctic tern with a BTO ring on its leg. This was brought back to the museum in its entirety by Mrs Paddy Cottam and the ring number was sent to the British Trust for Ornithology at Thetford. The information was returned in September 1996: the bird had been ringed at Kinloss airfield in the Grampian region, and had lived only eighty-four days but had already travelled 2,393km.

On days when the party was not looking at raptors migration other birds like spoonbills, flamingos, various waders, ducks and azure-winged magpies made it a memorable holiday. The most amazing find was at Arcos where we went to see choughs and found two eagle owls roosting on the cliffs below the town.

GOSFORTH PARK NATURE RESERVE

The year began with two members, Mr Steve Davison and Mrs Linda Kergon, finding an unusual combination of rare fauna and flora on a single day in August. They saw a Camberwell Beauty *Nymphalis antiopa* near the entrance to the reserve and beside the feeding station discovered Young's Helleborine *Epipactis youngiana*. This is only the third extant site in Northumberland and the eighth known locality in the county where this rare plant has been recorded and this added to the botanical importance of the reserve. Also the Management Committee had success in locating the coralroot orchid *Corallorrhiza trifida* in both 1995 and 1996's site visits to the reserve. These were the first documented records since 1990.

Talks with Northern Racing Since the last annual report there have been a number of important meetings with our landlords and their consultants. The main objective has been to explore the possibilities of a cooperative scheme of water control that would benefit both the racecourse and the reserve.

If the plan goes ahead it will give the Society real control of water levels from suitable sluices and a larger, deeper lake than could be achieved with the limited financial resources at its disposal. In September a hydrological survey was carried out around the lake area. This necessary background information was required to enable both the Society and the racecourse company to make decisions on the viability of the project to increase the lake capacity and use water for maintaining the turf. In October, test boreholes and pits were being dug in the areas of the old lake bed adjacent to the racecourse with the objective of examining the substrate of the lake area to be desilted.

Prior to this the Secretary had a meeting with Sir Nicholas Beaumont, Director of Racing, who was able to outline the racecourse's main aims for the Park. Also discussed in outline was how to proceed with the idea of using water from the lake to reduce the cost of watering the course during the summer. The meeting was very amicable and a mutual understanding of the different problems that face both the Society and the Company were openly discussed and common ground explored.

When the findings of the survey and substrate sampling are available it is hoped that a further meeting between the Company, the Society, English Nature and the City Planning Department will be able to produce a plan that gives the reserve lake the necessary protection to maintain the *Phragmites* reedbeds but at the same time allows the racecourse to use the newly dug lake to water its course when required. With cooperation on all sides this should not be too difficult to organise and would give the Society a deeper and larger lake than it could possibly hope for under other circumstances.

Reserve Maintenance The autumn maintenance work included reed cutting, willow removal, the beginning of work on the new board walks for the ringing group and construction of the new ringing station on one of the bunds.

Reed cutting is part of the management committee's plan to increase the quality of the existing beds by cutting and removal of the dead material, allowing much better growth in the spring. This is being carried out by the Rising Sun Countryside Centre who wish to use the reeds for thatching. The new ringing station was constructed by the Urban Fringe Area Management Scheme (UFAMS) and is aimed at increasing the capacity of the growing ringing group to process more birds. The results of this year's work is outlined under the ringing report below.

Birds in the reserve The resident breeding species are discussed under the ringing report. However there were one or two unusual birds during the year. In August there was a common buzzard, the last record of one staying around being twelve years ago, and during the winter a lesser-spotted woodpecker took up residence. The presence of this 'rarity' greatly increased the number of members and, it appears, non-members(!) visiting the reserve. Other birds of note have been waxwings, which is hardly surprising as they seemed to be everywhere in the area, and two whooper swans which dropped in to the flooded fields near the reserve for a short visit and were recorded in the logbook on a number of days.

RINGING GROUP

The Ringing Group pursued three main projects in the period August 1995-July 1996: the 'constant effort' monitoring project at Gosforth Park, coastal migration studies at Newton Pool and seabird studies on Coquet Island RSPB reserve. To this, the Group added exploratory ringing studies on the Farne Islands aimed at designing a workable programme of ringing-based monitoring to aid conservation of this important seabird colony. The ringing team has continued to increase in strength: two new trainees joined this year, an existing team member gained his C-permit and others may follow soon. Completion of the new ringing hut in the reserve has been an enormous benefit, making it possible to accommodate an enlarged ringing team and offer better training facilities. In addition, the enlarged bench area with good natural light provides better research facilities and it has proved much easier to carry out studies

of plumage development in parallel with the constant effort ringing. Sedge warblers caught in the reserve and at Newton Pool in the past three years have contributed to a study of juvenile plumage development and moult, and the results of this study were published this year in the *Journal of Avian Biology* (volume 27, pages 157-163, 1996), one of the world's highest-ranked ornithological journals.

The constant effort ringing has gone well during the 1996 breeding season, although the total number of birds ringed during the period covered by this report (1 August 1995 to 31 July 1996) was down to 681 from the previous total of 737. However, the numbers of reed and sedge warblers ringed has nearly doubled compared with the previous period (in brackets): 156 (82) sedge warblers and 28 (15) reed warblers. It should be remembered that the reporting period effectively covers the output from two breeding seasons: second brood birds caught after the end of July in 1995 and 1st/2nd brood birds caught before the end of July in 1996. The range of nets operated remained similar to the last two reporting periods and it is likely that these high figures for reed and sedge warblers reflect two good breeding seasons in 1995 and 1996. The range of species ringed at Gosforth Park has remained about the same. Noteworthy captures were house martins, swallows and two juvenile kingfishers, and two broods of sedge warbler chicks were ringed. One significant control of a Gosforth Park bird has been reported during the period: a juvenile reed bunting ringed in July 1995 was caught (controlled) by ringers working at Kintbury Cress Beds, Kintbury, Berkshire, on 4 February 1996, a distance of 402km almost exactly due south.

Coastal passage at Newton pool in the autumn of 1995 remained light. As in previous years, the most abundant species were wrens, dunnocks and robins. Less common migrants included three redstarts and two lesser whitethroats. Two birds were controlled: a young sparrowhawk that had been ringed by Mr Ian Newton at one of his study sites in Dumfries and Galloway, and a young robin ringed a few weeks earlier at Rowlands Gill.

Apart from the Ringing Team's constant effort programme at Gosforth Park, the focus of effort this year has undoubtably been on the seabird studies on Coquet Island, extended, for this year at least but hopefully for future years as well, to the Farne Islands. The studies on the Farne Islands would not have been possible without the generous provision of a 23ft Rigid Inflatable Boat (RIB), complete with two outboard engines (Fig. 1), by Northumbrian Water, and without this the Coquet Island work would have been much more difficult. Ringing on Coquet Island is concerned mainly with obtaining growth data for arctic terns as part of a project to try and develop simple biometric methods for monitoring the quality of parental provisioning via the growth of their chicks. This year, a sample of forty chicks of known age was used to obtain data on weight, flight feather and bill growth. This is down by one-third on the sample for last year, partly as a result of a late start to the breeding season produced by the unusually cold conditions in May this year. The data for this year have not been analyzed in detail; however, a preliminary analysis is shown in Fig. 2 in which 3rd primary length is plotted against weight for the 1995 and 1996 data. The two sets of data are very similar, but whether this is because weight and flight-feather growth are tightly coupled, or because the food availability during the two seasons was good, can only be answered once we have completed a fuller statistical analysis. In addition to the 219 arctic and thirty-four common terns ringed during the work on Coquet, 417 Sandwich tern chicks, and forty fulmar chicks were also ringed. The ringing of Sandwich tern chicks may also produce valuable results, since their colonies are compact enabling chick survival to be monitored more closely. The total number of birds ringed on Coquet Island this year was 873, and this includes 163 black-headed gull chicks ringed earlier in the season. One recovery has been reported: a black-headed gull ringed as a chick on Coquet in 1995 was later seen in Stoke-on-Trent, Staffordshire between 24 October and 9 November the same year.

Permission to ring on the Farne Islands, for an initial exploratory period of one year, came as the breeding season was getting under way. The aim for this year was to gain experience of the islands in order to design monitoring programmes based around ringing and to find out what could be achieved realistically, given our limited manpower and other resources. During several trips to the islands, we ringed 1672 seabirds, this total consisting of 416 arctic terns, 875 Sandwich terns, 151 shags, 200 kittiwakes and 30 guillemots. Although we had hoped to

Fig. 1 *Sea Spray* moored at Coquet Inland with members of the ringing group and Dr Chris Spray from Northumbrian Water. From left to right: Mr David Noble-Rollin, Dr Chris Spray, Mr Deryk Shaw and Dr Chris Redfern.

obtain growth data on arctic terns of known age to complement the Coquet Island study, this was not possible, partly because the first visit was later than hoped. Nevertheless, the Sandwich tern colonies proved to be interesting: of the 686 ringed in the Inner Farne colony, 29 (approximately 4%) are known not to have survived to fledging. This compares with 0.5% of the Coquet Island Sandwich terns which did not survive. By continuing the ringing of these birds it is hoped to find out whether there are consistent differences in chick survival between Coquet and the Farnes, and, if so, try and identify the factors involved with the aim of improving the management of the Farne Islands colonies. To do this, it will be necessary to use simple staging criteria for the age of birds ringed and effectively designed and statistically robust methods of searching the colonies for those few chicks which do not survive.

During the ringing of Sandwich terns on Inner Farne we took the opportunity to ring the chick raised by Elsie, the well-known lesser crested tern which has taken up summer residence on the Farne Islands. This was possible because the nest was well marked and kept under observation by the wardens. The chick, a lesser-crested-Sandwich tern hybrid, now carries two red colour rings, has fledged and was last seen at the end of August this year. The presence of colour rings on this bird will enable its future progress to be monitored if it returns to breed.

Plans for next year are to continue with the three main projects: Gosforth Park constant effort monitoring, coastal migration at Low Newton and seabird studies on Coquet Island. We hope that the Farne Islands Local Management Committee of the National Trust will renew permission to extend the seabird work there and that we can carry forward a sustainable programme of seabird monitoring in the north-east. We are extremely grateful to Northumbrian Water for their support of our seabird studies, Mr James Robertson, a Durham University research student, for his help in marking arctic tern chicks while we were absent from Coquet Island, and Mr Rob Lidstone-Scott, RSPB warden for the island, for his invaluable help. We also thank the Farne Islands Local Committee for permitting exploratory ringing studies, the Farne Islands wardens for looking after us while we were on the islands, and Mr John Walton, the Property Manager, for agreeing to our visits and liaising with the wardens on our behalf. We are also grateful to Major John Carr-Ellison for the use of his beach chalet at Low Newton as a base for our coastal migration studies.

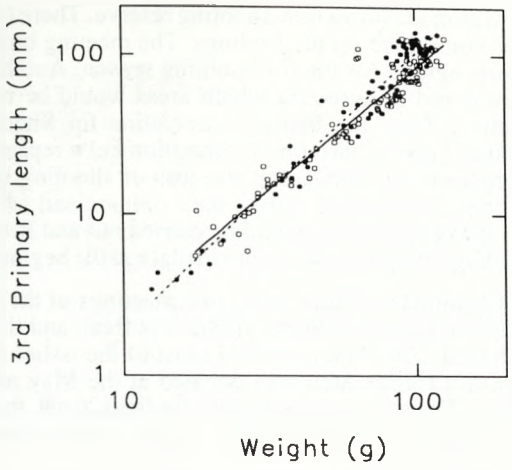

Fig. 2 The relationship between 3rd primary length and weight, plotted on Log axes, for arctic tern chicks on Coquet Island in 1995 (●, dashed regression line) and 1996 (O , solid regression line)

THE FONTBURN RESERVOIR WILDLIFE ADVISORY GROUP

There were no meetings of this group during the year.

COQUET ISLAND MANAGEMENT ADVISORY COMMITTEE

There were two meetings of the Management Committee during the year. The field visit had to be cancelled in August 1995 due to bad weather. There was an autumn meeting to discuss research and management and another field visit was held on 30 July 1996. The main concern was the continuing erosion of the soil from the island and attempts were being made to reduce the speed of loss. The field visit in July showed the effect of last year's dry summer with many areas of dead grass. The warden, Mr Rob Lindstone-Scott, had tried a number of different cutting and planting regimes some which showed promise. It was decided that there needed to be a study of how the birds used the different types of vegetation to maximize the available space for nesting birds.

The number of breeding pairs of roseate terns on the island was less than last year's but it still remains one of the largest colonies in Britain. Other species were also down. Although this followed a national trend for seabird colonies, the numbers were not significant and were well within the normal year-to-year fluctuations.

At the autumn meeting the results of the first year's ringing were tabled by the Secretary on behalf of the ringing group and the Society continued its research on the island this season, greatly assisted by the use of Northumbrian Water's Boat *Sea Spray*. The work is discussed in more detail under the 'Ringing Group' report.

LINDISFARNE NATIONAL NATURE RESERVE

Lindisfarne Wildfowl Panel Last year we reported an agreement to form a non-shooting refuge on the Holy Island mud flats and research planned to discover the most economic way to achieve this.

In March there was a meeting of the Wildfowl panel to hear the results of the winter's study carried out by Dr Steve Percival and Mr Matthew Denny. They had divided the area into a number of sections and studied the use of the area by all the nationally and internationally important species that inhabit the slake in winter, also assessing the loss of shooting

opportunity if each area was made into a non-shooting reserve. There followed a heated debate between members of the committee on the findings. The meeting broke up without any firm plan of action having been agreed for the forthcoming season. Another meeting was held to try to resolve the situation and to agree on which areas would be made into non-shooting refuges. The representatives from the British Association for Shooting and Conservation (BASC) wished for another year of base line information i.e. a repeat of the previous year's study but with more emphasis on calculating the loss of shooting opportunity. In the end members of the committee gave English Nature their opinion and advice and they made the following proposal: that further research would be carried out and BASC agreed to fund half of this but that a non-shooting refuge would be put in place at the beginning of the 1997 season.

Lindisfarne Advisory Committee There were two meetings of the Advisory Panel during the year, one in November at English Nature's offices at Beal, and the second in May at the Manor House on Holy Island. The Panel covered most of the issues discussed above and in particular the formation of a refuge area was debated at the May meeting when Dr Steve Percival and Mr Matthew Denny presented their findings from the winter's field work. Members were asked to submit their comments on the work to English Nature for their information.

The other issues that concerned the Advisory Panel were that although there had been a decline in bait digging in Budle Bay, it still remained a problem in other parts of the reserve. They also discussed the monitoring by the National Rivers Authority of the water quality coming into the reserve. Another major issue was the increase of water sports in Budle Bay, particularly jet skis. The south-east corner of Budle Bay has been designated for a trial period for the 1996 season as a water sports area and this had been supported by the Budle Bay Boat Club and local owners. However, it was suggested that signs should be erected to inform non-locals of this approved activity area.

DAVID GARDNER-MEDWIN

Chairman of Council

The 11th Duke of Northumberland

At the Pybus Memorial lecture on 3 November 1995 Mr Derek Shannon, as Chairman of Council, opened the meeting and announced that the Society's President since 1989, His Grace the 11th Duke of Northumberland, had died three days before. He said, 'For anyone to die suddenly at the age of forty-two is a tragedy and for the Society to lose its President at the age of forty-two is indeed a sad event - a tragedy. On Tuesday morning the 11th Duke of Northumberland died at Syon House.'

Mr Shannon then mentioned the Duke's caring qualities and his work on the estates at Alnwick, which cover over 162 farms and 700 rented cottages, quoting, 'He was a man of gentle courtesy and kindness and underneath his shy exterior there lurked a romantic soul'. He concluded by saying that he was pleased to read that the Presidency of The Natural History Society of Northumbria was listed in *The Telegraph* amongst the Duke's appointments and it was as the Society's President that we would remember him.

FINANCIAL STATEMENTS

31 JULY 1996

THE NATURAL HISTORY
INCOME AND EXPENDITURE ACCOUNT

1995			
£		£	£
	SALARIES, PENSION CONTRIBUTIONS AND		
25,119	NATIONAL INSURANCE		26,940
3,966	PRINTING AND STATIONERY		4,168
2,327	POSTAGE AND TELEPHONE		2,153
1,869	INSURANCE		1,947
1,109	REPAIRS AND RENEWALS		720
1,338	GENERAL EXPENSES		1,101
5	LICENCE FEE		5
400	ACCOUNTANCY FEES		400
903	SUBSCRIPTIONS TO SOCIETIES		790
1,838	LECTURE AND FIELD MEETING EXPENSES		1,561
	TRANSACTIONS		
7,093	Expenditure	3,169	
821	Less: Proceeds of sale	1,710	
6,272			1,459
2,193	LIBRARY		2,520
2,232	GOSFORTH PARK NATURE RESERVE		2,269
2,410	DEPRECIATION		3,034
	APPROPRIATIONS		
3,000	Gosforth Park Nature Reserve Restoration Fund		3,000
	EXCESS OF INCOME OVER EXPENDITURE		
—	FOR THE YEAR		5,124
£54,981			£57,191

SOCIETY OF NORTHUMBRIA

FOR THE YEAR ENDED 31 JULY 1996

1995			
£		£	£
	SUBSCRIPTIONS		
13,414	Annual subscriptions	15,754	
240	Add: Transfer from Life Members' Fund	240	
13,654			15,994
972	DONATIONS		857
7,500	UNIVERSITY OF NEWCASTLE UPON TYNE		7,600
—	SURPLUS ON HOLIDAY FIELD TRIP		1,348
26,582	INVESTMENT INCOME (GROSS)		30,731
1,490	SALES OF FLORA OF NORTHUMBERLAND		661
4,783	DEFICIT OF EXPENDITURE OVER INCOME FOR THE YEAR		—
£54,981			£57,191

BALANCE SHEET

1995			
£		£	£
	GENERAL FUND		
	Balance at 1 August 1995	101,895	
	Add: Excess of income over expenditure for the year (Note 4)	5,124	
101,895	Surplus on sale of investments	24	107,043
2,839	LIFE MEMBERS' FUND (Note 5)		2,599
	T B SHORT MEMORIAL FUND (Note 6)		
	Balance at 1 August 1995	95,531	
95,531	Add: Surplus on sale of investments	9,738	105,269
	GRACE HICKLING MEMORIAL FUND (Note 6)		
	Balance at 1 August 1995	78,532	
78,532	Add: Surplus on sale of investments	1,100	79,632
180,500	INVESTMENT REVALUATION RESERVE (Note 7)		176,992
	PROVISION FOR DEFERRED REPAIRS		
3,000	Balance at 1 August 1995 and 1996		3,000
	GOSFORTH PARK NATURE RESERVE RESTORATION FUND		
	Balance at 1 August 1995	8,000	
8,000	Add: Transfer from income and expenditure account	3,000	11,000
—	SIR JAMES AND LADY STEEL CHARITABLE TRUST (Note 8)		7,500
18,203	CREDITORS, ACCRUED CHARGES AND SUBSCRIPTIONS RECEIVED IN ADVANCE		12,334
£488,500			£505,369

Approved by Council on 4 October 1996

D GARDNER-MEDWIN – Chairman

R E SLACK – Honorary Treasurer

SOCIETY OF NORTHUMBRIA

31 JULY 1996

1995			
£		£	£
	FREEHOLD PROPERTY (Note 2)		
	Hancock Museum		Not valued
	Lake Lodge		
3,899	Cost	3,899	
5,300	Electrical installation	5,300	
9,199		9,199	
6,704	Less: Depreciation	6,782	
2,495			2,417
	HIDES, EQUIPMENT, OFFICE FURNITURE AND COMPUTERS (Note 3)		
17,406	Cost 1 August 1995	19,605	
2,199	Additions	5,638	
19,605		25,243	
15,157	Less: Depreciation	18,113	
4,448			7,130
	INVESTMENTS IN TRUSTEE SECURITIES, AT MARKET VALUE (Note 7)		
	Quoted		
157,856	Narrow range	152,557	
134,179	Wide range	125,376	
93,643	Special range	100,746	
	Unquoted		
	Charities Official Investment Fund		
67,103	9,750 shares of no par value	70,479	
452,781			449,158
	INCOME TAX RECOVERABLE, ACCRUED		
5,744	INCOME AND PAYMENTS IN ADVANCE		2,911
	CASH AT BANK		
16,979	Charities deposit fund	29,719	
4,015	Deposit account	9,513	
2,038	Current account	4,521	
23,032			43,753
£488,500			£505,369

STATEMENT OF TRUSTEES' RESPONSIBILITIES

The Trust deed, the Charities Act 1993 and the Charities (Accounts and Reports) Regulations 1995 require the trustees to prepare accounts for each financial year. In preparing these accounts, the trustees are encouraged to follow the recommendations outlined in Statement of Recommended Practice No. 2 - Accounting by Charities (issued by the Accounting Standards Board in 1995).

The trustees consider that in preparing these accounts, they have used appropriate accounting policies, consistently applied and supported by reasonable and prudent judgements and estimates.

The trustees are responsible for keeping proper accounting records to enable them to ensure that the accounts comply with the Charities Act 1993. They are also responsible for safeguarding the assets of the charity and hence for taking reasonable steps for the prevention and detection of fraud and other irregularities.

ACCOUNTING POLICIES AND NOTES

1 Basis of accounting

The acounts have been prepared under the historical cost convention.

2. Freehold property including Library and Collections

(a) No value was attributed to the Hancock Museum at the date of its completion in 1884. The building is leased to the University of Newcastle upon Tyne which is normally responsible for all repairs and improvements.

(b) (i) The cost of Lake Lodge, less donations and grants received, of £3,899 is depreciated at 2% per annum.

(ii) The cost of installing mains electricity, less donations received, of £5,300 has been fully depreciated.

3. Hides, equipment, office furniture and computers

The cost of the hides, equipment and office furniture is depreciated at 10% per annum and computers at 20% per annum.

4. Income and expenditure account

The excess of income over expenditure for the year is arrived at after appropriations to special funds for the purpose of setting aside temporary surpluses of income to meet future expenditure.

5. Life members' fund

Amounts received in payment of life subscriptions are taken to the life members' fund and are released to income and expenditure account over a period of 20 years in equal annual instalments.

6. T B Short and Grace Hickling Memorial Funds

The funds from these legacies are invested in accordance with the Trustee Investment Acts and are subject only to expenditure for special projects.

7 Investments are shown on the Balance Sheet at their market value. The investments as at 31 July 1995 have been restated at their market value in accordance with this accounting policy. The difference between market value and cost is shown as an Investment Revaluation Reserve.

8. Sir James and Lady Steel Charitable Trust

The funds from this are for the future development and improvements to the Gosforth Park Nature Reserve.

9. The Society is a registered charity, official number 526770.

ACCOUNTANTS' REPORT TO THE MEMBERS OF THE NATURAL HISTORY SOCIETY OF NORTHUMBRIA

We have carried out an independent examination of the accounts for the year ended 31 July 1996 set out on pages 87 to 91.

Respective responsibilities of trustees and reporting accountants

As described above the trustees are responsible for the preparation of the accounts. It is our responsibility to form an opinion, based on our independent examination, on those statements and to report our opinion to you.

Basis of opinion

Our work was conducted in accordance with the general directions of the Charity Commissioners, and so our procedures consisted of comparing the accounts with the accounting records kept by the society, and making such limited enquiries of the officers of the society as we considered necessary for the purposes of this report. These procedures provide only the assurance expressed in our opinion.

Opinion

In our opinion:

a) the accounts are in agreement with the accounting records kept by the society;

b) having regard only to, and on the basis of, the information contained in those accounting records;

i) the accounts have been drawn up in a manner consistent with the accounting requirements of the regulations of the Charities Act 1993.

ii) the Society satisfied the conditions for exemption from an audit of the accounts for the year specified in the regulations of the Charities Act 1993.

PRICE WATERHOUSE

Reporting Accountants

89 Sandyford Road

Newcastle upon Tyne

NE99 1PL

4 October 1996

Trans. nat. Hist. Soc. Northumb. **57**, 93-113 (1997)

BIRDS ON THE FARNE ISLANDS in 1996

compiled by

JOHN WALTON[1]

National Trust Property Manager

ringing report by

CHRIS REDFERN[2]

edited by

MARGARET PATTERSON[3]

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INTRODUCTION

Severe weather conditions on 22 March kept all boats in harbour and it was Saturday 23 March when the wardens were able to move out to Inner Farne and Brownsman, both islands then being occupied until 1 December. Twenty-five species bred with the total population estimated at a record 70,500 pairs - although see under guillemot with regard to a change in the count criteria. This new high masks the fact that it was a good year for some species but not so good for others. The season got off to a very slow start with the cold, windy weather delaying many of the breeders and at one point it looked as though the kittiwakes might not breed at all. Eider numbers, at 1,912 nests, were only bettered in 1983 and guillemots were at their highest ever total. Arctic terns put in their poorest showing since 1978 and common terns were at their lowest since 1982. Roseate terns remained steady at two pairs, whilst an extra five pairs may give hope for the future. Elsie, the lesser-crested tern, was present for her thirteenth season and fledged one hybrid chick. A pair of swallows nested in St Cuthbert's chapel for the seventh year in succession and laid three clutches in two nests.

Passage birds were represented by 150 species. There was one addition to the island list: great reed warbler. Second appearances were made by soft-plumaged petrel and booted warbler, Sabine's gull was recorded for the third time and Cory's shearwater made its fifth appearance. Recorded for the sixth, seventh, and eighth times respectively were Pallas's warbler, Mediterranean gull and yellow-breasted bunting while a hoopoe made its ninth appearance. Other birds of note included Mediterranean shearwater, storm petrel, garganey, *islandica* race black-tailed godwit, grey phalarope, Iceland gull, black tern, turtle dove, cuckoo, grey-headed wagtail, bluethroat, stonechat, icterine warbler, barred warbler, yellow-browed warbler, red-breasted flycatcher, treecreeper, red-backed shrike, house sparrow, common rosefinch and little bunting.

Thanks go to the 1996 wardening team of Andy Baxter, Juan Brown, Simon Chambers, Dan Chaney, Stephen Ernst, Stef McElwee, Dante Munns, Mark Thomas, and Colin (alias Nick) Williams, as well as to various boatmen, for supplying the records which make up this report.

Details of all the birds are given in the following list: this follows the order and scientific nomenclature of Professor Dr K H Voous' list of recent holarctic species (1977), except for the shearwaters and gannet which adopt the new changes recommended by *Ibis* **133**, p438. Where appropriate, the figures for 1995 breeding birds are included, for comparison, in brackets.

Red-throated Diver *Gavia stellata*

1-15 were recorded regularly from 24 March until 19 April. Eighteen moving north in five hours on 1 May was the largest spring count, with 1-8 on four further May dates. 1-2 were seen on six days between June and August, then noted regularly from 6 September onwards. Thirty-seven south through Inner Sound on 21 September was the largest count.

Black-throated Diver *G. arctica*

1-2 recorded on two days in April, two days in September, and on single days in October and November. Nine north through Inner Sound during 3 April was the only large count.

Great Northern Diver *G. immer*

Singles seen on ten days from 21 September-29 November. A bird on 27 September which flew over Brownsman was still in summer plumage. The only day on which single figures were exceeded was 7 November when two were recorded.

Great Crested Grebe *Podiceps cristatus*

One spring record of a bird north through Inner Sound on 30 March. Three flew south through Staple Sound on 24 October, then singles on 17 and 30 November.

Red-necked Grebe *P. grisegena*

Spring records of two on 24 March and one on 30 March. Singles were seen on 6 and 7 August, the latter a juvenile. Then 1-2 on twenty-five days from 12 September-30 November. One bird 'resident' from 11-30 November accounted for the majority of records.

Fulmar *Fulmarus glacialis*

Birds were paired and occupying potential sites on 23 April. After the usual honeymoon period the first eggs were laid on 14 May on Inner Farne and 16 May on Staple Island, with first young on 4 July on Staple Island and 7 July on the inner group. 257 (262) pairs nested as follows: Inner Farne 37 (37), Knoxes Reef 29 (17), West Wideopens 15 (20), East Wideopens 13 (16), Skeney Scar 1 (2), Staple Island 39 (44), Brownsman 56 (57), North Wamses 25 (27), South Wamses 35 (33), Big Harcar 3 (1), Northern Hares 3 (4), Longstone End 1 (4). The first young fledged from Knoxes Reef on 20 August with the last on 26 September from Brownsman. A blue phase bird flew north over the Kettle on 28 August. An individual with a white back and three white patches on each wing flew through Staple Sound on 25 November. *Ca* 230 were around the islands from mid-November.

Soft-plumaged Petrel *Pterodroma* sp.

An individual of this genus flew north-south-north past Crumstone at 09.46 on 20 September. Second record for the islands and last recorded in September 1993.

Cory's Shearwater *Calonectris diomedea*

One close inshore off Brownsman drifted slowly north past Longstone on 28 August. Fifth record for the islands and last recorded in 1995.

Sooty Shearwater *Puffinus griseus*

Singles recorded from both inner and outer groups on 4 August followed by 1-110 on fifteen days from 22 August-12 November. The only count to exceed these numbers was when 219 north passed Crumstone in six hours on 13 September.

Manx Shearwater *P. puffinus*

1-95 recorded regularly from 18 April-11 November, with the bulk of records from July-September.

Mediterranean Shearwater *P. yelkouan*

One flew north past Crumstone on 9 September.

Storm Petrel *Hydrobates pelagicus*

Singles moved north through Staple Sound on 11 and 12 November. One was found dead under the Longstone light on 29 November.

Gannet *Morus bassanus*

Observed almost daily throughout the season. Singles were on Inner Farne on 6 April and 12 May, with two on the Pinnacles on 3 September. The heaviest passage occurred on 8 September when 1,417 moved north through Staple Sound during a one hour count.

Cormorant *Phalacrocorax carbo*

Birds were present on the islands when the wardens arrived, with nest building evident from 27 March. First eggs were noted around 8 May - the two sites are visited infrequently to minimise disturbance so egg-laying dates are always suspect. 195 (223) pairs nested as follows: East Wideopens 96 (105), North Wamses 99 (108). First young fledged on North Wamses on 9 July, with the last on 27 August. As usual birds became scarce from late September.

Shag *P. aristotelis*

Nest-building was evident from 31 March with first eggs on Inner Farne on 20 April. 994 (1,016) pairs nested as follows: Megstone 10 (6), Inner Farne 184 (171), West Wideopens 62 (85), East Wideopens 61 (60), Skeney Scar 60 (70), Staple Island 260 (255), Brownsman 118 (157), North Wamses 27 (22), South Wamses 45 (61), Roddam and Green 16 (14), Big Harcar 109 (72), Longstone End 42 (43). The first young was noted on Inner Farne on 3 June with the first fledging on 22 July and the last, on Big Harcar, not until 7 November. *Ca* 1,400 were around the islands in mid-November.

Grey Heron *Ardea cinerea*

1-3 were seen regularly throughout the season, the majority of records being from September onwards.

Mute Swan *Cygnus olor*

Five, first seen to the east of Inner Farne, flew inland on 8 April.

Whooper Swan *C. cygnus*

Five adults flew north-east through Staple Sound on 24 March, then seven north past Longstone on 4 May.

Pink-footed Goose *Anser brachyrhynchus*

Thirty-two north through Inner Sound on 27 March was the only spring record. Autumn records were of skeins of forty-one, twenty and twenty-nine on three days in October, and sixty-five, fifteen and seventy-four on three November dates.

Greylag Goose *A. anser*

1-3 were noted on four days in March-April, thirty-five flew north through Staple Sound on 6 May, and *ca* twenty moved north through Inner Sound on 28 September

Canada Goose *Branta canadensis*

Twenty-seven flew north-east over Inner Farne on 1 June, with forty-eight north through Inner Sound on 5 June.

Barnacle Goose *B. leucopsis*

2-46 were seen on three days in May (with two on Knoxes Reef on 4 May), then 2-14 on seven days between 20 September and 14 November. One was 'resident' on Little Harcar from 27 September-17 October.

Brent Goose *B. bernicla*

Fifty flying east over the Wamses on 24 March, one on South Wamses on 25 March, two over the Kettle and two on East Wideopens on 5 May were the only spring records. Autumn sightings were of 2-31 on six days from 24 August-14 November. Something of a novelty was a juvenile which spent 27 November on the central meadow of Inner Farne.

Shelduck *Tadorna tadorna*

2-6 were seen daily on both the inner and outer groups throughout March-June although there was no firm evidence of breeding. Eight flew north over Inner Farne on 25 August, two north on 10 September and one west on 12 September. An adult with five immatures off Inner Farne on 16 September raised the possibility of island breeding.

Wigeon *Anas penelope*

1-22 were noted on nine days from 24 March-1 May, with almost daily records of 1-100 from 2 September-16 November.

Gadwall *A. strepera*

Eight flew north through the Kettle before landing on Knoxes Reef on 13 September, with one male north over Brownsman on 15 October.

Teal *A. crecca*

Twelve spring records of 1-18, then seen regularly from 7 August onwards. By late November some 450 were roosting on the islands.

Mallard *A. platyrhynchos*

Birds were seen regularly throughout the season with a maximum count of seventy-one on 27 November. A leucistic bird was present on Knoxes Reef from 29 March-22 April. 1 (0) pair nested as follows: West Wideopens 1 (0). A nest with ten eggs was discovered on 11 June but was deserted by 15 June.

Pintail *A. acuta*

Spring records were of an immature male on 24 March, and a male and female north through Inner Sound on 1 May. Six flew east over Inner Farne on 5 September, then singles on 12 September, 21 October and 3 November.

Garganey *A. querquedula*

A male and female noted flying across Staple Sound on 11 May made landfall on South Wamses before moving to Brownsman. On 16 May a male flew north below the lighthouse cliffs of Inner Farne.

Shoveler *A. clypeata*

Spring records of two on 17 April and two on 1 May. Singles were seen on 23 and 28 August and 12 October.

Pochard *Aythya ferina*

An immature male was around the outer group on 24 March, with four noted from Inner Farne on 25 March. A male flew north through Staple Sound on 8 October.

Tufted Duck *A. fuligula*

1-2 were seen on two days in April with similar numbers on three May dates. Two on 20 September, then 1-3 on five days in October and November.

Scaup *A. marila*

In a five hour sea watch on 1 May five moved north through Inner Sound. An immature bird, with mallard, alighted briefly in the Kettle on 5 October.

Eider *Somateria mollissima*

Birds were prospecting sites on both the inner and outer groups from 4 April onwards with the first eggs found on Inner Farne on 18 April. 1,912 (1,462) females nested as follows: Inner Farne 1,308 (1,006), Knoxes Reef 7 (9), West Wideopens 55 (41), East Wideopens 5 (17), Staple Island 46 (41), Brownsman 449 (295), North Wamses 15 (10), South Wamses 17 (24), Big Harcar 6 (8), Northern Hares 1 (1), Longstone main rock 1 (3), Longstone End 2 (7). This is the second highest number of ducks ever to have nested on the islands, only bettered in 1983 when 1,952 nests were located. First ducklings were noted on 20 May with the last leaving Inner Farne on 29 July. *Ca* 2,150 were around the islands in mid-November.

Long-tailed Duck *Clangula hyemalis*

1-13 seen on nine days from 25 March-4 May, then 1-13 on five days in November.

Common Scoter *Melanitta nigra*

Singles and small flocks were seen regularly throughout the season. A resident flock of some ninety-five birds present in Inner Sound from 22 April-6 May was the largest count of the season.

Velvet Scoter *M. fusca*

1-4 noted on four days between 17 September and 21 November.

Goldeneye *Bucephala clangula*

1-12 seen on twenty-six days from 23 March-11 May. One female flying north through Inner Sound on 19 June was the only summer record, with 1-20 seen on eight days from 20 September-26 November.

Red-breasted Merganser *Mergus serrator*

1-6 noted on twenty-one days from 24 March-27 November. There were no records during July and August.

Goosander *M. merganser*

One female flying south over Brownsman on 9 April was the only record.

[Honey Buzzard *Pernis apivorus*

A bird flying west over Staple Island on 23 May was most probably of this species. Unfortunately insufficient plumage details were noted and the record was not accepted by the Northumbrian Rarities Committee.]

Sparrowhawk *Accipiter nisus*

There were records of single birds on three days in April and on 5 May, and autumn sightings on nine days from 9 September-29 November.

Kestrel *Falco tinnunculus*

Singles were noted on twenty days between 27 March and 24 October but with no records in June or July. A bird on Inner Farne on 15 September was observed eating caterpillars.

Merlin *F. columbarius*

Singles were seen regularly from 23 March-7 April, then 1-2 almost daily from 9 September-30 November.

Peregrine *F. peregrinus*

Singles on three days in March, two days in April and on 6 May were the only spring records. Singles were again observed on seventeen days from 14 August-26 November and included a very vocal bird which roosted on the Inner Farne lighthouse cliffs on 20 November. Two roosted on the lighthouse cliffs on 3 October.

Water Rail *Rallus aquaticus*

Lone birds were on Inner Farne on 14 and 28 October, with one on Brownsman on 22 October.

Moorhen *Gallinula chloropus*

One was flushed from Brownsman pond on 1 December - the last new species of the season.

Coot *Fulica atra*

One, first located on Inner Farne on 25 April, was a novel sight as it spent the morning commuting across the Kettle between West Wideopens and Inner Farne.

Oystercatcher *Haematopus ostralegus*

Ca seventy were present from March-early May. First eggs were found on Inner Farne on 2 May, with first young on the same island on 16 June. 33 (30) pairs nested as follows: Inner Farne 6 (6), Knoxes Reef 3 (2), West Wideopens 4 (5), East Wideopens 2 (2), Staple Island 4 (4), Brownsman 8 (6), North Wamses 2 (1), South Wamses 1 (1), Big Harcar 1 (0), Northern Hares 1 (1), Longstone main rock 1 (1), Longstone End 0 (1). The first young fledged on Inner Farne on 21 July and on Brownsman on 24 July. Numbers built up from early August with a peak count of 108 on 29 August and 80-90 thereafter.

Ringed Plover *Charadrius hiaticula*

Displaying birds were noted from 5 April with first eggs on Inner Farne on 28 April. 12 (12) pairs nested as follows: Inner Farne 6 (5), Knoxes Reef 0 (1), West Wideopens 1 (2), Staple Island 1 (1), Brownsman 3 (2), Longstone main rock 1 (1). The first young hatched on 28 May. Thirty-six on 17 August was the maximum count with numbers reducing to 1-5 by mid-November.

Golden Plover *Pluvialis apricaria*

Regular in small numbers throughout April and early May with 140 flying north on 6 May being the largest count of the year. Observed from mid-August until late September, generally in numbers of 1-26 but with 120 over Knoxes Reef on 11 September.

Grey Plover *P. squatarola*

Singles were seen on six days from 24 March-29 May: the bird on the latter date was in summer plumage. A summer-plumaged bird was on Knoxes Reef on 6 September then 1-6 on twenty-six days from 17 September-27 November.

Lapwing *Vanellus vanellus*

1-10 seen on nine days in March and April, then 1-18 on ten days from 11 August-29 November.

Knot *Calidris canutus*

A most unusual feature of the season was a resident flock on Inner Farne from late April until mid-September. Numbers varied, with up to 190 in May, 272 throughout June rising to 320+ on 8 July, then gradually decreasing until dispersal around 13 September. Away from Inner Farne, records of 1-60 were regular from 24 March-26 November.

Sanderling *C. alba*

Singles on Knoxes Reef on 19 and 21 July, with twenty-seven west over Inner Farne and Brownsman on 3 September.

Little Stint *C. minuta*

In common with much of Britain the Farne Islands enjoyed an excellent autumn. Birds were recorded daily from 19-26 September with the highest count of eleven on 20 September - the largest flock ever recorded on the islands. Outside this period two were present on Brownsman and Staple Island on 4-5 October.

Purple Sandpiper *C. maritima*

Recorded in every month of the season with lowest numbers, just two birds, from early June until mid-July. Highest spring count was 268 on 4 May. 115 in late August declined to *ca* ten by late November.

Dunlin *C. alpina*

1-17 recorded regularly throughout the season. The largest count was fifty in the high-tide roost on Knoxes Reef on 28 October.

Ruff *Philomachus pugnax*

A male in full breeding plumage was on Brownsman on 19-21 July. 1-3 were seen on seven days between 16 August and 29 November.

Jack Snipe *Lymnocryptes minimus*

Single birds, on Brownsman and Staple Island, were seen on five days between 20 September and 29 November.

Snipe *Gallinago gallinago*

1-2 were noted on eleven days from 24 March-29 April, then on nineteen days between 19 August and 20 November. A group of fifteen, seemingly lost in fog, flew over Inner Farne on 3 September.

Woodcock *Scolopax rusticola*

1-4 seen on six days between 23 March and 15 April, with 1-8 on seventeen days from 16 October-29 November.

Black-tailed Godwit *Limosa limosa*

Two birds of the *islandica* race were on Brownsman on 27 April. Three over Staple Island on 2 August was the only other record.

Bar-tailed Godwit *L. lapponica*

1-23 observed on eight days from 23 March-29 May, then 1-4 on twelve days from 2 August-29 November.

Whimbrel *Numenius phaeopus*

1-11 noted on fifteen days from 22 April-19 May, then 1-15 on twenty-four days between 9 July and 14 September.

Curlew *N. arquata*

Birds seen daily except during the period 1-20 June when none was present. Maximum spring count of 320 on 15 April, with an autumn high of *ca* 400 throughout late October-early November.

Spotted Redshank *Tringa erythropus*

A juvenile was on Brownsman on 22 August. One flew south-west over Inner Farne on 17 September.

Redshank *T. totanus*

Recorded daily throughout the season. The largest count was of forty on Brownsman on 1 August.

Greenshank *T. nebularia*

One on Brownsman on 21 April was the only spring record. 1-2 were noted on eight days from 12 August-5 November.

Green Sandpiper *T. ochropus*

One on Staple Island on 19 May was the only spring record. Singles were observed on six days from 12-22 August.

Common Sandpiper *Actitis hypoleucos*

1-2 noted on twelve days from 2-31 May, then 1-4 on thirty-six days between 10 July and 15 September.

Turnstone *Arenaria interpres*

Observed daily throughout the season with lowest numbers in mid-summer. *Ca* 700 on Longstone and Knoxes Reef on 2 September was the highest count.

Grey Phalarope *Phalaropus fulicarius*

On 3 November one flew south through Staple Sound.

Pomarine Skua *Stercorarius pomarinus*

Singles were seen on 30 April and 3 May. 1-4 were noted on four days in September then one flew north and two south on 26 November.

Arctic Skua *S. parasiticus*

Spring records of one on 13 April, seven on 1 May and one on 3 May. 1-27 seen regularly from 17 June-11 November. There was only one large count of forty-four north past Crumstone on 6 September.

Long-tailed Skua *S. longicaudus*

An adult flew north over the Kettle on 20 August. Two juveniles were around Longstone on 6 September, then single juveniles on 9, 12, and 17 September.

Great Skua *S. skua*

There were three records in May, three in June, two in July, then becoming regular from 2 August-25 November. Numbers were in the 1-21 range.

Mediterranean Gull *Larus melanocephalus*

One, in second summer plumage, was on Brownsman for approximately five minutes on 13 July. The same bird was again present on 16 July. Seventh record for the islands and last recorded in 1995.

Little Gull *L. minutus*

An excellent year for this species with 1-7 recorded on sixteen days from 1 May-12 November.

Sabines Gull *L. sabini*

A juvenile was loitering around Crumstone for twenty minutes on 12 October. Fourth record for the islands and last recorded in 1993.

Black-headed Gull *L. ridibundus*

Birds were displaying from 1 April with first eggs on Brownsman on 26 April. 69 (63) pairs nested as follows: Inner Farne 30 (28), Brownsman 39 (35). First young were noted on 10 June, with the last fledging on 10 August. The largest autumn count was of *ca* 190 fishing in the Kettle on 10 November

Common Gull *L. canus*

1-30 noted daily from 23 March-13 May. An immature was in the Kettle on 29 June then there were regular sightings from early August until the end of the season. 100+ seen daily from mid-late September with day-counts dropping to *ca* forty in October and *ca* fifteen in November.

Lesser black-backed Gull *L. fuscus* and **Herring Gull** *L. argentatus*

1,389 (1,382) pairs nested as follows: Megstone 1 (1), Inner Farne 11 (8), Knoxes Reef 37 (40), West Wideopens 235 (245), East Wideopens 217 (169), Skeney Scar 29 (60), Staple Island 94 (75), Brownsman 31 (10), North Wamses 249 (241), South Wamses 197 (180), Roddam and Green 27 (15), Big Harcar 167 (260), Little Harcar 17 (7), Northern Hares 66 (59), Longstone main rock 5 (5), Longstone End 6 (7). First eggs were noted on 6 May. The last record of lesser-black backed gull was on 11 November whilst herring gull numbers increased to *ca* 2,000 by late September.

Iceland Gull *L. glaucoides*

One first-summer bird spent the afternoon of 27 March around the islands of the outer group.

Glaucous Gull *L. hyperboreus*

Singles were observed on 16 April, 9 September and 12, 22 and 24 November.

Great Black-backed Gull *L. marinus*

Ca fifty were present daily in the spring becoming scarce from late May. 2 (2) pairs nested as follows: East Wideopens 1 (0), North Wamses 1 (1), South Wamses 0 (1). Numbers began to build up from mid-August with a peak count of *ca* 300 on 13 October.

Kittiwake *Rissa tridactyla*

Birds were present on 23 March with some nest building in evidence. One egg was laid, on Brownsman Cottage cliff, on the remarkably early date of 2 April although this had disappeared by the 4 April. Nest building commenced in earnest around 21 April but was dogged by poor weather and storms with many nests being washed away during 4-5 May. Consequently it was not until 26 May that the first eggs were located on both Inner Farne and Brownsman, with first young on 20 June. 6,236 (6,313) pairs nested as follows: Megstone 34 (49), Inner Farne 1,691 (1,735), West Wideopens 309 (361), East Wideopens 428 (496), Skeney Scar 310 (291), Staple Island 1,643 (1,613), Brownsman 1,514 (1,459), North Wamses 87 (86), South Wamses 53 (118), Roddam and Green 35 (14), Big Harcar 132 (91). The first young fledged on 26 July with the last on 25 August although young birds roosted on the cliffs until 4 September. Birds became scarce after this date with never more than thirty seen on any one day.

Lesser Crested Tern *Sterna bengalensis*

One of the hybrid young, from 1989 or 1992, was present in the Inner Farne tern roost on 6-7 May but it was not until 16 May that Elsie reappeared for her thirteenth summer. Seen almost daily thereafter, although absent from 30 May-6 June, she was paired with a Sandwich tern and incubating one egg in the Inner Farne colony by 12 June. This hatched on 5 July and the hybrid young fledged successfully, leaving the islands on 29 August.

Sandwich Tern *S. sandvicensis*

One fishing in the Kettle on 25 March was the first record. Seen daily from 2 April numbers built up gradually with the evening roost holding some 1,700 birds by 7 May. First eggs were recorded on 20 May on Brownsman with first young on 15 June. 2,179 (1,837) pairs nested as follows: Inner Farne 1,786 (1,657), Brownsman 393 (180). First young fledged on 12 July with the last fledging around 16 August. Birds roosted on Inner Farne until 4 September with just two subsequent records: one flying south on 3 October and two south on 8 October.

Roseate Tern *S. dougallii*

Two in the Inner Farne tern roost on 5 May were the first of the season. 2 (2) pairs nested as follows: Inner Farne 2 (2). Both pairs nested inside car tyres on the meadow. First egg was

located on 27 May, with the first young on 19 June and fledging on 12 July: the two pairs fledged four young. In addition to the breeding pairs at least another ten birds, apparently paired, were present on Inner Farne throughout June. Birds left the islands around 16 August although one was seen in Staple Sound on 1 September and another was heard calling on 3 September.

Common Tern *S. hirundo*

One on Knoxes Reef on 17 April was the first record. The first egg was noted on 11 June with the first young on 1 July - these dates are approximate. 183 (250) pairs nested as follows: Inner Farne 183 (249), Brownsman 0 (1). Although small numbers, maximum ten, were present daily on Brownsman there were no nesting attempts. The first young fledged on 23 July, the last in late August. An immature was in the Kettle on 3 September.

Arctic Tern *S. paradisaea*

One on Inner Farne on 10 April was the first sighting. There was a slow build-up through April with a roost of *ca* 2,600 by 7 May. First eggs were found on Inner Farne on 21 May with first young on 13 June. 2,420 (3,066) pairs nested as follows: Inner Farne 1,541 (1,895), Knoxes Reef 1 (1), Staple Island 27 (4), Brownsman 851 (1,166). First young fledged on 13 July and the last on 13 August, with birds becoming scarce after this date. The final record was of an adult in Inner Sound on 1 November.

Little Tern *S. albifrons*

Twelve flying around in the Kettle on 28 April was the first sighting. The now expected roost in St Cuthbert's Cove continued: five on 4 May increased to eighty-three on 15 May followed by a steady decline to four on 5 June. Two records of 1-3 in June, two July records and last recorded in Staple Sound on 17 July.

Black Tern *Chlidonias niger*

One summer-plumaged adult roosted on the north-east rocks of Inner Farne on 15 June and a juvenile flew north past Crumstone on 22 August.

Guillemot *Uria aalge*

Birds were present when the wardens arrived with nesting cliffs occupied from 30 March. First eggs were located on Brownsman on 24 April with the first young on 5 June. To comply with national monitoring standards the count unit for this species is now the individual adult and not the pairs arrived at by a conversion factor of 0.67 - having been used on the islands since 1983 this is now considered to be unsafe for universal use. 28,650 individuals were present on the breeding cliffs (this would have converted to 19,135 pairs in contrast to the 1995 total of 18,994) as follows: Megstone 209, Inner Farne 3,386, West Wideopens 1,567, East Wideopens 2,048, Skeney Scar 1,000, Staple Island 13,332, Brownsman 5,730, North Wamses 956, South Wamses 303, Roddam and Green 89, Big Harcar 30. First young fledged on 18 June with the last on 18 August. Small numbers were seen offshore from the latter date but the return to the breeding cliffs, generally evident from mid-October onwards, did not occur. Birds did not return to the Pinnacles and south end of Brownsman until 1 December.

Razorbill *Alca torda*

Birds were offshore on 23 March becoming regular on the breeding ledges from 2 April. The first egg was noted on 9 May with first young on 17 June. The first bird fledged on 5 July, and the last on 24 July. 141 (216) pairs nested as follows: Inner Farne 55 (112), West Wideopens 22 (37), East Wideopens 16 (28), Skeney Scar 4 (3), Staple Island 23 (21), Brownsman 2 (2), North Wamses 7 (6), South Wamses 6 (4), Big Harcar 5 (3), Longstone End 1 (0). Very small numbers were around the islands in October and November.

Black Guillemot *Cepphus grylle*

One summer-plumaged bird in Staple Sound on 24 March was the only spring sighting. There were two records of single birds in late August, then regular sightings throughout October and daily in November. The highest count was of twelve on 29 October, with 3-5 in Staple Sound during November.

Little Auk *Alle alle*

One flying south through Staple Sound on 24 October presaged large movements of this species. Present daily from 29 October. The largest counts occurred on 2 November with *ca* 2,300 (the majority flying south), 3 November when *ca* 1,800 flew south, and 12 November when, in one hour, 1,838 flew south and 127 north through Staple Sound. Whilst no birds were seen to fly inshore with starling flocks, as in 1995, some did arrive inland and were brought to the Property Manager's house in a variety of containers. All were released safely onto the sea.

Puffin *Fratercula arctica*

Birds were present offshore on 23 March and had moved onto the islands by 31 March. Attendance was intermittent until 14 April when burrow-cleaning/digging started in earnest. The first egg was noted, in a gull's mouth, on 29 April, and evidence of first young on 4 June. The first fledgling was on Staple Island on 6 July with the last noted on 2 August. The clear-out of birds was almost complete by 16 August although one was seen flying around with sand eels on 29 August, suggesting it still had a chick. 1-2 were seen occasionally after this date. No population count was undertaken this year - the 1993 estimate was 34,710 pairs.

Woodpigeon *Columba palumbus*

1-2 seen on four April days, singles on three days in May, then singles again on 7 June and 10 November.

Collared Dove *Streptopelia decaocto*

Records of single birds on two April days, six days in May and on 20 August.

Turtle Dove *S. turtur*

One on Brownsman on 22 May, and one on Staple Island on 13 October.

Cuckoo *Cuculus canorus*

One was on Inner Farne on 19 May.

Long-eared Owl *Asio otus*

Singles were on Inner Farne on 21 September, and Brownsman-Staple Island on 25 October and 27 November.

Short-eared Owl *A. flammeus*

Singles were seen on four days between 25 March and 26 April, with singles again on seven days from 7 October-6 November.

Swift *Apus apus*

1-7 recorded regularly from 19 May-11 August. One was over Inner Farne, apparently ahead of a weather-front, on the late date of 26 October. This is the latest ever record from the islands.

Hoopoe *Upupa epops*

A female was on Brownsman north hill on 11 May. The Inner Farne wardens, alerted to the bird's presence, made the Zodiac trip to see it. Unfortunately, the wardens and the bird passed each other about halfway across Staple Sound: the bird may have seen the wardens but, sadly, not vice versa. Ninth record for the islands and last recorded in 1993.

Skylark *Alauda arvensis*

1-24 seen regularly from 23 March-6 May, then 1-22 almost daily from 16 September-27 November.

Sand Martin *Riparia riparia*

1-9 noted on five days between 17 and 29 April, then singles on 5 May, 31 August and 11 September.

Swallow *Hirundo rustica*

For the seventh year in succession a pair nested in St Cuthbert's chapel on Inner Farne and, for the first time, laid three clutches (using the 1995 nest for the first and third broods, and a newly constructed one for the second). Thirteen young fledged from the fifteen eggs laid, birds from the first brood fledging on 18 June and from the last on 22 September. 1-10 were seen almost daily from 15 April-1 July, then intermittently from 16 August until 9 October when one flew over Staple Island. One large count was of 120 feeding over Inner Farne on 16 August.

House Martin *Delichon urbica*

Singles on 25 April and four days in mid-May. Five over Inner Farne on 21 September was the final record.

Tree Pipit *Anthus trivialis*

1-6 seen on sixteen days from 12 May-7 June, then 1-4 on fourteen days from 22 August-29 October.

Meadow Pipit *A. pratensis*

1-35 noted almost daily from 23 March-20 May with seventy-three flying south on 17 April. Then 1-30 seen almost daily from 7 August-26 November with a passage of 80+ on 3 September.

Rock Pipit *A. spinoletta*

Present throughout the season. 16 (17) pairs nested as follows: Inner Farne 5 (6), West Wideopens 1 (1), Staple Island 2 (2), Brownsman 7 (7), Longstone main rock 1 (1). *Ca* 150 were present around the inner group in early October with numbers dropping to around thirty-five by November.

Yellow Wagtail *Motacilla flava*

One was seen on 25 April, with 1-2 on five days in May. Singles on 18-19 September, then one flew west over Brownsman on 28 October, the latest ever recorded from the islands. A grey-headed wagtail *M. f. thunbergi* was present on Brownsman on 19 May.

Grey Wagtail *M. cinerea*

Singles over Inner Farne on 1-2 April, with 3+ on the island on 27 April.

Pied Wagtail *M. alba*

Recorded daily from 23 March-29 August. 5 (5) pairs nested as follows: Inner Farne 2 (2), Staple Island 1 (1), Brownsman 2 (1), Longstone main rock 0 (1). First young were noted on Brownsman on 31 May with fledging on 16 June. Single birds were on Inner Farne on 10 and 28 October.

Wren *Troglodytes troglodytes*

1-7 seen throughout March-early May, one on 17 August, then 1-4 almost daily from 20 September-early December.

Dunnock *Prunella modularis*

1-4 seen daily from 23 March-17 April, one on 22 August, then 1-10 daily from 18 September-early December.

Robin *Erithacus rubecula*

1-10 seen almost daily from 23 March-20 May, singles on Inner Farne and Staple Island on 26 August, then 1-10 almost daily from 5 September-early December.

Bluethroat *Luscinia svecica*

Birds were present daily from 17-21 May. At least nine, possibly more, were recorded over the five days.

Black Redstart *Phoenicurus ochruros*

1-5 were noted almost daily from 4 April-1 May, then 1-3 regularly between 14 October and 12 November. One bird which made landfall on Brownsman on 15 April appeared to have come off *Glad Tidings VI* - ship-assisted passage?

Redstart *P. phoenicurus*

1-9 seen regularly from 24 April-30 May, one male on Inner Farne on 21 August, then 1-7 almost daily from 5-26 September. Fifteen were present on Brownsman on 18 September.

Whinchat *Saxicola rubetra*

1-8 observed regularly from 1-23 May, then 1-8 on fourteen days from 19 August-24 September.

Stonechat *S. torquata*

A male and female were on Brownsman on 24 March, then one male on Inner Farne from 1-7 May.

Wheatear *Oenanthe oenanthe*

1-15 seen daily from 23 March-31 May, 1-2 on three days in June, singles on 15 and 21 July, then becoming regular from 13 August-28 October. The highest autumn count was a minimum of twenty-six on 31 August.

Ring Ouzel *Turdus torquatus*

Singles on 6 and 13 April, then 1-2 on nine days between 14 and 31 October, with a party of twelve flying west over Brownsman on 23 October.

Blackbird *T. merula*

1-45 recorded almost daily from 23 March-20 May. A female was on Inner Farne on 25 September with 1-150 seen daily from 9 October until the end of the season. Two days of strong passage were noted on 23 and 24 October when a minimum of 3,000 a day flew in over the islands.

Fieldfare *T. pilaris*

1-30 noted on twenty-one days from 23 March-20 May with 117 on Inner Farne on 11 April. 1-2 on four days in August, then 1-200 regularly from 13 October-14 November. There was a heavy passage on 23 October with *ca* 800 over the islands.

Song Thrush *T. philomelos*

1-12 seen regularly from 23 March-20 May with *ca* forty on Brownsman on 24 March. Single records in July and August with 1-100 seen regularly from 5 October-26 November. *Ca* 500 over the islands on 23 October was the largest day count.

Redwing *T. iliacus*

1-30 noted regularly from 23 March-19 May then 1-500 regularly from 19 September-15 November. There were two large day counts: *ca* 1,300 over on 18 October and *ca* 3,500 on 23 October

Mistle Thrush *T. viscivorus*

1-3 seen on six days from 23 March-11 April, with one on Inner Farne on 24 October.

Grasshopper Warbler *Locustella naevia*

Singles seen on Inner Farne on 20-21, 27 and 29 April - the bird on the latter date was reeling. One was on Brownsman on 1 May and one on Inner Farne on 2 May.

Sedge Warbler *Acrocephalus schoenobaenus*

1-4 observed on nine days from 22 April-31 May, then one on Staple Island on 3 September and one on Brownsman from 18-21 September.

Reed Warbler *A. scirpaceus*

Singles on Brownsman and Inner Farne on 19 May, two on Brownsman on 20 August and one on the same island on 22 September.

Great Reed Warbler *A. arundinaceus*

One arrived on Inner Farne at 18.20 on 19 May, visited the Wideopens on the afternoon of 20 May, and was back on Inner Farne for the 21 May. On the evening of its arrival it perched within three feet of a common sandpiper and one foot of a red-backed shrike - not a sight one sees every day. First record for the islands.

Booted Warbler *Hippolais caligata*

A first-winter bird was on Brownsman on 20-21 August. Second record for the islands and last recorded in 1990.

Icterine Warbler *H. icterina*

One was present on Brownsman from 26-27 August.

Barred Warbler *Sylvia nisoria*

A sub-adult observed on 21 August spending the day in the elder bushes on Inner Farne may have been present the previous evening.

Lesser Whitethroat *S. curruca*

1-2 noted on eight days between 7 and 23 May, then 1-2 from 27-28 August, with a final sighting of one on Brownsman on 21 September.

Whitethroat *S. communis*

1-8 seen on thirteen days from 26 April-31 May, singles on three days in mid-June, then 1-2 on seven days between 25 August and 24 September.

Garden Warbler *S. borin*

1-4 noted from 18-22 May, 1-5 on twenty-four days from 12 August-24 September, then singles on 14 October and 9 November.

Blackcap *S. atricapilla*

Singles on five days from 17 April-19 May, 1-10 from 17-25 September, and 1-5 on twelve days between 14 October and 16 November.

Pallas's Warbler *Phylloscopus proregulus*

One, on the very early date of 19 September, flew into the Inner Farne Information Centre at 10.00. Released into the courtyard it spent the rest of the day in the hemlock patch. Sixth record for the islands and last recorded in 1995.

Yellow-browed Warbler *P. inornatus*

One was on Brownsman and Staple Island from 22-24 September, and one on Brownsman on 14 October.

Chiffchaff *P. collybita*

1-6 were seen regularly from 6 April-7 June. Birds present in late April/early May were frequently heard singing. Then 1-5 were observed on fifteen days from 28 August-28 October.

Willow Warbler *P. trochilus*

1-20 observed regularly from 16 April-31 May, then 1-18 almost daily between 8 August and 18 October. Birds showing characteristics of the northern race were present on 31 May and 13-14 October.

Goldcrest *Regulus regulus*

1-12 seen almost daily from 6-22 April, one was on Brownsman on 14 August, then 1-22 noted regularly from 3 September-27 October.

Spotted Flycatcher *Muscicapa striata*

Singles noted on four days from 18-31 May, then singles again on four days from 3-21 September.

Red-breasted Flycatcher *Ficedula parva*

One first-winter bird was on Brownsman on 20 September.

Pied Flycatcher *F. hypoleuca*

One was noted on 24 April then 1-2 were seen on five days from 18-23 May. On 20 May a female used one of the warden's legs as a perch from which to flycatch! 1-12 were present on eighteen days from 6 August-26 September.

Treecreeper *Certhia familiaris*

One was found in the bathroom of Brownsman cottage on the evening of 16 August. When released it spent the remainder of the evening on the walls of the cottage and old lighthouse.

Red-backed Shrike *Lanius collurio*

One sub-adult male was on Inner Farne on 19 May whilst a female was present on Brownsman and Staple Island from 19-21 May.

Jackdaw *Corvus monedula*

1-9 seen on nine days between 31 March and 5 May, then nine flew west over the islands on 24 October.

Rook *C. frugilegus*

1-3 noted on nine days in April. Four flew north over Brownsman on 8 October with two west over Inner Farne on 1 November.

Carrion Crow *C. corone*

1-12 seen regularly in spring and autumn with just two records in June, one in July and none in August. A pair had two nesting attempts on West Wideopens but eggs of the first clutch were washed away by heavy rain whilst the second clutch, in the beached *Children's Friend*, were predated. Last attempted to breed in 1994.

Starling *Sturnus vulgaris*

1-90 observed regularly in spring and summer with larger numbers in autumn. Passage in late October saw regular counts of *ca* 300. For the fourth year in succession a pair nested in the 14th century window of St Cuthbert's chapel whilst a second pair nested in a crevice on Prior Castell's Tower. In spring and autumn the birds' mimicry included golden plover, grey plover, curlew, yellow wagtail, treecreeper, great grey shrike, jackdaw, house sparrow, chaffinch and yellowhammer.

House Sparrow *Passer domesticus*

A juvenile was on Brownsman from 17-24 July but died on the latter date. The bird appeared very recently fledged and was begging for food when found on 17 July. Ship-assisted passage was suspected when, on the 18th, it was seen to fly from Brownsman onto *Glad Tidings* before fluttering back to Brownsman. Eleventh record for the islands and last recorded in 1995.

Chaffinch *Fringilla coelebs*

One was on Brownsman on 25 March, 1-3 were seen almost daily from 5-17 April, then 1-20 on eighteen days between 18 September and 16 November.

Brambling *F. montifringilla*

1-3 were seen on twelve days from 6 April-12 May, then 1-50 observed regularly from 17 September-15 November. Ninety flying west over Inner Farne on 18 October was the largest count.

Greenfinch *Carduelis chloris*

1-3 seen on six days from 24 March-1 May, with 1-4 on five days from 18 September-12 November.

Goldfinch *C. carduelis*

1-4 were noted on ten days between 24 March and 8 May, three were on Inner Farne on 25 August, then 1-2 on three days from 15 October-6 November.

Siskin *C. spinus*

Four flying north-east over Inner Farne on 14 May was the only spring record. 1-12 were seen on ten days from 5 September-23 October.

Linnet *C. cannabina*

1-34 seen regularly from 24 March-2 June, and 1-50 on twenty-four days from 27 September-29 November.

Twite *C. flavirostris*

One, with three linnets, was on Inner Farne on 13 November.

Redpoll *C. flammea*

1-7 were noted on seven days between 2 and 23 April.

Common Rosefinch *Carpodacus erythrinus*

An immature/female was on Brownsman from 5-6 September.

Lapland Bunting *Calcarius lapponicus*

A male, moulting into summer plumage, was present on Inner Farne on 27 March.

Snow Bunting *Plectrophenax nivalis*

1-3 were at Inner Farne lighthouse from 23-27 March. 1-11 were seen almost daily from 8 October-30 November.

Yellowhammer *Emberiza citrinella*

A female was on Inner Farne on 10 April.

Little Bunting *E. pusilla*

One was on Brownsman on 24 October.

Yellow-breasted Bunting *E. aureola*

The log reads: 'Within minutes of finding a booted warbler, a stripy bunting dropped into the same patch of *Atriplex* causing the wardens to lose control'. The bird, a juvenile, was present on Brownsman from 20-23 August. Eighth record for the islands and last recorded in 1995.

Reed Bunting *E. schoeniclus*

1-7 seen on seven days from 24 March-21 May, with 1-12 on fourteen days from 20 September-26 October.

Feral Pigeon

Present throughout the season with a maximum count of *ca* 200 in October. Breeding was confirmed on a number of islands.

BIRD RINGING

by

Dr Chris Redfern

This report summarises the recoveries (birds found dead), controls (birds intentionally caught elsewhere and released) and re-sightings (rings read in the field) of birds ringed up to 1987, and describes the new programme of ringing initiated in 1996. Many of the field records of Farne Islands birds were from 1996, but reports of recoveries and controls often relate to birds recovered or controlled the previous year. The ringing of seabirds on the Farne Islands up to 1987 has provided important information on survival rates and sources of seabird mortality. Seabirds are long-lived and recoveries and sightings of ringed birds are still being reported and contribute to a greater understanding of seabird populations. However, recent events and analyses of previous data have emphasised the value of maintaining ringing effort as a vital part of conservation and environmental monitoring. For example, in 1994, a wreck of shags and guillemots occurred along the east coast (Harris & Wanless, 1996) but it was not possible to say how badly this affected young birds from the Farnes. Similarly, the continued trapping of Sandwich terns along the west coast of Africa may significantly reduce the number of young birds returning to breed (Green *et al*, 1990). Because of the national importance of the Farnes seabird colonies, ringing was restarted in 1996 to enable the continued monitoring of mortality and population movements, and to contribute to the local management of the seabird colonies. It is hoped that the application of new statistical techniques and a planned approach to ringing will increase the information that can be obtained from ringing seabirds on the Farne Islands.

Ringing recoveries

The colonies of Sandwich terns breeding on Inner Farne and Brownsman are of national importance, and represent about one-sixth of the British population (*cf.* Gibbons *et al*, 1993). In the past, annual recoveries of Farne Island-ringed Sandwich terns have accounted for about 40% of the total recoveries for this species generated each year by the UK Ringing Scheme, and the Farnes ringing efforts have thus had a major impact on our knowledge of Sandwich tern movements and mortality. In 1996, ten recoveries were reported, three from Senegal (recovered in winter) and one from South Africa, the remainder being birds recovered dead from British shores in the breeding season. The three Senegal recoveries indicate that the winter trapping of terns on the west coast of Africa is a continuing problem. Previous analyses have suggested that young birds are most seriously affected (Green *et al*, 1990), but since 1987 it has not been possible to assess the extent to which trapping continues to affect young birds from the Farne Islands. This is a factor of some importance to the Farnes colonies as studies have suggested that trapping could significantly affect the recruitment of young birds into the breeding population (Green *et al*, 1990). In addition to recoveries of dead birds, nineteen controls and twenty-two re-sightings of Farnes-ringed birds were reported. Of the controls, thirteen were reported from Griend in the Netherlands, one from Limburg (Netherlands), two from Belgium and four from the UK. Of the twenty-two sightings, all but three were reported from Griend between mid-April and mid-May 1995. If these birds were breeding there, it is an indication of the scale of movement or post-juvenile dispersal between colonies and illustrates the important contribution that ringing can make to understanding the population dynamics of these birds. Two Sandwich terns ringed as chicks elsewhere were reported from the Farne Islands, both in 1995: one was from Donegal, Ireland and the other was from Northern Ireland. Since these birds were seven and four years old respectively, they were presumably breeding on the islands.

The Farne Islands are also nationally important for their arctic terns, which represent about 7% of the British total. However, unlike Sandwich terns, the distance and remoteness of their wintering areas generates few long distance recoveries; in 1996, eleven recoveries were reported, all of them from within Northumberland. The oldest of these was twenty-three years old, and the mean age of the recoveries was sixteen years. In addition, five arctic terns were re-sighted back on the islands in 1996.

The majority of shags, kittiwakes and eiders reported in 1996 were birds seen or retrapped back on the Farnes. There were thirty-nine sight records and two retraps of shags, ranging in age from nine to sixteen years old, including three originally ringed on the Isle of May, Fife. Three ringed shags were found dead, either on the Farnes or on the main coastline nearby, two of which were also from the Isle of May. Of the forty-four shags sighted, retrapped or controlled, thirty-four had been reported in previous years.

For the kittiwakes, forty-six were identified by reading their rings in the field, and many of these were back in their original colonies, apart from one ringed on the Farnes as a chick in 1985 and recorded on Coquet Island in 1996. In addition, three kittiwakes, ranging in age from twelve to seventeen years, were recovered dead on the Farnes, one was recovered in the Faeroe Islands in January 1996 and one was controlled in Lothian region.

There were fifty-six local sightings of eiders, mainly on the same island as their original ringing and twenty-nine of these birds had been seen in previous years. Two were recovered in the area, twelve and thirteen years after being ringed as adults.

The fact that so many ringed birds are subsequently seen back on the Farnes is very exciting, as by continuing to record the numbers of adults that return to breed (or go elsewhere) each year, more accurate estimates of adult survival and emigration can be obtained. This is particularly important for species such as kittiwake and arctic terns, which tend to generate too few recoveries for estimates of survival rates to be made with confidence from the recoveries of ringed birds.

Auks breed in large numbers on the Farne Islands, with a population of 30-35,000 pairs of puffins and 15-20,000 pairs of guillemots. Six puffin recoveries were reported in 1996, ranging in age from eleven to thirty years; one of these had been ringed as a chick on the Farnes in 1970, controlled on the Isle of May in 1972, and finally recovered dead on Inner Farne at the age of twenty-six. There were eight field records or sightings of ringed puffins: one was from the Isle of May and the others were all from the Farnes. Two of these Farnes birds were also reported in previous years. The Isle of May puffin is more evidence of the continual exchange of seabirds between these two important colonies, and this is further exemplified by the sighting of a guillemot, ringed as an adult on the Isle of May in 1993 and seen on Inner Farne in 1994 and again in 1996, and the ring found on the Farnes which had been put on a herring gull chick thirteen years earlier on the Isle of May.

The 1996 Ringing Programme

Four visits were made by a small team of ringers to Inner Farne, Brownsman and Staple Island during the 1996 breeding season to ring the chicks of Sandwich and arctic terns, shags, guillemots and kittiwakes. These visits were made possible though the generous sponsorship of Northumbrian Water plc who provided a rigid inflatable boat which meant that the ringing team could get access to the islands after public visits had ended. Ringing in this first season was exploratory, and the aim was to identify the best strategy to maximise the value of the ringing data. Ringing was mainly concentrated in the study plots used by the resident wardens to monitor nesting success and productivity. In addition to providing a cohort of ringed birds for continuously monitoring survival and movements, the one important aim was to find out whether it would be possible to use ringing to assess chick survival more accurately, and to design an appropriate strategy for future work.

Ringing totals overall were 875 Sandwich terns, 416 arctic terns, 151 shags, 30 guillemots, and 198 kittiwakes, giving an overall total of 1,670. The hybrid chick of Elsie, the lesser crested tern, was closely monitored by the resident wardens: once it had reached an appropriate age it

was ringed with a metal BTO (British Trust for Ornithology) ring and two colour rings to enable it to be identified if it returns to the Farnes in future years. Although Elsie has successfully produced chicks in previous years, this will be the first time that one of her offspring can be identified unambiguously if it returns to the Farnes to breed. This will enable the breeding success of hybrid birds to be monitored and studied as part of a unique natural experiment, and should be of considerable interest to many of the visitors landing on the islands in the summer months.

Looking to the future

The marine environment is under continual threat as a result of oil spills, overfishing and the accumulation of toxic chemicals. Ringing is an important tool for monitoring the risks to which birds are exposed and the consequences for the size and breeding success of specific colonies. Recovery analyses of different seabird species show that the causes of seabird death may vary markedly in different regions of the North Sea in relation to fishing and other activities. It is thus important to continue to ring Farne Islands seabirds in order to warn of unusual mortality which may affect these important populations. Many species of birds are now declining in Britain, and to identify the causes of these declines, apart from unusual incidents of mortality or seabird wrecks (not necessarily man-made), it is necessary to know how breeding productivity and the survival rates of full grown birds vary over time in relation to population decreases. Identifying the causes of Sandwich tern mortality in west Africa is a specific example of the importance of ringing recovery data in conservation. Furthermore, ringing is the only method by which mortality and emigration rates can be estimated and thus is vital for conservation. Survival rates for adult birds are best estimated by capture/recapture or mark/re-sighting studies of mature birds, and thus continuing to ring, retrap and read rings in the field will make an important contribution to survival estimates.

On the basis of the ringing in 1996 a number of priorities have been identified which it is hoped can be carried through in future years with the support and collaboration of the Farne Islands Local Committee of the National Trust and the Property Manager and his staff. In particular, it is wished to emphasise mark/re-sighting for obtaining good age- and year-specific survival estimates, to work out a scientifically-disciplined approach to monitoring tern chick survival, and to incorporate chick-growth monitoring into the programme. Although much of the recovery data generated from ringing on the Farne Islands over the past few decades has made a major contribution to seabird biology, there is a wealth of additional retrap and re-sighting data and this needs to be fully analysed in order to plan effective monitoring programmes for the future. Transferring these data to computer is a major task that is now underway; once this is complete it will be possible to carry out these analyses.

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BRYOPHYTES OF CASTLE EDEN DENE

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SUMMARY

The most species-rich areas of bryophytes in Castle Eden Dene (SSSI, Peterlee Co. Durham) were identified by reference to a survey carried out by A. J. Richards in 1975. These areas were sampled and the results compared with Richards' survey. The effects on bryophyte flora by the removal of elm (*Ulmus* spp.), because of infection by Dutch elm disease, were investigated and profiles with and without elm canopy were recorded in similar areas of the Dene. The conclusions were: a) that there had been changes of bryophyte flora which were similar to those which had occurred in other parts of Britain, and b) the removal of elm canopy had led to a disruption of the microclimate necessary for the growth of bryophytes.

INTRODUCTION

Castle Eden Dene is the largest of several steep sided valleys, carved out by burns and tributaries which empty into the North Sea along the coast of Durham County (VC 66). Castle Eden Dene lies between Horden and Blackhall Colliery (Grid ref. NZ 457408), stretching four miles inland to near Wingate (Grid ref. NZ 405389) and covers 200ha. The area has been managed as a nature reserve since its purchase from the Burdon family in 1951. It is now managed and owned by English Nature as a National Nature Reserve. The site also has SSSI status partly because of its extensive yew woodland, the most important woodland on the magnesian limestone in Britain (Ratcliffe, 1978).

Management of Castle Eden Dene is aimed at retaining the semi-natural deciduous woodland. Where human interference has resulted in the destruction of the natural vegetation, remedial action by way of felling and replanting with trees native to the area and encouragement of regeneration of these species has taken place (Doody, 1982).

The Dene is an immature valley lined by steep sided cliffs which form a gorge in the west of the Dene. Deposits of boulder clay above the cliffs are being worn away resulting in many landslips. Under cliffs, alkaline soils have been formed by weathering of the limestone. The microclimate is constantly humid with relatively even temperature, similar to that of many Atlantic regions which are rich in bryophyte species. This, combined with the local geology and diversity of woodland, has led to many varied habitats suitable for bryophytes. It contains a third of the number of species of bryophyte which occur in vice county 66 (Corley & Hill, 1981). According to Richards' survey of 1975 (Richards, 1977), 113 species of Musci and 29 Hepatic species are to be found in Castle Eden Dene.

The Nature Conservancy Council was concerned that loss of elms (*Ulmus* spp.) as a result of Dutch elm disease had removed much of the cover for the bryophyte population in certain areas of the Dene, placing those bryophytes at risk. The extent of the bryophyte population was last recorded twenty years ago in a survey by A. J. Richards during 1975 (Richards, 1977). The National Vegetation Classification Woodlands Community Survey of the Dene (Williams, 1989) had only included a few terricolous bryophytes excluding epiphytes, epiliths and bryophytes found on rotting and dead wood.

In 1990, the survey reported here was carried out to gain more information about elm bryophyte interactions and to assess the potential damage to bryophyte populations resulting from removal of the elm canopy. The survey was designed to measure the distribution of bryophytes over various substrates, together with associated biotic and abiotic factors which were thought to be important in defining possible interactions between elm and bryophytes.

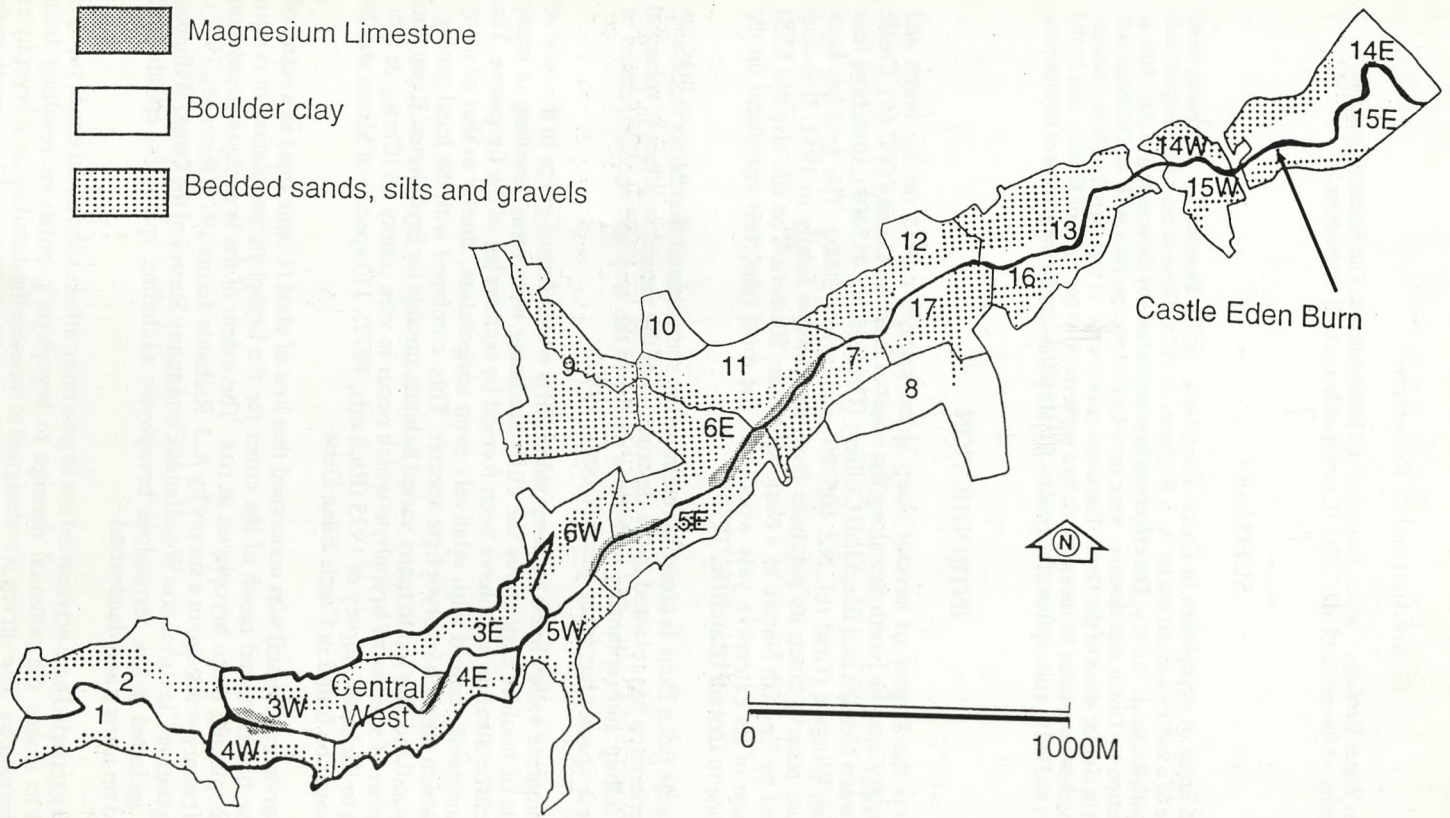

Fig.1 The map is adapted from a compartment map found in the National Vegetation Classification Woodland Committee Survey of Castle Eden Dene (Williams 1989). The area known as Central West is outlined.

Interactions between elm and bryophytes are as follows:

i) epiphytic where bryophytes grow on elm and have elm canopy;

ii) epiphytic on elm under canopy other than elm;

iii) bryophytes on other substrates: soil, rock, dead wood, leaf litter, trees other than elm, under elm canopy.

These interactions are further complicated by the effects of changes in the microclimates surrounding the elms associated with different locations within the Dene.

The investigation consisted of:

i) identification of the area to be studied;

ii) a detailed survey of the selected area;

iii) profiles: cross sections of the Dene by bryophyte transects.

METHODS

Richards' survey of bryophytes was used to identify those compartments of the Dene which were most species-rich, and also at risk from loss of elm canopy. Data collection was concentrated in an area known as 'Central West' (Fig.1) consisting of compartments 3 and 4 (combined area 38.5ha), containing fifty-five and fifty-nine species of bryophyte, respectively at the time of Richards' survey. Compartment vegetation maps (Williams, 1989) were used to note the bryophyte-rich areas and substrates to be found. This was done by a preliminary walk through each discrete vegetation area. Specimens for identification were taken from each bryophyte area and the identification confirmed by G. G. Graham (County Recorder). In the survey, the location (by grid reference), biotic and abiotic factors were recorded for each random sample. The samples were variable in terms of area, but each sample was homogeneous in terms of slope and aspect. This allowed comparisons to be made of bryophyte populations from various substrata and was more likely to ensure uniformity of microclimate within each sample. The area covered by the bryophyte population was recorded for each sample together with its slope and aspect. Small samples of species were taken and identified by microscope. Naming of bryophytes and order of nomenclature in Appendix 2 follows Corley & Hill, 1981. Watson (1981) and Smith (1978) were used for identification.

Abiotic measurements were as follows:

Temperature by battery operated temperature probe

Relative humidity by moving hair hygrometer, to record relative humidity close to bryophyte samples

Light and shade were measured by five scaled categories:

nil shade	1
little shade	2
mid shade	3
heavy shade	4
deep shade	5

Substrate moisture was estimated using five scaled categories

dry ground	1
normal ground	2
damp ground	3
waterlogged	4
in water	5

Table 1

Correlation coefficients between abiotic factors and bryophyte heights

	Bh	Sh	M	T	H
Bryophyte height (Bh)	_				
Shade (Sh)	0.75 *	_			
Moisture (M)	0.90 ***	0.74	_		
Temperature (T)	-0.74 *	-0.99 ***	-0.77 *	_	
Humidity (H)	0.80 *	0.81 *	0.69	-0.88 **	_
Slope (S)	-0.96 ***	-0.65	-0.91 **	-0.65	-0.63

Significant results are marked

* $p \leq 0.05$

** $p \leq 0.01$

*** $p \leq 0.001$

Table 2

A table to show changes of relative humidity with changes in temperature

Temperature (^{o}C)	**Relative Humidity (%)**	**Relative Humidity at 20^{o}C**
17	82	65
16	88	68
19	62	60
14	82	55

Relative humidity varies with temperature. Relative humidities measured at one temperature can be recalculated for different temperatures using a vapour pressure versus temperature curve, Randall & Jarell (Pearcy, 1989). Examples of this recalculation are shown in the table. A drop of 3 degrees celsius when the relative humidity is 65% can increase this reading to 82%. Thus reducing the air temperature around bryophytes would increase the relative humidity of the air substantially.

Table 3

Epiphytes of central west, Castle Eden Dene

Species	Ash	Alder	Rose	Syc.	Elm	Beech	Oak	Haw.	Lime	Birch	Yew	Pine
Eurynchium swartzii	X											
Brachythecium rutabulum	X	X		X	X	X	X	X		X		X
Hypnum cupressiforme	X			X						X		
Bryum capillare	X	X										X
Weissia controversa			X	X								
Dicranum montanum			X									
Dicranum tauricum	X		X	X	X	X	X		X			X
Lophocolia heterophylla				X							X	X
Dicranella heteromalla											X	X
Brachythecium velutinum	X				X							
Eurynchium praelongum	X			X	X	X	X		X	X	X	X
Mnium hornum				X	X	X	X					
Thuidium tamariscinum										X	X	
Dicranoweissia cirrata	X											
Hypnum cupressiforme var. cup.				X	X						X	X
Hypnum cupressiforme var res.						X						
Thamnobryum alopecurum					X				X		X	
Metzgeria furcata					X						X	
Lophocolea cuspidata						X						
Conicephalum conicum					X							
Mnium undulatum					X							
Total Number of Species	8	2	3	8	10	6	4	1	3	4	7	7

Table 4

Profile of bryophyte distribution and associated biotic and abiotic factors on a north facing slope of CED

COMPARTMENT 4 WEST

Section of slope reference	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Length of section (metres)	9	20	22	11	19	21	20	25
Slope (degrees)	40	38	46	40	39	39	35	34
Moisture (scale 1-5)	4	3	3	3	3	3	3	3
Relative humidity (%)	80	80	78	78	75	75	75	75
Shade (scale 1-5)	4	4	4	4	4	3	3	2
Canopy species								
Acer pseudoplatinus	p	p	p	p	-	p	p	p
Fagus sylvatica	-	-	-	-	-	-	p	p
Fraxinus excelsior	p	p	p	p	-	p	-	-
Quercus spp.	-	-	-	-	-	-	-	-
Rhododendron ponticum	-	-	-	-	p	-	p	p
Taxus baccata	p	p	p	p	p	-	-	-
Ulmus glabra	-	-	-	-	-	-	-	-
Herbaceous species								
Hyacinthoides non-scriptus	-	-	-	-	-	-	-	-
Mercuralis perennis	-	-	-	-	-	-	p	-
Pteridium aquilinum	-	-	-	-	-	-	p	p
Rubus fructicosus	p	p	p	p	-	-	-	-
Urtica dioica	-	-	-	-	-	-	-	-
Dominant bryophyte species (ground)								
Brachythecium rutabulum	-	**p**	-	-	p	-	**p**	p
Conocephalum conicum	-	p	p	p	p	p	p	p
Eurynchium praelongum	-	-	p	-	**p**	-	**p**	-
Eurynchium swartzii	-	p	-	-	-	-	-	-
Fissidens taxifolius	-	-	-	-	-	-	p	-
Hypnum cupressiforme	**p**	-	**p**	**p**	p	**p**	-	-
Mnium hornum	-	-	-	-	**p**	-	-	**p**
Plagiomnium rostratum	-	p	-	-	-	-	-	-
Plagiomnium undulatum	-	p	-	-	p	p	**p**	-
Other bryophyte substrates								
Rock	-	-	-	-	-	p	-	-
Tree trunks	p	p	p	p	p	p	-	-
Tree roots	p	p	p	p	p	p	p	-
Rotten wood	-	-	-	p	-	-	-	-

p = dominant bryophyte species p = present

Biotic factors

Canopy of the bryophyte sample
Distance and species of nearest tree upslope
Bryophyte height (the modal height above substrate for each sample).

A total of 162 sites distributed over various substrates was sampled in the area of Castle Eden Dene known as 'Central West'. These comprised fifty-two epiphytic samples, thirteen samples on rock, eighty-one on soil and sixteen on dead wood. Samples taken from three cross-section profiles of the Dene were also included. Species accretion curves were constructed for each substrate to ensure that the majority of species had been included in the survey.

Correlation coefficients between bryophyte sample heights (used as an indicator of the suitability of the microclimate for bryophyte growth) and abiotic factors were calculated for one hundred samples using Pearson's product-moment correlation coefficient (Zar,1996).

The profiles

Many parts of the Dene were difficult to access but a suitable cross-section of the Dene was found in compartment 3 West and 4 East. Ground distance was measured and the slope of the measured ground was taken by clinometer readings. The most abundant species of moss and liverwort were recorded for each section of the profile.

Two shorter profiles were made, one in 3 East from the bed of Castle Eden Dene burn to the foot of the cliff face and one in compartment 6 East also from the stream bed to the base of the cliff. Elm had been removed from the area of the profile in 6 East three years before the profile was recorded and, from the profile area of 3 East, five years. The profiles were similar in aspect and type of woodland and all three locations originally had healthy bryophyte flora (Castle Eden Dene Warden, personal communication).

RESULTS AND DISCUSSION

Microclimates of bryophytes, correlations of height of bryophytes with abiotic factors

Records of samples recorded under elm canopy together with abiotic and biotic factors are to be found in Appendix 1. Bryophyte heights from all samples followed a normal distribution and were used to calculate the correlation coefficients shown in Table 1. Although correlations between factors do not prove causal relationships, significant positive correlations between bryophyte height and shade, surface moisture, and relative humidity, also significant negative correlations between bryophyte height, temperature and slope provide evidence that shade could be important in reducing temperatures close to bryophytes. Shade would lower temperatures and reduce the rate of evaporation of substrate water whilst flat surfaces would also retain surface water longer than slopes. Relative humidities are increased with a fall in temperature, a relative humidity of 65% at 20°C increasing to 82% at 17°C. Other examples can be seen in Table 2.

Ectohydric mosses such as pleurocarpous *Thamnobryum alopecurum* are dependent on high humidity and obtain water over the whole of the surface of the moss. Endohydric mosses e.g. *Mnium hornum* also need a moist environment but obtain water from substrate moisture rather than damp air (Buch 1945, 1947, cited in Smith, 1978). Relative humidity increases with decrease in air temperature and pressure. Reduction of insolation on bryophytes because of increasing shade from woodland canopy has the effect of reducing temperatures and so increasing relative humidities close to bryophytes. The canopy also reduces windspeed close to bryophyte samples, so increasing humidity. Thus the shade and reduction in windspeed provided by the canopy are essential for maintaining microclimates suitable for bryophytes during months of higher insolation. The canopy maintains a thermocline during summer with cooler temperatures at ground level and higher temperatures within the canopy (Dajoz, 1977). It can be seen (Table 1) that significant positive correlations between bryophyte height and shade, ground moisture and relative humidity support this explanation. Although Dajoz (1977) classifies relative humidity as a density independent factor, there is a sense in which it is

Table 5

Profile of bryophyte distribution and associated biotic and abiotic factors on a south-facing slope of CED (canopy intact)

COMPARTMENT 3 WEST

Section of slope reference	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Length of section (metres)	12	19	14	19	15	13	20	16	16	31
Slope (degrees)	17	9	35	25	36	24	11	14	14	16
Moisture (scale 1-5)	4	4	4	4	2	3	3	3	2	2
Relative humidity (%)	80	78	80	80	78	78	75	75	75	75
Shade (scale 1-5)	4	3	4	4	4	3	4	2	2	3
Canopy species										
Acer pseudoplatinus	p	p	p	p	p	-	p	-	-	-
Fagus sylvatica	-	-	-	-	-	-	p	-	-	-
Fraxinus excelsior	p	-	p	p	p	p	p	-	-	-
Quercus spp.	-	-	-	-	-	-	p	p	p	p
Rhododendron ponticum	-	-	-	-	-	p	-	-	-	-
Taxus baccata	-	-	-	-	p	-	-	-	-	-
Ulmus glabra	p	p	p	-	-	-	-	-	-	-
Herbaceous species										
Allium ursinum	p	p	p	-	-	-	-	-	-	-
Hyacinthoides non-scriptus	-	-	-	-	-	-	-	-	-	p
Mercuralis perennis	-	-	-	-	p	-	-	-	-	-
Pteridium aquilinum	-	-	-	-	-	p	-	p	p	-
Urtica dioica	p	p	-	-	-	-	-	-	-	-
Dominant bryophyte species (ground)										
Brachythecium rutabulum	-	-	-	-	-	**p**	-	**p**	-	-
Conocephalum conicum	-	-	-	p	-	p	-	-	-	-
Eurynchium praelongum	-	-	p	p	-	p	-	-	p	p
Eurynchium swartzii	-	**p**	-	-	-	-	-	-	-	-
Hypnum cupressiforme	p	-	p	p	-	-	-	-	-	p
Mnium hornum (endohydric)	-	-	-	-	**p**	-	**p**	-	**p**	-
Plagiomnium rostratum	-	-	p	-	-	-	-	-	-	-
Plagiomnium undulatum (mesohydric)	-	-	-	**p**	-	-	-	-	-	-
Thamnobryum alopecurum (ectohydric)	**p**	-	**p**	-	-	-	-	-	-	-
Other bryophyte substrates										
Rock	p	p	-	-	-	-	-	-	-	-
Tree trunks	p	p	-	p	-	-	-	-	-	-
Tree roots	p	p	-	p	-	-	-	-	p	-
Rotten wood	p	-	p	-	-	-	p	-	-	-

p = dominant bryophyte species p = present

dependent on the density of the canopy in woodland. Large gaps in the canopy can be expected to be detrimental to bryophyte microclimates at times of high insolation if it is the only source of shade. This was found to be the case in 6 East profile where the canopy had been removed (Table 7). A source of moisture is provided by the bed of Castle Eden Dene burn which never becomes completely dry although the stream disappears underground for long stretches during the summer months.

Thus, increased surface moisture and humidity levels are sustained during summer when rainfall is lowest, temperatures highest, and hours are of sunshine are at their maximum. This would enable bryophytes to survive adverse conditions and extend their growing period to the following year. Between 1975 and 1989 decreased rainfall and increased temperatures above the mean (calculated from annual weather records between 1940 and 1989) have occurred in the locality during ten out of fifteen years since 1975 (Wheeler, 1990).

Profiles in Castle Eden Dene

The results of the profiles in the Dene are shown in Tables 4, 5, 6 and 7. The profiles of the north- and south-facing slopes of the Dene were taken at the only accessible point in the 'Central West' area. The canopy is intact and the profiles show zonation of endohydric and ectohydric species of moss with accompanying changes in abiotic factors, shade, moisture, and relative humidity. *Thamnobryum alopecrum* is an ectohydric moss and is found as the dominant moss only on the lower slopes (sections 1 and 3, Table 5), where shade and moisture are ranked 4 and relative humidity levels are 88%. It is not found on the steeper north-facing slope. On the less steep south-facing slope early morning mists may be expected to collect and linger longer over a greater area of ground, so providing more constant levels of humidity, suitable for the growth of this ectohydric moss.

Mnium hornum is an endohydric moss which prefers drier more acidic conditions and is the dominant moss in those sections of the profile 5 and 9 (Table 5) and 5 and 8 (Table 4), where moisture and shade are reduced to 2 or 3 and also relative humidity is in the 60%s compared with the 80%s lower down the slope closer to the burn. *Plagiomnium undulatum* is a mesohydric moss which is also capable of internal and external conduction of water and would be expected to grow best where there are intermediate levels of ground moisture and humidity. It is found as the dominant moss in section 4 (Table 5) where ground moisture and relative humidity levels are high and in section 7 (Table.4) where moisture and shade are intermediate but relative humidity is reduced.

Hypnum cupressiforme, *Eurynchium swartzii* and *Conocephalum conicum* are also found on the lower slopes of both the north- and the south-facing profiles. These are species which do not rely on the internal conduction of water and so require constantly high levels of humidity. *Hypnum cupressiforme* and *M. hornum* show a wider distribution to higher levels on the cooler north-facing slope. Increased humidity, shade, and moisture of the lower slopes allows a greater range of substrates to be colonized, e.g. rock, dead wood and tree branches. However, as humidity and moisture decrease, the range of substrates colonized falls. In section 7 (Table.4) and section 9 (Table 5) only tree roots are colonized by mosses. *Hypnum cupressiforme* is epiphytic on sycamore (*Acer pseudoplatanus*), ash (*Fraxinus excelsior*) and yew (*Taxus baccata*), and is found on rocks as far as section 6 on the north-facing slope. However no mosses are epiphytic in sections 7 and 8 (Table 5) at the top of the north-facing slope. Only a small amount of *B. rutabulum* is found on beech root in section 7 (Table.5). On the south-facing slope, *Thamnobryum alopecurum* is epiphytic on elm, sycamore, and ash up to section 4 (Table 4), but no epiphytes are found from section 6 (Table 4) upwards although some *B. rutabulum* is found at the base of sycamore roots in section 9 (Table 5).

In addition to the main profile through the Dene, two shorter profiles in 3E and 6E on south facing slopes were recorded. The elm had been removed completely in 6E and some of the elms had been removed in 3E. Specimens in sample 4 in 6E were very poor and the only shade was provided by nettles which were 2m high. It would appear that species on the stream bed are protected by the shade cast by the stream banks and high levels of humidity provided by the moist silt on the stream bed. However 10m from the stream bed (Tables 6 and 7) humidity

levels begin to fall together with a drop in the number of species of bryophytes found in both profiles. Vegetation appears to compensate for lack of elm canopy in both places but eventually mosses must be outcompeted by ground vegetation, the only surviving specimens being found on substrates such as rock and dead wood where herbaceous plants are out-competed by bryophytes in the early stages of succession.

Epiphytes

Elm supports the greatest number of species of bryophyte (Table 3). Elm has ten species which are epiphytic, ash (*Fraxinus* spp.) has eight. In this study, a number of species have been found to be unique to elm; most notably *Mnium stellare* which is rare in VC 66. *Dicranum montanum* also rare in VC 66 was found on wild rose and had last been recorded in the Dene in 1957 (Graham, 1988). *Dicranum tauricum* is an epiphyte which was not recorded in the 1975 survey and is now abundant (Appendix 2). Bates (1995) also reported an increase in *D. tauricum* in VC 22, now frequent on tree boles, stumps and logs in woodland in east and central Berkshire, the areas formerly most affected by SO2. *Anomodon viticulosus*, *Cryphaea heteromalla* and *Neckera complanata* are species which were rare in the Dene in 1975 but were not sampled in 'Central West' in 1990 (Appendix 2). These species have also decreased in VC 22 and in the opinion of Bates reflect the loss of mature elms by Dutch elm disease (Bates, 1995) since it is known to have restricted the occurrence of basiphilous epiphytes elsewhere (Bates et al.,1994, cited in Bates 1995)

If canopy drip from elm was more important in determining species than substrate or position of sample in the Dene then those samples under elm canopy would form a cohesive group. However, it seems that substrate and position in the Dene are equally important when all samples under elm canopy are considered (Appendix 1). *Dicranium tauricum* and *Mnium hornum* are found as epiphytes on the upper slopes where humidity levels are lower, however, *Conocephalum conicum* and *T. alopecurum* are found as epiliths in the bed of the burn at the lowest point of the Dene where humidity levels are highest.

The distance between sample tree and nearest tree upslope was recorded, but no clear pattern has emerged correlating bryophyte samples with these measured distances. This is possibly because the size of the tree and hence the extent of canopy was not taken into account. However all but five epiphyte samples had nearest tree distances of less than 10m. The mean of all distances to nearest tree upslope was 5m (s.d. 5.14). Gaps in canopy determine the way in which woodland regenerates itself. Gap phase regeneration theory states that the most frequent gap size determines the next generation of tree species. Ancient woodland would be expected to have smaller and less frequent gaps than managed woodland, trees only being removed by natural causes such as wind blow and wood being left to rot where it falls. This would encourage the persistence of bryophytes which take as many as twenty years to fully colonize a tree.

A COMPARISON WITH THE 1975 SURVEY

The results of this survey (March - June 1990) are compared with those of the bryophyte survey of Richards (summer 1975), Appendix 2. The same area was used for comparison, that of compartments 3 and 4 (as defined by Richards) which is 'Central West' in the present survey. In comparing the results of the two surveys, the following differences in methology should be borne in mind:

Richards' extensive survey records the incidence of species in compartments of the Dene with a general comment on abundance, substrate, and location of species. However the 1990 survey was more concerned with the ecology of recorded species and was not an exhaustive search for rare species. Because of the lack of equivalence of aims and recording methods between the two surveys, any differences in distributions of bryophytes between 1975 and 1990 should be treated with caution. However changes in the bryophyte flora have occurred which are similar to those recorded elsewhere in Britain (Bates, 1995).

Table 6

Profile of bryophyte distribution and associated biotic and abiotic factors on a south facing slope of CED (canopy missing)

COMPARTMENT 3 EAST

Section of slope reference	1	2	3	4
Length of section (metres)	3	7	4	8
Slope (degrees)	15	0	20	23
Moisture (scale 1-5)	4	4	4	2
Relative humidity (%)	80	80	80	68
Shade (scale 1-5)	4	4	4	2
Canopy species				
Fraxinus excelsior	p	-	-	-
Herbaceous species				
Geranium robertianum	p	-	-	-
Impatiens glandulifera	p	p	-	-
Mercuralis perennis	p	p	p	-
Pteridium aquilinum	-	-	p	p
Urtica dioica	p	p	p	p
Dominant bryophyte species (ground)				
Brachythecium rutabulum	p	-	-	-
Campylium stellatum	-	p	-	-
Conocephalum conicum	p	-	-	-
Eurynchium praelongum	p	p	-	p
Mnium hornum	-	-	-	-
Plagiomnium undulatum	p	-	p	-
Rhizomnium punctatum	p	-	-	-
Riccia glauca	-	p	-	-

p = present

In total sixty-one species of bryophyte were recorded in 'Central West' in 1990, including eleven species not recorded in the 1975 survey. The species that were occasional in Durham County were *D. tauricum* and *Mnium stellare* and those that were rare were *Brachythecium populeum* and *Hyocomium amoricum* (Graham, 1988). *D. tauricum* was abundant in Central West although this species had not been recorded in 1975, but had been previously recorded in the Dene in 1971 (Graham 1988). The 1975 survey (Richards 1977) included forty species in the 'Central West' area of Castle Eden Dene that had not been recorded in the present survey of the same area. Species that had only one or two records in 1975 would not have been expected to be recorded since it is unlikely that they would be located in 1990 .

Dicranium tauricum has been remarkable in its spread throughout this area of the Dene. Another species, *Brachythecium rutabulum* was unrecorded in the 1975 survey although it had been found previously on logs (Richards, 1975). It is now ubiquitous throughout this area of the Dene and it appears to have replaced *Brachythecium rivulare* and *Eurynchium riparoides*, found on rocks and in the stream bed in the 1975 survey. "It is reported that under a regime of nutrient flushing of the habitat certain species such as *Brachythecium rutabulum* and *Hypnum cupressiforme* showed enhanced survival and luxuriant growth in polluted environments" (Gilbert, 1970) (this is not to imply that pollution is a factor in this case as no measurements of nutrient levels were made in this study). Certain species that were frequent or abundant in

Table 7

Profile of bryophyte distribution and associated biotic and abiotic factors on a south facing slope of CED (canopy missing)

COMPARTMENT 6 EAST

Section of slope reference	**1**	**2**	**3**	**4**
Length of section (metres)	2	9	5	5
Slope (degrees)	45	40	30	32
Moisture (scale 1-5)	4	3	1	1
Relative humidity (%)	80	80	77	68
Shade (scale 1-5)	3	2	1	1
Canopy species				
Ulmus glabra	p	-	-	-
Ulmus glabra (dead)	-	p	p	-
Herbaceous species				
Asplenium scolopendrium	-	p	p	-
Cirsium arvensis	-	-	p	-
Urtica dioica	-	p	p	p
Dominant bryophyte species (ground)				
Brachythecium rutabulum	p	-	-	-
Conocepalum conicum	p	p	-	p
Eurynchium praelongum	-	p	-	p
Hypnum cupressiforme	-	p	p	p
Mnium hornum	p	-	-	-
Thamnobryum alopecurum	p	p	-	p

p = present

the 1975 survey have become rare. These are *Lophocolia bidentata, Cirryphyllum piliferum, Fissidens bryoides, Pellia endiviifolia* and *Pellia epiphylla.*

In the 1990 survey the majority of species that are frequent or abundant are found on more than one substrate. Thus *T. alopecurum* is found on all substrates, rock, soil, trees and dead wood. Similarly in 1975 species which were abundant in their distribution were also found on four substrates. *L. bidentata* is found on all four types of substrate. When a species has apparently become rare it also has a reduced number of substrates e.g. *C. piliferum* occurred on dead wood, rock, soil and trees in 1975 but was only recorded on soil in 1990. Bryophytes occupying certain substrates appear to be more sensitive to air pollution than others. Generally the order of increasing sensitivity is from terricolous, to saxicolous and corticolous species. Species growing on trees are generally far more sensitive than those growing on other substrates. (Gilbert, 1970).

Primary pollutants causing acid deposition are SO_2 and NO_x, and may be deposited on to surfaces by dry deposition or incorporated in to raindrops or snow and transferred to surfaces indirectly as wet deposition. Windblown cloud or fog may be directly captured by vegetation, known as occult deposition. Pleurocarpous mosses would be expected to be mostly susceptible to occult deposition whilst wet and dry deposition would be most likely to affect acrocarpous species. The Dene is subjected to mists or 'haars' from the sea (Graham, 1988). Dry deposition can be to some extent buffered by limestone based soils or rocks (United Kingdom Terrestrial review group, 1988).

CONCLUSION

The effects of elm death on bryophyte populations

The effects of elm death on bryophyte populations could be caused by alterations in microclimates due to canopy gaps, or because of more specific effects. For example, nutrients necessary for the growth of specific bryophytes may only have been provided by run off from elm bark or canopy, or elm may have been a unique substrate for certain bryophytes. Results show that although elm supports the greatest number of species, each of these species can be found growing on other tree species or on other substrates. However, as evidence from Richards' survey has shown, the rarer species may have already been reduced or disappeared because of loss of elm. Elm canopy is necessary a) to provide cover for bryophytes in order to increase humidity levels, b) to provide shade to prevent the growth of competing herbs and c) possibly to provide canopy drip. These three functions could be provided by other canopy species. However as findings from profiles indicate, canopy is essential in providing a suitable microclimate for bryophytes except close to the moist bed of Castle Eden Dene burn.

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Appendix 1

Castle Eden Dene - bryophyte samples under elm canopy

Compartment	**04W**	**03W**	**03W**	**03W**	**03W**	**03W**	**03W**	**03W**	**03W**
Easting	**418**	**418**	**419**	**419**	**419**	**419**	**419**	**421**	**421**
Northing	**387**	**388**	**387**	**387**	**387**	**388**	**388**	**388**	**389**
Substrate (see key)	**BR**	**BR**	**SO**	**BR**	**SO**	**BR**	**SO**	**SO**	**EP**
Shade (scale 1-5)	**4**	**4**	**4**	**4**	**5**	**4**	**5**	**4**	
Slope (degrees)	**55**	**70**	**0**	**0**	**40**	**0**	**10**	**30**	**90**
Aspect (degrees)	**240**	**200**			**65**		**30**	**204**	**310**
Area (square metres)	**0.25**		**1**	**0.25**	**1**	**0.4**		**0.25**	**0.5**
Moss Height (mm.)	**10**		**10**	**10**	**20**	**10**	**10**	**10**	
Moss Cover (%)	**60**		**50**	**70**	**70**	**100**	**70**	**30**	
Moisture (scale 1-5)	**4**	**3**	**4**	**3**	**4**	**4**	**4**	**3**	
Nearest Tree	**ELM**		**ELM**	**ELM**	**ELM**	**ELM**	**ELM**	**YEW**	**ELM**
NT Distance (metres)	**5**		**2**	**2**	**3**	**3**	**5**	**10**	**0**
Humidity (%)	**82**	**82**	**78**	**78**	**78**	**78**	**78**	**80**	**68**
Dicranoweissia cirrata									
Dicranum tauricum									p
Barbula fallax		p							
Bryum bicolor									
Mnium hornum		p							p
Rhizomnium punctatum						p			
Plagiomnium undulatum					p		p		
Thamnobryum alopecurum		p							
Amblystegium riparium									
Brachythecium rutabulum	p	p	p	p	p	p	p	p	
Bracythecium velutinum									
Eurynchium praelongum									
Eurynchium swartzii									
Hypnum cupressiforme									
H.c. resupinatum									
Conocephalum conicum	p	p	p		p	p	p	p	
Lunularia cruciata									
Marchantia polymorpha									
Metzgeria furcata									
Lepidozia reptans									

Substrate Key:
BR = Bare Rock
SO = Soil
EP = Epiphyte
DW = Dead or Rotting Wood

04E	04E	04E	04E	04E	04E	04E	04E	04E	04E	04E	05W	05W	03E
422	422	423	423	423	423	423	424	426	426	426	427	427	4281
388	388	387	387	388	388	388	388	390	390	390	387	388	3926
SO	SO	BR	DW	EP	BR	SO	BR	DW	DW	DW	BR	BR	EP
2	2	3	3	3	4	3	3	4	2	4	5	5	3
30	10	80	90	65	70	10	60	70	54	50	50	80	65
0	330	30	0	100	280	300	341	0	350	100	260	2	70
0.2	1	0.3	0.25	0.1	0.25	0.25	0.2	0.2		0.25	0.04		0.5
10	20	30	50	40	10	10	10	20	20	10	30	20	1
60	70	90	80	60	80	50	80	60	100	90	100	100	70
3	3	3	3	3	3	3	3	4	1	1	5	5	2
ELM	ELM	ELM	ELM	YEW	ASH	ELM	ELM	ELM	SYC	ELM	ELM	ELM	SYC
20	4	5	25	5	20	4	7	2	0.5	2	0.5	5	0
					84	83		68			78	76	

			p										
						p							
								p					
p	p							p	p	p			
		p		p					p				
						p							
p				p		p	p				p	p	p
								p					
	p						p	p	p				
p	p												p
					p								p
				p						p			
	p						p						
p					p	p							
								p					
				p									
								p					

Appendix 2

RESULTS COMPARING BRYOPHYTES PRESENT IN CED IN CENTRAL WEST AREA IN 1975 WITH THOSE PRESENT IN 1990

SPECIES	1990	1975	SPECIES	1990	1975
Musci			*B. fallax*	R (R)	E (R)
Acrocarpous species			*Eucladium verticillatum*	R (R)	R (R)
Tetraphis pellucida	NS	R (DW)	*Weissia controversa*	R (E)	E (S)
Polytrichum commune	R (DW)	NS	*W. rostellata*	NS	R (R)
Atrichum undulatum	R (DW)	R (DW)	*W. longifolia*	NS	R (R)
Diphiscium foliosum	NS	R (S)	*Tortella tortuosa*	R (R)	NS
Ditrichum flexicaule	R (R)	R (R)	*Funaria hygrometrica*	R (S)	F (S)
Ceratodon purpureus	R (DW)	F (S R)	*Orthodontium lineare*	R (S)	E (E)
Dichodontium pellucidum	R (S)	F (R)	*Pohlia carnea*	R (S)	NS
Dicranella varia	R (S)	A (S)	*P. wahlenbergii*	NS	R (S)
D. heteromalla	R (S)	F (S E)	*Bryum capillare*	R (E DW)	R (S R)
Dicranoweisia cirrata	R (DW)	R (E)	*B. flaccidum*	R (DW)	NS
Dicranum montanum	R (E)	NS	*B. caespiticium*	NS	F(S)
D. tauricum	A (E R DW)	NS	*B. bicolor*	R (R)	R (R)
Campylopus paradoxus	NS	F (E)	*Mnium hornum*	A (S E)	A (S E DW)
Fissidens bryoides	R (S)	A (S)	*M. stellare*	R (R)	E
F. taxifolius	F (S E)	F (S)	*Rhizomnium punctatum*	R (DW R)	F (R)
F. adianthoides	R (R)	NS	*Plagiomnium undulatum*	A (E DW S)	A (S DW)
Tortula laevipila	NS	R	*P. rostratum*	R (S)	NS
T. muralis	NS	R (R)	*Amphidium mougeoutii*	NS	R (R)
Barbula convoluta	NS	R (S)	*Zygodon viridissimus*	NS	R (E)
B. unguiculata	NS	R (S)	*Ulota crispa*	NS	R (E)

SPECIES	1990	1975	SPECIES	1990	1975
Pleurocarpous species			*Cirriphyllum piliferum*	R (S)	A (S E R DW)
Cryphaea heteromalla	NS	R (E)	*C. crassinervium*	NS	R(DW)
Neckera complanata	NS	R (E R)	*Rhynchostegium confertum*	R (S)	R (R)
Thamnobryum alopecurum	A (S E R DW)	A (S DW)	*Eurynchium.striatum*	NS	A(S)
Leskea polycarpa	NS	F(S E DW)	*E. praelongum*	A (S E R DW)	A (S)
Anomodom viticulosus	NS	R (E)	*E. swartzii*	F (S E)	A (S)
Thuidium tamariscinum	R (E)	R (DW)	*Rhychostegiella tenella*	NS	F (R)
Cratoneuron filicinum	NS	R (R)	*Plagiothecium succulentum*	R (S)	F (DW)
C. commutatum	R (R)	R (R)	*P. nemorale*	NS	E (E)
Campylium stellatum	R (S)	E (S)	*Isopterygium elegans*	R (S)	NS
Amblystegium serpens	R (S DW)	F (E)	*Hypnum cupressiforme*	A (R E DW)	A (E S)
Amblystegium fluviatile	NS	F (E)	*H. cupressiforme* res.	R (E)	F (E)
A. riparium	R (R)	NS	*Ctenidium molluscum*	R (R)	F (R)
A.compactum	NS	R (R)	*Hyocomium amoricum*	R (R)	E (E)
Platydictya jungermannoides	NS	F (R)	*Hylocomium splendens*	NS	R (R)
Hygrohypnum ochraceum	NS	R (R)	Hepaticae		
H. luridum	NS	F (R)	*Conocephalum conicum*	A (S R)	A (S R)
Calliergon cuspidatum	NS	F (S)	*Lunularia cruciata*	F (S R)	F (S)
Isothecium myurum	NS	R (E)	*Marchantia polymorpha*	R (DW)	R (E)
I. myosuroides	R (R)	F (E S R DW)	*Riccia glauca*	R (S)	NS
Homalothecium sericeum	NS	F(S E R)	*Metzgeria furcata*	R (E)	F (E)
Brachythecium rutabulum	A (S E R)	R (DW)	*Aneura pinguis*	R (R)	R (S)
B.rivulare	NS	F (E R)	*Pellia epiphylla*	R (DW)	A (S)
B. velutinum	F (E)	F (R S)	*P. neesiana*	NS	R (S)
B. populeum	R (DW)	E (DW)	*P. endiviifolia*	R (S R)	A (S)
B. plumosum	R (E)	F (DW)			

SPECIES	1990	1975	SPECIES	1990	1975
Leiocolea turbinata	OS	F (R)	*L. heterophylla*	F (E R)	NS
Jungermannia atrovirens	R (R)	F (R)	*Chiloscyphus polyanthos*	OS	R (S DW)
J. pumila	NS	R (S)	*Diplophylum albicans*	NS	R (DW)
Plagiochila asplenoides	NS	R (S DW)	*Cephalozia connivens*(GGG)	NS	R
Lophocolea bidentata	R (DW)	F (S E R DW)	*Lepidozia reptans*	R (DW)	E (E)
L. cuspidata	F (E DW)	F (S E DW)	*Radula complanata*	NS	R (E)

Key to substrates where bryophytes occured

S = soil **E** = epiphyte **R** = epilith **DW** = dead wood

Present in 10 or more samples = abundant **A**

Present in 3 to 10 samples = frequent **F**

Present in less than three samples = rare **R**

Bryophytes not present in the Dene in Central West (1975 survey but present elsewhere in the Dene = elsewhere **E**)

Species not sampled in the 1975 survey of the Dene = **NS**

Species not sampled in the 1990 survey but recorded in 1994 = **OS**

(*Pleurocarpous* moss bears the fruit on a short side branch and not on the main stem or branch as in *acrocarpous* species)

The species recorded in 1975 in compartments other than central west (3 and 4) have not been considered in the table except when recorded in 1990

Table to show changes in bryophyte diversity and abundance from 1975 to 1990

THE BIRDWING BUTTERFLIES IN THE HANCOCK MUSEUM AND TYNE & WEAR MUSEUMS

R. H. Stobbart[1], with appendix by R. H. Stobbart and L. Jessop[2].

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SUMMARY

The great majority of the birdwing butterflies (genera *Ornithoptera, Trogonoptera, Troides* - Lepidoptera: Papilionidae) held in the Hancock Museum has been curated and rehoused as a single composite collection. This collection and those that contributed to it are described briefly as are some of the more notable specimens. Finally, the relationship between *Ornithoptera meridionalis* (Rothschild, 1897) and *O. paradisea* Standinger, 1893, is reconsidered.

In addition, the small number of birdwings held by Tyne & Wear Museums has been re-examined. Most belong to the relatively early collection of Edward Backhouse and several specimens are of special interest.

INTRODUCTION

The term 'birdwing' is applied to those papilionid butterflies which are nowadays generally referred to the genera *Ornithoptera, Trogonoptera* and *Troides,* and placed together with five other genera in the tribe Troidini of the subfamily Papilioninae (*cf.* Howarth, 1977; Collins & Morris, 1985). Almost all species in this tribe feed as larvae on members of the Aristolochiaceae, a dicotyledonous family of herbs, shrubs and woody lianas which is well-represented in wet tropical forests. The affinities of the family are uncertain (Heywood, 1978). The great majority of birdwing larvae feeds upon members of its largest genus *Aristolochia.* The flowers of *Aristolochia* are generally elongated and may be of bizarre shape, the perianth tube consisting of fused sepals, the petals being vestigeal or absent. The birthwort *A. clematitis* is a European example.

The birdwings are large to very large butterflies, *Ornithoptera alexandrae* being the largest in the world with an average wingspan in the female of 25cm. The males of *Ornithoptera* and *Trogonoptera* are noted for their spectacular colouring (iridescent greens, blues, gold and copper on a black background). In *Ornithoptera* (Plate 1) the colours of the iridescent scaling are partly due to a combination of yellow or orange pigments and partly to a structurally produced blue iridescence (Haugum & Low, 1978-80, Vol. 1, Part 1). Sexual dimorphism ranges from very pronounced to extreme in *Ornithoptera,* with the females being much larger than the males and drably coloured in (generally) dark brown, white and yellow (Plate 1). There is appreciable sexual dimorphism in *Troides* with regard to both size and coloration which is based throughout the genus on black, yellow and smaller amounts of white, though one species has a large area of translucent silver-grey on the hindwing; in general the females are larger than the males, the yellow of the hindwing is invaded by black and there is a greater degree of white striping in the forewing; in contrast the males generally have a distinctive livery of largely black forewings and largely yellow hindwings. In *Trogonoptera* sexual dimorphism is limited to duller coloration in the female.

Of the three genera, *Troides* has the widest distribution, being found in India, Burma, Indochina, China, Malaysia, Indonesia, the island of New Guinea and the northern part of the Australasian region. With twenty species assigned to it, it is also the largest genus. *Ornithoptera* is restricted to the Australasian region ranging from the Moluccas (Indonesia), through the eastern islands of Indonesia, the island of New Guinea (and its associated islands) to the Solomon Islands and extending down the Cape York Peninsula of Australia to north-eastern New South Wales. Some eleven to fourteen species have been assigned to this genus. *Trogonoptera,* with only two species is much the smallest of the three genera and has

the most restricted range: the Malay Peninsula, Sumatra, and the islands of Borneo and Palawan.

The nomenclature used in this work is largely based on that of Collins & Morris (1985). It has been chosen for its simplicity and because the details of birdwing nomenclature are under current discussion (*cf.* Haugum & Low, 1978-1980; Hancock, 1983). Three genera are recognized here: *Ornithoptera, Trogonoptera* and *Troides*. However, as the monograph of Haugum & Low is the most detailed recent treatment of the group, and as some aspects of their treatment have been accepted here, the relationship between the two nomenclatures is clarified below.

With respect to Ornithoptera, the subgenus *Aetheoptera* (Haugum & Low, 1978-80) is included in *Ornithoptera*, the subgenus *Schoenbergia* (Haugum & Low) is treated as the *tithonus* species-group, and the subgenus *Ornithoptera* (Haugum & Low) is treated as the *priamus*-species group; however in agreement with Haugum & Low the following are all regarded as subspecies of *Ornithoptera priamus*[1]: *richmondia*, *euphorion*, *hecuba*, *arruana*, *poseidon*, *boisduvali**, *admiralitatis**, *bornemanni*, *miokensis**, *caelestis**, *urvilliana*, while *teucrus*, *demophanes* and *pronomus* are regarded as local forms of *poseidon*. *Ornithoptera aesacus** and *O. croesus* are treated as separate species (as in Haugum & Low) but bearing in mind known hybridizations within the genus (Schmid, 1973; Haugum & Low, 1978-80, Vol. 1, Part 2), they could well prove to be merely geographically and not reproductively isolated from *O. priamus*.

The genus *Trogonoptera* is accepted in both nomenclatures.

With regard to *Troides,* the genus *Ripponia*, erected by Haugum & Low for *hypolitus*, is here regarded as a subgenus of *Troides*, and corresponds to the *hypolitus* species-group of Collins & Morris. Within *Troides* (*Troides*) the *amphrysus* species-group is the same in both nomenclatures but the *aeacus* and *haliphron* species-groups of Haugum & Low are included in the *helena* species-group of the present nomenclature (the *helena* species-group of Haugum & Low contains only *helena* and *oblongomaculatus*). Finally *plateni* and *dohertyi* are here regarded as subspecies of *rhadamantus* (as in Haugum & Low) but *staudingeri* is regarded as a subspecies of *haliphron*.

When dealing with assemblages that have been assigned to various species on purely morphological grounds, it is important to bear constantly in mind the accepted definition of species; *i.e.* populations which do not normally interbreed in nature are to be regarded as belonging to different species provided that their reproductive isolation from one another is not due merely to geographical separation. This is particularly important with respect to birdwings as there has been a strong tendency amongst workers on the group to assign slightly different forms on separate islands to different species in the absence of any information about mechanisms of reproductive isolation. This inter-island variation is a notable feature of the Indonesian fauna and was one of the factors which led A. R. Wallace to his formulation of the theory of evolution. A related though less important problem is the readiness of workers to describe new subspecies of these notoriously variable insects on the basis of trivial differences in patterning and male external genitalia, an exercise which many would regard as being of doubtful value.

An additional word of caution is appropriate concerning the use of differences in male genitalia in determining species and subspecies of birdwings. The external genitalia of the females of different species are all exceedingly similar, so that highly selective 'lock and key' mechanisms can hardly be operating between the genitalia of the two sexes; this is borne out by the increasing information on interspecific and indeed intergeneric hybridization within the group (Haugum & Low, 1978-80 Vol. 1, Parts 1-3).

These matters are considered again later when discussing the relationship between *Ornithoptera meridionalis tarunggarensis* and *O. paradisea*.

1 * = not represented in the collections of the Hancock Museum or Tyne & Wear Museums.

Until now the birdwing butterflies in the Hancock Museum have been housed among the several collections of which they form part.

In view of their importance and value, it was decided in 1992 that they should be curated and rehoused together, as far as possible, as one composite collection. Due to the recent acquisition by the Museum of three high-quality butterfly cabinets it has been possible to carry out the rehousing to very satisfactory standards.

These cabinets are now labelled as follows -

BIRDWING BUTTERFLIES CABINETS 1 - 3

Ornithoptera, Trogonoptera, Troides
(Lepidoptera: Papilionidae)
COMPOSITE COLLECTION

The birdwings form part of the following collections (the acquisition dates, where known, the genera and the total number of specimens[2] contributed are shown in brackets).

1. J. J. Joicey collection (1934; *Ornithoptera, Trogonoptera, Troides*; 471)
2. H. Eltringham collection (1913; *Ornithoptera, Trogonoptera, Troides*; 119)
3. C. H. E. Adamson collection (1904; *Troides*; 28)
4. J. M. Clayton collection (1929; *Ornithoptera, Trogonoptera, Troides*; 34)
5. Rev. G. Brown collection (1908; *Ornithoptera, Troides*; 13)
6. Collection of Exotic Lepidoptera (*Ornithoptera, Troides*; 7)
7. W. R. A. Brown collection (1994; *Trogonoptera*; 2)
8. T. H Carr collection (1995; *Trogonoptera*; 13)

As far as the birdwings are concerned the first of these collections is the most important and extensive. It consists of material that was donated to the Museum in 1934 by the Trustees of Mrs J. J. Joicey and also apparently material that was rejected by the British Museum of Natural History, and specimens consisting of remnants from a sale of J. J. Joicey material at Oxford. Most of the J. J. Joicey specimens had been housed in a spare cabinet but many were found in eighteen cardboard boxes and in an isolated drawer of a cabinet.

The H. Eltringham collection (No. 2) contains large numbers of tropical butterflies and many examples of mimetic species and their models (mimicry in insects was a long-standing interest of the collector). The collection was bought by the, then, Natural History Society of Northumberland, Durham and Newcastle upon Tyne from Dr Eltringham in 1913.

The C. H. E. Adamson collection (No. 3) is of Burmese butterflies and so contributes only specimens of *Troides*.

The J. M. Clayton collection (No. 4) consists of specimens (all in excellent condition) sealed into Denton's patent glass-covered ceramic butterfly tablets (Shelley W. Denton & Co., 52 and 99 Regent St, London W).

These butterfly tablets were manufactured around the beginning of the century and were presumably aimed at wealthy amateur collectors. The body of the butterfly is accommodated in a depression in a specially-moulded ceramic base, and the butterfly is held in position and protected by a sheet of glass placed over it and sealed to the edges of the ceramic base. Only one surface of the specimen can be displayed, and there is no pin through the thorax. Specimens mounted in this way are very well protected and may be moved about more or less with

2 For the purposes of this work, the term specimen refers both to complete individuals and to ones with small parts broken off and/or missing (generally antenna(e), leg(s), proboscis, or occasionally head or abdomen).

impunity; however, the tablets have the disadvantages of being rather bulky, of allowing only one surface to be seen and of hindering detailed examination of the specimen.

The remaining collections (Nos. 5-8) are small - nos. 7 and 8 were made in Peninsular Malaysia and consist for the most part of specimens in extremely poor condition. Nevertheless, it was possible to salvage some material of *Trogonoptera brookiana* from these collections.

The fifty or so specimens of *Troides* (*helena* and *darsius*) of the H. Stevens collection have not been dealt with in the present work. This large collection of butterflies (mainly from Assam) was acquired in 1965 *via* the executors of the will of H. and A. Stevens. Prior to acquisition the collection had been under the care of the British Trust for Ornithology. Unfortunately during this time the collection was spoilt by dredging it with DDT dust under the mistaken assumption that this would be an excellent way to prevent damage by insect pests. Damage was indeed prevented, but the dust is now intimately dispersed amongst the scaling of the butterflies' wings. Although it is possible to achieve a reasonable degree of cleaning, the cleaning of the whole collection would be an expensive undertaking requiring suitable protective techniques and a great deal of time.

Thirty-one specimens of birdwing which are held by Tyne & Wear Museums at the Sunderland Museum and Art Gallery are dealt with below in the Appendix.

CURATION

Curation of the birdwings of the Hancock Museum was carried out between November 1993 and October 1995; it consisted of the following:

1, checking the identifications of specimens and identifying previously unidentified ones using Haugum & Low (1978-1980) and D'Abrera; (1975)

2, repairing damaged specimens (where feasible); where repair was not feasible appendages or fragments which had been broken off were carefully glued to pieces of card or paper which were placed with the specimen(s);

3, assigning a computer database number to each specimen, to pupal case(s), and to appendage(s) and fragment(s) which could not be associated with an individual specimen;

4, completing record cards (bearing database numbers) for the items in (3) and transferring the information on the cards to the Museum's computerised database (see Appendix for details);

5, pinning the specimens (with appropriate labelling) into the new Birdwing Cabinets according to the modified species-groups of Collins & Morris (1985) (see above, and Table 1);

6, preparation of tables giving abbreviated database numbers and general (i.e. drawer) location in these cabinets for (i) specimens, (ii) pupal cases and fragments, (iii) unattributable labels - these tables to go with the collection;

7, preparation of plans showing the positioning and abbreviated database numbers of specimens, pupal cases and fragments, and also the positioning of unattributable labels, in the drawers of these cabinets - these plans to go with the collection;

8, in the case of the thirty-four Clayton collection specimens in Denton's Patent Butterfly Tablets, curation consisted mainly of identification and assignation of database numbers which were written on the sides of the tablets; it was not practicable to house these specimens with the rest so together with the plans of (7) is a list showing these thirty-four birdwings, their abbreviated database numbers, and the drawers of the Clayton collection cabinet in which they are to be found.

COMMENTS

So far 687 specimens of birdwing have been curated and, except for those of the Clayton collection, rehoused. A curtailed list of this material is given in Table 1.

Table 1

Composite birdwing collection of Hancock Museum

Species	no. of specimens
Ornithoptera Boisduval, 1832	
tithonus species-group	
goliath goliath Oberthür, 1888	2
chimaera chimaera (Rothschild, 1904)	1
tithonus tithonus deHaan, 1840	1
tithonus waigeuensis (Rothschild, 1897)	1
meridionalis tarunggarensis (Joicey & Talbot, 1926) (topotype specimen)	1
paradisea paradisea Staudinger, 1893	5
rothschildi Kenrick, 1911	1
priamus species-group	
alexandrae (Rothschild, 1897)	2
victoriae victoriae (Gray, 1856)	7
victoriae regis (Rothschild, 1895)	3
victoriae epiphanes Schmid, 1970	2
priamus priamus (Linnaeus, 1758)	17
priamus poseidon Doubleday, 1847(38 are labelled as *p. teucrus*)	148
priamus hecuba Röber, 1891	11
priamus bornemanni Pagenstecher, 1894	5
priamus arruana Felder, 1859	20
priamus euphorion (Gray, 1852)	17
priamus richmondia (Gray, 1852)	17
priamus urvillianus (Guérin, 1829)	24
croesus croesus Wallace, 1859	10
croesus lydius (Felder, 1865)	3
Trogonoptera Rippon, 1898	
brookiana ssp?	1
brookiana brookiana (Wallace, 1855)4	
brookiana trogon (Snellen van Vollenhoven, 1860)	2
brookiana albescens (Rothschild, 1895)	4
brookiana albescens (probably)	13
trojana (Honrath, 1886)	2
Troides Hübner, 1823	
subgenus *Ripponia*	
hypolitus hypolitus (Cramer, 1775)	8
hypolitus cellularis Rothschild, 1895	1
hypolitus sulaensis (Staudinger, 1895)	3

Species	no. of specimens
subgenus *Troides*, *amphrysus* species-group	
amphrysus amphrysus (Cramer, 1782)	4
amphrysus flavicollis (Druce, 1873)	15
amphrysus ruficollis (Butler, 1877)	18
cuneifera cuneifera (Oberthür, 1879)	18
miranda miranda (Butler, 1878)	6
andromache marapokensis Fruhstorfer, 1898	2
helena species-group	
helena helena (Linnaeus, 1758)	17
helena cerberus (Felder, 1864)	39
helena heliconoides (Moore, 1877)	7
helena nereis (Doherty, 1891)	1
helena mannus? Fruhstorfer, 1908	1
helena hephaestus (Felder, 1864)	4
haliphron haliphron (Boisduval, 1836)	5
haliphron naias (Doherty, 1891)	10
haliphron pallens (Oberthür, 1897)	4
haliphron iris (Röber, 1888)	1
haliphron ikarus Fruhstorfer, 1904	1
haliphron socrates (Staudinger, 1891)	2
haliphron pistor Rothschild, 1896	3
darsius (Gray, 1852)	27
criton criton (C. & R. Felder, 1860)	9
criton celebensis (Wallace, 1865)	1
aeacus aeacus (C. & R. Felder, 1860)	50
aeacus formosanus Rothschild, 1899	1
minos (Cramer, 1779)	16
rhadamantus rhadamantus (Lucas, 1835)	14
rhadamantus plateni (Staudinger, 1888)	8
rhadamantus dohertyi (Rippon, 1893)	5
oblongomaculatus oblongomaculatus (Goeze, 1779)	25
oblongomaculatus bouruensis (Wallace, 1865)	9
oblongomaculatus papuensis (Wallace, 1865)	13
oblongomaculatus bandensis Pagensecher, 1904	3
vandepolli vandepolli (Snellen 1890)	8
vandepolli honrathiana (Martin, 1892)	2
riedeli (Kirsch, 1885)	1
prattorum (Joicey & Talbot, 1922)	2

Total: 687 specimens

Fifty specimens still remain to be curated. These are specimens (of all three genera) which are at present on public display; most seem to have been taken from the Joicey and Eltringham collections. Two of the curated specimens are also on public display. These are a male and female of *O. p. euphorion* (nos. NEWHM : 1993. H170 and H171 respectively) from the Clayton collection.

The assembly of birdwings in the Hancock Museum is important in a number of respects.

1. All species of *Ornithoptera, Trogonoptera* and *Troides* are currently placed on Appendix II of the Convention on International Trade in endangered Species of Wild Fauna and Flora (CITES) and are protected by import and export restrictions. The Museum holds examples of the following species which are more or less threatened (IUCN[3] status in brackets).

   O. alexandrae (endangered)
   O. meridionalis (vulnerable)
   O. paradisea (indeterminate)
   O. chimaera (indeterminate)
   O. rothschildi (indeterminate)
   O. tithonus (insufficiently known)
   O. priamus euphorion (threatened by habitat destruction)
   O. croesus (vulnerable)
   Troides andromache (indeterminate)
   T. prattorum (indeterminate)
   T. rhadamantus dohertyi (indeterminate)

   The situations for *O. alexandrae* and *O. meridionalis* may well have deteriorated as there has been a recent report (Kobayashi, 1981) of considerable destructions, both actual and proposed, of some of the known habitats of these species.

2. Almost all the specimens come from old collections. Dates on specimens range from 1878 to 1927, a very few being as late as 1970. Not all the specimens are dated, but rough dates for undated specimens can be deduced given the knowledge of the collections from which such specimens came. Clearly the age of the specimens and their accompanying data, when combined with modern information, could reveal reductions in the ranges of individual species and increases in habitat degradation in very large areas of the Oriental and Australian Zoogeographical regions (*cf.* Introduction).

3. Fairly large numbers of the following four species are held (*cf.* Table 1).

Ornithoptera priamus	(259)
Troides helena	(69)
T. aeacus	(51)
T. oblongmaculatus	(50)

   Such material could be of importance in any future revision of the group.

4. The assembly contains a number of noteworthy specimens which are considered below.

(i) NEWHM: 1993.H103 *Ornithoptera priamus poseidon* ♂(*ex* J. J. Joicey collection)

According to the accompanying data this specimen, which was acquired by J. J. Joicey in 1910 from the Grose Smith collection, was obtained by A. R. Wallace in Palu - presumably a locality at Dorei (now Andoi) Bay at the extreme north-west of Cenderawasih Bay (Irian Jaya). Wallace visited Dorei Bay from March to July 1858 (Wallace, 1869). Palu, Sulawesi, and the island of Palu, near Flores (both also in Indonesia) lie far outside the range of this subspecies.

(ii) NEWHM: 1993.H135 *O. p. poseidon* ♂(*ex* H. Eltringham collection)

This specimen shows a marked colour abnormality on the *recto* surface. The iridescent areas instead of being the normal green are a fairly light turquoise, with the left hind

3 International Union for Conservation of Nature and Natural Resources.

wing shading into a pinkish colour at the outer margin; the colours on the *verso* are more or less normal. Haugum & Low (1978-80 Vol. 1, Part 2) show that a change from iridescent green to blue is brought about by exposure to light (presumably an effect on a pigment which contributes to the overall colour). The fact that the *verso* of H103 is more or less normal suggests that the *recto* has been exposed to strong light at some time, probably when the specimen was dead. However the possibility of a natural abnormality in the pigmentation and/or the fine structure of the scales cannot be ruled out.

(iii) NEWHM: 1993.H86 *O. p. poseidon* ♀ (*ex* J. J. Joicey collection)

In this specimen there is some iridescent green scaling (characteristic of the male) at the proximal edge of the white mark in the cell of the front wing *recto,* there are also some scales showing a faint green iridescence on the hindwing *recto* in 1a - 5; on the *verso* there is iridescent greenish/yellow scaling at the subcostal edge of the white mark in the front wing cell, and on the hind wing small amounts of iridescent yellow scaling in 6 and 5.

(iv) NEWHM: 1993.H203 - 207 *O. p. paradisea (ex* H. Eltringham, J. M. Clayton and J. J. Joicey collections)

Three females and two males; except for one of the females, these specimens are in good to excellent condition (H203, H205 and H206 are possibly *p. borchi*). This species is one of the most sought-after birdwings.

(v) NEWHM: 1993.H1, H2 *O. alexandrae* (*ex* J. M. Clayton collection)

A pair of what is the largest butterfly and probably the most sought-after species of birdwing. The species is currently listed as endangered. The specimens are in excellent condition, there is however a slight developmental fault in the tornus of the right front wing of the male.

(vi) NEWHM: 1995.H937, H938 *Troides prattorum* ♀♀ (*ex* J. J. Joicey collection)

According to D'Abrera (1975) there are only about 20 specimens of this striking and (in the male) iridescent species in the museums of the world. The species was described by Joicey & Talbot (1922) from 1 male and three females.

The two specimens above were discovered amongst J. J. Joicey material. Unfortunately both specimens have badly damaged wings and no accompanying data, but it is still possible to detect the iridescence (very much stronger in the male) in the yellow of the hind wings.

The pattern of damage suggests strongly that pieces were cut from the wings with scissors by an ill-informed individual in order to repair other specimens! It seems likely that these specimens (H937, H938) were part of the material collected in Buru (Indonesia) by C., F., & J. Pratt and from which Joicey & Talbot (1922) took their type material.

(vii) NEWHM: 1993.H202 (topotype specimen, Plate 1e) *Ornithoptera meridionalis tarunggarensis* ? ♀ (*ex* J. J. Joicey collection)

This subspecies of *O. meridionalis* was described from 2 female specimens (holotype and paratype) by Joicey and Talbot (1926) on the basis of relatively slight differences in the spotting pattern of the wings of the female. The specimens are from the Wanggar River area of Irian Jaya (see Fig. 1).

In general the white spots of the forewing *recto* are smaller, and the diffuse stripe of greyish powdering at the base of the wing is larger, than in the nominate subspecies. On the hindwing *recto* the black spots in 5 and 6 and the white cell-spot are smaller than in the nominate subspecies, and in one of the type specimens the edge of the cell between veins 2 and 5 is strongly outlined with black. The type specimens are now deposited in the British Museum (Natural History).

PLATE 1

Examples of *Ornithoptera*. a & b, *O. victoriae* ♂ & ♀ ; c & d, *O. paradisea* ♂ & ♀ ; e, *O. meridionalis tarunggarensis* ♀ (NEWHM: 1993.H202) from Wanggar River area, Irian Jaya; f & g, *O. croesus* ♂ & ♀ (b, d & e *ex* J. J. Joicey collection, rest *ex* H. Eltringham collection); length from base to tip of forewing in mm, a-g respectively, 77.5, 103, 58.5, 90.5, 87.2, 78, 96.

(a)

(b)

(c)

(d)

(e)

(f)

(g)

D'Abrera (1975) is not convinced that there is any difference between the nominate subspecies and *tarunggarensis* and adds that he was not able to locate suitable males of the latter. He states that the only firm reason for separate treatment seems to be the different locations of the two subspecies (see Fig. 1). These are south eastern Papua, Papua New Guinea (nominate subspecies) and the area to the south of Geelvink (now Cenderawasih) Bay, Irian Jaya, Indonesia (*m. tarunggarensis*). Nevertheless, because of the absence of material adequate for more extensive studies, and the disjunction of the two populations, he retains *tarunggarensis* as a valid name for the western population.

In view of all this, it is interesting to note that specimen H202 is intermediate in appearance between *m. meridionalis* and *m. tarunggarensis* and that it was collected at the same time and locality (i.e. Wangaar, now Wanggar, River 15 miles from coast *ca* 600ft Jan 1921 - see Fig. 1) and by the same collectors (C., F., and J. Pratt) as for the paratype. One is left with the suspicion that this specimen was not used as type material precisely because of this intermediacy, and this tends to confirm D'Abrera's opinion.

Recently, Pasternak (1981) rediscovered *meridionalis in* two areas, one to the south and the other to the south-west of Cenderawasih Bay, the former being relatively close to where the specimens of Joicey & Talbot (1926) were obtained. These localities were the Lake Jamur area to the west of the Weyland Mountains and the Kamrau Bay area (see Fig. 1). Other *Ornithoptera* species are known to occur in the Lake Jamur area: *O. paradisea, tithonus, goliath* and *priamus poseidon.*

Pasternak described his material as *m. tarunggarensis*, though differences between it and *m. meridionalis* are extremely slight.

Subsequently Hancock (1982) claimed that the specimens described by Joicey & Talbot (1926) should be referred to *O. paradisea*. His reason for doing so is not strong, and is that records show that while both males and females of *paradisea* have been collected in the precise area from which Joicey & Talbot obtained their *m. tarunggarensis* material, only females of *m. tarunggarensis* have been found there. He also refers to the occurrence together of these two closely related species as an anomaly. He suggests that the two type specimens of *m. tarunggarensis* should be associated with the two female and two male *paradisea* from this area, and as these males have an extended area of green in the forewing, that the population from which they came should be recognized as another subspecies of *O. paradisea, O. p. tarunggarensis* comb. nov.

With respect to all of this the following should be borne in mind:

(a) The number of specimens under consideration by Hancock is only six and they come from an area poorly explored and collected from.

(b) The males of *meridionalis* are notoriously retiring and elusive, so that the sight of females on the wing may be for a long time the only indication to a collector that the species is in a given area (Pasternak, 1981).

(c) There are many records of closely related species being broadly sympatric though occupying different ecological niches (e.g. in birds, teleosts and insects to name only three animal groups).

(d) O. meridionalis and *O. paradisea* do appear in fact to occupy different niches, *meridionalis* being low flying and in the male very sedentary unless disturbed, *paradisea* being active and high flying; nevertheless both species use the same food plant (D'Abrera, 1975; Pasternak, 1981).

(e) Like most *Ornithoptera* these two species are quite variable, this is particularly the case with their females, which as Hancock remarks can be extremely difficult to separate (see Plate 1d and e).

These considerations surely suggest that it would be more appropriate at present to retain *tarunggarensis* as a valid subspecific name for the western-most population of *O. meridionalis,*

and to await the accumulation of more adequate data before designating a fourth subspecies of *O. paradisea* in the general area of peninsular Irian Jaya (*cf.* Haugum & Low, 1978-80 Vol. 1, Part 3; Kobayashi & Koiwaya, 1979).

With respect once more to H202, it has a very rounded tornus to the hind wing: this character has been used by Haugum & Low (1978-80, Vol. 1, Part 3) to separate females of *meridionalis* from those of *paradisea* in which the tornus is distinctly pointed. This difference is apparent in all the specimens illustrated in D'Abrera (1975), and the three females of *paradisea* in the Hancock Museum certainly show the pointed tornus. However Hancock (1982) states that this tornal character is not always reliable. Bearing in mind the description of H 202 given above and the tornal configuration of its hind wings, I think it should be assigned to *meridionalis.*

In conclusion it is worth pointing out that the relationship between *meridionalis* and its sister species *paradisea* poses some interesting problems; these are considered below.

THE RELATIONSHIP BETWEEN *O. MERIDIONALIS* AND *O. PARADISEA*

(frequent reference to the map in Fig.1 is necessary for this section).

The following are the relevant considerations:

1. These two very elegant species are clearly extremely closely related. Morphologically the males of the two species are very similar (in spite of differences in flight behaviour) and the females are exceedingly similar and not reliably separable (Plate 1d, e). Both species use the same host plant.

2. Generally, *paradisea* occurs to the north and *meridionalis* to the south of the great east-west mountain chain of the island of New Guinea. However, they occur together to the south of Cenderawasih Bay near the only low gap in the mountain chain which is provided by the valley of the Wamma River to the west of the Weyland Mountains.

3. As far as is known at present, the populations of both species have a very disjunct character; this is particularly so for *meridionalis* which occurs in Central and Milne Bay Provinces at the east end of the island and in areas to the south and south-west of Cenderawasih Bay near the west end.

4. Given the morphological situation described in 1., above, and the absence of detailed work (both field and experimental) on the reproductive biology of the populations of both species from the south of Cenderawasih Bay, how does one distinguish between the following?

(a) *meridionalis* and *paradisea* represent two good species;

(b) some degree of gene flow occurs between the two populations (i.e. females mate with both types of male).

In fact *meridionalis* has been assigned to a separate species on the basis of differences in the male genitalia between it and *paradisea* (those of *meridionalis* being simpler). There is however no particular reason (see Introduction) to suppose *a priori* that these differences represent an isolating mechanism.

Adequate information on the reproductive biology of these forms is urgently needed.

If (a), above, holds then it seems reaonable to suppose that in the past the ancestral population became separated into two isolated components, one moving north and one south of the mountain chain, which evolved into *paradisea* and *meridionalis* respectively. Haugum & Low (1974) speculate that this separation occurred somewhere in the central mountains of New Guinea (where there is no low gap in the mountain chain). These two forms subsequently reached the same area to the south of Cenderawasih Bay and are now reproductively isolated from each other either behaviourally and/or physiologically.

If (b) holds, then we should expect the differences between the two forms in the area to the south of Cenderawasih Bay eventually to be degraded and the population to take on an

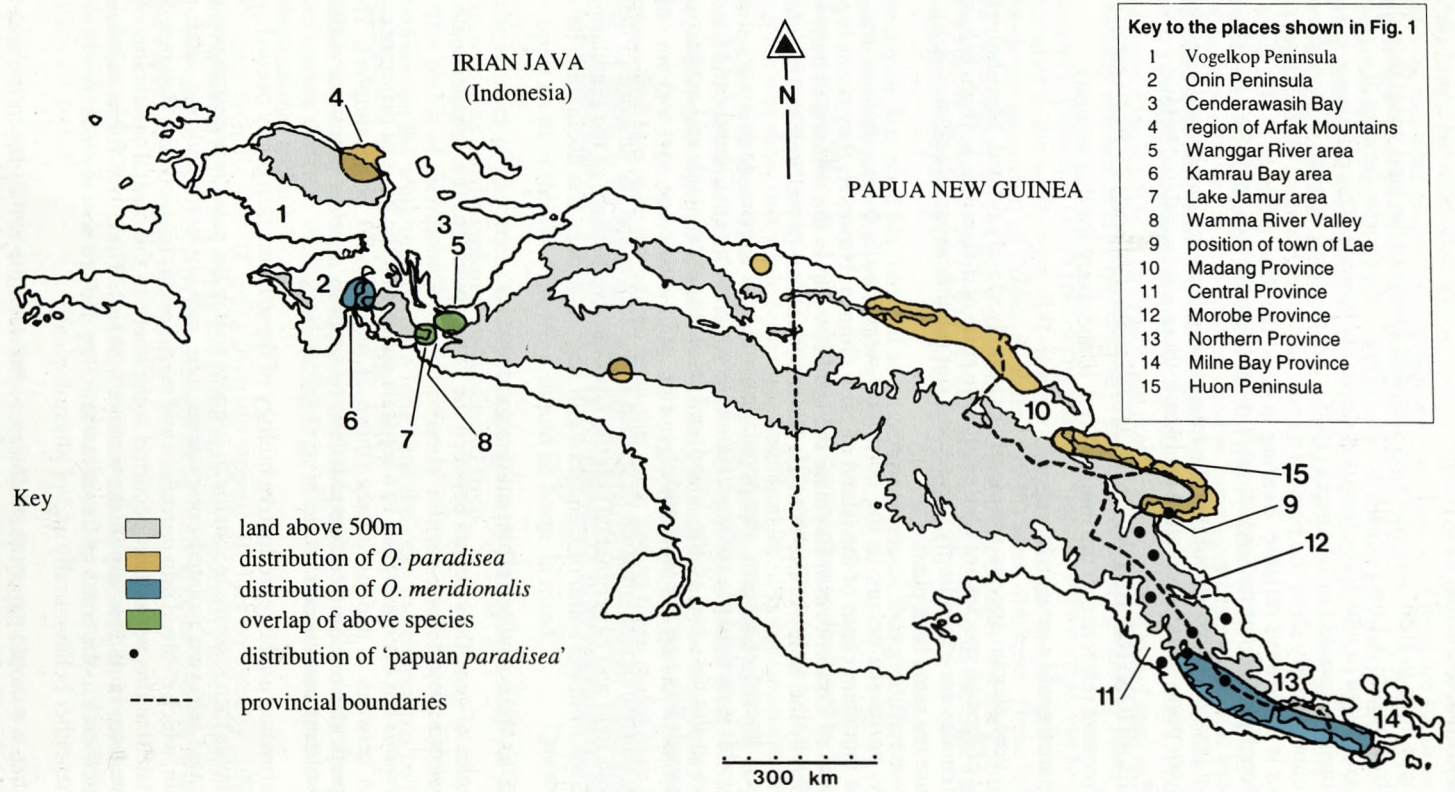

Fig. 1 Map of the island of New Guinea showing the distributions of *Ornithoptera paradisea* and *O. meridionalis.* Distributions taken from Haugum & Low (1978-80, Vol. I, part 3) and Pasternak (1981).

intermediate character. However this would not happen if *meridionalis* and *paradisea* here represent a case of ongoing incipient speciation with the *meridionalis* type, or morph, occupying a low-flying reclusive niche in the forest and the *paradisea* morph occupying a high-flying more active niche. It may then be supposed that as a result of migrations from this area in the past, the *paradisea* morph has been successful to the north, and the *meridionalis* morph to the south of the mountains. Such a scenario (bi) does not exclude the eventual development of isolating mechanisms. It does imply, however, that the general area of peninsular Irian Jaya has been the centre of origin of the *paradisea/meridionalis* complex, and as the main centres of population are currently far to the east and east-south-east of this area, the scenario may not find much favour. Nevertheless, it should not be ruled out until we have adequate information about the reproductive biology of these forms, and it is interesting to note that the females of *O. m. tarunggarensis* and *O. p. arfakensis* (from the Arfak Mountains) are exceedingly similar. Furthermore, information from the F1 generation of the hybridization of *O. priamus poseidon* (wandering behaviour in the female) and *O. p. urvillianus* (sedentary behaviour in the female) suggests strongly that morphs showing different behaviours are possible in *Ornithoptera* (Haugum & Low, 1978-80, Vol. 1, part 2).

Another interesting problem is posed by records and specimens of what Haugum & Low (1978-80, Vol. 1, part 3) refer to as the 'Papuan' *paradisea*. This form has been found near the town of Lae, in areas to the north of the Wharton and Owen Stanley Ranges (Morobe and Northern Provinces) and in areas to the south of these ranges (Central Province), the latter areas being near the stronghold of *m. meridionalis*. Records and specimens of this insect are scarce. Haugum & Low refer to it as a small, variable and seemingly degenerate form of *paradisea* whose females are particularly small and dull. They also state that there now seem to be no breeding populations of these insects left in these areas.

A possibility which is not mentioned by Haugum & Low is that this form may be a natural hybrid (probably sterile or of reduced viability) between *paradisea* and *meridionalis*, showing in the F1 generation the general morphology of *paradisea* and the smaller size of *meridionalis*. If this is the case, there would either never have been breeding populations, or at most only precarious ones, as these rare forms would have resulted from stray individuals of *paradisea* or *meridionalis* penetrating into the territory of the other species. Obviously, hybridization experiments using *p. paradisea* from the area of the Huon Peninsula (Madang and Morobe Provinces) and *m. meridionalis* from Central Province would help to elucidate these matters.

Such an interpretation is of course compatible with both scenarios (a) and (b) above, with the isolating mechanism not being completely developed in these areas.

Finally, we may end these comments on *meridionalis* and *paradisea* by referring to the interesting observations of Pasternak (1981) on the cannibalistic/carnivorous behaviour of the larvae of *meridionalis*, and the way in which it destroys the aerial part of the food plant just before pupation (as do larvae of *O. goliath*). Clearly competition with *meridionalis* will not occur just in the adult stage, and as the larvae of *Ornithoptera* all feed on *Aristolochia* spp. it will be interesting to know whether this type of behaviour is widespread in the genus.

CONCLUDING REMARKS

It is appropriate to end this report by noting that the development of distinctive iridescent colour patterns (and presumably distinctive sexual displays) in the males seems clearly to have been the way in which speciation has proceeded in the genus *Ornithoptera*. The females of the different species resemble each other much more closely than do their males, and except those of *O. croesus lydius*, they all have the same cryptic coloration of white to yellowish spots and blotches on a background of dark brown or brown. Such a situation of similar (and cryptic) females and distinctive males is common enough in the animal kingdom, and it is often the case that in nature such species are isolated purely by the behavioural response of the female to the colour and/or sexual display of the appropriate male (*e.g.* in the bird genera *Anas* and *Aythya* (Anatidae)). Such isolating mechanisms break down readily under crowded conditions or when the availability of appropriate mates is reduced. Clearly it is probable that much light

could be thrown on speciation in the genus *Ornithoptera* by appropriate programmes of experimental breeding, and such an approach is also likely to be useful for studies on *Troides* and *Trogonoptera.*

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Appendix

Birdwing butterflies in Sunderland Museum & Art Gallery

(by R. H. Stobbart and L. Jessop)

The collections of Tyne & Wear Museums, housed at Sunderland Museum and Art Gallery, currently hold thirty-one specimens of birdwings. Twenty-two come from the collection of Edward Backhouse, six from a mixed collection from South Shields Museum and three have no data regarding their origin. These birdwings (together with other exotic Lepidoptera) were curated in the late 1970s by Job Creation Scheme staff, who added typed determination labels to some of the specimens.

All of these specimens were examined by R.H.S. in April 1996. When found, eighteen bore no name, six were misidentified or not identified to species level, and six were not identified to subspecies. Accordingly the identifications of all were checked as above.

The following were found to be present (numbers of specimens given in brackets):

Ornithoptera

croesus croesus (3)
priamus poseidon or *priamus arruana* (2)
priamus poseidon (2)
priamus richmondia (2)
Trogonoptera
brookiana brookiana or *brookiana albescens* (1)
brookiana albescens (1) (by locality)

Troides

hypolitus cellularis (2)
amphrysus flavicollis (4)
helena cerberus (3)
helena nereis (1)
darsius (4)
aeacus aeacus (3)
minos (3)

The specimens of *O. croesus croesus* (two males and a female) from Edward Backhouse's collection are of particular interest. This species was discovered by A. R. Wallace in 1859 on the island of Bacan (Bachan, Batchian) during his collecting activities in south-east Asia (1854-1862). Wallace described its discovery in a letter to Stevens, who published an extract from it in 1859, and to whom he also sent six male and five female specimens. The species was formally described five months later by Gray (1859) under the name (*croesus*) that Wallace had suggested for it. Gray's description was clearly based on both male and female specimens and although he did not state how many specimens he had seen, it is implicit in his description that he had seen more than one male. The depository of the specimens was also not stated though there is now one male and one female (both syntypes) in the Natural History Museum in London (Howarth, 1977).

Wallace (1869) in his book on the Malay Archipelago states that after his stay in Bacan he brought away "more than a hundred of both sexes, including perhaps twenty very fine males, though not more than five or six that were absolutely perfect".

Edward Backhouse (1808-1878) was a very wealthy banker from Sunderland who amassed a large natural history collection. The handwritten labels of the *O. c. croesus* in Sunderland Museum are in Edward Backhouse's handwriting: one of the males bears a label reading "O. croesus Batchian Wallace" and the female and other male bear "Batchian Wallace".

There is no way of knowing how, or precisely when, Backhouse acquired the specimens, but it may be assumed that the labels indicate that Wallace was the collector (or at least that Backhouse *believed* that Wallace was the collector) of the specimens rather than author of the species name, as there is a separate drawer label attached to one of the specimens. While it is possible that Backhouse was able to obtain three of the eleven specimens sent by Wallace to Stevens (and which would possibly be syntypic), it is more likely that his specimens came from among the hundred or so that Wallace subsequently brought back from Bacan. Although probably not, therefore, syntypes, the Sunderland specimens are of interest in being probably collected by Wallace and in being amongst the first examples of this species to enter Western collections.

Among other specimens of interest in Sunderland Museum are a male and a female of *Troides hypolitus cellularis* that bear the label "New Guinea Wallace", again in Edward Backhouse's manuscript. To the best of current knowledge this species is restricted to Sulawesi and Talaud Island, so it would seem that Backhouse either made an error with respect to locality, or interpreted the term 'New Guinea' very broadly. Either way, these specimens are very early examples of *T. hypolitus cellularis*. Wallace collected in Sulawesi and the Moluccas in about 1858: the subspecies was unrecognized by science at that time, and was described by Rothschild in 1895.

Also of interest are three further specimens in the Backhouse collection, labelled in Edward Backhouse's manuscript "Borneo Jas B". These were probably obtained by James Backhouse, a second cousin of Edward. James Backhouse (1794-1869) was a botanist and Quaker missionary who owned a plant nursery in York, and who travelled in the southern hemisphere between 1831 and 1841 mainly to spread the Quaker doctrine in New South Wales (Backhouse, 1843; Davis, 1989). The specimens are a male and two females of *Troides amphrysus flavicollis*: again the subspecies was not recognized at the time of collection (it was described by Druce in 1873). There is no evidence that James Backhouse actually visited Borneo during his travels, so we must assume that they were not collected by him personally although they may have been obtained by him from other travellers in the region. A fourth specimen of *T. amphrysus flavicollis* probably came to Sunderland Museum as part of the Backhouse collection, but bears no collection data.

To conclude, although the number of birdwings in the Tyne & Wear Museums collection is small, most belong to the relatively early collection of Edward Backhouse, and several specimens are of special interest.

The MODES computerized Database

A computerized catalogue was prepared using MODES (the **M**useum **O**bject **D**ata **E**ntry **S**ystem). MODES is a database program widely used in UK museums for the purposes of documenting collections: it provides the capability to generate indexes on a wide range of fields provided that data are entered in a standardized way.

Following discussion as to the data to be recorded and the recording protocols to be used, a proforma was designed and multiple photocopies produced. Each object (butterfly, chrysalis or set of unattributable fragments) was recorded separately using these proformas, which were then computerized using the MODES program. The data are stored on the University of Newcastle upon Tyne's mainframe computer and are accessible via computer workstations at the Hancock Museum.

Indexes have been established so that the items listed in the database can be located by searching for named species (using English or Latin names), collectors, localities or donors.

STUDIES ON THE DISTRIBUTION OF *FUCUS CERANOIDES* L. (PHAEOPHYTA, FUCALES) IN ESTUARIES ON THE NORTH-EAST COAST OF ENGLAND

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SUMMARY

Fucus ceranoides L. was found in the middle and lower estuaries of the Tweed and Wear but was absent from the Tyne estuary. *Fucus vesiculosus* L. was widespread on the open coast and in the lower estuary in the Tweed, Tyne and Wear. A high percentage cover of *F. ceranoides* was found in the areas which have low salinity whereas *F. vesiculosus* was found on the coast as well as in the areas which have lower than marine salinity.

In cultures, *F. ceranoides* was well developed in reduced salinities and the optimum salinity was 10‰. Tissue damage and decay occurred in cultures at full marine salinities and also at 0‰. Water from the River Tyne inhibited growth of *F. ceranoides* although, in small concentrations, it was found to stimulate *F. ceranoides* to grow faster than in other treatments. The optimum treatment was 75% River Tweed water plus 25% River Tyne water, and the worst was 100% Tyne water.

INTRODUCTION

F. ceranoides is confined to habitats such as estuaries where it is subjected to the influence of freshwater for part of each tidal cycle. However, it is clearly not a freshwater alga, for it penetrates into estuaries no further than the limit of tidal influence (Khfaji & Norton, 1979). Burrows (1964) contrasted its growth and reproduction in culture with those of *F. serratus* a fully marine species which occupies a lower level on the shore than *F. ceranoides*. Khfaji & Norton (1979) also explain the success of *F. ceranoides* in streams and estuaries and its failure to colonize the open coast. They indicate that in comparison with *F. vesiculosus* L., a clearly marine species, *F. ceranoides* seems better suited physiologically to brackish water conditions even though little is known of the underlying physiological or structural changes that take place in large benthic algae chronically exposed to salinity stress. Even if *F.ceranoides* did not decay at high salinities, it is unlikely that it could compete with other fucoid algae on the open coast, for it seems to grow much more slowly at full salinity than *F. vesiculosus*, a potential competitor (Khfaji & Norton, 1979).

The present research attempts to answer three questions. First, why *F. ceranoides* is so successful in estuaries and is never found in fully marine situations; second, how does its distribution reflect its ability to compete with *F. vesiculosus*; third, does the distribution of *F. ceranoides* and *F. vesiculosus* indicate their respective tolerances to pollution.

METHODS

Location of Study

Field observations and experiments were carried out in three estuaries in north-east England between September 1994 and August 1995. Areas were chosen to represent (1) the range of salinity fluctuations along the river from the mouth upstream and (2) the pollution load where *F. ceranoides* and *F. vesiculosus* were present.

Each station was observed during low and high tide, and salinity measured by salinorefractometer. Rainfall did not appreciably affect the freshwater flow in the rivers during this study and changes in salinity from this source are likely to have been insignificant.

Tweed estuary (Fig. 1a and Table 1)

The Tweed estuary is in north Northumberland. The estuary is relatively short and the substrata are of sand, mud, gravel and rock. The estuary is very flat which makes it an excellent habitat for the growth and development of seaweeds. This estuary is basically very clean because there are no major industrial establishments along the estuary, though there are outflows from agricultural land and some inputs of domestic waste. The Tweed is one of the least polluted rivers in the UK and the entire Tweed river system is categorized as a class 1 river (the highest classification) in terms of water quality (Tweed Forum, 1994). However, a number of minor pollution incidents have been recorded in recent years, which have affected the river's population of mute swans, and these are a continuing cause for concern.

Tyne estuary (Fig. 1b and Table 2)

The Tyne estuary is hydrographically a narrow stratified estuary, flowing through densely populated urban and industrial areas. Until the early 1970s the River Tyne received 91 x 10^4 m^3 of raw sewage per day, together with 68 x 10^4 m^3 of mixed industrial wastes (Edwards, 1972). Recent clean-up measures have significantly reduced these sources of pollution (Hardy *et al.*, 1993).

The estuary is the most polluted of the field work sites: industrial areas along Tyneside discard waste into the estuary. The tidal reach of the River Tyne is about 30km long extending from the piers at Tynemouth to Wylam (James, 1972). There are concrete and steel walls along the estuary so that a vertical substratum is available for seaweed growth. At low tide a muddy substratum is uncovered which is unsuitable for the growth of macroalgae.

Wear estuary (Fig. 1c and Table 3)

The Wear estuary is relatively short, about 17km in length, and has a much smaller inflow of fresh water than the Tyne. The estuary although relatively clean, receives 0.9 x 10^4 m^3 of sewage, and 9.1 x 10^4 m^3 of industrial and engineering wastes per day (Hardy *et al.*, 1993).

Most of the urban and industrial areas including Sunderland are located in the lower Wear valley. Urban developments in the catchment area have been influenced by past industrial activities, the most important being mining, ship building and shipping. Agriculture is the predominant land use in the upper catchment, although, in the past, the area was important as a metal mining centre.

The Wear estuary has fewer industrial estates adjoining it than the Tyne estuary. In the industrial areas the environment along the river bank has changed in many areas. Concrete and steel walls have been built in some areas to protect the bank of the river, but in other parts of the area along the study location, especially near North Hylton, the condition of the river bank is still natural even though the slope is very steep. The conditions near North Hylton allowed competition between *F. ceranoides* and *F. vesiculosus* to occur.

Survey techniques

The survey of the patterns of the distribution of *F. ceranoides* and *F. vesiculosus* was undertaken over a period of twelve months. The study was carried out up the estuaries during low tides and the locations were chosen where *Fucus* growth could be quantified using a quadrat.

The abundance of *Fucus* was examined by laying a transect of quadrats at right angles to the river in every station at each study site. The number of quadrats per transect was determined by basing this on the largest habitat where *Fucus* was present and the difficulties of doing a transect of quadrats at the location. Ten to thirty 0.5 x 0.5m quadrat were used for each transect (the size of the quadrat chosen following Hawkins & Jones (1992)).

Fucus ceranoides and *F. vesiculosus* were recorded as a percentage cover in each quadrat.

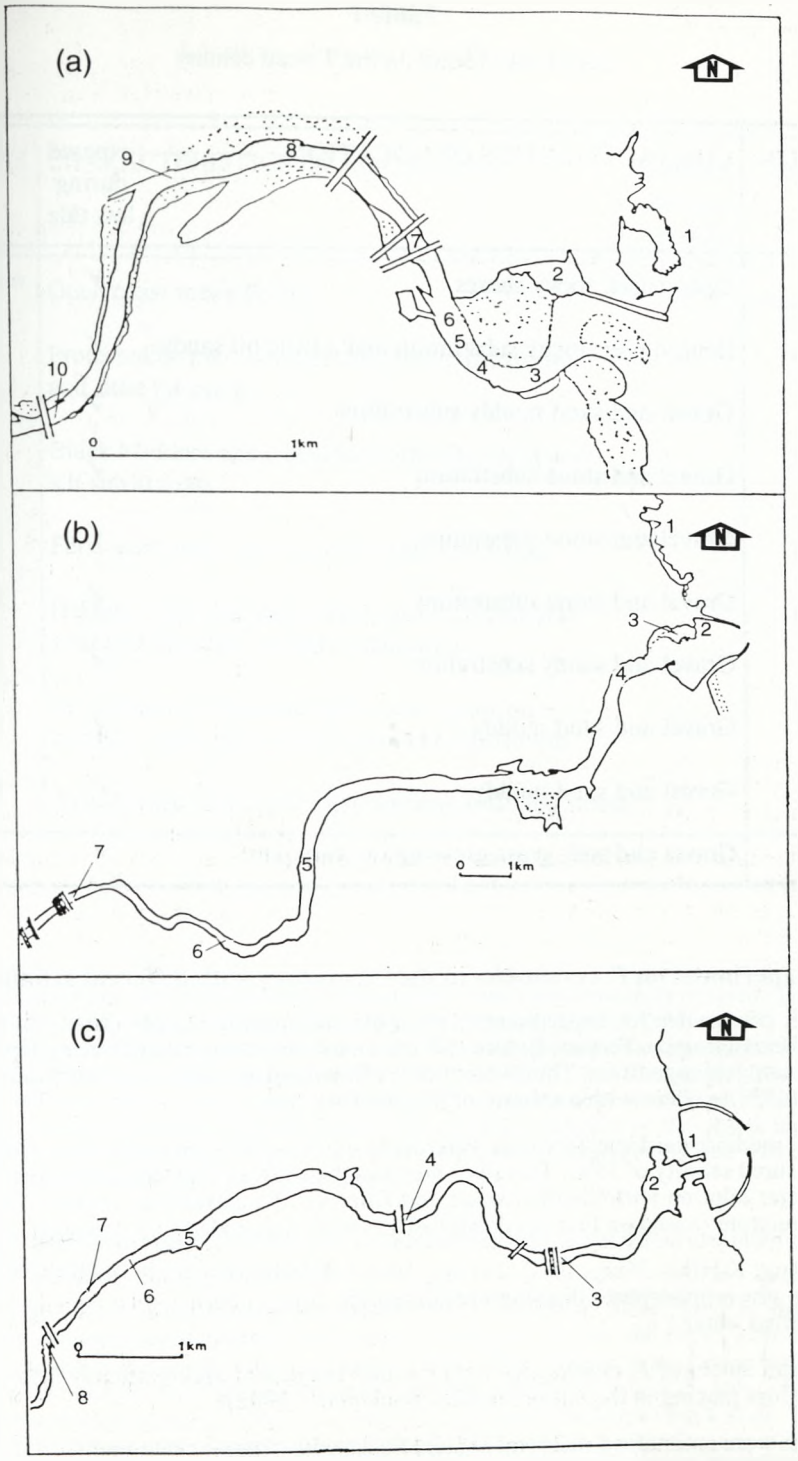

Fig. 1 Stations of the research sites in the Rivers (a) Tweed, (b) Tyne and (c) Wear.

Table 1

Locations of study in the Tweed estuary

STATION	CHARACTERISTICS OF LOCATION	exposed during low tide	salinity ‰
1	Open coast, rocky shores	✓	marine (34)
2	Behind pier, rocky substratum and a little bit sandy	✓	28 - 32
3	Gravel and sand muddy substratum	✓	18 - 30
4	Gravel and stone substratum	✓	15 - 28
5	Gravel and stone substratum	✓	12 - 25
6	Gravel and stone substratum	✓	11 - 25
7	Gravel and sandy substratum	✓	3 - 18
8	Gravel and sand muddy	✓	0 - 17
9	Gravel and sand muddy	✓	0 - 10
10	Gravel and soil; grass growing in every part	✓	0 - 4

Culture experiment on *F. ceranoides* in the laboratory with different salinities

Plants of *F. ceranoides* for experiments were collected from the upper estuary of the River Tweed at Berwick-upon-Tweed. Before use the seaweeds were cleaned using tap water to remove all attached organisms. They were then acclimatized in a cool room with a temperature of 10°C ± 0.5°C in water with a salinity of 8‰ for five days.

The culture medium used was fresh sea water from the Dove Marine Laboratory, Cullercoats, with a measured salinity of 35‰. This sea water was the source of all treatments with different salinities after dilution with distilled water and filtering. To enrich the medium 25ml of the following mixture (based on Fulcher & McCully, 1969) was added to 1l medium

K NO_3 200mg; K_2HPO_4 35mg; $FeCl_3$ 1.0 mg; $MnCl_2$ 0.01mg; B_{12} 10mg; thiamine HCl 2mg; biotin 2mg; glycerophosphate disodium pentahydrate 10mg; ethylenediaminetetraacetic acid 10mg; distilled water 1 l.

Healthy clean apices of *F. ceranoides* were cut into lengths of approximately 2cm and were weighed before placing in the culture media (Back *et al.*, 1992).

The cultures were maintained in 250ml conical flasks with different salinities (0, 5, 10, 15, 20, 25, 30, 35 ‰) and with two replicates. All the flasks were placed in the same tray and the position of the flasks was arranged to ensure that all of the flasks got the same effect from the room conditions, especially illumination.

Table 2

Locations of study in the Tyne estuary

STATIONS	CHARACTERISTICS OF LOCATIONS	exposed during low tide	salinity ‰
1	Open coast rocky shores	✓	marine (35)
2	Protected by pier, boulder and gravel substratum and little bit sandy	✓	29 -34
3	Black Middens area, boulders, gravels, sand and silt substratum		20 -32
4	Ferry port areas, grow on concrete and wood		18 -32
5	Hebburn riverside park areas, grow on concrete wall and boulders, muddy substratum		10 -30
6	St. Anthony's riverside park areas, grow on concrete wall and boulders, muddy substratum		5 - 20
7	Tyne bridge areas, grow on concrete wall and wood		0 -20

The culture medium was renewed every seven days and was constantly aerated. The cultures were maintained in constant temperature rooms at a temperature of 10°C ± 0.5°C. They were illuminated by white fluorescent tubes for a 14L:10D daily photoperiod (Schonbeck & Norton, 1978). Every seven days the algae were removed and dried, and the weights recorded with electrical balance with a precision of 0.0001g. The experiment was finished when the *F. ceranoides* in each treatment indicated different growths and part of the plants had decayed causing them to stop growing. The growth in weight (g) was analysed by one way analysis of variance with a Minitab statistical programme.

Culture Experiment on *F. ceranoides* in the laboratory with different concentrations of water resources of culture media

The *F. ceranoides* used for this experiment were similar to those used in the previous experiment and were given the same preliminary treatment. At first the plants were maintained in culture media using water with a salinity of 8‰. This dilution was chosen because adult plants of *F. ceranoides* have maximum growth in that salinity (Khafji & Norton, 1979). These experiments were conducted using 2cm-long parts of adult plant tips (Back *et al.*, 1992). The water for this culture came from the river Tweed at Berwick (representing unpolluted water) with a salinity of 8‰ and from the river Tyne (representing polluted water) with a salinity of 8‰. The cultures were maintained in 300ml conical flasks with five treatments and three replicates, as follows :

Table 3

Locations of study in the Wear estuary

STATION	CHARACTERISTICS OF LOCATIONS	exposed during low tide	salinity ‰
1	Rocky shores, protected by piers, sandy and gravel substratum, seaweeds grow on rock		28 - 32
2	Sandy, gravel and muddy substratum, gentle slope, seaweeds grow on rock	✓	24 - 28
3	Gravel, sandy and muddy substratum, seaweeds grow on steel wall and gravel	✓	14 - 26
4	Gravel and muddy substratum, seaweeds grow on steel wall	✓	6 - 26
5	Muddy substratum, seaweeds grow on concrete wall	✓	5 - 25
6	Sandy and gravel substratum	✓	5 - 25
7	Sandy, gravel and muddy areas	✓	4 - 24
8	Rocky, gravel, sandy and muddy substratum	✓	0 - 22

(i) 100% water from Tweed and 0% water from Tyne

(ii) 75% water from Tweed and 25% water from Tyne

(iii) 50% water from Tweed and 50% water from Tyne

(iv) 25% water from Tweed and 75% water from Tyne

(v) 0% water from Tweed and 100% water from Tyne

The culture medium was changed every three days and was constantly aerated. The cultures were maintained and the plants measured as in the previous experiment. The experiment was continued until plants showed differences in growth for all treatments, and all *F. ceranoides* cultured in unsuitable media decayed and died. The growth, reflected by changes in weight (g), during the course of the experiments in different treatments was analysed as previously described.

RESULTS

In the Tweed estuary, *F. ceranoides* is distributed from stations 3-10 and *F. vesiculosus* from stations 1-6 (Fig. 2a). *F. ceranoides* is dominant in stations 7-10 where *F. vesiculosus* is absent. In stations 3-6 *F. ceranoides* and *F. vesiculosus* grow together in the same habitat, and they

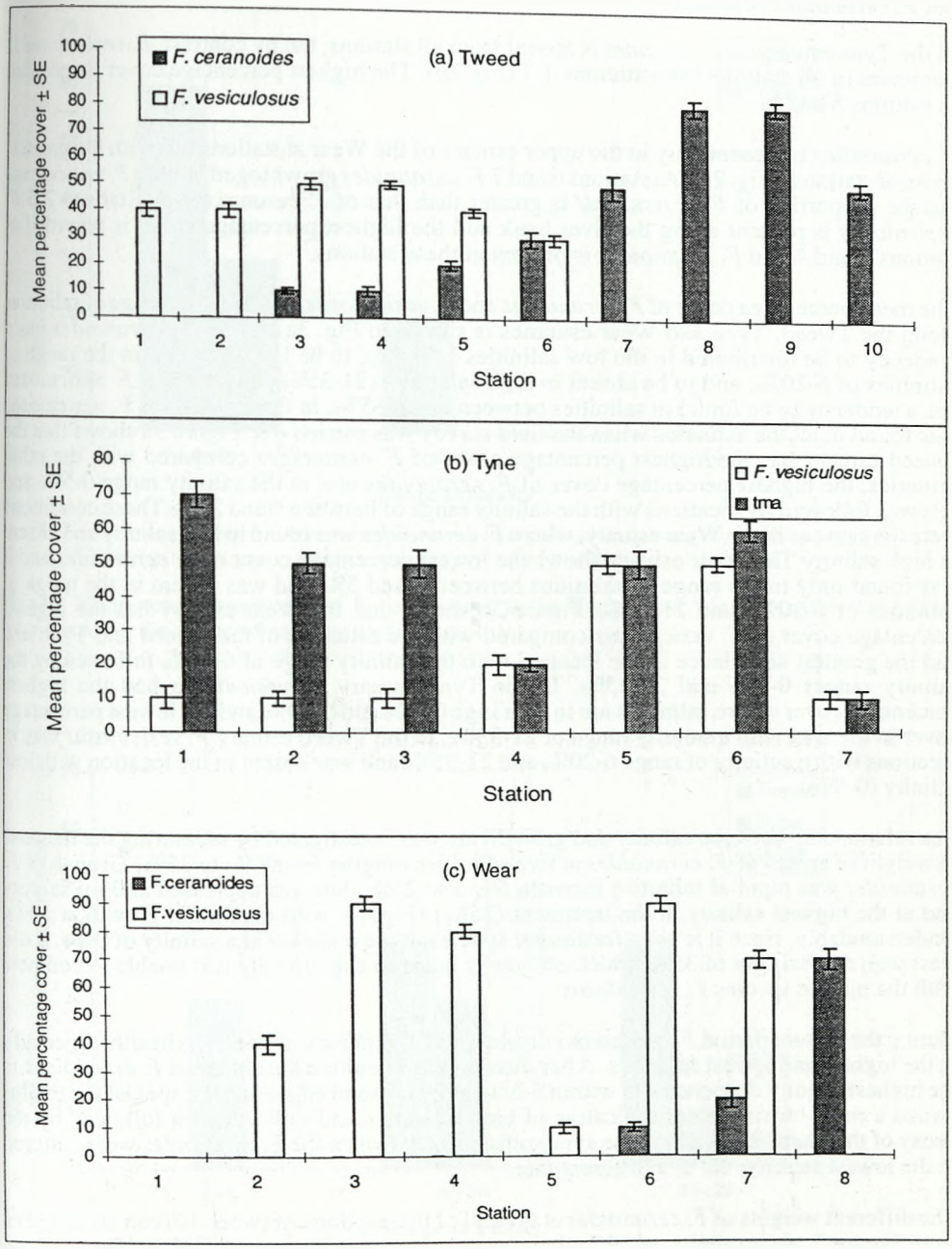

Fig. 2 Mean percentage cover (standard error) of *F. ceranoides* and *F. vesiculosus* and total macro algae (tma) in the (a) Tweed, (b) Tyne and (c) Wear estuaries.

compete. Both fucoids can live together in the same habitat if the conditions are suitable.Both species can tolerate a salinity of 11-25‰ if the substratum is able to support their growth; they can coexist. At stations 1 and 2 only *F. vesiculosus* is present in these locations of high salinity, but *F. ceranoides* is absent.

In the Tyne estuary *F. ceranoides* is absent from all stations, but by contrast, *F. vesiculosus* is dominant in all stations from stations 1-7 (Fig 2b). The highest percentage cover is recorded in stations 5 and 6.

F. ceranoides is present only in the upper estuary of the Wear at stations 6-8 with the greatest cover at station 8 (Fig. 2c). At stations 6 and 7 *F. ceranoides* grows together with *F. vesiculosus* but the proportion of *F. vesiculosus* is greater than that of *F. ceranoides*. At stations 2-5 *F. vesiculosus* is present along the river bank and the highest percentage cover is recorded at stations 3 and 4. No *F. ceranoides* is present at these stations.

The mean percentage cover of *F. ceranoides* and *F. vesiculosus*, based on the range of salinities along the Tweed, Tyne and Wear estuaries is shown in Fig. 3a and 3b. *F. ceranoides* has a tendency to be distributed in the low salinities of 0-5‰, to be less abundant in the range of salinities of 6-20‰, and to be absent in high salinities (21-35‰). In contrast, *F. vesiculosus* has a tendency to be found in salinities between 6 and 35‰. In these salinities *F. vesiculosus* was found in all the estuaries when the field survey was carried out. Figure 3a shows that the Tweed estuary has the highest percentage cover of *F. ceranoides* compared with the other estuaries, the highest percentage cover of *F. ceranoides* was in the salinity range 0-5‰ and this was followed by locations with the salinity range of between 6 and 20‰.These conditions were the same as in the Wear estuary, where *F. ceranoides* was found in low salinity and absent in high salinity.The Wear estuary shows the lowest percentage cover of *F. ceranoides* and it was found only in the range of salinities between 0 and 5‰ and was absent in the range of salinities of 6-20‰, and 21-35‰. Figure 3b shows that the Wear estuary has the highest percentage cover of *F. vesiculosus* compared with the estuaries of the Tweed and Tyne and had the greatest abundance in the location with the salinity range of 6-20‰ followed by the salinity ranges 0-5‰ and 21-35‰. In the Tyne estuary *F. vesiculosus* had the highest percentage cover where salinities are in the range 0-5‰ and 6-20‰ and the lowest percentage cover in the area with a salinity range of 21-35‰. In the Tweed estuary *F. vesiculosus* was in locations with a salinity of range 6-20‰ and 21-35‰ and was absent in the location with low salinity (0-5‰).

The relationship between salinity and growth rate was investigated by measuring the increase in weight of apices of *F. ceranoides* at five salinities ranging from 0‰ to 35‰. Growth of *F. ceranoides* was rapid at salinities between 5‰ and 25‰, but was depressed at 0‰o salinity and at the highest salinity in the treatment (35‰) (Fig. 4), with maximum growth at 10‰. Understandably, since it is not a freshwater species, it grew slower at a salinity of 0‰o. It did least well at a salinity of 35‰ which obviously helps to explain why it is unable to compete with the marine species *F. vesiculosus*.

During the culture period *F. ceranoides* displayed different indications of its health, especially in the highest and lowest salinities. After three weeks in culture the colour of *F. ceranoides* in the highest salinity deepened and within 5-6 weeks the lateral edges and the apex of the thallus turned a rusty brown colour indicative of tissue damage and this was then followed by the decay of the plant tissue. The same symptoms occurred when the *F. ceranoides* were cultured in the lowest salinity, but at a different rate.

The different weights of *F. ceranoides* at the end of the experiment (week 10) can also be seen from Figure 5. At a salinity of 10‰ there was the greatest increase in weight. By contrast, treatment with salinities of 0‰, 30‰ and 35‰ showed the least increase weight at the end of the experiment.

The differences of weight increase in different salinities is highly significant ($p < 0.001$) as shown by one-way analysis of variance (Table 4).

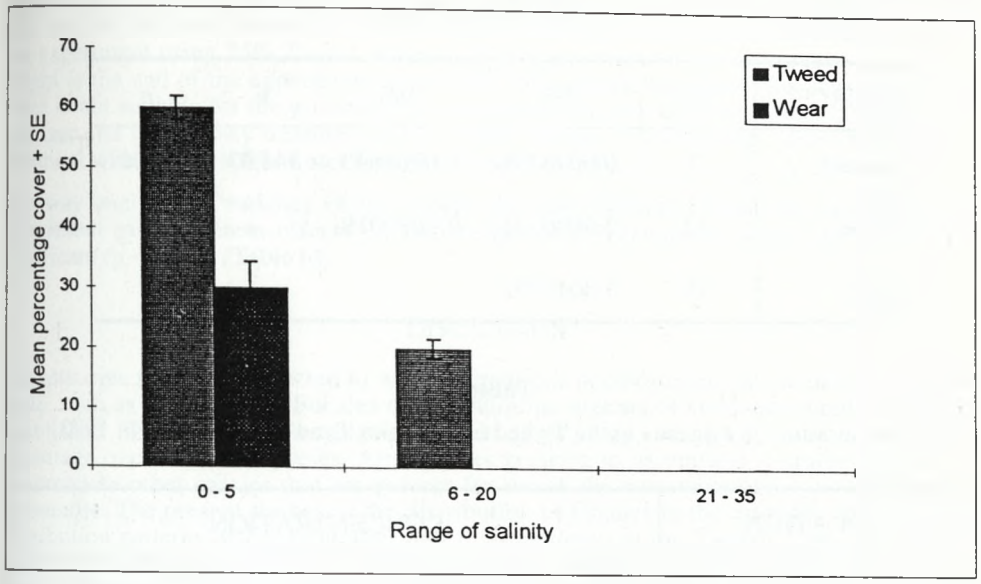

Fig. 3a Mean percentage cover of *F. ceranoides* in the Tweed and Wear estuaries ± standard error based on the range of salinity during low tide.

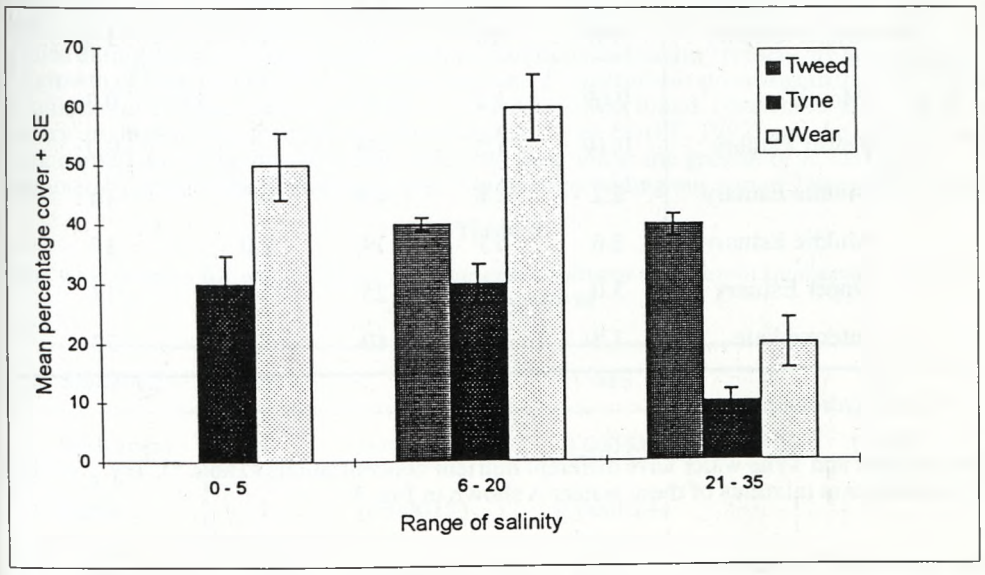

Fig. 3b Mean percentage cover of *F. vesiculosus* in the Tweed,Tyne and Wear estuaries ± standard error based on the range of salinity during low tide.

Table 4

One way analysis of variance for weight (g) of *F. ceranoides* cultures in different salinities at the end of culture

SOURCE	DF	SS	MS	F	*p*
Salinity	7	0.0046498	0.0006643	344.03	0.000
Error	12	0.0000231	0.0000019		
Total	19	0.0046792			

Table 5

Concentration of nutrients in the Tweed estuary and Tyne estuary (MAFF, 1992)

LOCATION		CONCENTRATION				
		$\mu mol\ l^{-1}$				$\mu g\ l^{-1}$
		P	**Si**	**Nitrate**	**Nitrite**	**THC***
Tweed	Mouth	0.17	1.4	< 0.1	-	0.5
	Lower Estuary	1.5	18	52	0.8	1.8
	Upper Estuary	1.8	20	60	1.1	1.9
Tyne	Mouth	0.09	1.1	< 0.1	-	0.3
	Lower Estuary	0.19	1.5	0.4	-	0.7
	Middle Estuary	2.2	6.8	4.8	0.7	16
	Middle Estuary	2.6	13	14	2.0	17
	Upper Estuary	3.0	22	25	3.7	18
	Intermediate	3.8	30	40	4.7	22

*Total Hydrocarbons

Tweed water and Tyne water have different nutrient concentrations (Table 5). The growth of *F. ceranoides* in mixtures of these waters is shown in Fig. 6.

The growth of *F. ceranoides* was rapid in 100% Tweed water and 75% Tweed water + 25% Tyne water, and was depressed in 50% Tweed water + 50% Tyne water, 25% Tweed water + 75% Tyne water, and 100% Tyne water. During the culture period plants that were cultured in higher concentrations of Tyne water died after 4-8 weeks. This happened in treatments iv and v. Before they died they showed several changes in their tissues: the apex of the thallus

turned rusty brown in colour (indicative of tissue damage) and this was then followed by the decay of the *F. ceranoides*.

Figure 7 also shows the different weights of *F. ceranoides* at the end of experiment. It is very clear that the different concentrations of culture media give different effects on the growth. The experiment using 75% Tweed water + 25% Tyne water shows the greatest increase in weight at the end of the experiment and 100% Tyne water the least. This shows that Tyne water is not suitable for the growth of *F. ceranoides*. In low concentrations it may act as a fertilizer and in that way treatment (75% Tweed water) *F. ceranoides* grew faster than in treatment which used 100% water from the Tweed estuary.

One way analysis of variance of the results that the different treatments used during the experiment give different effects on the weight of *F. ceranoides* which are very highly significant ($p < 0.001$) (Table 6).

DISCUSSION

The estuarine region is subjected to wide fluctuations in environmental conditions. Attached algae, such as the dominant Fucales of the estuarine regions of north-east England, become established in areas most favourable to their physiology, so giving them a competitive advantage over any rival species. Any species growing in its optimal conditions is likely to out-compete other species that are present for which the environmental conditions are less favourable. The present studies of the distribution of Fucales in the estuaries shows how the distribution patterns of *F. ceranoides* and *F. vesiculosus* in the Tweed, Tyne and Wear are affected by differences in the ambient physical and chemical conditions. The majority of *F. ceranoides* were found in the upper part of estuaries (with low salinity) and *F. vesiculosus* was distributed from marine to brackish water. The present study suggests that *F. vesiculosus* grows strongly in marine or near-marine conditions and F. *ceranoides* is unable to displace it. *F. ceranoides* favours conditions of low salinity which *F. vesiculosus*, being a marine species, cannot tolerate. Both species coexist and compete for space in areas which are optimum for neither species and in which, therefore, neither species has an advantage over the other. In those rivers where both species are present (the Tweed and Wear) *F. ceranoides* and *F. vesiculosus* are present together in the same stations. The results of this survey, indicate the different salinity requirement/tolerances of the two species. The Tweed is the cleanest river studied during the present field study and the conditions and salinity present are able to support the growth of both fucoids. *Fucus ceranoides* and *F. vesiculosus* grow together in the Tweed at salinities of 5-20‰. In the Tyne only *F. vesiculosus* was found. Nutrient levels in the Tyne estuary are higher than those in the Tweed estuary (see MAFF, 1992) and the experimental work carried out in the present study indicates that, whilst the growth of *F. ceranoides* was promoted by an increase in nutrient levels (obtained by adding one part of Tyne water to three

Table 6

One way analysis for weight (g) of *F. ceranoides* cultures at different treatments at the end of the experiment

SOURCE	DF	SS	MS	F	*p*
Treatment	4	0.0065742	0.001644	67.25	0.000
Error	7	0.000171	0.0000244		
Total	11	0.006745			

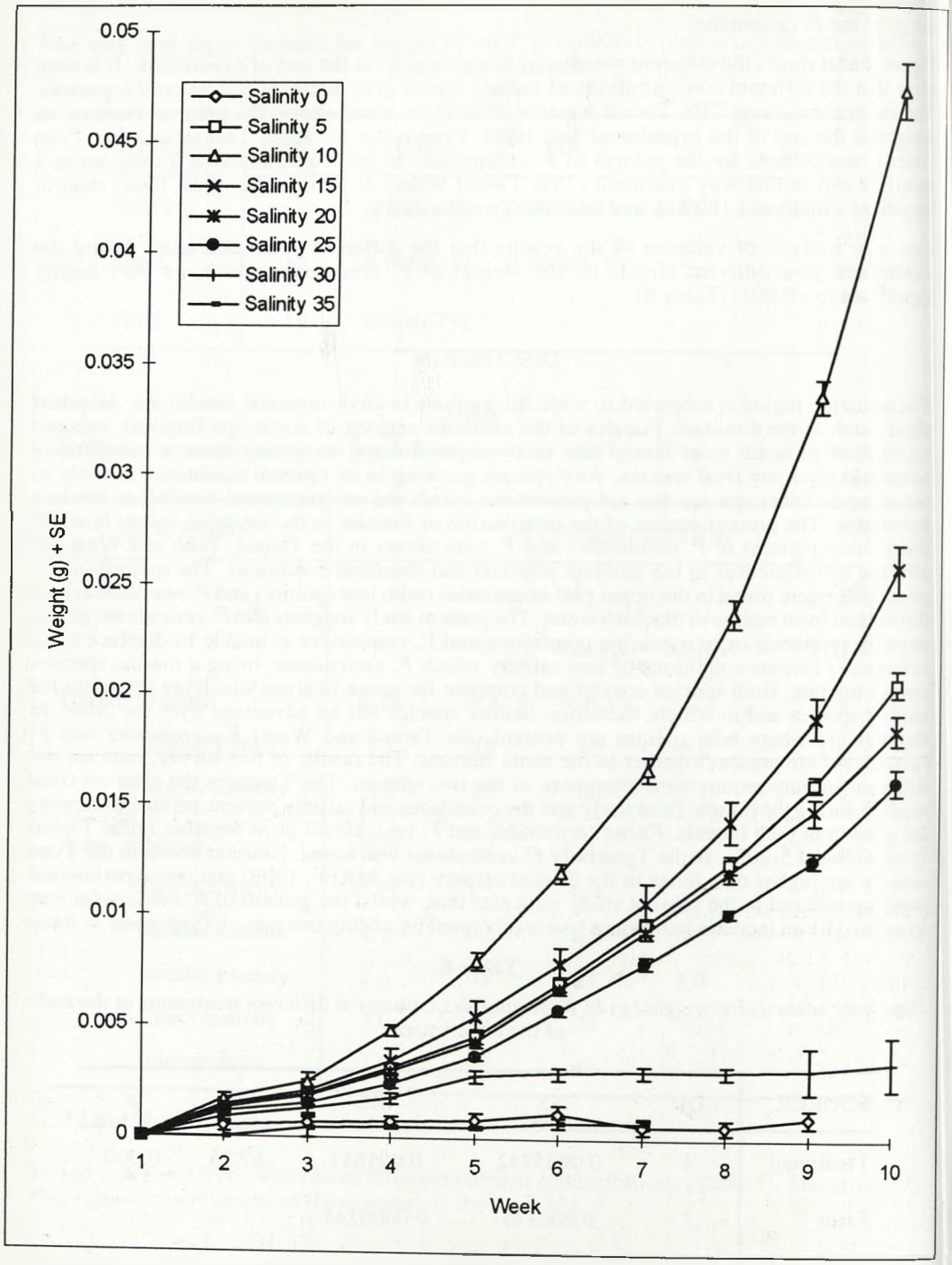

Fig. 4 Increase in mean weight (g) (standard error) of tips of adult *F. ceranoides* cultured for 10 weeks at various salinities.

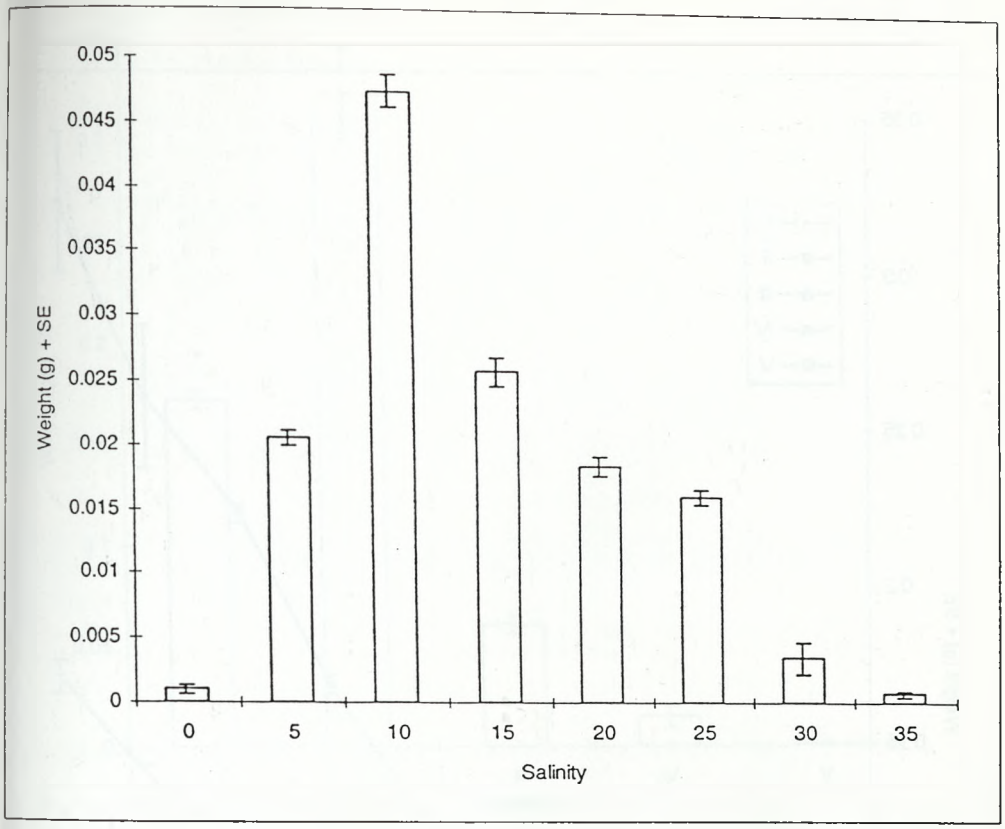

Fig. 5 Mean weight (g) ± standard error at the end of the culture (week 10) of *F. ceranoides* at various salinities

parts of Tweed water), the nutrient levels in Tyne water exceeded those tolerated by *F. ceranoides*. In view of the similar conditions found in the rivers Tyne and Wear, it is perhaps unexpected that *F. ceranoides* should be present in the Wear but absent from the Tyne. It is possible that more unpolluted water flushes through the Wear from its upper reaches than flows through the Tyne. These results can be compared with those of Edwards (1972) and Wilkinson (1973) who carried out surveys in the Wear estuary and found *F. ceranoides* only at Hylton (mid estuary) and *F. vesiculosus* on the open coast and in the lower estuary.

A study of the effects of salinity on *F. ceranoides* was carried out in the laboratory by Khfaji & Norton (1979). The effects of different salinities were tested firstly on microscopic germlings of both *F. ceranoides* and *F. vesiculosus*. These were cultured at five salinities ranging from 1‰ to 34‰ and the results show that neither species grew at a salinity of 1‰. The growth of *F. ceranoides* was rapid between 8.5‰ and 24‰, but was depressed at full salinity. That of *F. vesiculosus* on the other hand proceeded progressively faster at higher salinities and was maximal at 34‰. *F. ceranoides* grew marginally faster than *F. vesiculosus* at all reduced salinities, but was significantly outgrown by *F. vesiculosus* at full salinity. Germlings transferred from this salinity to higher salinities indicated that *F. ceranoides* could recover even after 24h exposure to freshwater whereas *F. vesiculosus* could not. The experiment was repeated, but this time the zygotes were settled directly in the salinity at which they were to grow. The results showed that this time *F. vesiculosus* could not survive at

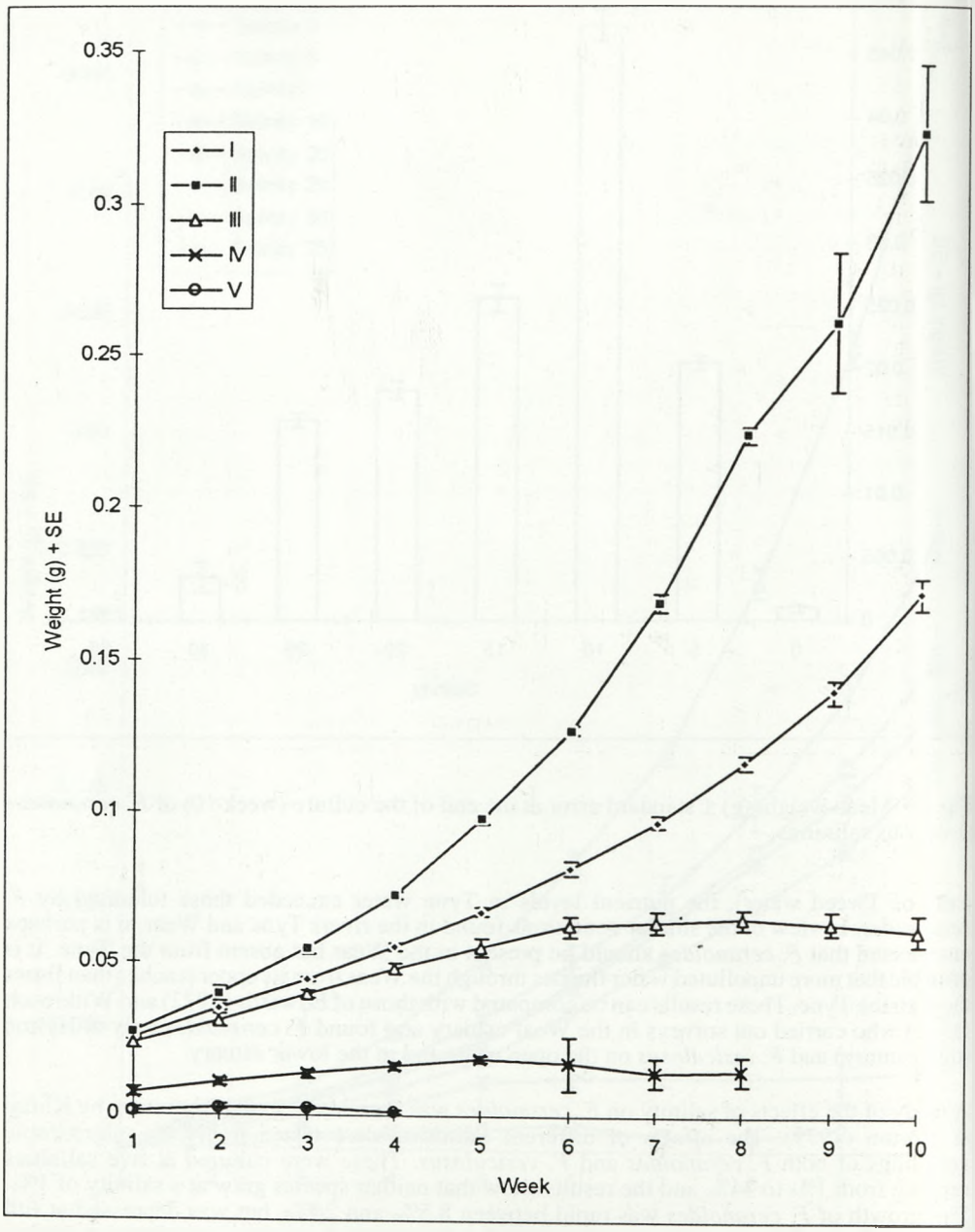

Fig. 6 Increases in mean weight (g) ± standard error of tips of adult *F. ceranoides* cultures for 10 weeks at various treatments: (**I**) 100% Tweed water, (**II**) 75% Tweed water + 25% Tyne water, (**III**) 50% Tweed water + 50% Tyne water, (**IV**) 25% Tweed water + 75% Tyne water and (**V**) 100% Tyne water.

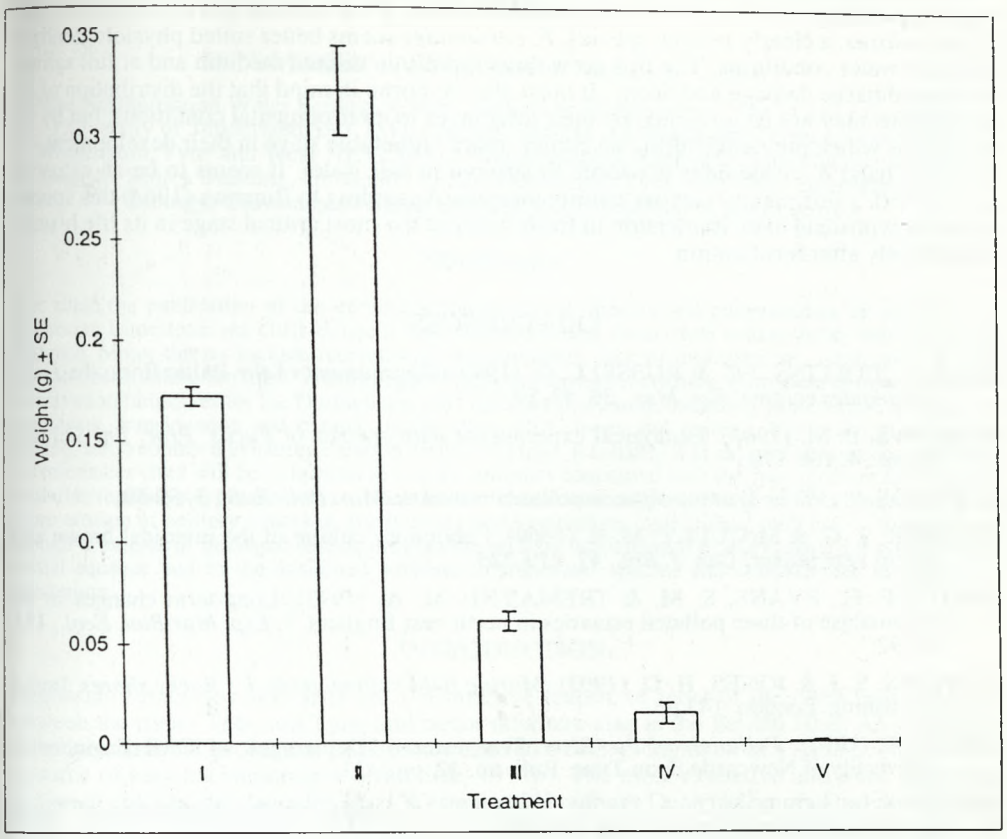

Fig. 7 Increases in mean weight (g) ± standard error of tips of adult *F. ceranoides* cultures for 10 weeks at various treatments: (**I**) 100% Tweed water, (**II**) 75% Tweed water + 25% Tyne water, (**III**) 50% Tweed water + 50% Tyne water, (**IV**) 25% Tweed water + 75% Tyne water and (**V**) 100% Tyne water.

salinities below 24‰, but the tolerance range of *F. ceranoides* was unchanged. Furthermore Khafji & Norton (1979) discovered that the response of the adult plant may differ from that of juveniles. Vegetative tips were also cultured at a range of salinities. The growth of *F. ceranoides* was maximal at a salinity of 8.5‰. It even grew, albeit slowly, at 1‰ and did least well at full salinity.

The present study was carried out to determine why *F. ceranoides* was absent from the Tyne estuary. A laboratory experiment was set up to culture *F. ceranoides* with different concentrations of polluted water from the Tyne estuary and unpolluted water from the Tweed estuary. The results indicate that *F. ceranoides* grew better in media with 75% Tweed water plus 25% Tyne water than in 100% Tweed water, and the worst growth was in 100% Tyne water. The water which contained the highest nutrient pollution had the worst effect on growth. It appears possible that *F. ceranoides* will grow better with the addition of a low amount of nutrient pollution. Nutrient pollutants in low concentrations act as a stimulant or fertilizer for *F. ceranoides* growth but in high concentrations they act as a toxin and cause *F. ceranoides* to die.

The experiments described here help to explain the success of *F. ceranoides* in streams and estuaries and also its failure to colonize the open coast. They indicate that in comparison with *F. vesiculosus*, a clearly marine species, *F. ceranoides* seems better suited physiologically to brackish water conditions. The tips grew most rapidly in diluted medium and at full salinity developed tissue damage and decay. It must also be borne in mind that the distribution of the adult plants may not be governed by their tolerances to environmental conditions, but by the conditions which prevailed during an earlier, more vulnerable stage in their development. On the other hand *F. ceranoides* is unable to survive in salt water. It seems to be an estuarine species with a sufficiently narrow salinity interval. According to Burrows (1964) this species is able to withstand even immersion in fresh water at the most critical stage in its life history, immediately after fertilization.

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CONSERVATION MANAGEMENT OF THE DURHAM SEA CLIFF FLORA

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SUMMARY

Ever since the publication of the earliest accounts of the species and communities on the Durham Magnesian Limestone sea cliffs concern has been expressed about their vulnerability and continued existence. Major threats include recreational developments, lack of management, scrub and tall-herb encroachment, deliberate fires, fertilizer runoff and excessive cliff erosion. With these in mind, practical conservation initiatives for the Durham sea cliff flora are discussed, including gap creation and species monitoring, translocation and control on the steep cliff slopes and grazing, hay making, controlled burning, scrub control and habitat creation on the cliff tops. It is likely that many of the options described and references cited will be of interest to conservationists concerned with the management and creation of similar vegetation types elsewhere. Integration of these conservation management techniques with the future erosion of colliery wastes on the beaches and sympathetic agricultural land use on the cliff tops through a long-term managed retreat programme will be fundamental in alleviating the symptoms of coastal squeeze and to the sustained survival of important species and communities into the next millennium.

INTRODUCTION

Magnesian Limestone sea cliffs are a distinctive feature of most of the north east coastline between the rivers Tees and Tyne and occur nowhere else in the British Isles. As such, they are of international geological importance and have been recognized as a nature conservation resource of national importance (Ratcliffe, 1977b). The most extensive and most important section of cliffs occurs between Hart Warren and Hawthorn Dene in County Durham (VC 66) where steep, drift-covered cliff-slopes, sea banks and several remaining fragments of semi-natural cliff tops are characterized by a complex assemblage of vegetation types including scrub, tall herb, unusual calcareous flush and fen communities and calcicolous, mesotrophic and maritime grasslands (Doody, 1981; Mitchell, 1995; Mitchell *et al.*, 1994). Using an ad hoc criterion of 'Magnesian Limestone grassland' it has been calculated that this stretch of cliffs accounts for 79.6 ha of the remaining semi-natural Magnesian Limestone grasslands in England, almost 30% of the estimated remaining national resource of 279 ha (Dalby, 1991; updated from Pritchard, 1989). Rare plant species recorded on these cliffs include *Asplenium marinum*, *Astragalus danicus*, *Astragalus glycyphyllos*, *Dactylorhiza traunsteineri*, *Epipactis palustris*, *Genista tinctoria*, *Geranium sanguineum*, *Hypericum montanum*, *Juncus subnodulosus*, *Juniperus communis*, *Lithospermum officinale*, *Primula farinosa*, *Pyrola rotundifolia* and *Samolus valerandi* (Doody, 1980; 1981; Graham, 1988; Mitchell *et al.*, 1994; Wheeler, 1980). This section of cliffs also supports populations of several rare insects, including the local subspecies of the Northern Brown Argus butterfly, *Aricia artaxerxes salmacis*, of which over 20 small and isolated colonies are scattered along the cliffs in association with their food plant *Helianthemum nummularium* (Sheppard, 1987). Most of the cliffs have been designated as a Site of Special Scientific Interest (SSSI) and have been proposed as a future National Nature Reserve.

Ever since the publication of the earliest accounts of the plant species and communities of the Durham sea cliffs concern has been expressed about their vulnerability and continued existence. In an early account of the sea cliff plants at Blackhall Rocks Preston (1915) warned fellow naturalists that "they must be quick, for the increasing population, due to the opening of the new collieries, will soon improve these localities out of existence". Following a visit to the same locality a few years later Heslop-Harrison (1923) confirmed that "the coast denes have been used as tips for shale from the collieries" and that many plants had been lost due to

fires caused by combustion of these wastes. Some years later he expressed concern about the continued survival of the only remaining coastal population of *Primula farinosa* in County Durham in a calcareous flush at Blackhall Rocks, where he observed that "the whole colony is in danger of being swallowed up by coarse grasses" (Heslop-Harrison, 1947). Other threats to the flora at this time included the development of new roads and railway links between the coastal colliery villages which it was feared could lead to increased human pressures on the coastline (Heslop-Harrison & Richardson, 1953).

Following the decline of the collieries on the Durham coast recent botanical accounts have focused on other potential threats to the sea cliff vegetation. At the moment major recreational development is restricted to a large municipal caravan park at Crimdon Dene. Here the erosive effects of tourists are obvious on the adjacent cliffs and sand dunes (Doody, 1980), whilst other potentially adverse developments have been associated with the reclamation of the former coastal collieries, including the development of new coastal footpaths and landscape works on the cliff tops (Doody, 1981). Rubbish dumping in cliff hollows, scrub and tall-herb encroachment and deliberate burning of the semi-natural grasslands also represent localized threats to important plant communities on the cliffs (Doody, 1981; Mitchell *et al.*, 1994). Concern has also been expressed about agricultural activities on the cliff tops, which may be causing modification of some important assemblages of plants in localized seepage flushes through fertilizer runoff and changes to the water table (Mitchell *et al.*, 1994; Wheeler, 1980) as well as leading to localized invasion of the cliffs by arable crops. In addition the recent cessation of colliery waste tipping into the sea and onto the beaches following the closure of all of the local collieries has resulted in increased beach erosion. This may lead to increased erosion of the soft Magnesian Limestone cliffs in the near future (Cooke & Gray, 1984; Posford Duvivier, 1993a) and consequently represents a potentially imminent threat to a number of rare species and important plant assemblages. A recent extensive ecological survey of these cliffs suggested that a number of important species and vegetation types had declined or disappeared over the last few decades and that monitoring and active conservation management initiatives would be required in the near future (Mitchell *et al*, 1994). It is therefore the aim of this paper to outline the possible conservation management options available for the species and vegetation of the Durham sea cliffs between Hawthorn Dene and Hart Warren with reference to contemporary published research. It is likely that many of the options described and references cited will be of interest to conservationists concerned with the management of similar vegetation types elsewhere. For convenience management options are discussed in terms of small-scale species conservation initiatives on the steep cliff slopes and more extensive vegetation management and creation options on the flat cliff tops. Nomenclature of species follows that of Stace (1991).

SPECIES CONSERVATION ON THE CLIFF SLOPES

Much of the vegetation on the steep seaward facing cliff-slopes is probably maintained as a climatic climax and is outside of a management framework such that conservation management initiatives here are likely to remain extremely limited (Pritchard, 1989). However, despite the difficult topography of these slopes, some small-scale species conservation initiatives are feasible and probably desirable in light of the imminent threat of severe cliff erosion in certain locations.

Species monitoring

From the outset the formulation of any species conservation initiatives should ideally be associated with a structured monitoring programme (Sutherland, 1995), which should include invasive and aggressive species as well as rare plant populations (Hirons *et al.*, 1995). The main focus of extended monitoring work must be to safeguard against loss of scientific interest and to detect or predict change at an early stage so that management regimes can be applied or changed accordingly (Crompton, 1981; Hirons *et al.*, 1995; Smith *et al.*, 1985). For example, many rare species are characterized by a single method of regeneration only (Grime, 1979; 1980; 1986) and future autecological studies on the Durham coast must attempt to investigate the conditions necessary for the survival, germination and establishment of individuals of their

constituent rare and invasive species so that a full autecological profile of the target species is available when planning future species conservation management options.

In the case of both rare and invasive species, the successful management of defined populations implies the ability to understand and manipulate the number of individuals and the structure of the population (Davy & Jeffries, 1981), but in many cases very little is known about the autecology of the target species (Bradshaw & Doody, 1978; Sutherland, 1995; Wells *et al.*, 1981). In particular, there is a lack of information regarding the establishment and recruitment of new individuals in relation to environmental factors and management operations (Grubb, 1977; 1990). This is certainly the case with both rare and common species on the Durham sea cliffs and it is suggested that field experiments could be conducted to investigate the responses of different species to various management regimes in marked plots. Data generated from such studies would assist conservation managers in the selection of the most appropriate future species management techniques (Duffey *et al.*, 1974; Hirons *et al.*, 1995; Sutherland, 1995). Several workers have advocated the use of detailed demographic approaches to assess accurately the effects of management practices (Bradshaw, 1981; Hutchings, 1991), but such monitoring is extremely time-consuming, labour-intensive and difficult to conduct in rank vegetation and other workers have suggested that regular monitoring using rapid and simple techniques (e.g. fixed point photography of sites, counts of flower spikes, estimating presence/absence of forbs in nested quadrats, etc.) may be most appropriate in many situations where the work may be conducted by volunteers (Duffey *et al.*, 1974; Hodgson *et al.*, unpublished; Smith *et al.*, 1985). In some locations on the Durham sea cliffs, where isolated populations of rare species (e.g. *Primula farinosa*, *Samolus valerandi*) are extremely vulnerable to sudden and catastrophic losses, it is likely that emergency conservation management measures, such as the translocation of individuals, may be required without comprehensive autecological and monitoring data.

Species translocation

The process of moving rare species is highly contentious, but of the available options listed by Sutherland (1995) the conservation initiatives of species reinforcement and translocation may be justified in the Durham coastal flushes. Reinforcement represents an attempt to increase the size of a defined population by releasing additional individuals into an existing population and may be appropriate for some rare species populations which do not appear to be immediately threatened (e.g. *Pyrola rotundifolia*). However, in the case of other species growing in precarious and vulnerable locations at the base of eroding cliffs (e.g. *Primula farinosa* and *Samolus valerandi*), the translocation of individuals from their current sites to new donor sites will be necessary. This may be achieved in two ways; direct sowing of seeds collected from existing populations or by germinating seeds under controlled conditions and then transplanting well developed seedlings or semi-mature plants into the donor sites.

Direct seeding represents a quick and relatively non labour intensive method of translocating plants to donor sites but at present there is little information available about the viability of native plant seeds (Grime *et al.*, 1981; Gorer, 1978; Roberts, 1972) and the chemical and physical properties of the substrate required for their successful germination (Rorison, 1967). However, Wells *et al.* (1981) have shown that if seeds are sown in autumn most will germinate adequately throughout the winter, with those seeds requiring stratification germinating the following spring. It is therefore suggested that small experimental plots could be marked in appropriate donor sites to monitor the success of a known number of sown seeds. Investigations could compare the germination success of seeds sown into different substrate types and into patches of bare substrate, bryophytes and various sward densities or heights to establish optimum germination requirements, following similar work conducted by other workers elsewhere (e.g. Fenner, 1978; Fenner & Spellerberg, 1988). To facilitate such investigations it will be necessary to collect seeds from the known populations of rare species and to establish a 'seed bank', an advisable strategy in any case in light of the possibility of a sudden catastrophic loss of one or more population.

Recent research in grassland plots has suggested that the extra labour involved in growing seeds on to seedlings under controlled conditions and transplanting them into the sward may

be justified by the more successful establishment of species compared to direct seeding (Fenner & Spellerberg, 1988), although this is only likely to be applicable to small areas (Wells, 1983). However, when 120 small seedlings of *Primula farinosa* were transplanted into six 10 x 10cm plots of cleared bare ground at a donor site at Blackhall Rocks during May 1994, all perished in a very short time. This may have been due to the hot, dry weather at the time, although similar work aimed at the conservation of the last remaining *Primula farinosa* plants in Northumberland has shown that it is important that plants are grown on to semi-maturity before transplantation (A.J. Richards, 1995, *pers comm*). The ability of seedlings within a sward to tolerate canopy shading, competition for nutrients and other processes varies between species (Fenner, 1978; Grubb, 1977) and clearly much useful research could be directed towards investigating the effects of seedling age and size and different sward and substrate types on the establishment of transplanted seedlings of rare species at different times of year.

Gap creation to assist species regeneration

Although the natural processes of cliff erosion and slippage of glacial materials appear to provide gaps or regeneration niches (Grubb, 1977) for rare species on the Durham coast, it is likely that continued '*laissez faire*' management or non-intervention in some existing or possible future donor sites may no longer be advisable. This is due to the possible loss of appropriate gaps or vacant microsites as a result of excessive cliff erosion and slippage or increasing invasion by competitive species as a result of human induced changes to soil nutrient levels, hydrological regimes and coastal processes. Almost certainly a lack of positive action has contributed to the decline and loss of important populations over the past few decades (Mitchell *et al.*,1994). The regulation of the intensity and type of disturbance therefore poses an important issue for the future management of these populations, whether existing or translocated. For example, if current rates of gap creation are excessive this may render the habitat more vulnerable to invasion by aggressive species (Hobbs & Hunneke, 1992) and the type of disturbance may also affect the germination of species from the seed bank (Ward & Jennings, 1990). Further research into the relationships between gap creation and seed germination of rare species on the cliffs may provide useful information towards assessing the likely value of deliberate gap creation for their future conservation.

Despite the theoretical basis to the processes of disturbance, gap creation and regeneration niches, the creation of gaps is usually left to chance by the conservation manager and remains an underused management option (Hillier, 1990). This is particularly pertinent when considering the future of the small, isolated populations on the Durham sea cliffs as many traditional techniques of vegetation management (e.g. grazing, cutting, etc.) are unavailable owing to the difficult and dangerous topography of the cliff face slopes. The small size of these populations does, however, lend them to small-scale, intensive management operations aimed at improving the regenerative opportunities of the target species. Such operations have recently been proposed for the conservation of rare species in dune slacks (Jones & Etherington, 1992) and include the deliberate creation of bare ground by removal of turf and control of bryophyte patches. Despite the apparent importance of bryophytes in the dynamics of gap creation and the restriction or enhancement of seed germination and subsequent seedling establishment (During *et al.*, 1984; van Tooren, 1988; van Tooren *et al.*, 1986; 1988), they are seldom seriously considered by the conservation manager (During, 1990). It is therefore suggested that more attention needs to be directed towards the relationships between rare plants and the bryophyte component of the sea cliff vegetation. At present it is unclear whether the bryophytes compete with the rare species for available bare ground or whether the bryophytes occupying former bare ground provide important microhabitats for the germination of seeds and refugia for the establishment of seedlings. It is also unclear what management initiatives are required to maintain the remaining patches of rare bryophytes such as *Gymnostomum recurvirostrum*, an upland species occurring mainly in Upper Teesdale but reaching the Durham Coast at Blackhall Rocks (Graham, 1988; Mitchell, 1995). A major problem here is that attention towards the conservation of bryophytes lags far behind that of vascular plants (Hodgetts, 1992) and our knowledge of their specific environmental requirements remains rudimentary and possibly innaccurate compared to higher plants (Soderstrom *et al.*, 1992).

Control of invasive species

As well as managing rare species on the Durham sea cliffs it will also be important to monitor and, if necessary, control or debilitate potentially invasive species such as *Eupatorium cannabinum*, *Equisetum telmateia* and *Pteridium aquilinum*. In some places these species now completely dominate the cliffs (Mitchell *et al.*, 1994) and have resulted in a loss of scientific interest. Such losses may be prevented in some of the remaining important rare plant populations by simply hand-pulling or weeding of tall herbs or thick grass swards, a task which could feasibly be conducted rapidly and regularly by volunteers owing to the small size of the areas in question. This operation may have to be repeated numerous times to restrict the further spread of some of the rhizomatous species listed above, although care will be necessary to avoid excessive disturbance to the turf as this may promote recolonization by other undesirable species and loss of gaps. An alternative approach may be to selectively treat individual plants with a selective translocated herbicide, applied with a long tubular stick or glove soaked with herbicide (Roberts, 1982), so that their underground parts are killed. This would avoid ground disturbance but this approach should generally be avoided unless the control of the target species can be guaranteed and there is no potential damage to other species (Ausden & Treweek, 1995; Duffey *et al.*, 1974). Another effective technique involves cutting back of tall herbs and removal of cut material during their main growth period in the summer before they set seed. This reduces the competitive advantage of tall herbs, promotes light penetration to the ground layer and prevents the build up of plant litter and organic nutrients (Gryseels, 1989; Rowell *et al.*, 1985; Wheeler & Giller, 1982; Wheeler & Shaw, 1991). In some areas invading bracken may prove difficult to eradicate completely as it has substantial reserves of carbohydrate stored in rhizomes (Dolman & Land, 1995). Recent research suggests that long established stands can be most successfully controlled when cut twice yearly for several years (Lowday & Marrs, 1992; Marrs *et al.*, 1992), or by spraying the fronds with Asulam in July or August when the fronds are fully extended but have not had time to recharge carbohydrate stores in their roots (Cooke, 1989; Dolman & Land, 1995). However, bracken may still persist after several years of such treatment, and the associated problem of high nutrient levels derived from bracken litter is less easily attended to (Dolman & Land, 1995; Marrs & Lowday, 1992).

VEGETATION MANAGEMENT AND CREATION ON THE CLIFF TOPS

Several significant areas of species-rich, semi-natural grassland vegetation occur on the flat cliff tops at Hive Point (Grid Reference NZ 443457) and adjacent to Cross Gill (Grid Reference NZ 475383) towards the northern and southern boundaries respectively of the defined study area and a wider range of management options may be available at these sites compared to the steep cliff slopes. As these cliff top grasslands are located on the thicker boulder clay deposits which are least influenced by the Magnesian Limestone bedrock (Smith & Francis, 1967) and are not subject to the intensity of disturbance and exposure experienced on the cliff slopes there is little reason to expect climatic and edaphic factors alone to arrest succession and loss of botanical interest. In recent years rank grassland characterized by *Brachypodium sylvaticum*, *Festuca arundinacea*, *Arrhenatherum elatius* and *Helictotrichon pubescens* has become well established at Hive Point (NZ 443457), whilst dense patches of *Ulex europaeus* scrub have developed at Cross Gill cliff top (NZ 476383) (Mitchell 1995; Mitchell *et al.*, 1994). Human intervention will therefore be necessary and practical conservation management techniques are considered in turn, together with options for improving the extensive areas of arable land which occur along most the cliff tops for nature conservation.

Grazing

Although pastoral farming was prevalent on the Magnesian Limestone up to the second world war (Leverton, 1980) it is uncertain to what extent the coastal grasslands have been grazed in the past. There is presently no grazing of the semi-natural cliff top grasslands with domestic livestock and grazing by rabbits appears to be negligible. Re-introduction of grazing animals into these areas could be beneficial in several respects; it is a selective management technique which reduces the dominance of palatable competitive species and encourages the establishment of subordinate species and the physical disturbance of the ground by livestock

results in the breakdown of plant litter and the development of gaps for seedling establishment (Ausden & Treweek, 1995; Bacon, 1990; Duffey *et al.*, 1974; Green, 1981; Sutherland, 1995; Wells, 1969). However, any grazing initiatives will have to be carefully planned as the possible effects on sward composition and structure are complex (Mitchley, 1988) and will depend on the method of grazing, type of grazing animal and the season, intensity and duration of the grazing regime (Ausden & Treweek, 1995; Bacon, 1990).

Although there are guidelines relating to recommended times of year, intensity and duration of grazing for different animals on Magnesian Limestone grasslands (English Nature, 1994b) it is difficult to predict the precise effects of any one regime in a particular area and sites may need to be considered on an individual basis as on other calcicolous grasslands (Bacon, 1990; Oates, 1992). However, it is clear that when grasslands have been left unmanaged for some time, such as those on the Durham cliff tops, it is not advisable to reintroduce a method of heavy or 'blitz' grazing as this could be detrimental to important plant and invertebrate populations (Ausden & Treweek, 1995; Bacon, 1990; Grubb, 1990; Oates, 1992), such as the scattered populations of the local subspecies of the Northern Brown Argus butterfly which occur along these cliffs. As an alternative regime less intensive autumn-winter-spring grazing facilitates greater control of relatively unpalatable vigorous grasses (e.g. *Brachypodium sylvaticum*), which are most palatable at this time of the year, with less damage to important plant populations (Bacon, 1990). However, this may require extra feed to be supplied during the winter, resulting in nutrient enrichment and further encouragement of rank grasses (Green, 1981). It may also cause considerable localized poaching of the ground and is therefore not encouraged in a recently launched scheme aimed at improving Magnesian Limestone grasslands, in which the emphasis is towards grazing between July to November (English Nature, 1994b). It is likely that such low intensity summer grazing will cause minimal disturbance to important plant and animal populations and has been shown to be useful in retarding vigorous forbs and woody species elsewhere (Bacon, 1990).

As well as the time of grazing the choice of livestock will be an important consideration in the introduction of any grazing on the Durham coastal grasslands. For example, excessive localized enrichment of calcicolous grasslands is often associated with the use of cattle, horses and ponies and this, combined with severe poaching of the ground, can lead to invasion by competitive, undesirable species such as thistles and docks (Bacon, 1990). These problems are generally avoided with the use of sheep, the traditional grazing animal of calcicolous grasslands (Bacon, 1990), although these are relatively poor at removing rank grasses such as *Brachypodium sylvaticum*, which they find relatively unpalatable (Wells, 1969). It is therefore likely that any proposed introduction of sheep grazing on the Durham cliff top grasslands should be preceded by horse or cattle grazing to assist in the reduction of the area of rank foliage. As with sheep the effectiveness of these alternative grazers depends largely on the breed, age and density of the introduced stock. For example, in southern England sedate suckler herds of cows or hardy native breeds of horses have been used with considerable success in the conservation management of chalk grassland vegetation (Green, 1981; Kydd, 1964; Oates, 1992). It is possible that sheep could be grazed with either cattle or horses, as such mixed grazing can produce a variety of sward types and vegetation mosaics suitable for important plants and invertebrates (Bacon, 1990). However, unless such mixed grazing is carefully managed it can lead to the creation of a relatively uniform sward which is poor for both plants and invertebrates (Ausden & Treweek, 1995).

Irrespective of the most appropriate choice of grazing animal, a major problem is that the Durham cliff top grasslands are located in relatively inaccessible areas within a predominantly arable landscape so that any form of grazing may be difficult to arrange. The costs of fencing, providing a water supply and animal husbandry combined with known local problems, such as vandalism and dog worrying of livestock (Pritchard, 1989), may render such methods uneconomic or unattractive to farmers. To overcome such problems it will be necessary to promote appropriate land management grants for landowners and farmers, such as English Nature's recently launched Wildlife Enhancement Scheme for the Magnesian Limestone grasslands (English Nature, 1994b). Other novel initiatives, such as the raising of rare breeds of cattle or sheep may be worthy of consideration when traditional animal husbandry is uneconomic (Green, 1981). The role of rabbits as co-grazers with domestic livestock should

not be discounted, although it is impossible to manage carefully their density and distribution due to considerable population fluctuations, such that it remains very difficult to control rabbit grazing intensity (Oates, 1992). Also, it is unlikely that local arable farmers would desire a population expansion of such a potential pest so close to their crops.

Hay making

An attractive alternative management technique to grazing could involve hay making on the Durham cliff top grasslands, where the foliage is cut at a defined time and the arisings removed from site soon afterwards. This differs from grazing in that nutrients are not returned to the soil as dung or urine and timing and intensity can be controlled more precisely (Ausden & Treweek, 1995; Duffey *et al.*, 1974; Wells, 1980). However, cutting is a sudden and largely unselective form of vegetation removal that can be catastrophic to important plant and animal populations alike and tends to produce a sward of more uniform structure and composition (Ausden & Treweek, 1995; Oates, 1992). Also, cutting does not create bare ground and gaps for the regeneration of subordinate species as does grazing (Duffey *et al.*, 1974; Green, 1981). In addition, cuttings left on the ground can cause nutrient enrichment and encouragement of coarse grasses and competitive forbs, prevent seed germination, smother smaller plants and limit the efficiency of nutrient cycling (Ausden & Treweek, 1995; Dickinson, 1984; Wells, 1969). It is therefore essential that they are removed shortly after cutting, although collection and disposal of these cuttings can present major problems (Green, 1981).

Despite the above problems cutting could represent a more viable management option than grazing on the Durham cliff top grasslands as there are no costs in terms of animal husbandry, provision of water supply and maintenance of fences. However, it is essential that management objectives are clearly defined beforehand, as there is no best time to conduct this sudden treatment (Wells, 1971). The timing and height of cut is therefore critical and should be related to the phenology of the important species (e.g. *Genista tinctoria*, *Hypericum montanum*, *Geranium sanguineum*) to allow flowering, seed set and dispersal (Mitchley, 1994; Smith & Jones, 1991; Wells, 1971). Therefore, in the recently introduced Wildlife Enhancement Scheme for the Magnesian Limestone grasslands, landowners and managers are obliged to conduct grass cutting and raking operations in September (English Nature, 1994b). However, the timing of the cut should also aim to suppress the more competitive grass species in the sward (e.g. *Brachypodium sylvaticum*, *Arrhenatherum elatius*, *Helictotrichon pubescens*, *Festuca arundinacea*) and this is generally most effective when applied during the peak biomass production, usually between May and August (Grime, 1980; Wells, 1969), rather than in September. Retardation of such species by cutting in summer has been shown to restore species diversity in rank calcicolous swards within five years, due to increased availability of light within the canopy (Bobbink *et al.*, 1987; Bobbink & Willems, 1991). It is possible, therefore, that summer grass cutting may be necessary in those areas of the coastal grasslands which require retardation of rank grasses. The principal aims of any grass cutting operation on the cliff tops should therefore be carefully defined and it is suggested that experimental plots within areas of rank cliff top grassland could be set up and monitored to assess the effects of different cutting regimes (times, frequency and height) on species diversity and composition.

Controlled burning

Another possible technique for the restoration of rank grasslands on the Durham cliff tops is controlled burning, which has proved to be a useful management technique in chalk grasslands in southern England (Green, 1981). This is a cheap and quick method of disposing of the dead standing crop and excessive plant litter as well as the removal of large amounts of nitrogen and phosphorus and is mainly used in the restoration of rank grassland prior to resumption of grazing or cutting (Ausden & Treweek, 1995; Duffey *et al.*, 1974; Green, 1981). Burning results in the creation of bare ground and vacant microsites between grass tussocks for annuals and small perennial forbs (Duffey *et al.*, 1974). It can also promote the production of inflorescences in the year following the burn, thereby helping to restore botanical diversity in derelict calcicolous grasslands (Lloyd, 1968), its effectiveness depending on the timing and extent of the burn (Mitchley, 1994). Like cutting, burning is a sudden, unselective process

which can promote uniformity of floristic composition and sward structure and may be particularly damaging to the seed bank or underground parts of some important plant species and grassland invertebrate populations (Ausden & Treweek, 1995; Oates, 1992). It may also be unpopular with the public in high profile amenity areas in the countryside (Ausden & Treweek, 1995; Green, 1981). For safety purposes the burn can be controlled more easily by burning into the wind rather than burning downwind, although this results in a more intensive and hotter burn which may be detrimental to plant and invertebrate populations (Green, 1981). Therefore burning should only be conducted in small controlled areas or mosaics on a rotational basis and should preferably occur in winter or spring when the sward is damp enough to prevent complete scorching of buried seeds and sensitive underground plant organs (Green, 1981).

After burning has taken place, an additional problem is that the nutrients released can promote the invasion and growth of undesirable forbs, ferns and grasses (Ausden & Treweek, 1995: Oates, 1992; Page, 1988; Wells, 1969). On the Durham sea cliffs deliberate and accidental burning have occurred for many years (Heslop-Harrison, 1923; Mitchell *et al.*, 1994) and in some areas this has led to the development of coarse vegetation characterized by species such as *Arrhenatherum elatius*, *Cirsium arvense* and *Pteridium aquilinum* (Mitchell, 1995). However, accidental burning in other locations may have benefited important species such as *Geranium sanguineum* and it is suggested that monitoring of such deliberately burned areas could prove useful to assess the potential of burning as a management technique. As with cutting the effects of controlled burning on community composition and structure within areas of rank cliff top grassland could be investigated in small experiment plots.

Scrub control

In the Durham cliff top grasslands scattered patches of scrub have developed, including *Rubus fruticosus* agg, *Prunus spinosa*, *Ulex europaeus*, *Crataegus monogyna* and *Rosa canina* agg (Mitchell *et al.*, 1994). These are generally insignificant at present but will require monitoring to assess whether they are spreading and threatening important grassland communities. It may be that scrub invasion is not a major problem as records have shown that elsewhere in Britain some rank calcicolous grasslands have remained relatively stable for over 30 years (Rodwell, 1992), as the dense canopy and thick layer of litter can inhibit invasion by woody species (Ward, 1990). Scrub communities should not be regarded merely as woody weeds of grassland as they may provide microhabitats for plant, insect and bird species through the provision of sun traps, structural diversity and shelter (Ausden & Treweek, 1995; Ratcliffe, 1977a; Ward, 1990) and it is important that any future scrub control initiatives take these into account.

Where scrub clearance is deemed necessary this is best achieved by tackling the advancing front or isolated patches on a rotational basis rather than attempting to clear dense, well established areas of scrub (Ward, 1990). In the Magnesian Limestone grasslands it is suggested that this can be achieved by hand cutting followed by immediately painting freshly exposed stumps with herbicide in September or October when the herbicide will be most effective (English Nature, 1994b). Some shrubs may still regenerate after such treatment and can be killed by drilling holes of 1 cm diameter 8-10 cm deep into the stump surface and filling with supersaturated ammonium sulphamate solution (Dolman & Land, 1995). All stumps should be cut close to ground level to allow future mechanical grass cutting to arrest re-invasion of cleared areas (Emery, 1986; Ward, 1990). In the special case of the few remaining prostrate bushes of *Juniperus communis* in the cliff hollows at Blackhall Rocks (Mitchell *et al*, 1994) some hand weeding of rank grasses may be necessary, as the germination of *Juniperus* seedlings is usually associated with open ground (Ward, 1990).

Changes in agriculture and habitat creation on cliff top arable land

At the present time most of the cliff tops within the study area are under intensive arable cultivation, primarily for the production of cereals and rape seed oil, with ploughed field margins extending right up to the cliff edge. This appears to have resulted in agricultural eutrophication and dereliction of important plant assemblages on the cliff face slopes through fertilizer runoff (Mitchell, 1995; Mitchell *et al*, 1994), a process which has also been described

for other species-rich calcareous cliffs in Britain (Etherington & Clarke, 1987). Numerous studies have shown that the experimental addition of fertilizers to plots in calcicolous grassland encourages the growth of competitive species, resulting in reduced species diversity (e.g. Bobbink, 1991; Bobbink & Willems, 1987; Bobbink *et al.*, 1988; Grime & Curtis, 1976; Jeffrey & Pigott, 1973; Lloyd & Pigott, 1967; Smith *et al.*, 1971). Future conservation initiatives should therefore consider the possibility of introducing more sympathetic land management in these areas by encouraging farmers to adopt alternative agricultural practices. For example, reintroduction of pastoral farming on the cliff tops or setting aside fallow field strips at the cliff edge could be beneficial to the flora by reducing nutrient inputs on to the cliff face slopes and represents the favoured land use for the future by conservation organizations (Posford Duvivier, 1993a).

As well as benefiting existing semi-natural plant communities on the cliff face slopes changes of agricultural practices on the cliff tops offer possibilities for the creation of new grasslands. For example, the Countryside Stewardship scheme offers payments to landowners for the re-creation of flower-rich pasture on cultivated land along the coastal fringe, preferably by natural regeneration, or with an appropriate seed mix if no suitable seed source is located nearby (Countryside Commission, 1994). Recent research suggests that, if there is a natural seed source nearby in the form of semi-natural calcicolous grassland vegetation, natural recolonization of abandoned arable fields can lead to the establishment of flower-rich grassland within ten years (Brown & Gibson, 1994; Wilson, 1994), although it is likely to take many decades before these closely resemble the structure and composition of semi-natural calcicolous grasslands (Gibson & Brown, 1991; 1992). For example it may be necessary to reduce the availability of macronutrients in the soil before species-rich grasslands can be created on ex-arable land (Gough & Marrs, 1990a; Magid, 1993; Marrs *et al.*, 1991), as high nutrient status favours the more competitive species which grow rapidly and leave fewer gaps for recolonization by subordinate species (Ausden & Treweek, 1995). This problem can be made worse if the soil is subject to excessive disturbance, as this can lead to the mass germination of annual weeds of arable cultivation which leaves little opportunity for other species to become established (Graham & Hutchings, 1988a,b).

It has been suggested that natural processes alone, such as leaching, are inadequate to reduce soil nutrient levels on ex-arable land and that further research into nutrient depletion techniques is required (Marrs *et al.*, 1991). For example, it may take 5 - 15 years to achieve a low phosphate soil unless there is active management to reduce high residual levels of such macronutrients (Gough & Marrs, 1990b). Possible options aimed at the reduction of nutrient availability in the soil include the wholesale removal of the topsoil as a saleable product, stubble burning to release nitrogen and phosphorus into the atmosphere, cereal cropping without fertilizers to exhaust macronutrient supplies, hay making and grazing to remove nutrients from the system (Bakker, 1994; Marrs, 1986). Of these, grazing has received the most attention and recent research has suggested that species richness and the abundance of individual plant species in ex-arable land is significantly increased in areas subject to sheep grazing (Brown & Gibson, 1994; Gibson & Brown, 1992; Gibson *et al.*, 1987). Potential problems with this technique however are that farmers are often reluctant to graze coastal land and such areas set aside from cereal farming are subject to restrictions on the type of grazing animal to be used (Hill *et al.*, 1995). There is clearly a need to change the narrow focus of set aside from a purely production control measure to part of a multi-purpose policy aimed at increasing biodiversity in the countryside (Royal Society for the Protection of Birds, 1995). A promising alternative approach to reducing soil nutrient levels on the Durham cliff tops could involve growing and harvesting cereal crops without fertilizers for several years, a technique which has been shown to reduce soil fertility in abandoned arable land in southern England (Marrs, 1986), although the precise effects of this and other possible techniques will require further research.

Another consideration in the creation of new grasslands is the location of available seed sources. Several investigations have shown that the colonization and establishment of calcicolous grassland species on abandoned arable land is influenced by the nature of the seed bank and seed rain and the proximity of semi-natural grasslands (Brown & Gibson, 1994; Gibson & Brown, 1991; Wilson, 1994). In many areas such natural seed sources are now very scarce and the chance of propagules of many species being available for natural recolonization

of abandoned arable land is much reduced (Wells, 1990). In these circumstances the direct sowing of wildflower seed mixes can result in the creation of an imitation of a calcicolous grassland sward within 7-15 years, with appropriate management such as cutting (Wells, 1990). On the Durham cliff tops this option is likely to prove inhibitively expensive and may not be justified due to the proximity of the semi-natural cliff face communities. However, under the Countryside Stewardship scheme supplementary payments are available for spreading hay taken from local species-rich grassland (Countryside Commission, 1994) and this could be linked to the proposals for hay making on the semi-natural cliff top grasslands discussed earlier.

INTEGRATED MANAGEMENT OF THE DURHAM SEA CLIFFS: 'COASTAL SQUEEZE', 'MANAGED RETREAT' AND SUSTAINABLE CONSERVATION OF THE FLORA

The main human influence on the Durham coast has undoubtedly resulted from the tipping of millions of tonnes of colliery wastes directly into the sea since the middle of last century (Doody, 1981; Hydraulics Research Station, 1970; Posford Duvivier, 1993a). Over the years longshore drift has carried the wastes along the coast where it has accumulated in long submarine mounds (Hydraulics Research Station, 1970), fractions of which are continually washed on to the beaches by the incoming tide. Initially the unconsolidated mudstone spoil eroded at a rate of 10-20 m per year but as this has degraded chemically to form a consolidated clay-like material it has tended to erode at a slower rate of approximately 0.5-2 m per year (Posford Duvivier, 1993a).This consolidated material has resulted in the formation of artificial raised beaches which have protected the soft Magnesian Limestone sea cliffs from excessive erosion and which, in some places, have been colonized by woody and herbaceous vegetation (Forster & Cooke, 1984). However, in recent decades increased erosion of these raised beaches has commenced (Hydraulics Research Station, 1977). This is likely to lead to accelerated erosion of some sections of cliff within the next few years and decades following the recent closure of all of the coastal collieries and cessation of all waste tipping on the beaches (Posford Duvivier, 1993a,b). In some areas this may pose a potentially imminent and irreversible threat to important plant species and assemblages. Depending on the amount, type and location of the wastes the period of beach erosion may vary from 3 to 242 years, after which the cliffs are expected to erode at approximately 0.3 m per year in bays and 0.1-0.2 m per year at headlands (Posford Duvivier, 1993a,b).

In recent years it has become clear that there is a pressing need for an enlightened, integrated and sustainable approach to coastal zone protection and management in Britain (Carter, 1988; Department of Environment, 1993; Doody, 1992) and this is of direct relevance to the Durham coastline. In particular, the promotion of natural processes or 'soft' engineering approaches of coastal management have been advocated to reduce the symptoms of 'coastal squeeze' (Burd, 1995), such as recent support for the processes of natural beach nourishment and managed retreat in English Nature's 'Campaign for a Living Coast' (English Nature, 1994a; July, 1993). At the same time, however, there have been considerable pressures locally (Hilton, 1990), regionally (Durham County Council & Easington District Council, 1982) and internationally (Mason, 1991) to force an artificial 'clean up' of the beaches. This may be detrimental to the sea cliffs (Cooke & Gray, 1984) and a recent preliminary evaluation of coastal defence options (Posford Duvivier, 1993a) does not demonstrate any particular need to remove the beach wastes or for any hard coastal protection works (e.g. sea walls, groynes, breakwaters, etc.) along most of the coastline.

As a result of beach and cliff erosion and unsympathetic agricultural practices on the cliff tops along the Durham coast many important plant species and communities have undoubtedly become trapped on the steep cliff slopes and suffer the symptoms of 'coastal squeeze'. The preparation of a long term 'managed retreat' (Burd, 1995) which integrates the future conservation of the sea cliff flora with agricultural land use and natural erosion rates will be fundamental to the success of all of the other management initiatives previously discussed. What is urgently required is a clearer understanding of the processes at work on the Durham coast so that informed decisions can be made when considering future coastal management

initiatives. Therefore future research needs to be directed towards the relationships between beach erosion and cliff erosion on the seaward side and the feasibility of ecologically sensitive land management practises on the landward side so that important plant species and communities on the steep cliff slopes are not squeezed out of existence and to ensure their sustained survival well into the next Millennium. The recent award of £4.5 million aid from the Millennium Fund (Wilkinson, 1995) offers a unique opportunity to achieve this aim and it is to be hoped that conservationists will take this chance to create a sustainable coast.

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THE USE OF A COMMERCIAL INSECT-TRAPPING COMPOUND TO MAINTAIN GRAZER DENSITIES ON ROCKY SHORES

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SUMMARY

Experiments on rocky shores which involve the manipulation of grazer density are common in the literature. Such manipulations are usually achieved using cages or fences that prevent the passage of grazers. Unfortunately, these devices can have additional, unwanted effects on the local habitat. An alternative method is to use a sticky insect-trapping compound as a barrier to prevent the passage of grazers and here we evaluate the usefulness of such a compound ('Tree Tanglefoot Pest Barrier'). In laboratory experiments in the UK 'Pest Barrier' prevented *Littorina littorea* from crawling vertically upwards and a complete circle of 'Pest Barrier' prevented six common littoral grazing species from escaping, even until death. In the field 'Pest Barrier' performed as well as cages and fences in exclusion experiments. In field experiments in Hong Kong, 'Pest Barrier' failed to exclude grazers and performed no better in this respect than open controls. Thus, whilst 'Pest Barrier' can be recommended for use in temperate regions, it should not be used for manipulations in tropical environments.

INTRODUCTION

Rocky shores are spatially and temporally dynamic and are of interest to ecologists as ecosystems in their own right. They also provide an environment which can be easily manipulated, giving results over relatively short temporal scales (days and weeks), which contribute to general ecological theory (see Lewis, 1964). Such manipulations of rocky shores often involve the addition or removal (exclusion) of grazers (mostly molluscs) from a defined area (e.g. Turner & Todd, 1991, on temperate shores; Liu, 1993, on tropical shores) and clearly a mechanism is required to maintain the desired densities of grazers. In the main this has involved the use of metal or plastic cages or fences (for a review of earlier literature see Hawkins & Hartnoll, 1983). Whilst these function well in manipulating numbers of animals, they can modify habitats in other ways. They may alter the drainage of the rock surface (Hawkins & Hartnoll, 1983) and can reduce insolation: Hayworth & Quinn (1990) found cages blocked 60-80% of incident solar radiation, which has an obvious effect on photosynthetic organisms within the caged area. Application of copper-based and TBT-based antifouling paints around the margins of manipulated areas to prevent the passage of grazers has been used by McQuaid & Froneman (1993) and Watson & Norton (1985), but Johnson (1992) points out that leachate from the paints may have undesirable effects which are unquantified. More inert barriers such as petroleum jelly (Dudley & D'Antonio, 1991) and sticky insect-trapping compounds used singly (Williams, 1994) or in conjunction with plastic turf (Kitting, 1980) have been used successfully but their efficacy has not been evaluated.

In minimizing undesirable effects of manipulation, these latter techniques seem to be the way forward and here we investigate the efficacy of a commercial compound used as a barrier to insects in spatially maintaining grazing molluscs. Experiments were conducted in the UK and Hong Kong to provide a temperate/tropical comparison of the effectivity of the substance.

MATERIALS AND METHODS

Barrier substance

'Tree Tanglefoot Pest Barrier' was obtained from The Tanglefoot Company, Grand Rapids, Michigan, USA. It has a proprietary formula which contains castor oil, natural gum resins and vegetable wax, is an opaque amber in colour and is designed to be a sticky barrier that can be placed around the trunk of a tree to protect from destructive climbing insects by trapping the insects within its matrix.

Laboratory experiments

These experiments were devised to test the ability of animals to cross a barrier of 'Pest Barrier'. All animals were collected from Whitburn, north-east England (grid reference NZ 415645) and were used within 24h of collection. Each animal was used only once. All experiments were performed at 12 ±1°C in an aquarium with a 12h:12h day:night artificial light regime.

The tendency of littorinids to climb the walls of aquaria (Imrie *et al.*, 1989) was exploited as follows. The upper halves of five polyethylene soft-drink bottles (192mm diameter) were removed and discarded, and a complete ring of 'Pest Barrier' (10mm width, 3mm height, 0.23g cm^{-2}) was placed around the inside of each bottle at 70mm from the base. Each bottle was then filled with seawater to 10mm above the top of the barrier. A similar set of bottles was prepared without the 'Pest Barrier' and acted as controls. A single *L. littorea* was introduced into each bottle and its position (either above or below 70mm from the base of the bottle) was noted after 1h. The bottles were cleaned and the experiment repeated a further three times so that n = 20 for each treatment.

A range of littoral molluscs were tested for their ability to escape from a complete ring of 'Pest Barrier'. A ring of 'Pest Barrier' (80mm internal diameter, other dimensions as above) was placed on a glass plate submerged horizontally in seawater which was aerated. Twenty such plates were prepared. A further twenty were prepared without 'Pest Barrier' and these acted as controls. One animal was placed in the centre of each plate such that it was at the centre of the ring (if present). Observations on the number of animals escaped were made once per day for twenty-eight days. The following species were used: *Littorina littorea* (L.), *L. obtusata* (L.), *L. fabalis* Turton, *L. saxatilis* (Olivi), *Melarhaphe neritoides* (L.), *Patella vulgata* L. Sample sizes were twenty animals per species per treatment.

Field experiments

A flat area of bedrock (about 10 x 5m), free from macroalgae, was selected at mid-shore at Whitburn (moderately exposed shore) for experiments to compare the efficacy of 'Pest Barrier' with alternative exclusion treatments. Twenty 200 x 200mm areas were selected and were randomly assigned to five treatments such that each treatment had four replicates. All animals within the areas were removed. As procedural controls, the margins of all these areas were scrubbed using a wire brush to remove any algal film present, a blow-torch was applied to the scrubbed margins to ensure a dry substratum (since 'Pest Barrier' will not adhere to a wet surface), a hole was drilled into each of the four corners of each area and washers and screws were fixed into the rock. The treatments were: control, no other procedure applied; caged, where a 7mm mesh cage at a height of 10mm covered the area and was retained by the screws; roofless caged, where similar caging material was fixed to a height of 10mm such that the cage had no roof but had a lip at roof-height extending outwards for 15mm; barrier, where a layer of 'Pest Barrier' (dimensions as for laboratory experiments) was placed on the scrubbed and blow-torched area so that a 200 x 200mm area was enclosed; and barrier-repair, where 'Pest Barrier' was introduced as above and breaks in the barrier which appeared during the experiment were repaired by blow-torching the affected area and replacing the lost 'Pest Barrier'. The number and species of animals within each area was recorded and repairs were made as above at low-tide every 2-3 days for a total of sixty-nine days from 4 July 1995 to 11 September 1995. Animals found within the areas were removed.

Eight similar 200 x 200mm areas of scrubbed and blow-torched bedrock were prepared at 1.5-2m above chart datum (mid-shore) at Telegraph Bay (moderately exposed shore), Cape d'Aguilar, Hong Kong (22°N, 114°E) in April 1995. The areas were arranged in pairs (maximum intra-pair distance, 300mm) and one of each pair had a layer of 'Pest Barrier' applied as above so as to enclose the 200 x 200mm area. Spacing between the pairs along the shore was about 3m. The presence of fauna within the areas was scored at low-tide one, two, three, five and twelve days after preparation and on these occasions the animals were removed and any breaches in the barrier were repaired as above.

RESULTS

Laboratory experiments

The behaviour of each *L. littorea* that came in contact with 'Pest Barrier' within the bottles was the same. Each first made contact with its tentacles which were then quickly withdrawn. The tentacles were then slowly extended again to the 'Pest Barrier' and the front portion of the foot also came into contact. The tentacles and foot were then slowly withdrawn and the animal began to move around the bottle in proximity to the 'Pest Barrier' which it touched frequently with its tentacles. After completing one circuit the animal either remained stationary and withdrew its head or began to move toward the base of the bottle. Thus no animal crossed, or attempted to cross, the 'Pest Barrier'. In the control bottles, sixteen snails crawled to a height >70mm, and the numbers exceeding this height in the two treatments were significantly different ($G = 27.8$, $p < 0.001$).

No animal of any species tested placed within a ring of 'Pest Barrier' on a glass plate moved outside that ring, and after twenty-eight days all the animals so confined were dead. All the animals on control glass plates had moved beyond the position of the 'Pest Barrier' after 24h. The only species to make any attempt to breach the barrier was *P. vulgata*. Six limpets were observed to have pushed against the 'Pest Barrier' using their shell, so that the shell became entangled in 'Pest Barrier', although no animal crossed the barrier. The littorinids, in initial exploration of their confinement, made tentacular contact with the 'Pest Barrier' then moved around the ring touching the barrier with their tentacles at about 10-15mm intervals.

Field experiments

At Whitburn repairs to the barrier were only necessary on three occasions. In each case a length of barrier of about 20mm was missing. In each of two of the barrier treatments which were not repaired a gap of about 20mm had developed by the end of the experiment. Over the course of the experiment animals (with one exception) were found only in the control treatments: examination at low-tide revealed no animals in any of the other treatments on any visit, except for one *Carcinus maenas* (L.) found in a barrier (not repaired) area on 17 July 1995. Within the control areas *L. littorea, L. fabalis, L. obtusata, L. saxatilis* and *P. vulgata* were found regularly. At the end of the experiment the barrier was still sticky and thus presumably functional. The shore was re-visited almost one year later in June 1996 and areas were still completly enclosed by 'Pest Barrier', although its surfaces were no longer sticky owing to the adhesion of sand and silt particles. Thus it was presumably no longer an effective barrier.

At Telegraph Bay (Hong Kong) 'Pest Barrier' failed to prevent the ingress of littoral malacospecies. Seven different species (*Acanthopleura japonica* (Lischke) (chiton), *Thais clavigera* Küster (whelk), *Patelloida pygmea* Dunker (limpet), *Siphonaria sirius* Pilsbry (limpet), *S. japonica* Donovan, *Cellana grata* (Gould) (limpet), *C. toreuma* Reeve) were noted in the control areas throughout the experiment and seven (*Nodilittorina vidua* Gould (winkle), *A. japonica*, *T. clavigera, P. pygmea, S. atra* Quoy et Gaimard, *C. grata, C. toreuma*) were recorded in the barriered areas. The total number of animals recorded was sixty-seven in control areas and forty-three in barriered areas. No obvious trend with time was apparent (Table 1). There was no significant difference between barrier/control pairs in terms of the total numbers of molluscs found (Wilcoxon paired-sample test, $T = 9$, $P > 0.5$, $n = 4$). Often there was no evidence of how the animals had crossed the barrier, although occasionally the barrier had been moved aside to allow the passage of a limpet or a chiton, and we then effected a repair. The shore at Telegraph Bay is populated at low-tide by numerous species of insect, especially mosquitoes, and on one day tens of insects were trapped within the sticky matrix of the 'Pest Barrier' around one area.

DISCUSSION

Field and laboratory experiments in the UK demonstrated 'Tree Tanglefoot Pest Barrier' to be a useful alternative to previously-used methods of grazer exclusion. In the laboratory a range of grazing mollusc species failed to cross a barrier of 'Pest Barrier', even when under

Table 1

Numbers of animals (all malacofauna) found in each area on each visit to Telegraph Bay (B = barriered area, C = control area).

Pair	Day 1		Day 2		Day 3		Day 5		Day 12	
	B	C	B	C	B	C	B	C	B	C
1	5	7	2	5	0	4	5	5	3	6
2	5	2	2	4	3	2	3	7	0	9
3	2	2	1	1	3	1	6	5	2	1
4	0	2	0	1	0	1	0	2	1	0

threat of fatal starvation, and in the field no grazers were discovered within areas enclosed by 'Pest Barrier'. Thus for grazer exclusion experiments on rocky shores in the UK this barrier substance can be recommended for use, with the proviso that it is checked regularly for breaks and that it has not been rendered ineffective by a coating of sand or silt. Although the substratum must be completely dry to ensure good adhesion, it is much quicker and easier to apply than cages and is cheaper. In addition, the local environment around the excluded area is much less disturbed by 'Pest Barrier' and so confounding effects of exclusion material (Hawkins & Hartnoll, 1983) will be much less likely to occur: the barrier used in our experiments was only 3mm high. Nevertheless, 'Pest Barrier' is extremely sticky and should not be used where other organisms within the shore ecosystem (e.g. algal fronds) are likely to come into contact with it. It may also affect rock drainage. 'Pest Barrier', applied as in this study, would not exclude the activity of some organisms, e.g. Crustacea, especially crabs, and grazing fish, which feed when the tide is in (e.g. Hartnoll, 1983). This could be advantageous or disadvantageous, depending on the aims of the manipulation.

In tropical environments such as Hong Kong, however, 'Pest Barrier' is not a viable alternative to caging since most of the malacofauna present on the shore we investigated breached the barrier. The mechanism by which this occurred is unclear and although some organisms (limpets and chitons) will undoubtedly have entered by displacing or crawling over the barrier, others may have been deposited there by the rough sea. Clearly the possibility of this latter phenomenon occurring on temperate shores cannot be discounted. Since on many occasions limpets were observed within the barriered area, but the barrier remained complete, it seems that these limpets crawled across the barrier. This is interesting in view of the data for temperate species which clearly showed that the limpets were unwilling to cross the barrier. The action of crawling across the barrier is presumably facilitated by pedal mucus which effectively isolates the animal from the barrier.

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BANKS' RIBBON-FISH (*REGALECUS GLESNE* ASCANIUS, 1772): A REVIEW OF OCCURRENCES IN BRITISH WATERS

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SUMMARY

British occurrences of Banks' Ribbon-Fish (*Regalecus glesne* Ascanius, 1772, formally *Gymnetrus banksii* Valenciennes, 1835) are collated. A summary of historical accounts is presented, with quotations of interest. A more comprehensive list of strandings and captures than has been previously available is presented in a table and map charting the time and location of each occurrence. Confusion and contradiction between accounts is discussed. Current British museum holdings are reviewed, and photographs of the preserved specimen and one of the two paintings held at the Hancock Museum are included. A greater understanding of the biology of the species is given by re-assessing the historical data, and combining this with more recent and global references.

INTRODUCTION

Banks' Ribbon-Fish, Oar-Fish, Ceil Coning, King-of-the-Herrings, Sild-Kung, Chinesefish, Storm Serpent: all terms that have one time or other been used to refer to a creature that is among the most striking and enigmatic in existence, and with which the north-east of England has a long and close association. The fish is *Regalecus glesne* Ascanius 1772, although it has enjoyed at least thirteen synonyms over the years (see Table 1), being best known as *Gymnetrus banksii* (Palmer, 1973).

Particularly in Britain, but also globally, records of this fish are largely confined to strandings upon beaches of dead or incapacitated specimens, primarily in the late 18th and 19th centuries. Always found damaged in some way, even when suitably qualified naturalists were on hand to record the finding, an element of mystery remained as to the fish's natural appearance and mode of life. However, the accounts do share some common ground from which a picture can be composed. This fish has a most unusual form; its remarkable size and coloration are the subject of many vivid descriptions.

The body is extremely long, typically 15ft (4.57m) in length. It is horizontally compressed into a ribbon-like strip with a height of about 1ft (30cm) and thickness typically 3-5in (8-13cm). The head, pectoral and pelvic fins are compressed together at the front, leaving the remainder as a tail with a uniform dorsal fin present along its extent, and no caudal fin. The body has maximal height approximately in the centre and gradually tapers to a point towards the tail. The dorsal fin expands to a crest above the head, and each pelvic fin is reduced to a single ray of at least 2ft (60cm) with a paddle-like lobe at the extremity. The skin is described as an intense silvery colour, whilst the fins, particularly the crest and the pelvic rays, are pink to red.

The north-east of England has a well documented history of episodic strandings of dead or incapacitated ribbon-fish, records which prompted a survey of local occurrences of *Regalecus*, which grew to include strandings and captures on the east coast of Scotland. Together, these records become practically the sum total for the British Isles.

For a fish with a distribution described as 'probably cosmopolitan' (Wheeler, 1969) the north-east of England has approximately a third of all north European records (Wheeler, 1969, combined with my data). On a world-wide scale: Norway, the Mediterranean, the Gulf of Mexico, South Africa, Australia and Japan all have a history of *Regalecus*, but the north-east of England probably has as many, if not more, records than any of these regions.

Table 1

Synonyms for *Regalecus glesne* in the north-eastern Atlantic and Mediterranean.

From Palmer (1973).

Regalecus glesne Ascanius, 1772
Ophidium [glesne] Ascanius, 1788
Regalecus remipes Brünnich, 1788
Gymnetrus Hawkenii Bloch, 1795
Gymnetrus Grillii Lindroth, 1798
Gymnetrus Hawkinsii Bloch and Schneider, 1801
Gymnetrus Ascanii Shaw, 1803
Cephalepis octomaculatus Rafinesque, 1810
Gymnetrus longiradiatus Risso, 1826
Gymnetrus gladius Valenciennes, 1835
Gymnetrus telum Valenciennes, 1835
Gymnetrus Banksii Valenciennes, 1835
Gymnetrus capensis Valenciennes, 1835
Regalecus caudatus Zugmayer, 1914

A HISTORY OF LOCAL RECORDS

It seems that the earliest British record of a fish resembling Banks' Ribbon-Fish appears in the 'Annual Register' pertaining to Whitby, Yorkshire, on 23 January 1759. It is reproduced in full by Hancock & Embleton (1849). It begins, "Yesterday (Jan. 22) a very extraordinary fish was brought here by our fishermen, which broke into three pieces as they were hauling it into the coble ...". Another extract of interest from the description of this 11ft 4in (3.45m) specimen is: "It was covered in an infinite number of white scales, which stuck to and dyed every thing that it touched; and might be said in some sort to resemble the quicksilvered back of a looking-glass". The next occurrence is known from a hand-bill dated 27 March 1794 received by Hancock & Embleton in 1849. It reads, "To be seen at Moses Hopper's, Flesh Market, a most curious fish, taken at Newbiggen by the Sea, 10ft. long, 1ft. broad, 2in. thick, and is thought to be the greatest curiosity that was ever seen in the kingdom before". This Northumberland specimen was apparently sketched by Thomas Bewick, but Hancock & Embleton noted that the sketch had been lost by 1849.

The species name of *Gymnetrus banksii* was given by Cuvier and Valenciennes from a manuscript found in the library of Sir Joseph Banks, which refers to a 13ft (3.96m) fish thrown up at Filey Bay, Yorkshire, on 18 March 1796. They felt sure that its length and features, particularly the extended rays of the dorsal fin upon the head, were concordant with fish of the genus *Gymnetrus* that they had observed in the Mediterranean (Hancock & Embleton, 1849).

In that same year "one was got at Cullercoats ..." and apparently recorded by John Leech in 1849 according to Howse's *Catalogue of Fishes* (Howse, 1890). However, where this record was made is not noted, so no more information on this specimen is available.

There are no further documented occurrences until 1849, when three fishermen, Bartholomew Taylor and his two sons, pulled a moribund specimen aboard their boat six miles from shore near Cullercoats. This was exhibited the same day at Tynemouth, North and South Shields, and brought to Newcastle the next morning. That afternoon it was brought to the attention of Hancock and Embleton.

They presented a detailed account of this fish to the Tyneside Naturalists' Field Club (Hancock & Embleton, 1849), in which they identified it as a 12ft 3in (3.73m) *Gymnetrus banksii* in reference to several previous accounts. Apart from the three mentioned above, these consisted of an orally-related account by John Blackett Anderson, of Walker, near Newcastle. He recalled the taking of two sick fish at the outer Farne islands some fifty years earlier (i.e. roughly 1800). They had been trapped by the tide in a shallow pool. One was 14ft (4.27m) long and the other 18ft (5.49m). "It could not be less, for it was as long as the breadth of a house end which measured 18ft. and against which it was laid out on a bench." He also told of their intense silvery colour, and processes of 18in (46cm) in length from the head, "like the feelers of boiled lobsters; they tapered gradually towards their ends, which were enlarged to the form and size of a large button".

Additionally, a letter received by Hancock & Embleton from George Tate of Alnwick tells of a 16ft (4.88m) fish found alive and which was "... exhibited in January or February of the year 1845, similar in its general form to that a drawing of which you showed me ...". This fish was found by a Preventive Service man, "Its great length and unusual appearance at once raised the man's curiosity and excited his fears. On approaching it the creature bent itself around so as to appear like the rim of a coach-wheel, and the man supposing it was about to dart upon him, drew his sword and struck it on the head. The fish struggled much, but the man striking it repeatedly, at length succeeded in cutting off its head".

Subsequent to Hancock & Embleton's well received account, additional records of ribbon-fish on the north-east coast have appeared sporadically at intervals of a few years. Rudd (1850) adds two others, one of 10ft 11in (3.33m) he saw at Redcar in that year, and another without a date placed only in Yorkshire, that was reputed to have a length of 24ft (7.32m).

1866 was a good year for *Regalecus*; there were two strandings, 14ft 6in (4.42m) at Seaton Snook, Durham, and 10ft (3.05m) at Whitby, Yorkshire, (Hogg, 1866a, b). Both of these were preserved at the time, and at least one remains in good condition (see later).

An excellent specimen, 13ft 4in (4.06m), was spotted alive in shallow water at Amble, opposite Coquet Island (Wright, 1876). The man who saw it "ran into the sea and seized it by the gills, and with some extra help it was dragged on shore". Wright gives a good description of various features, including: "The silvery matter covering the fish, on being examined with the microscope, is found to consist of granular matter in which minute crystalline bodies are embedded".

Towards the end of the 19th century and in the early 20th century various catalogues of fish fauna were produced, both locally (Bolam 1919; Howse 1890) and several national works (Buckland, 1883; Couch, 1877; Day, 1884; Jenkins, 1925; Yarrell, 1859). These serve as a useful summary of occurrences, although no one work contains a complete list, and entries are often erroneous or do not cite any first hand account. From Day (1884) 11ft (3.35m) and 16ft (4.88m) specimens can be added to the local list, dated at 1870 somewhere in Yorkshire and 1880 at Staithes near Whitby, Yorkshire, respectively. Bolam (1919) mentions "a fish of over 10 feet in length which had been dead for a day or two before it was thrown ashore at Alnmouth on 12th June 1882". I have found no mention of this elsewhere.

Collecting records for this century is more troublesome. Rather than an actual decrease in occurrences, this may be more due to the different style of recent fish guides. There are fewer of them, they tend to be less 'anecdotal' and do not contain lists of citations for occurrences. However, Davis (1983) gives a lead to some primary sources.

A letter from Fishery Officer W. Douglas to Storrow (1932) at the Dove Marine Laboratory gives two more records. One of 14ft 9in (4.50m) in which: "the head was damaged when found, a rope had been placed around the head and the fish dragged along the sands". Additionally Douglas refers to "pieces of a strange fish he had seen at Holy Island, February or March of 1930" which he felt sure were of the same species; however, here there is a possibility of confusion with a species of the genus *Trachipterus,* as with a such a vague account the length alone is the best indicator of *Regalecus.*

PLATE 1

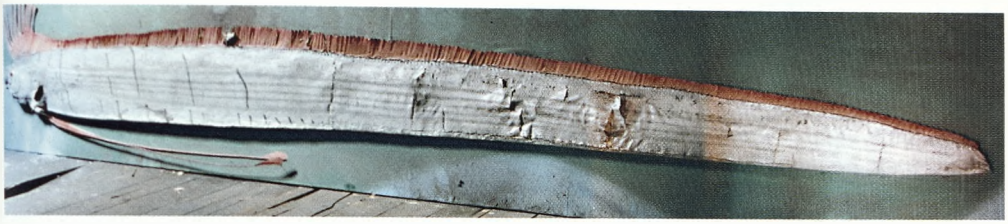
Detail from Painting Labelled 'PAINTING OF INTERNAL ANATOMY OF RIBBONFISH, CULLERCOATS 1849 (IN WALL CASES OF ZOO ROOM) ARTIST:- A. B. VON WORRELL, R:H:A:B 1849.'

An example was found alive on the beach at Whitburn, 1953; it was lacking the extremity of the tail. In Rennison (1953a) the length is stated to be 11ft (3.35m) but judging from the photograph there shown, this is an exaggeration. Davis (1983) quotes a more probable 10ft 3in (3.12m).

Finally, seemingly the last recorded occurrence in Britain to date was in 1981 when a 12ft (3.66m) specimen was found on the beach at Whitby, Yorkshire, by a dog called 'Prince'

PLATE 2

Regalecus glesne specimen of 1849, preserved and stored in the attic of the Hancock Museum, Newcastle upon Tyne.



(Anon., 1981a). This was cut into sections and is preserved in spirit at the Natural History Museum, London. There seems to be no published scientific study of this specimen.

A similar history can be traced for Scottish occurrences (Jenkins, 1925; Sim, 1903).

PRESERVED SPECIMENS

Compiling a complete list of British museum holdings of *Regalecus* is not a straightforward task as many large museums do not have complete catalogues, and curators cannot always be sure of what is in the collections. More often than not, the primary accounts contain no indication of whether or not there was any intention to preserve the specimen. Occasionally there are references such as: "the specimen being sent to the university ..."; or "being purchased by so-and-so ...", but the purpose of such acquisition is often unexplained, and probably more than one *Regalecus* has ended up on a dinner plate. However, the following material has been traced.

The Natural History Museum, London, holds at least three British *Regalecus*. The 1896 specimen from Findhorn, Scotland, and the most recent occurrence from 1981 at Sandsend, Whitby, are in storage, sectioned and preserved in spirit. A third specimen, from Redcar, Yorkshire, 1850, is apparently part of the stuffed collection, but has yet to be located.

The subject of Hancock and Embleton's detailed 1849 account was initially presented to the Newcastle Museum by a Mr Whitfield, as recorded by Howse (1890). The Hancock Museum of Newcastle upon Tyne now holds this specimen, which is stuffed, but in a poor condition. It is stored in the attic (see Plates 2 and 3). Additionally there are two paintings, contemporary with Hancock and Embleton (1849) held at this museum: a painting of internal anatomy, by A. B. von Worrell, (Plate 1) and a second much larger painting hanging in the library of the Natural History Society of Northumbria. Suffice to say that this painting is life-size, if not larger. Due to its size, height of hanging and items obstructing a clear view, it was impossible to obtain a photographic copy of it for this account.

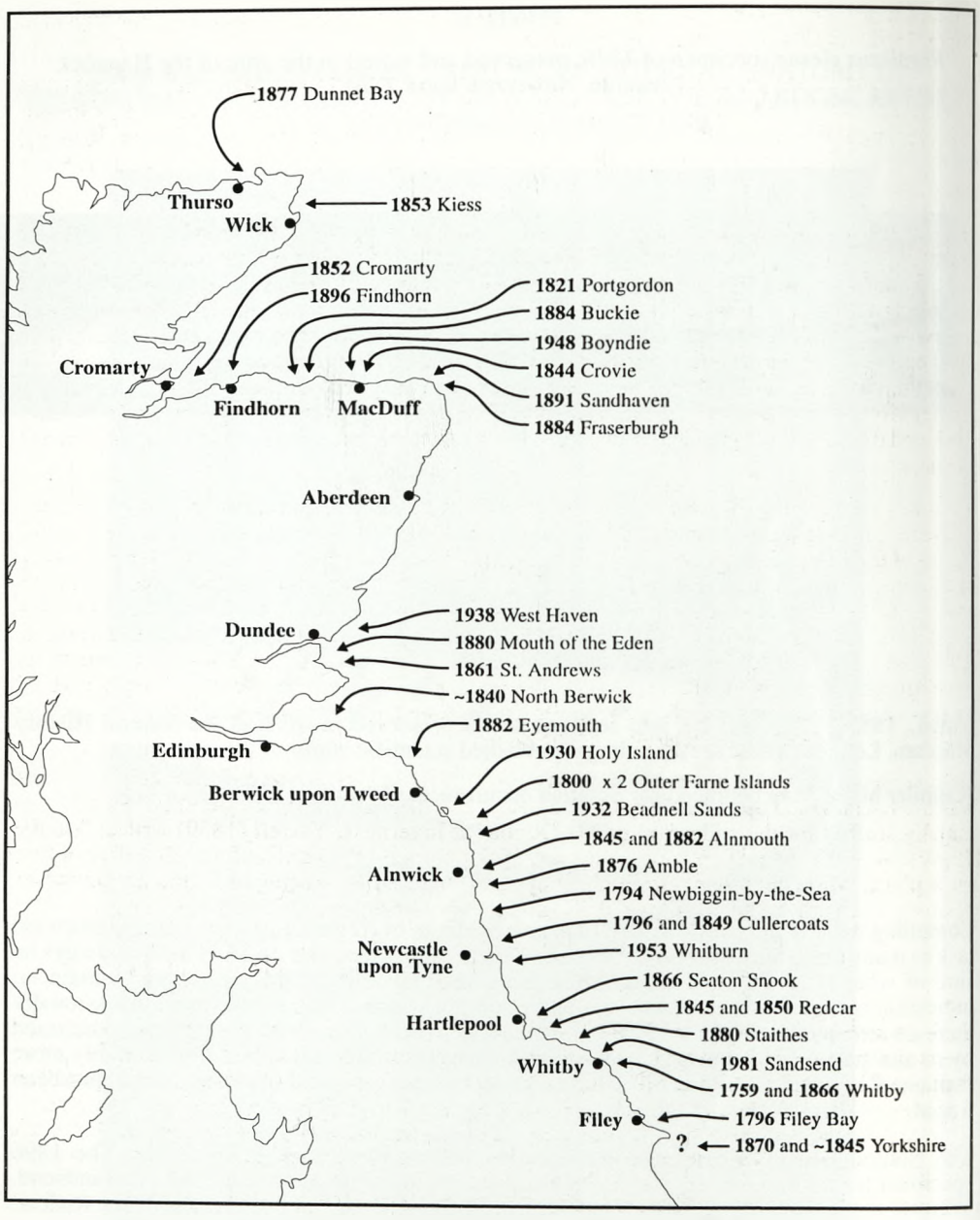


Fig. 1 *Regalecus glesne* reported occurrences: location and year. Probably complete for Britian, excluding 1788, Newlyn, Cornwall. ? indicates exact location unknown.

There is at least one other locally preserved stuffed specimen, this one is on display to the general public at the new Hartlepool Quayside Museum. The history of this fish is by no means certain, being only recently 'rediscovered' by Langbaurgh Museums Service (Davis & Edwards, 1988). It was restored by Eric Morton of the Hancock Museum in 1990 and subsequently resided at the Gray Museum, Hartlepool, until 1995. There is no definite link to any particular specimen in the documentation at Hartlepool, but it seems likely that this is the one stranded at Seaton Snook (near Seaton Carew) on 2 March 1866. It was apparently "sent

to Leeds to be sold and exhibited" (Hogg, 1866a), but the best clue comes from the reported length, 14 ft 6 in (4.42m), which matches exactly.

Two Yorkshire specimens were recorded as being taken by Whitby Museum in 1866 and 1870 respectively (Day, 1884; Hogg, 1866b). The first of these was stuffed and cased, the treatment of the second is not recorded. However, today there is no trace of either specimen at Whitby, or any record of their existence. It seems probable that they have been discarded due to poor condition.

The Royal Museum of Scotland has at least two relevant pieces of material. The first is a fibreglass cast, made probably in the mid-1960s from stuffed specimen that was in a poor state. The original specimen (i.e. original skin on a plaster mannequin) was then discarded. This is labelled as dating from 1908, so is easily matched up with a specimen found dead among rocks at Dunbar, Lothian, in that year. This was recorded as being bought by the museum at the time. More enigmatic is the second piece of material, a small piece of curled up tissue, about 2cm in length, preserved in fluid and labelled: "Gland ? testis from ureta of oarfish (*Regalecus glesne*) Moray Firth 26 1 48". A specimen was recorded at Boyndie, Grampian, on 21 January 1948, and this seems to agree with the date, but why such a bizarre item was preserved remains a mystery.

St Andrews University Museum, Fife, (the Bell Pettigrew Museum) also has some material, although not that which is indicated in the primary records. A specimen washed up in the Mouth of the Eden, St Andrews, on 21 August 1880, was recorded as being stuffed and taken by the University Museum (Evans, 1908). However the material now present at that institution consists of two sets of sections preserved in alcohol. One, consisting of three slices through the posterior of the body is labelled as 1884, and originating from Professor Struthers, Aberdeen. This could be one of two Grampian specimens from 1884: 8 February at Fraserburgh, or around 23 April, Buckie (Sim, 1903). The second item is a single vertical section through the intestine, pickled in a jar and mounted. There is no indication as to whether this is from the same specimen or a different one.

At least one other specimen, preserved with good intentions, has been unfortunately lost. This was the fish washed up in the Bay of Cromarty, North Scotland, 17 September 1852. It was initially stuffed for the collection of Mr Dunbar at Inverness. Yarrell (1859) writes: "on the dispersion of that collection some years ago, [it] came into the hands of a bird-stuffer of that same place, who kept it hanging in his shop, until he tired of looking at it, and no purchaser offering, it was at length consigned by him to the dust-cart".

TABLE AND MAP

Table 2 summarizes a list of known British occurrences of *Regalecus glesne*. For each specimen the date, location and length are given, together with a mention of its condition and circumstances under which it was found. An indication is given as to whether the specimen was preserved, and its current location if so. Any items of interest are mentioned in 'Notes'. 'Primary Reference' refers to a first hand account or earliest record available for each specimen, whereas 'Source' cites my source for the preceding information.

The times and locations are charted in Fig. 1. This represents the entire list with the exception of the specimen from Newlyn Bay, Cornwall, 1788.

SPECIES STATUS AND ORIGINS OF NAMES

No aspect of *Regalecus* has caused more confusion than its taxonomic status and origin of its various appellations. As mentioned in the introduction, globally there are at least 13 synonyms (Palmer, 1973, see Table 1). Another can be added if *Regalecus russelli* Shaw (widely used in Japanese literature), is not recognized as a distinct species. However, in this country there has rarely been any doubt that occurrences are of one species only, with the exception of a great amount of confusion surrounding an example in Cornwall, 1788, which Couch (1877)

Detail of Hancock Museum *Regalecus glesne* specimen.

documents at great length (as do others). Today, however, little argument will be evoked by the statement that there is only one species of *Regalecus*.

Regalecus is derived from *rex* and *halec* literally meaning King-of-the-Herrings (Smitt, 1893), as it was believed to accompany herring on their migration to our shores. Jenkins (1925) refutes that it does and the idea of any association with herring seems long since discarded. *Glesne* is the name of the village near Bergen, Norway, where the type specimen was found.[1]

The popular name Oar-fish might seem obviously derived from the 'paddle-like' pelvic appendages, and indeed this is often suggested to be the case (e.g. Evans 1908; Jenkins 1925;

[1] The original type specimen of *Regalecus glesne* is generally considered to be unknown or lost (Palmer, 1973). However, in a relatively recent development it appears that this specimen may reside at the Linnæus Museum at Hammarby, Sweden. This has yet to be verified. See: Wallin, L. (1985). Silkungen på Linnés Hammarby. *Särtryck ur Svenska Linnésällskapets Årsskrift*. Årgång 1984-1985. Uppsala.

Table 2

British occurrences of *Regalecus glesne*

YEAR	DATE	PLACE FOUND	LENGTH	CONDITION	PRESERVED	NOTES	PRIMARY REFERENCE	SOURCE
1759	22 Jan	Whitby, Yorkshire	11' 4" (3.45m)	Implication is, was alive when found	No Record	First British record	'Annual Register' for Whitby by Lionel Charlton	AH & DE
1788	23 Feb	Newlyn Quay, Cornwall	8' 10" (2.69m) Portion of tail wanting	Caught on sands by the tide - alive?	No Record	Cause of much confusion, differing accounts give year as 1788, 1791, 1796, 1798	Drawing amongst notes in the back of Banks' copy of Pennants 'British Zoology'	JJ
1794	27 Mar	Newbiggin by the Sea, Northumberland	10' (3.05m)	To quote: 'was taken' i.e. caught alive?	No Record	Known from a hand-bill and recollection of Mr Stanton ~1849. Sketch by Bewick lost by 1849	Hand-bill in Albany Hancock's Notes at the Hancock Museum	AH & DE
1796	No Record	Cullercoats, Tyne & Wear	No Record	'was got' i.e. caught alive?	No Record	Very tenuous unless Leech's account can be found	A record by John Leech - but where?	RH
1796	18 Mar	Filey Bay, Yorkshire	13' (3.96m)	Cast ashore dead	No Record	This was the type specimen of *Gymnetrus banksii*	Manuscript in Banks' copy of Pennants 'British Zoology' and *York Chronicle* of Thurs Mar?	AH & DE JJ
~1800	No Record	Outer Farne Islands, Northumberland	14' and 18' (4.27&5.47m)	Alive but sick, stranded by the tide	No Record	Oral account by John Blackett Anderson - 50 years after the event	Related in Hancock & Embletons account	AH & DE
1821	12 Nov	nr. Portgordon, Grampian	12' 9" (3.87m) Head missing	Cast ashore, dead	No Record	Note: FD and GGa put the date at 1812, but GS corrects (?) this to 1821	An account by J Hoy in *Trans. Linn. Soc.* Date not given	WY GS
~1840	No Record	nr. North Berwick, Lothian	15' (4.57m)	Washed ashore	No Record	No record appears to have been made at the time	Orally related account about 60 years after the event	EC
1844	Mar	Crovie nr. Macduff, Grampian	12' (3.66m) Portion of tail wanting	Cast ashore alive during north-easterly gale	No Record	Any more information in original letter ?	Letter by J Martin sent to W Yarrell and G Johnston. Reproduced in JJ	JJ
1845	Jan or Feb	Alnmouth, Northumberland	16' (4.88m)	Alive, trapped by the tide	No Record	Killed by a Preventive Service man	Letter by Mr George Tate to Hancock & Embleton ~1849	AH & DE

Table 2 continued

YEAR	DATE	PLACE FOUND	LENGTH	CONDITION	PRESERVED	NOTES	PRIMARY REFERENCE	SOURCE
1845 ? certainly before 1850	No Record	Yorkshire	24' (7.32m)	Found ashore, no record if alive	No Record	Very dubious account, more information required	TR mentions, AG also does but not by reference to TR - so where from ?	TR AG
1849	26 Mar	Cullercoats, Tyne & Wear	12' 3" (3.74m)	Found at sea, moribund	Stuffed, now in attic of Hancock Museum	First well documented account, good details of capture and anatomy	Two papers by Hancock & Embleton. Also the *Rare Fish* pamphlet (JJ)	AH & DE
1850	3 Jan	nr. Redcar, Yorkshire	10'. 11" (3.33m) Portion of tail wanting ?	Beached, alive but mutilated	Stuffed, somewhere in storage at Natural History Museum	May have been complete, as caudal fin was expected (JG). Specimen not yet located in Nat. Hist. Mus.	TR appears to have seen the specimen, but gives few details other than size	TR AG
1852	17 Sep	Bay of Cromarty, Highland	11' 10" (3.61m)	Cast ashore, implied dead	Stuffed, but later discarded	WY gives details of the unfortunate loss of the specimen	GGb appears to have examined it, although he gives few details	GGb WY
1853	14 Dec	Kiess nr. Wick, Highland	15' 6" (4.72m)	Cast ashore, implied dead	No Record	JC mentions another 2 or 3 specimens, but with no information or reference	Communication by Peach direct to JC. Date is from 'minute-book of Royal Physical Society' (WE)	JC WE
1861	Apr	St. Andrews, Fife	7' 2" (2.18m) Head & part of tail absent	Cast ashore among rocks, dead	No Record	Possible confusion with *Trachipterus*, but given the incomplete state would probably be too long	First hand account by RW	RW
1866	2 Mar	Seaton Snook, Durham	14' 6" (4.42m)	In shallow water, dead or moribund	Stuffed, now exhibited at Hartlepool Museum	Similarity of lengths is best (and only) indication that this is the Hartlepool specimen	Copy of T Richmond's 'Local Records of Stockton, 1868', in fish record at Hartlepool Museum, and JHa	Stockton records JHa
1866	23 Apr	nr. Whitby, Yorkshire	10' (3.05m)	Cast ashore, dead ?	Was stuffed at Whitby Museum. Now lost	Hogg suspected it wasn't a *G banksii*, but doesn't give a reason why	JHb examined it after it had been stuffed	JHb

Table 2 continued

YEAR	DATE	PLACE FOUND	LENGTH	CONDITION	PRESERVED	NOTES	PRIMARY REFERENCE	SOURCE
1870	2 Oct	Yorkshire	11' (3.35m)	No Record	Was sent to Whitby Museum. Now lost	Almost no information available, it appears	If FD cites a reference, he does so in a nomenclature I don't understand	FD
1876	8 Mar	Amble, Northumberland	13' 4" (4.06m)	Alive, dragged ashore.	No Record	A reasonable first hand account	Wright examined the fish himself, no additional information exists	JW
1877	Jul	Dunnet Bay nr. Thurso, Highland	12' 4" (3.76m)	Came ashore alive in calm weather	Two casts made - where now ?	FB's account confuses *Regalecus* with Deal-Fish, but length implies former	Communication by Mr Traill direct to FB	FB
1880	Jan	Staithes nr. Whitby, Yorkshire	16' (4.88m)	Stranded on rocks by tide	No Record	Need to see primary reference	Day (1884) cites 'C Elliot, in the Field'	FD
1880	21 Aug	Mouth of the Eden, St. Andrews, Fife	12' 9" (3.88m)	Found dead on sands	Was stuffed and taken to museum	Originally in 'St. Andrews University Museum' (WE). Where now ?	WE refers to FD, who gives no further reference, or any more information	FD WE
1882	16 Apr	Eyemouth, Borders	9' (2.75m) Portion of tail absent	Cast up dead	No Record	Broken in two, length when complete estimated at 12'-15'. (3.66-4.57m)	No primary reference given	GB
1882	12 Jun	Alnmouth, Northumberland	Over 10' (3.05m)	Thrown ashore dead	No Record	No primary reference	No primary reference given	GB
1884	8 Feb	Fraserburgh, Grampian	17' (5.18m)	Caught	Could be the three slices at St. Andrews University	No more information than that given here found	No first hand account given or found	GS
1884	~23 Apr	Buckie, Grampian	17' 1" (5.21m)	Caught in a stake-net	Could be as above	Was examined at Aberdeen University - any account ?	GS cites *Aberdeen Free Press*, 23 April 1884	GS
1891	25 Jan	Sandhaven, Grampian	12' (3.66m)	Washed up, dead ?	No Record	No more information than that given here found	GS cites *Aberdeen Evening Express*, 27 Jan. 1891	GS

Table 2 continued

YEAR	DATE	PLACE FOUND	LENGTH	CONDITION	PRESERVED	NOTES	PRIMARY REFERENCE	SOURCE
1896	Apr	Findhorn, Grampian	16' 3" (4.96m)	'Captured', presumably alive ?	Preserved in spirit at Natural History Museum	This stands in a jar next to the 1981 specimen, below	GS's source is *Aberdeen Free Press*, 1 May 1896	GS
1908	23 May	Dunbar, Lothian	13' 6" (4.11m)	Found dead among rocks	Royal Scottish Museum has a cast of	Evans took a photo but it wasn't published (ever ?). Worth tracking down	Evans (1908) examined two days after discovery	WE
1930	Feb or Mar	Holy Island, Northumberland'	Pieces only	Pieces of fish found washed up	No	Pieces of fish found. Possibility for confusion with *Trachipterus*	Original letter by Douglas to BS might be useful	BS
1932	~12 Feb	Beadnell Sands, Northumberland	14' 9" (4.50m)	Dead on beach	No	Contained spawn. Was cut up for crab bait	Original letter by Douglas to BS might be useful	BS
1938	19 Apr	West Haven, Tayside	17' 10" (5.44m)	Left by the tide, dead around a rock	No Record	The best verified 'record' length for the British Isles	AP examined the specimen and briefly describes it. Any photographs taken ?	AP
1948	21 Jan	Boyndie nr.Whitehills, Banff, Grampian	16' (4.88m)	Washed up, presumably dead	Royal Scottish Museum has 'gland' of	Press article states 'small specimens have been found in past years'?	Cites: *Press and Journal*, Aberdeen, 22 Jan. 1948, apparently has photograph	VW & JC
1953	5 May	Whitburn, Tyne & Wear	10'3" (3.12m) Portion of tail wanting	Found alive on beach	No Record	Complete length estimated at 13'. Rennison (1953a) includes a photograph	PD contains extra data over GR. Another reference, Rennison (1953b) probably has more information	GR PD
1981	Feb	Sandsend nr. Whitby, Yorkshire	12' (3.66m)	Found washed up on beach - dead ?	Preserved in spirit at Natural History Museum	Appears to be no account in the scientific literature	Two Newspaper articles: *Daily Mirror*, 27 Feb. 1981, *Angling Times*, 4 Mar. 1981	AN

'Primary Reference' indicates a first hand account or earliest mention. 'Source' is a reference to my sources for the information presented.

Key to abbreviations: AG - Günther (1890); AH & DE - Hancock & Embleton (1849); AP - Peacock (1938); AN - Anon. (1981a, 1981b, 1981c); BS - Storrow (1932); EC - Eagle Clarke (1900); FB - Buckland (1883); FD - Day (1884); GB - Bolam (1919); GGa - Gordon (1852a); GGb - Gordon (1852b); GR - Rennison (1953a); GS - Sim (1903); JC - Couch (1877); JG - Gray (1850b); JHa - Hogg (1866a); JHb - Hogg (1866b); JJ - Jacob (1849); JW - Wright (1876); PD - Davis (1983); RH - Howse (1890); RW - Walker (1862); TR - Rudd (1850); VW & JC - Wynne - Edwards & Campbell (1948); WE - Evans (1908); WY - Yarrell (1859).

Norman, 1937). However, an alternative interpretation is that with its elongate and flattened form, the fish as a whole has an oar-like appearance.

Hancock & Embleton (1849) also refer to a term from sailors of the White Sea, who describe a rarely seen fish of similar appearance to *Regalecus* as a 'Stone Serpent'. This appears to have been misheard at some point though, either by them or their source (a Norwegian Captain). Jacob (1849) states the people of Archangel (Russia): "occasionally meet with a fish they all call the Storm Serpent, being seen only during or after a tempest"; this seems much more plausible, and it is easy to imagine "stone" as a malapropism thus derived. The association with storms is known from other parts of the world and still holds true (Hulley & Rau, 1969).

Another major source of confusion is the temporal relation of *Regalecus glesne* with the synonym *Ophidium glesne* Ascanius. Most accounts are clear that *Regalecus* as a generic name dates from 1772, but there is disagreement as to whether Ascanius changed this to or from *Ophidium*, which is ascribed various dates, such as: 1766 (Gray, 1850a); 1776 (Yarrell, 1859) and 1788 (Palmer, 1973). Regardless, *Regalecus* is now universally accepted, despite Gray's (1850a) comment that it is not "quite unexceptionable" due to being a mixture of Greek and Latin.

THE FISH: MODERN VIEW

Modern fish guides are more authoritative in tone, and if compared to the old accounts the impression may be given that contemporary knowledge about *Regalecus* is more confident. Yet *Zoological Record* lists only two or three papers a year on the Regalicidae, and these are generally confined to recordings or taxonomic discussions. Work on life history, functional morphology or behaviour is very rare.

Consider, for example, the question of how *Regalecus* actually swims. The first hand account related in Hancock & Embleton (1849) clearly describes the moribund fish fleeing with "a vigorous and vertical undulating motion"; this would seem the obvious mode of propulsion given the morphology. Conversely, according to a modern treatise (Smith & Heemstra, 1986) it: "swims vertically by means of undulating waves of the D. [dorsal fin]", presumably meaning in the manner of a seahorse, or similar to the use of the anal fin by freshwater knifefish. They give no reference to the source of this information, and it would seem an unlikely method for a full grown *Regalecus* to propel itself. However, recent film (shown recently as part of the television series *Equinox*), does show a juvenile (or at least very small) ribbon-fish using this technique. I suggest the question is as yet unanswered.[2]

Regalecus is generally considered to be mesopelagic, inhabiting a depth of 20-200m (Smith & Heemstra, 1986; Wheeler, 1969). From Table 2 it can be observed that the vast majority of occurrences fall in the spring months, January to April. Additionally, although most references do not specify a gender, where they do it is usually female. The only example stated to be male is from Evans (1908) who adds: "hitherto only females have been noted from the Atlantic region". Combining these two pieces of information with the fact that specimens are invariably sick or moribund, suggests the time of incidence could be related to spawning behaviour. However, the spawning season of this fish is unknown, and not necessarily associated with surface climate. South African records are predominant in the same time period, but Hulley & Rau (1969) attribute this to "oceanic conditions brought about by the southeast gales". The distribution of occurrences on the north-east coast of England (Fig. 1) suggests there may be similar effect in operation, with *Regalecus* being occasionally driven down from the north-east.

2 In July of 1996, for the first time ever, a moribund *Regalecus* was captured on film as it came ashore at the Baja California peninsula, northern Mexico. The film clearly shows a movement pattern as described in Hancock & Embleton (1849). The body undulations were in a vertical direction because the dying fish was floating on its side. The film was broadcast in the UK as part of the series *The Deep* on 20 July 1997.

Some of the only work on functional morphology has concentrated on the role of the extended pelvic rays with their paddle-like lobes. Oelschläger & Schwerdtfeger (1979) have shown the distal enlargement "comprises a remarkable number of chemoreceptor cells in combination with supporting cells and spindle cells"; this supports their hypothesis that "[the pelvic fin] represents a precision instrument and ... it serves as an organ for taste and perception" (Oelschläger, 1978).

Smith (1977) explains the nature of the silvery substance that gives the fish its coloration, and so easily coats everything that touches it: "It is composed of fine scales of a shiny substance, 'Guanin', which is really a waste product of the kidneys, and appears to be produced most readily by oily fishes. In the skin these fine plates reflect the light and so give the metallic appearance".

The maximum length *Regalecus* can attain is a subject of much exaggerated speculation. Among the British specimens the record is most reliably set at 17ft 10in (5.44m) (Peacock, 1938), the average being about 13ft (3.96m). A mysterious account from about 1845 alludes to a specimen of 24 ft. (7.32m), and at least one modern fish guide quotes a maximum of 8 metres (Smith & Heemstra, 1986). *The Daily Mirror* (27 February, 1981) suggests a fairly creative 30ft (9.14m), but the record, an extravagant 50ft (15.24m), surprisingly goes to Norman (1937), one time assistant keeper at the British Museum.

Finally, on the question of gastronomy, reports are again contradictory. Smith & Heemstra (1986) describe the flesh as "unpalatable, soft and watery even after prolonged cooking"; however Lindroth said of it, "When boiled ... destitute of fat and almost tough. The dogs refused to eat it, whether raw or boiled" (Smith, 1893). Either way, it appears that *Regalecus* is not good eating.

CONCLUSION

The popular impression the appearance of this fish gives is timeless and unequivocal, compare: "The Great Sea-Serpent caught at last" a hand-bill, 1849, (Newman, 1849), with: "Landed at long, long last - the old-time sailors' 'sea serpent'" (*Daily Mirror*, 27 February 1981). Between the dates of these two very similar glamourizations, the truth is, that we know as much (or as little) about *Regalecus*, as was known 150 years ago.

Given that it is such a remarkable and distinctive animal, it is perhaps surprising that there seems to be no modern collation of information, and so little contemporary work being done. This is probably due to the paucity of occurrences. In order to study *Regalecus* today it will be necessary to go out looking for it, rather than waiting for it to turn up.

In a local sense, we are very fortunate in the north-east of England to have such an unusual and globally relevant creature so deeply entrenched in our natural history. For a part of the country where there is a strong sense of local culture, there should be more awareness of this phenomenon. It would be nice to see the Hancock Museum specimen restored and on display, for example.

It is my intention to extend this study ultimately into a global survey of occurrences, literature, and museum holdings for Regalicidae, Trachipteridae and related species. To this end, any relevant information, particularly that which might otherwise be hard to come by, would be appreciated. Corrections or amendments to the information contained here would be welcomed. A project such as this can never be said to be complete, but hopefully it can at least be kept moving towards that goal.

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BENTHIC COMMUNITY STRUCTURE AND SEDIMENT HEAVY METAL CONCENTRATIONS IN TWO ESTUARIES IN N E ENGLAND

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SUMMARY

The Tyne and Wear estuaries (north-east England) are sites of considerable industrial and urban development. The resulting discharges of waste to the estuaries have caused extensive contamination. To assess the effects of contaminants, samples of sediments and biota were taken in each March and September during 1992 and 1993 and during March 1994. The biota were identified and enumerated and sediment cadmium, chromium, copper, lead, mercury, nickel and zinc concentrations determined. The sediment silt/clay fraction and loss on ignition were also determined. The lower estuary areas were dominated by a fauna characteristic of highly organically polluted, anoxic, muddy sediments. Numbers of individuals were very variable both between sampling stations and through time. In the middle areas of both estuaries both the species abundance and diversity of benthos was reduced. In the Tyne, concentrations of lead and zinc were significantly higher in the mid-area than in the lower estuary, while in the Wear, nickel was significantly higher in the middle estuary than the lower estuary. The extent to which such patterns are caused by anthropogenic influence is discussed.

INTRODUCTION

Estuarine environments have historically been sites of intense human activity, and yet are often areas designated for their conservation importance (Davidson, 1991; Kennish, 1991). The broad, flat flood plain and the presence of a waterway, as a communication route, have stimulated commercial, industrial and residential development. Historically, the most convenient and cost-effective disposal route for wastes was the estuary channel. This led to considerable contamination problems as the flood plain became increasingly developed (McLusky, 1989; Hall, 1996). Recently, public opinion has brought about action to reduce pollution and improve water quality (Clark, 1991).

The estuaries of the Rivers Tyne and Wear in north-east England (Fig. 1) have been highly developed. Both estuaries run through major conurbations and their flood plains have been subject to intensive industrial development, with sites of shipbuilding and repair, chemical manufacture, metal smelting and warehousing (Potts, 1892; Middlebrook, 1950; Hall, 1996). Their principal geographical characteristics are summarized in Table 1.

The catchments of the Tyne and Wear estuaries are underlain by a similar geology, with Magnesian Limestone at the coastal margin, Coal Measures further inland, and Millstone grit, sandstones and limestones with some igneous intrusions forming the upland catchment in the Pennines (Johnson, 1981; Dunham, 1990). The upland catchments of both the Rivers Tyne and Wear include natural deposits of the ores galena (PbS) and shalerite (ZnS), which may also contain silver, cadmium and copper (Young *et al.*, 1987). Weathering of exposures of these minerals leads to metalliferous inputs to the headwaters. In the Tyne catchment, these occur principally by way of the tributaries Allen, Nent and Blackburn of the River South Tyne (Macklin & Dowsett, 1989), while in the Wear, the major sources are in upper Weardale and the Rookhope Valley. However, anthropogenic activity is the source of most metal contamination in the estuaries, both as a result of mining activity causing enhanced weathering, and direct inputs from industrial and domestic waste disposal (Hargreaves, 1981; Kennish, 1991).

The most widely perceived environmental problem in many UK estuaries, including the Tyne and Wear, has been anoxia caused by excessive levels of oxygen-demanding wastes (Day *et al.*, 1989; Clark, 1991; Ueda *et al.* 1994). Principally, these have been discharges of domestic sewage. The resulting anoxia has led to the loss of migratory salmonids, a reduced fish fauna, sediment anoxia and lowered benthic diversity (Pomfret *et al.*, 1991). Efforts to reduce the impact of such discharges were initially prompted by public concern over odour and visual

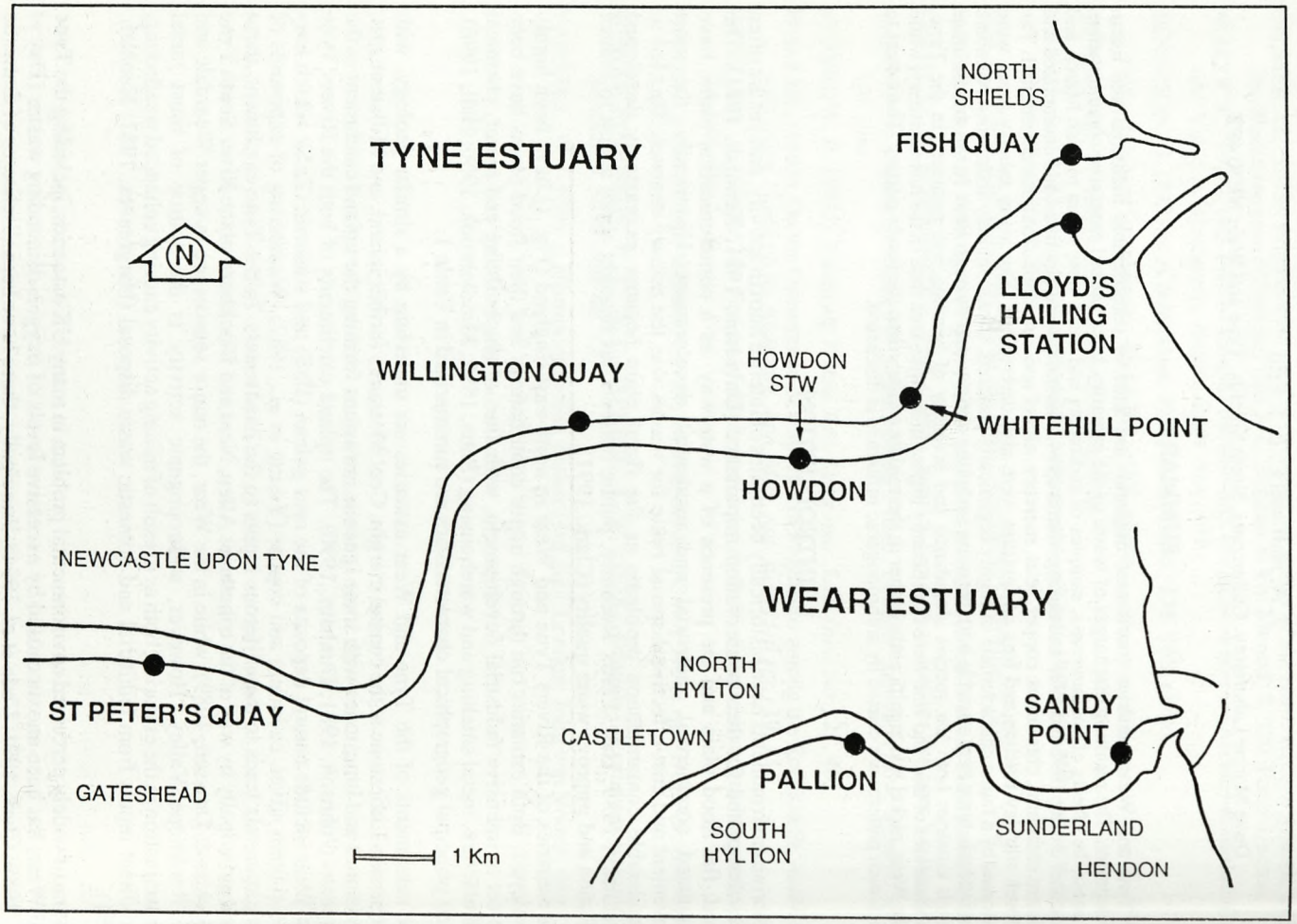

Fig. 1 Locations of the Tyne and Wear estuaries, and of the stations in them

Table 1

Summary of characteristics of the Tyne and Wear estuaries

	TYNE	WEAR
Geomorphological type[1]	Complex	Complex
Tidal type	Macrotidal	Macrotidal
Location (O.S. Grid)	NZ 3466	NZ 3958
NWC Classification[2] (Km)		
Class A	6	9
Class B	14	7
Class C	17	0
Catchment area (Km^2)	2935	1174
Total Area (Ha)	792	200
Intertidal (Ha)	59.7	29.4
Shoreline (Km)	83.1	37.5
Tidal Channel (Km)	32.7	17

[1] JNCC Estuaries Review Classification, (Davidson *et al.*,1991)
[2] National Water Council Classification, (NRA, 1994 a,b)

nuisance and these have been strengthened in the UK by the adoption of initiatives such as the National Rivers Authority catchment management plans (NRA, 1994 a, b).

Initiatives in the Tyne estuary were started by the Tyneside Joint Sewerage Board in 1966 (Anon, 1966). They were then taken on by the Northumbrian Water Authority in 1974 (Norgrove, 1977), and since 1989 have been furthered by Northumbrian Water plc and the National Rivers Authority (NRA 1994 a, b). In April 1996, the NRA became part of the Environment Agency.

In the Tyne estuary, the principal mechanism of remediation has been the removal of a large number of direct sewage discharges to the estuary by diverting them to an interceptor system. The combined effluent is taken to Howdon Sewage Treatment Works (STW) where it receives primary treatment. The sewage sludge (settled solids) is transported in a specially designed vessel to a licensed offshore disposal site where it is dumped. The supernatant is discharged to the estuary near Howdon STW. Primary treatment reduces the Biological Oxygen Demand of the effluents, thus reducing oxygen depletion in the receiving waters (Ord, 1988). As a result of the rising number of former discharges intercepted, increasing amounts of sewage are subject to primary treatment.

In the Wear estuary, similar initiatives are being put into place (NRA, 1994 b). Sewage from the Sunderland conurbation (Fig. 1) is at present still discharged in an untreated state to the estuary at Queen Alexandra Bridge, Castletown, and at North and South Hylton (NRA, 1994b). There are plans by Northumbrian Water plc to intercept these flows and discharge effluents through a long sea outfall at Hendon.

As is generally expected as a result of sewerage schemes (Ord, 1988), increases in fish population diversity (including the return of salmonids) and reduction in visible solids and odour nuisance have been seen in the Tyne with a similar reduction of odour and visible solids in the Wear. Improvements in sediment quality and subsequent recovery in benthic diversity are also expected as the water quality is improved. An additional benefit is that as the numbers of discharge points are reduced, the damaging effects of the remaining effluent have been localized, although impacts at the point of discharge may be exacerbated.

Monitoring of the impact of discharges to estuarine systems is principally carried out by determination of sediment quality, as changes in sediment contaminant concentrations tend to integrate water column pollutant patterns, making sediments a more reliable indicator of long-term change. Historically, sediment quality has been expressed in terms of chemical concentrations of contaminants, but this may not be directly related to the biological quality of the sediment (Chapman & Long, 1983; Gray *et al.*, 1992). Furthermore, when many chemicals are present, an approach involving more than simply measuring concentrations of the most common components is required (Matthiessen *et al.*, 1993). The concept of integrative assessment has been established to overcome these difficulties. This approach may use sediment toxicity tests, chemical analyses of sediment and faunal tissue, and community structure studies in conjunction with each other to obtain a more representative indication of sediment quality (Chapman *et al.*, 1992). The particular combination of techniques employed will often depend on the resources of the investigator, and the site to be investigated, but current trends tend to follow two or more of the above approaches in such methods as the 'Sediment Quality Triad' (e.g. Long & Chapman, 1985).

This study characterizes the benthic ecology and distribution of metal contaminants in the sediments of the mid and lower Tyne and Wear estuaries after twenty years of the Tyne clean-up programme, but before major remediative work on the Wear. It is the first comprehensive study to describe the benthos since 1978 and therefore serves as a useful bench mark against which laboratory and field experiments may be assessed.

STUDY SITE AND METHODS

Preliminary Survey

A preliminary subtidal survey was carried out on the Tyne estuary on 21 October 1991. Four 0.1m^2 van Veen grab samples were taken at the most seaward and most landward stations previously sampled by Sinton (1978) and one grab sample at each of the nine stations between them (Table 2). Sediments were sieved through a 500μm mesh and the residue fixed (0.01% Rose Bengal in 40% formalin). In the preliminary study, it was realized that difficulties in identification of some taxa may occur, and that it would not be practical to identify three taxa to species level. These were as follows:

Nematodes: Resolution of nematodes to genera and species level requires detailed microscopic observation of specimens. In the preliminary study it was found that greater than 95% of the nematode population sampled was composed of the large (12 to 18mm long) *Pontonema alaeospicula* (R. M. Warwick, Plymouth Marine Laboratory, pers. comm.). Given this observation, no attempt was made to resolve this group below phylum level.

Tubificoides spp.: In identification of oligochaetes to species level, many of the same problems found when describing nematodes arise. Detailed observation of very small structures, especially chaetae, is required. The oligochaetes recorded in the preliminary survey were principally from the genus *Tubificoides*, mainly *Tubificoides benedii*, although *Tubificoides swirencoides* were also recorded. Therefore oligochaetes were identified to genus level only.

Table 2

Positions as given by Sinton (1978) for sites used in previous Tyne estuary surveys and sampling intensity in the present study

STATION	ORDNANCE SURVEY GRID REFERENCE	NO. OF GRABS TAKEN IN THIS STUDY	COMMENTS
Baltic Flour Mills	NZ 256639	4	Landmost station, near Newcastle Quayside
Ouseburn Entrance	NZ 264641	1	Near polluted tributary
St Peter's Quay	NZ 278633	1	Near site of old chemical works
Hebburn	NZ 302655	1	Near former industrial area
Howdon	NZ 330660	1	Adjacent to sewage treatment works
Jarrow Slake	NZ 348658	1	Adjacent to mudflats (now Nissan Quay)
Whitehill Point	NZ 349660	1	North of channel, adjacent to quay
Albert Edward Dock (entrance)	NZ 354670	1	By dock entrance
Albert Edward Dock (mid channel)	NZ 356670	1	Away from dock entrance
Lloyds H S (north of channel)	NZ 365686	1	Close to mouth of estuary
Lloyds H S (mid channel)	NZ 386684	4	Close to mouth of estuary

Capitella: At least three species of *Capitella* are known to exist in the Tyne estuary, and probably also the Wear estuary (P. J. W. Olive, Dove Marine Laboratory, pers. comm.). Two distinctive body sizes can be observed, individuals with a small body size having a direct larval stage and brooding of eggs, the larger morph having a planktonic larval stage (Garwood, 1982). Despite the fact that the two different morphologies are found in this area, because of the taxonomic uncertainty that exists (Grassle & Grassle, 1976; Warren, 1976, 1991) individuals were pooled to species level as *Capitella* spp. Work on morphology using electrophoresis, and use of ecophysiology experiments is currently being carried out in order to resolve the taxonomy of *Capitella* (e.g. H. Parner, University of Copenhagen, pers. comm.).

Following Gilbert (1987), the number of samples to be taken in the main survey was determined empirically, using data for these three taxa and a precision of the mean over the five samples of 0.2 (Elliott, 1977).

Main Survey

Over the whole of the study, six stations were sampled in the Tyne estuary and two in the Wear estuary (Fig. 1, Table 3). Stations were selected to allow sampling of areas that were near potential sources of contamination (Table 3), and located in areas that were not expected to be affected by dredging activities during the study (J. Lambard, Port of Tyne Authority, Newcastle, pers. comm.). The Tyne Lloyd's Hailing Station site was not sampled after the first sampling occasion due to sand deposition, which smothered the original community. A station adjacent to the Fish Quay was established and sampled from the second sampling occasion to replace it (Fig. 1; Table 3).

It is understood that the three major groups in the benthos may reproduce all the year round (Brinkhurst, 1982; Bett & Moore, 1988; Grassle & Grassle, 1976). However, seasonally variable food availability and ambient temperature are known to affect such factors as fecundity, predation and mortality and thus population densities would be expected to be seasonally variable (Buchanan & Moore, 1986; Wolda, 1987). Therefore, sampling was carried out between 10-12 March and 2-4 September in 1992, 2-4 March and 26-31 September 1993, and 1-3 March 1994. This regime allows examination of the benthic fauna after winter mortality, but before spring increases in temperature and food availability. Autumn sampling allows the quantification of the benthos after a period of summer growth.

Circulation in the Tyne estuary may be described as having two layer flow with vertical mixing, a description used by Bowden (1968). This leads to a stratification of the water column in the lower part of the estuary, giving a saline water layer on the bed of the estuary, with fresh, riverine water on the surface. This situation prevails at the four lower estuary stations. However, further up the estuary a dominant river flow (James, 1972) and associated turbulence is expected to give a degree of mixing, and thus lower bottom water salinity (R. Inverary, National Rivers Authority, pers. comm.). This reduced salinity is observed at the St Peters Quay Station (Table 3).

Five replicate 0.1m^2 van Veen grab (van Veen, 1933) samples were taken at each station (Fig. 1, Table 3). Positioning was achieved by the use of waymarks and the Global Positioning System (Racal-Decca Mk.91). The quantity of sediment in each grab was noted to control sample volume, grabs less than 95% full were rejected. As in the preliminary survey, sediments were sieved through a 500µm mesh, and the residue was fixed (0.01% Rose Bengal in 40% formalin). In the laboratory the material was sorted and individuals identified to species level where possible and enumerated (Hartley, 1982; Eleftheriou & Holme, 1984).

Sediment samples for analysis of the particle size distribution, metal concentration and organic matter as loss on ignition were taken by means of a 135mm diameter x 250mm deep Haps corer (Kanneworff & Nicolaisen, 1973) at all stations at the time of faunal sampling. The particle size distributions of the highly silty sediment were determined by the 'Rapid Particle Size Analysis Technique' (Buchanan, 1984). Loss on ignition was carried out by heating dried sediments at 550°C for 24 h.

Concentrations of the heavy metals cadmium, chromium, copper, lead, mercury, nickel and

Table 3

Tyne and Wear estuary sampling stations used in the present study March 1992- March 1994

	STATION	POSITION	SALINITY (after Sinton, 1978)	COMMENTS
TYNE	St Peter's Quay	54° 57.81' N 01° 34.50' W	22	South of channel, opposite site of old chemical works
	Willington Quay	54° 59.31' N 01° 30.05' W	29	North of channel, adjacent to tributary (Willington Gut)
	Howdon	54° 59.19' N 01° 28.40' W	29	South of channel, opposite sewage treatment works
	Whitehill Point	54° 59.31' N 01° 27.30' W	30	North of channel, adjacent to quay
	Lloyd's Hailing Station	55° 00.49' N 01° 25.15' W	35	South of channel, changed after March 1992, due to sand encroachment
	Fish Quay	55° 00.52' N 01° 25.97' W	35	Used after March 1992, North of channel, adjacent to fish market
WEAR	Pallion	54° 55.02' N 01° 25.13' W		South of channel, in area of silt accumulation
	Sandy	54° 54.86' N		North of channel, opposite

zinc were determined for the top 1cm of sediment by carrying out a nitric and hydrochloric acid sediment digest, followed by analysis using a Varian SpectrAA300 atomic absorption spectrophotometer, with the addition of a Varian hydride generator for the mercury assay (MAFF, 1989). Reagent blanks and a sediment standard (CRM-277; EC Community Bureau of Reference, Brussels) were used during each assay to verify results.

All faunal data were transformed (log(x+1)) and percentage silt/clay and loss on ignition data were arcsin transformed before analysis. Faunal data were analysed separately using ANOVA according to season, followed by an *a posteriori* Tukey test to allow comparison of individual between-year and between-station observations (Zar, 1984). Serial Bonferroni tests were applied to tables of results to adjust for multiple observations (Rice, 1988). Bray-Curtis similarity of stations was also calculated (Bray & Curtis, 1957) followed by dendrogram plots and Multiple Dimensional Scaling (Field *et al.*, 1982; Warwick & Clarke, 1991; Clarke & Warwick, 1994). Analysis was performed using Minitab (Minitab Inc., Pennsylvania, USA), MVSP (Kovach Computing Services, U.K.) and PRIMER (Plymouth Marine Laboratory, UK) software.

RESULTS

Tyne estuary

The loss on ignition of, and silt/clay fractions of, the sediments were not found to be significantly different between stations, across the study period, or between seasons (ANOVA, $P>0.05$ in each case; Table 4). Concentrations of lead and zinc varied significantly between stations, (ANOVA, $F=10.52$, $P<0.001$; $F=13.58$, $P<0.001$ respectively; Table 4), with lead and zinc concentrations being significantly higher at St Peter's Quay than any other station (Tukey test, $P<0.05$). Cadmium, chromium, copper, mercury and nickel concentrations did not vary significantly between stations (ANOVA $P>0.05$ in all cases; Table 4). There were no significant differences in any metal concentrations at any station between sampling occasions (ANOVA, $P>0.05$).

The most abundant taxa in the Tyne estuary were nematodes, the genus *Capitella* and oligochaetes, comprising over 97% of the individuals (Figs 2, 3). Numbers of *Capitella* spp., *Eteone longa*, *Malacoceros fuliginosus*, *Ophryotrocha hartmanni* and *Parathalestris clausi* varied significantly both between stations and years in both March and September (Table 5; Fig. 3). Numbers of all species were lowest at St Peter's Quay.

In the Tyne estuary, numbers of *Eteone longa* varied significantly between stations in both March and September (Table 5). Population densities were significantly higher at Howdon and Whitehill Point than at all other stations in March sampling visits, and significantly higher at Howdon than at all other stations in September (Tukey test, $P<0.05$; Fig. 3). Numbers of *Eteone longa* varied significantly between years in both March and September, with significantly greater population densities being recorded in September 1992 than in September 1993 (Table 5; Tukey test, $P<0.05$; Fig. 3).

In March and September, *Malacoceros fuliginosus* population densities varied significantly between both stations and years (Table 5). In March sampling visits, numbers of individuals were significantly higher at Willington Quay than at any other station (Tukey test, $P<0.05$ Fig. 3). In September sampling visits, numbers of *M. fuliginosus* were higher at Willington Quay, Whitehill Point and Fish Quay stations than at Howdon and St Peter's Quay stations (Fig. 3). In March, *Malacoceros fuliginosus* densities were higher in 1993 than in 1992 or 1994.

Phyllodoce maculata populations were greatest in March 1992. However, in both March and September numbers present did not vary significantly between years (Table 5). Numbers of individuals present varied significantly between stations (Table 5). On September sampling occasions, *P. maculata* were present in significantly higher numbers at the Howdon station than at all other stations (Tukey test, $P<0.05$; Fig. 3), and significantly higher at the Howdon and Fish Quay stations than at all other stations in March sampling visits (Tukey test, $P<0.05$; Fig. 3).

Numbers of *Tharyx vivipara* varied significantly between stations (Table 5). In March sampling observations, *T. vivipara* was present in significantly higher numbers at the Fish Quay than at any other station (Tukey test, $P<0.05$). On September visits, highest numbers were recorded at Fish Quay station. Between year variability was significant in both March and September. Significantly higher numbers of *T. vivipara* were recorded in March 1992 than March 1993 and 1994 sampling visits (Fig. 3). Densities observed in September 1993 were significantly higher than those recorded in September 1992 (Table 5; Fig. 3).

Population densities of *Parathalestris clausi* were higher at Willington Quay, Howdon and Whitehill Point than Fish Quay and St Peter's Stations in both March and September (Fig. 3). Numbers of individuals present differed significantly between years (Table 5). Highest March abundances were recorded in 1994. Significantly higher abundances were recorded in September 1993 than in September 1992 (Table 5).

Significantly greater populations of *Tubificoides* were recorded in March sampling visits at Willington Quay, Howdon and Whitehill Point than at Fish Quay and St Peter's Quay stations (Tukey test, $P<0.05$; Fig. 4). Numbers of *Tubificoides* varied significantly between stations in September visits (Table 5). However, population densities were similar at all stations except

Table 4

Means (±1S.D., n=5) across the period March 1992- March 1993 for sediment metal concentrations (μg g^{-1}), loss on ignition and silt clay fraction at Tyne and Wear estuary stations

ELEMENT	TYNE ESTUARY				WEAR ESTUARY		
	St Peter's Quay	Willington Quay	Howdon	Whitehill Point	Fish Quay	Pallion	Sandy Point
Cadmium (**Cd**)	3.81 (± 3.15)	3.78 (± 3.15)	3.49 (± 3.02)	4.46 (± 4.23)	3.29 (± 2.79)	10.11 (± 18.49	3.54 (± 3.19
Chromium (**Cr**)	80.38 (± 30.46)	80.18 (± 37.41)	78.48 (± 23.10)	81.86 (± 36.78)	79.59 (± 27.11)	90.24 (± 37.91)	69.29 (± 32.68)
Copper (**Cu**)	109.76 (± 31.22)	105.91 (± 17.86)	94.50 (± 23.41)	122.56 (± 45.69)	85.75 (± 20.22)	133.69 (± 44.06)	87.69 (± 24.74)
Lead (**Pb**)	369.16 (± 104.44)	246.31 (± 41.59)	183.45 (± 45.43)	194.30 (± 64.86)	143.04 (± 47.81)	688.71 (± 314.12)	284.82 (± 208.1)
Nickel (**Ni**)	40.93 (± 2.57)	39.84 (± 4.10)	36.50 (± 3.58)	40.50 (± 2.08)	38.77 (± 5.18)	56.11 (± 2.39)	39.93 (± 3.47)
Mercury (**Hg**)	0.54 (± 0.36)	0.58 (± 0.39)	0.54 (± 0.34)	0.46 (± 4.23)	0.41 (± 0.29)	0.72 (± 0.47)	0.64 (± 0.75)
Zinc (**Zn**)	738.59 (± 259.74)	407.79 (± 86.24)	299.08 (± 51.37)	334.39 (± 79.25)	200.02 (± 56.34)	711.48 (± 278.26)	321.13 (± 244.77)
Loss on ignition (%)	18.45 (± 2.7)	18.44 (± 1.23)	19.55 (± 7.23)	17.00 (± 1.23)	28.69 (± 4.92)	36.39 (± 17.95)	25.97 (± 7.32)
Silt Clay fraction (%)	63.30 (± 1.5)	62.52 (± 1.25)	62.40 (± 0.59)	59.09 (± 2.97)	62.31 (± 5.27)	72.96 (± 3.60)	65.94 (± 6.15)

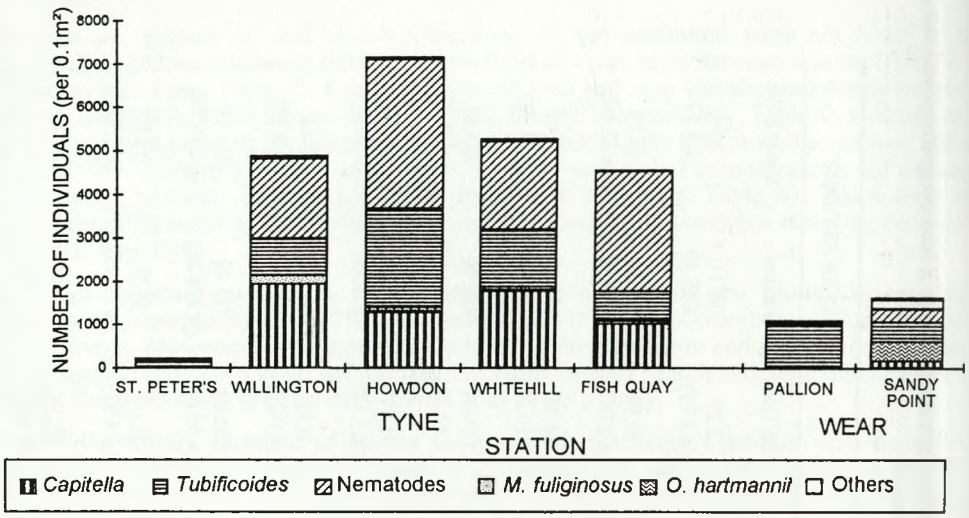

Fig. 2 Mean abundances of key taxa at all stations on the Tyne and Wear estuaries during the period March 1992-March 1994.

at St Peter's Quay where numbers of individuals recorded were lower (Fig. 4). In March sampling visits, numbers of *Tubificoides* were observed to increase across the period 1992-1994, with significant between-year variation (Table 5). However, there were no significant differences between September 1992 and September 1993 visits (Table 5).

In March, numbers of *Ophryotrocha hartmanni* varied significantly between stations. This was due to the greater abundance at Howdon than at all other stations (Table 5; Tukey test, $P<0.05$; Fig. 4). September samplings of O. *hartmanni* also revealed significant differences between stations, with significantly greater numbers of O. *hartmanni* at Howdon and Whitehill Point Stations than at the other stations (Table 5; Tukey test, $P<0.05$; Fig. 4). In March observations, numbers of *O. hartmanni* varied significantly between years, with lower population densities in 1994 than in the previous two years (Table 5; Tukey test, $P<0.05$; Fig. 4). Significantly fewer *O. hartmanni* were present in September 1993 than in September 1992 (Table 5).

Capitella spp. were present in significantly lower densities in March sampling visits at both St Peter's Quay and Fish Quay stations than at Willington Quay, Howdon and Whitehill Point, with lowest densities at St Peter's Quay(Table 5; Tukey test, $P<0.05$; Fig. 4). Numbers of *Capitella* spp. present varied significantly between March observations (Table 5; Fig. 4), with greatest densities recorded in March 1993. In September samplings, numbers of individuals were significantly lower at St Peter's Quay than any other station (Tukey test, $P<0.05$), with similar numbers of individuals at other stations (Fig. 4). Numbers of *Capitella* present were significantly higher in September 1992 than in the same period in 1992.

Non-metric Multiple Dimensional Scaling (MDS) analysis of the station/species/sampling period matrix (excluding the Lloyd's Hailing Station samples) plotted in two dimensions showed a clear separation of the samples taken at St Peter's Quay from those taken at the remaining four stations (Fig. 5).

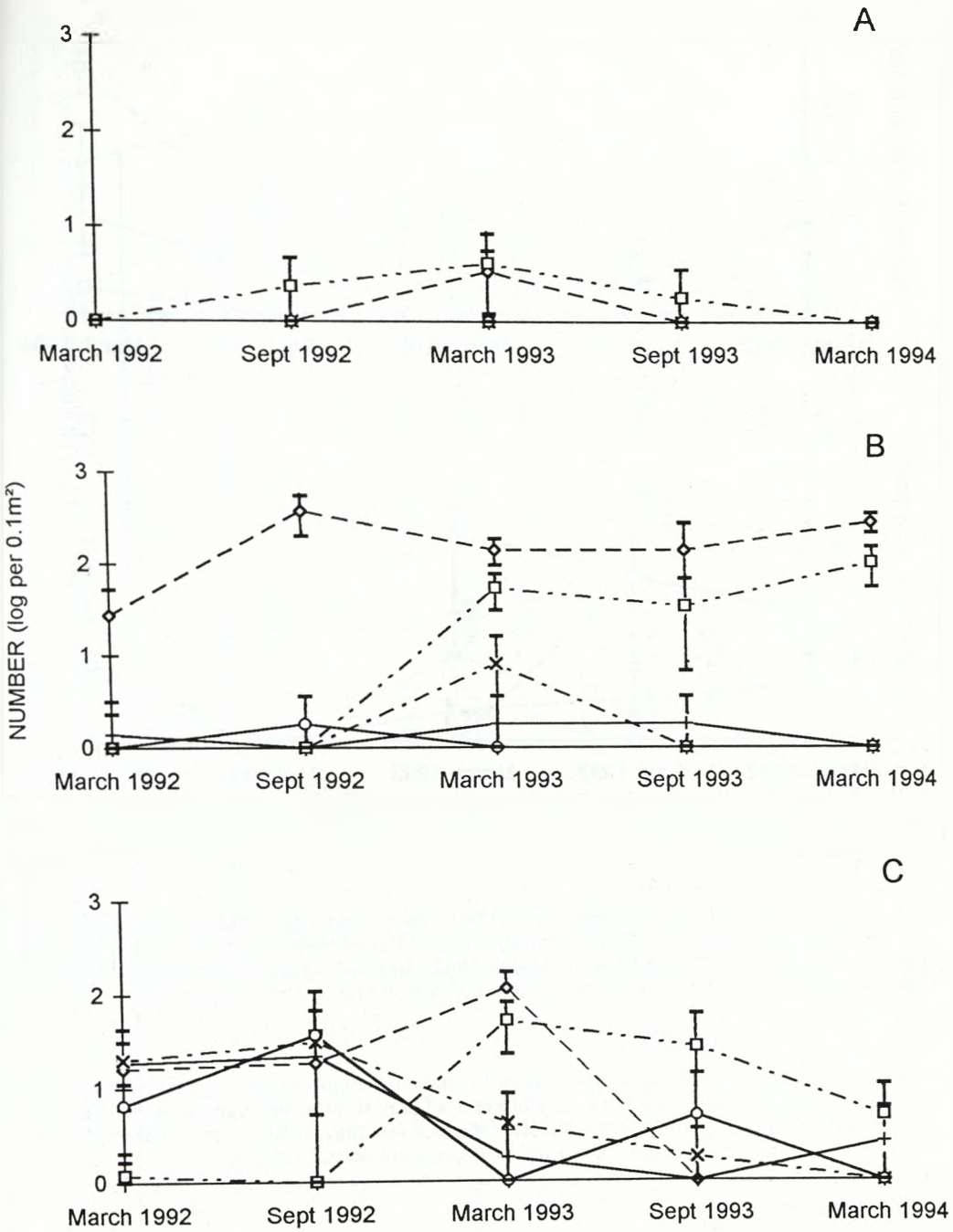

Fig. 3 Mean abundances (1 S.D.) of *Eteone longa* (+), *Malacoceros fuliginosus* (◊), *Phyllodoce maculata* (×), *Tharyx vivipara* (o) and *Parathalestris clausi* (□) at A) St Peter's Quay, B) Willington Quay and C) Howdon stations in the Tyne estuary throughout the period March 1992-March 1994 (continued overleaf).

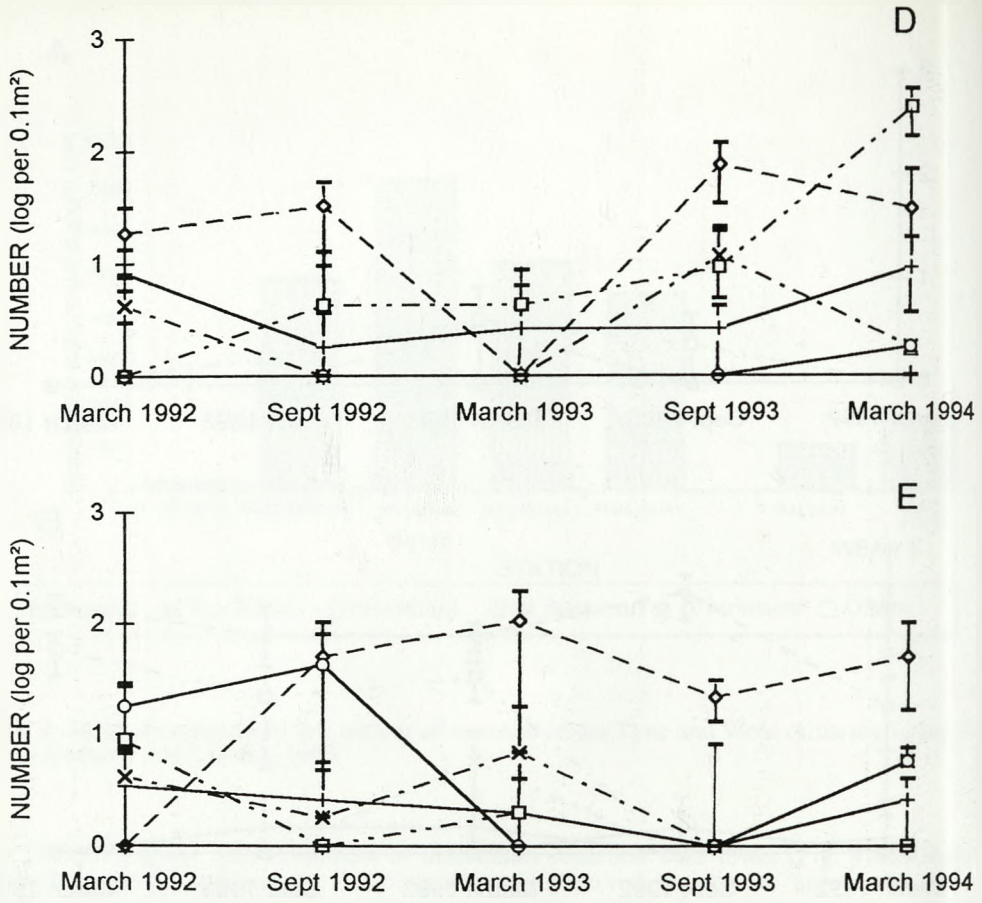

Fig. 3 (continued) Mean abundances (1 S.D.) of *Eteone longa* (+), *Malacoceros fuliginosus* (◊), *Phyllodoce maculata* (×), *Tharyx vivipara* (o) and *Parathalestris clausi* (□) at D) Whitehill Point and E) Lloyd's Hailing Station (March 1992) and Fish Quay (September 1992-March 1994) stations in the Tyne estuary throughout the period March 1992-March 1994.

A dendrogram plot using Bray-Curtis similarity analysis and group sorting gave separation of the Howdon 1992 stations (Group 1), the St Peter's Quay stations throughout the whole study period (Group 2), and two further clusters. Group 3 contains most of the Willington Quay samples, while Group 4 contains all of the Fish Quay stations (Group 3; Fig. 6).

Wear estuary

The loss on ignition of, and proportions of silt/clay in the sediments of the Wear estuary were not found to be significantly different between stations, or between seasons (ANOVA, $P>0.05$ in all cases; Table 4). Chromium was the only metal that varied significantly in concentrations between sampling occasions (ANOVA, $F=12.13$, $P<0.05$), with significantly higher concentrations recorded in March and September 1993 and March 1994 (101.2 ± 11.7) than in March and September 1992 (47.14 ± 2.73; Tukey test, P). Nickel was present in significantly higher concentrations at the Pallion station than at the Sandy Point station (ANOVA,

Table 5

Results of ANOVA for biota samples taken at all stations on the Tyne estuary (except Lloyd's H.S.) between March 1992 and March 1994

FACTOR	BY YEAR				BY STATION			
SEASON	**March**		**September**		**March**		**September**	
	F=	**P=**	**F=**	**P=**	**F=**	**P=**	**F=**	**P=**
Nematodes	23.85	<0.001	1.59	>0.05	238.35	<0.001	101.69	<0.001
Capitella spp.	18.13	<0.001	14.67	<0.01	207.24	<0.001	116.7	<0.001
Tubificoides	8.47	<0.01	3.15	>0.05	43.24	<0.001	49.11	<0.001
Malacoceros fuliginosus	12.4	<0.001	4.45	<0.05	315.38	<0.001	31.56	<0.001
Parathalestris clausi	49.64	<0.001	23.11	<0.001	29.09	<0.001	5.11	<0.01
Ophryotrocha hartmanni	4.13	<0.05	11.61	<0.01	14.88	<0.001	10.81	<0.001
Phyllodoce maculata	3.99	<0.05*	0.92	>0.05	7.66	<0.001	6.28	<0.01
Eteone longa	8.45	<0.01	6.751	<0.05	10.34	<0.001	5.11	<0.01
Tharyx vivipara	11.72	<0.001	9.14	<0.01	7.61	<0.001	4.65	<0.01

* Not considered significant after *a posteriori* testing (Rice, 1989)

F=121.37, P<0.05; Table 4). Cadmium, copper, lead, mercury and zinc concentrations did not differ significantly between stations or sampling occasions (ANOVA P>0.05; Table 4).

The most abundant taxa in the Wear estuary were nematodes, *Tubificoides* spp., *Capitella* spp. and *Tharyx vivipara*, comprising 91% of the individuals (Figs. 2, 3, 8).

On the Wear estuary, the numbers of *Tubificoides* were significantly greater at Sandy Point than at Pallion stations in September sampling visits (Table 6). The variation in the numbers of *Tubificoides* between stations in March was not significant, neither were the numbers of individuals present between years in either March or September (Table 6; Fig. 7).

Numbers of nematodes did not vary significantly between years in either March or September. Nematode population densities were, however, significantly higher at Sandy Point than at Pallion in both September and March (Table 6; Fig. 7).

Ophryotrocha hartmanni were recorded in significantly higher numbers at Sandy Point than at Pallion in March sampling visits, but not in September (Table 6; Fig. 7). Numbers recorded varied significantly between years in March sampling visits, but not in September (Table 6; Fig. 7). However, *O. hartmanni* were not usually recorded at either station on September sampling visits.

Significant inter-annual variation in population densities was observed for *Capitella* spp. in both March and September (Table 6), with greatest numbers of *Capitella* being recorded in September 1992 at Sandy Point (Fig. 7). Between station variations were not significant in March sampling visits (Table 6). However, significantly more *Capitella* were recorded in September 1993 than in the same period in 1992.

Eteone longa were present in significantly higher numbers at Sandy Point than Pallion stations in both March and September (Table 6; Fig. 7). Between year variability was not significant in either sampling period. *Phyllodoce maculata* and *Tharyx vivipara* were present in significantly higher numbers at Sandy Point than Pallion stations in both March and September, and absent from Pallion throughout the whole sampling period (Fig. 7). Between year variability in numbers of *T. vivipara* was not significant in either March or September. *P. maculata* numbers varied significantly between years in September, but not in March (Fig. 7; Table 6). An MDS analysis followed by a two-dimensional plot of species by sampling by station data showed a clear separation of samples from the two stations, with the Sandy Point (most seaward) station showing the greatest variability (Fig. 8). A dendrogram plot using Bray-Curtis measure of similarity followed by group average sorting showed separation of Pallion (Group 1) and Sandy Point (Group 2) stations (Fig. 9). Within the Sandy Point group, March and September 1993 and March 1994 sampling occasions were separated.

DISCUSSION

The benthic communities present in the Tyne and Wear estuaries are characteristic of those seen in organically polluted areas (Fig. 10; Pearson & Rosenberg, 1978; Shillabeer & Tapp, 1990; Tapp *et al.*, 1993), with many of the species found (Appendix 1) being listed as "very pollution tolerant" (Rygg, 1985a). Fine, anoxic sediments containing large amounts of organic matter are typically inhabited by a low diversity community, dominated in the mid-estuary by *Tubificoides* spp., *Capitella* spp., and nematodes (Sinton, 1978; Day *et al.*, 1989; Gray *et al.*, 1992). Such a species distribution is comparable to that observed on other east coast estuaries, for example, the Forth (Elliott & Kingston, 1990), Tees (Shillabeer & Tapp, 1990; Tapp *et al.*, 1993) and Humber (Barr *et al.*, 1990; NRA, 1993) estuaries.

In both the Tyne and Wear estuaries, high losses on ignition (up to 36%; Table 4) do not accurately reflect the sediment organic matter content, since the combustion of mineral coal present gives an additional weight loss. The sediment organic matter content in sites such as those visited was expected to be 1-7% (Warwick, 1971; Hursthouse *et al.*, 1994). This overestimation problem has also arisen in offshore sediments from the north-east of England (Buchanan & Longbottom, 1970), and analysis using a simple combustion method is not satisfactory (Hall, 1996).

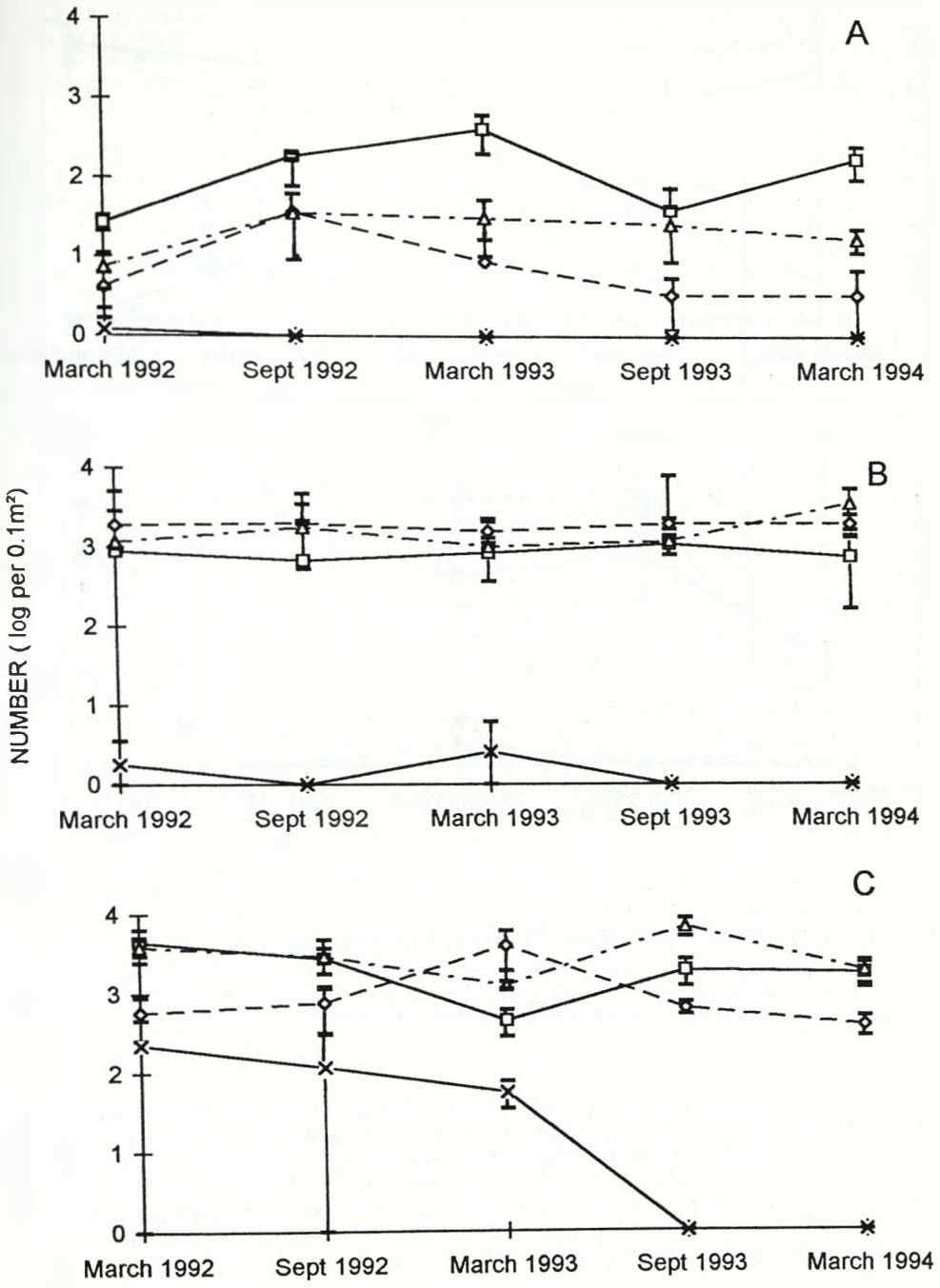

Fig. 4 Mean abundances (1 S.D.) of *Tubificoides* spp. (□), nematodes (Δ), *Ophryotrocha hartmanni* (×) and *Capitella* spp. (◊) at A) St Peter's Quay, B) Willington Quay and C) Howdon Station (March 1992) and Fish Quay (September 1992-March 1994) stations in the Tyne estuary throughout the period March 1992-March 1994 (continued overleaf).

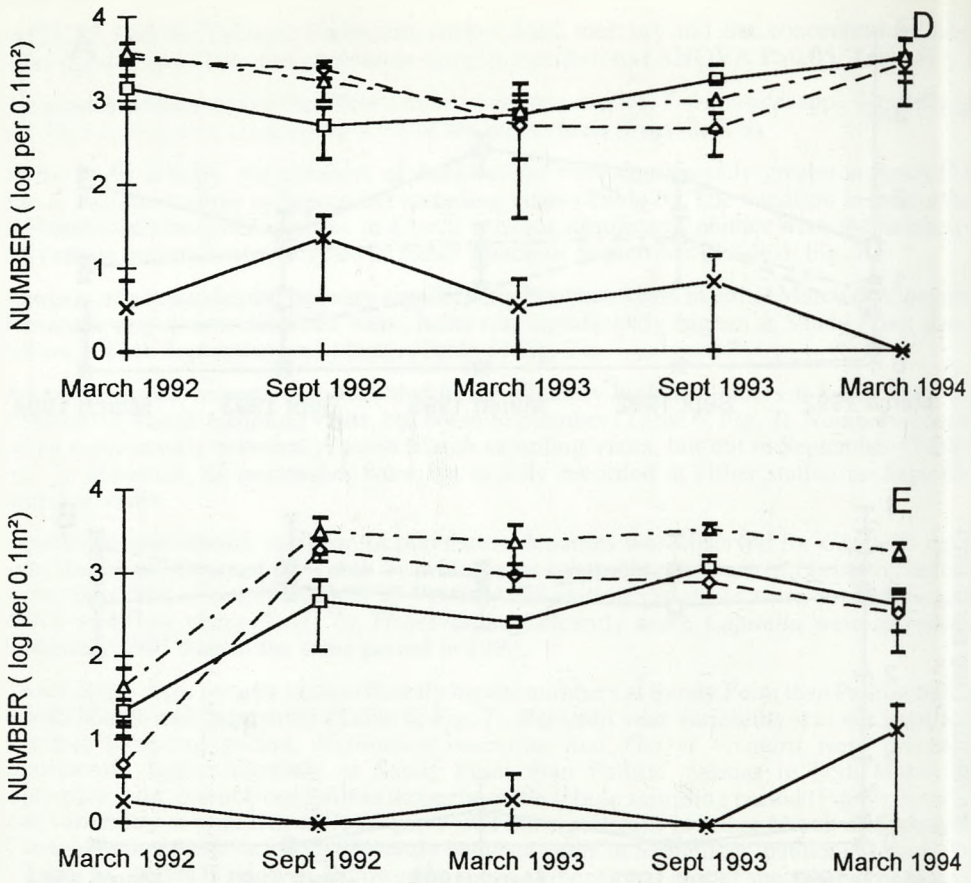

Fig. 4 (continued) Mean abundances (1 S.D.) of *Tubificoides* spp. (□), nematodes (Δ), *Ophryotrocha hartmanni* (×) and *Capitella* spp. (◊) at D) Whitehill Point and E) Lloyd's Hailing Station (March 1992) and Fish Quay (September 1992-March 1994) stations in the Tyne estuary throughout the period March 1992-March 1994.

Concentrations of metals recorded in the Tyne and Wear estuaries were high when compared to those observed in other UK estuaries (Table 7), particularly for the elements lead and cadmium. Both the Tyne and Wear estuaries have natural metal deposits in their catchments, but contamination also arises as a result of industrial activity (Table 7), and discharges of untreated, or only primarily treated, sewage. In the case of chromium, copper, lead and nickel, 60-80% of initial metal content of sewage can remain in the discharged supernatant effluent after primary treatment (Huntingdon & Neville-Jones, 1988), and therefore enters the receiving waters.

The high concentrations of zinc and lead in the Tyne (Table 4), particularly at St Peter's Quay, were probably due to industrial inputs. There is a history of lead processing to the west of Newcastle, and a battery manufacturer based on the River Team, which is a tributary entering the Tyne to the west of Newcastle, discharges effluents containing metal salts (Wehr *et al.*, 1981; NRA, 1994a; John Pomfret, Northumbrian Water Group plc, pers. comm.).

Table 6

Results of ANOVA for biota samples taken at all stations on the Wear estuary between March 1992 and March 1994.

FACTOR	BY STATION				BY YEAR			
SEASON	**March**		**September**		**March**		**September**	
	F=	**P=**	**F=**	**P=**	**F=**	**P=**	**F=**	**P=**
Nematodes	44.48	<0.001	28.65	<0.001	1.83	>0.05	4.33	>0.05
Capitella spp.	3.34	>0.05	12.43	<0.01	42.79	<0.001	7.52	<0.05
Tubificoides	0.45	>0.05	41.95	<0.001	0.46	>0.05	3.16	>0.05
Ophryotrocha hartmanni	64.60	<0.001	1.00	>0.05	79.83	<0.001	1.00	>0.05
Tharyx vivipara	67.58	<0.001	43.04	<0.001	1.76	>0.05	4.62	<0.05*
Phyllodoce maculata	8.97	<0.001	11.97	<0.001	1.00	>0.005	5.43	<0.05
Eteone longa	7.25	<0.05	6.80	<0.05	0.6	>0.05	2.88	>0.05

* Not considered significant after *a posteriori* testing (Rice, 1989).

Table 7

Average sediment metal concentrations (μg g-1) from a range of UK estuaries (after Burt *et al.*, 1992) compared with results of this study.

SITE	ELEMENTS						
	Cd	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**
This Study							
TYNE	3.80	80	104	0.50	39	227	396
WEAR	3.03	80	111	0.68	48	487	516
After Burt *et al.*, 1992							
TYNE	2.17	46	92	0.92	34	187	421
HUMBER	0.48	77	54	0.55	39	113	252
MERSEY	1.15	84	84	3.01	29	124	379
SEVERN	0.63	55	38	0.51	33	89	259
SOLWAY[1]	0.23	30	7	0.03	17	25	59
RESTRONGUET CREEK[2]	1.53	32	2398	0.46	58	341	2821

[1] Very little contamination - background concentrations.
[2] Exceptionally contaminated by mining of ore-bearing rocks.

Concentrations of nickel in the Wear were also elevated at the most landward, Pallion, station (Fig. 1). Inputs of nickel in the Wear may arise as a result of its presence in sewage effluents (Moriyama *et al.*, 1989), and mine drainage to the watercourse (Smith, 1981; NRA 1994b). The fauna at Sandy Point during the period March 1993-March 1994 were separated on the dendrogram plot of community similarities at the sampling period when chromium concentrations were significantly higher (Fig. 8). This may also explain the reduced benthic diversity.

In the Tyne, zinc and lead concentrations were both seen to decrease seaward along the length of the estuary. This pattern was also seen in the case of nickel in the Wear (Table 4). Similar patterns have been observed in estuaries of the Rhine-Meuse Delta (Day *et al.*, 1989), as a result of influxes of marine water and sediments diluting contamination.

When interpreting observations of benthic community structure obtained during studies of industrialized estuaries, and comparing these against sediment contaminant concentrations, the effects of both natural and anthropogenic processes on benthic communities must be borne in mind (Wilson, 1988; Dauer *et al.*, 1993).

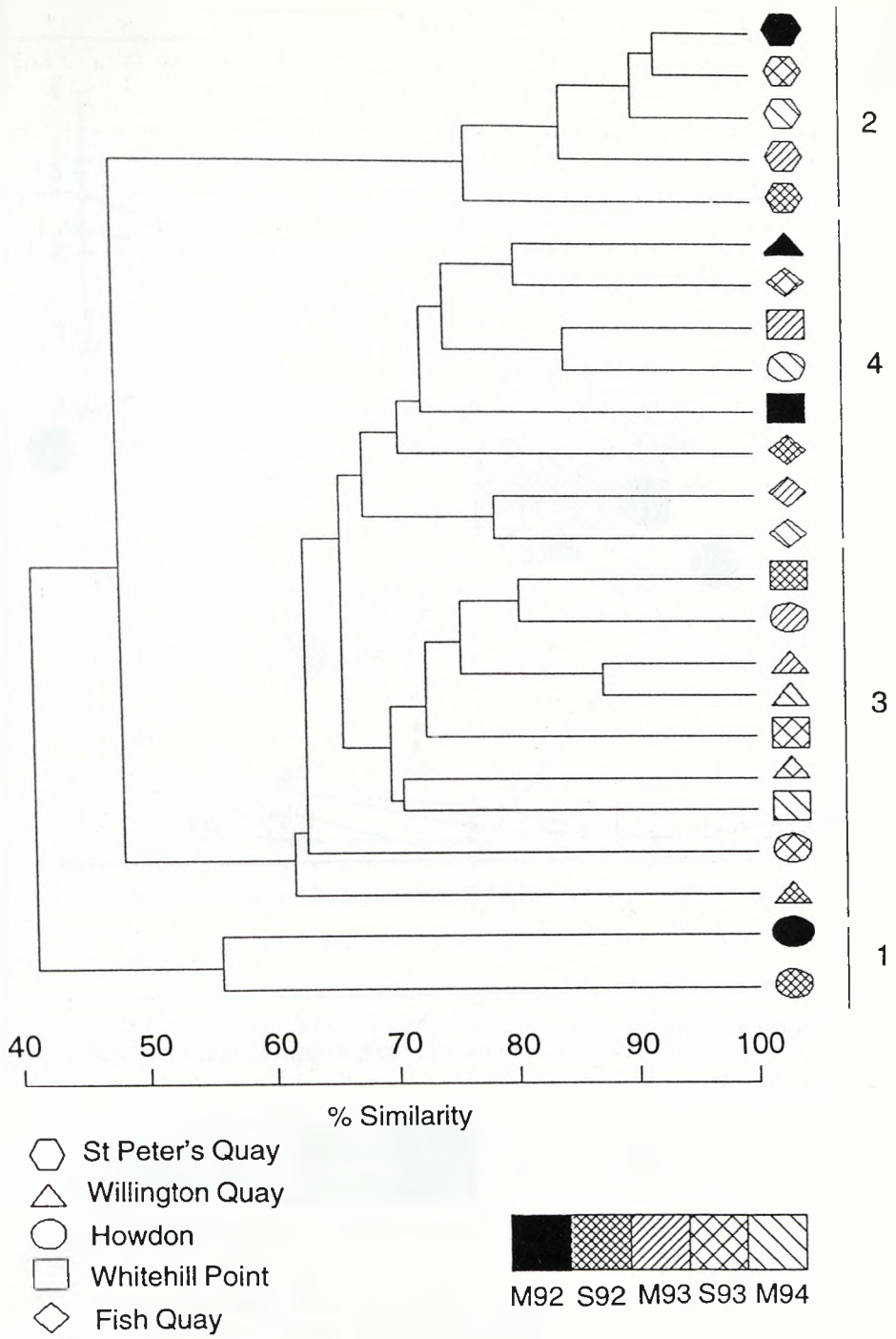

Fig. 5 Ordination of the five stations in the Tyne estuary sampled between March 1992 and March 1994. Abundances were log(x+1) transformed before Bray-Curtis analysis and the dendrogram formed by group-average sorting.

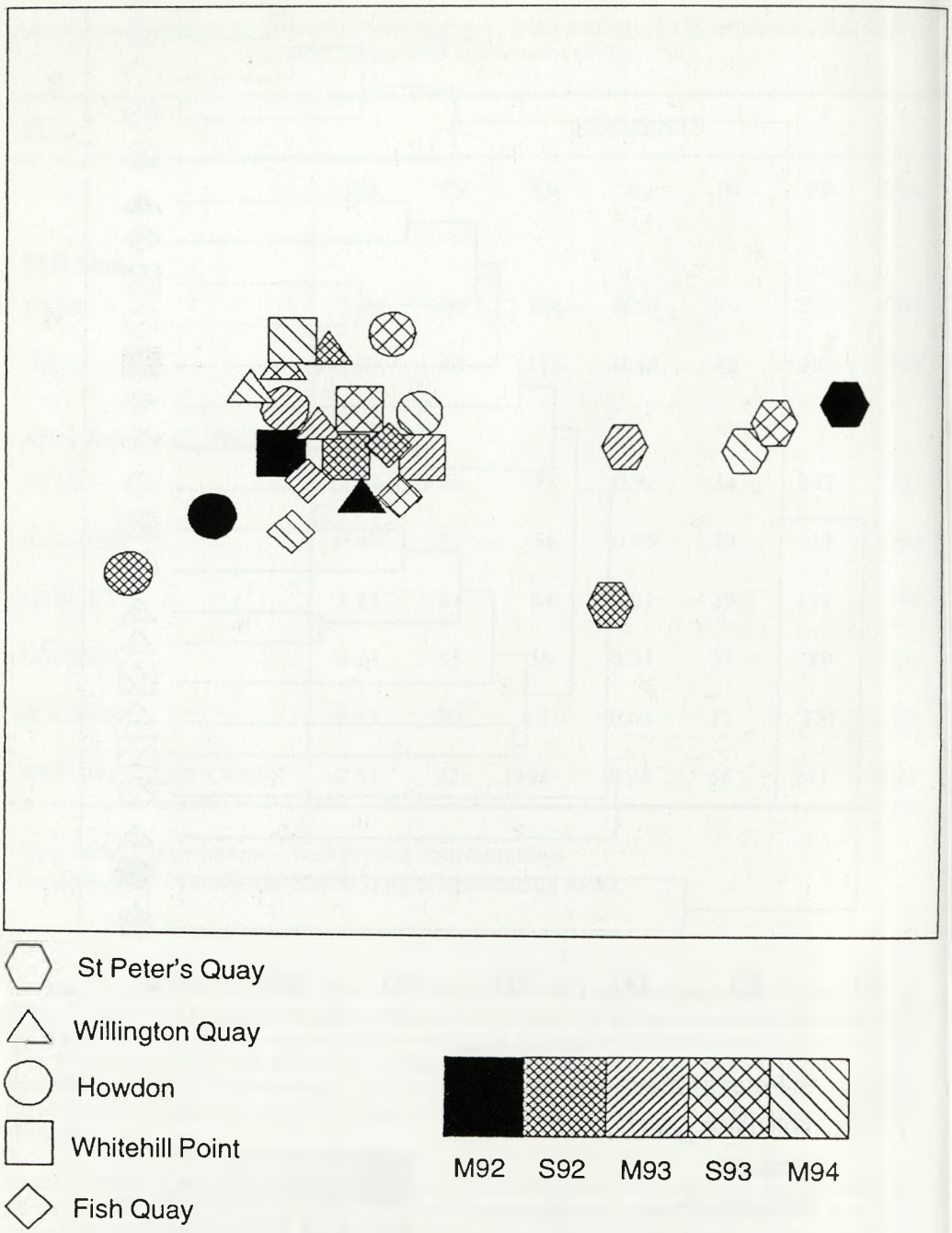

Fig. 6 Dendrogram showing classification of the five stations in the Tyne estuary sampled in the period March 1992-March 1994. Multiple Dimensional Scaling was used on the same data matrix as that used in Fig. 5.

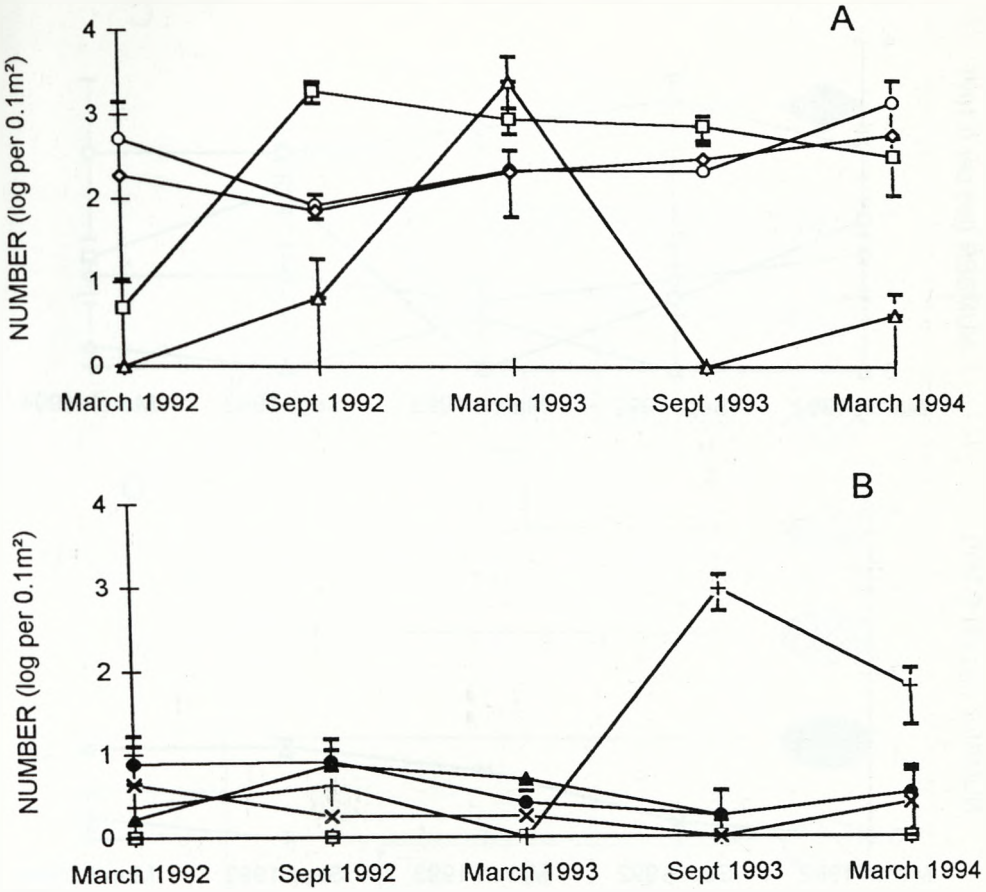

Fig. 7 Mean abundances (1 ± S.D.) of *Tubificoides* spp. (o), nematodes (◊) ,*Ophryotrocha hartmanni* (×), and *Capitella* spp. (□) at A) Sandy Point and B) Pallion stations (continued overleaf).

The prime affector of benthic community structure in uncontaminated estuaries is salinity (McLusky, 1989; McLusky *et al.* 1993). Other factors may include a sediment particle size gradient, a high sediment organic matter content, and sediment metal burdens which may be increased due to natural erosion of metal containing minerals in the upper part of the catchment (Wehr *et al.*, 1991).

There may also be extensive physical disturbance due to spring/neap erosion cycles, and periodic storm/flood events (Eagle, 1975). All of these natural processes affect the Tyne and Wear estuaries, and there are also a number of anthropogenic impacts. Loads of organic matter result from sewage effluent discharges, adding to natural organic matter concentrations (Pearson & Rosenberg, 1987). Physical disturbance in the already dynamic estuarine environment may be enhanced by dredging (Bonsdorff, 1983) and shipping wash (Bonsdorff *et al.*, 1986). Sediment metal concentrations may be increased due to accelerated weathering

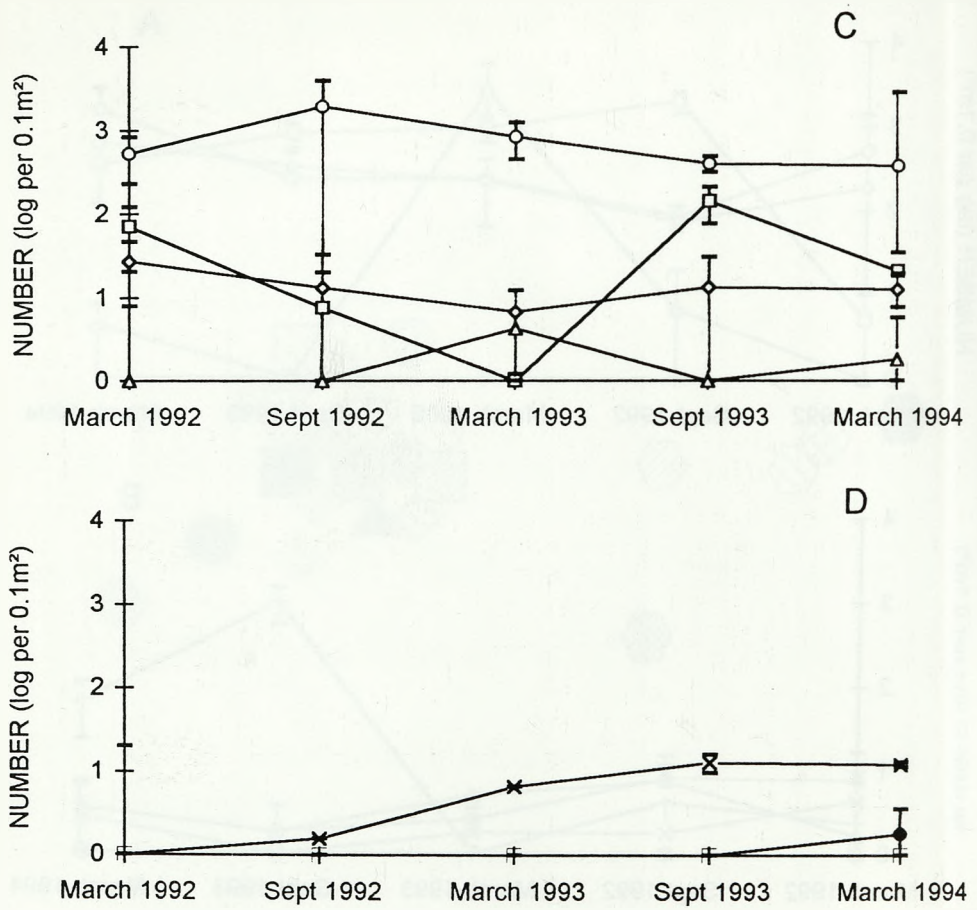

Fig. 7 (continued) Mean abundances (±1 S.D.) of *Eteone longa* (●), *Parathalestris clausi* (×), *Phyllodoce maculata* (Δ) and *Tharyx vivipara* (+) at C) Sandy Point and D) Pallion stations in the Wear estuary throughout the period March 1992-March 1994.

after mining operations, or discharge of metal containing effluents to the estuary (Macklin & Dowsett, 1989). The effects of lowered salinity in enhancing the direct and indirect toxicity of metals and organic matter must also be considered (McLusky *et al.*, 1986)

The fauna present in the upper-mid estuary at St Peter's Quay in the Tyne, and Pallion in the Wear (Fig. 1) were reduced both in terms of numbers of individuals and species. This is usually observed in euryhaline areas (Day *et al.*, 1989; McLusky, 1989). In the Tyne estuary there was abundant food for benthic deposit feeders in the mid estuary (Fig. 1), primarily as a result of discharges from Howdon Sewage Treatment Works. Food availability is known to be an important factor in altering the structure of benthic communities (Pearson & Rosenberg, 1987), but so is salinity (McLusky *et al*, 1986; Dauer *et al.*, 1993). For example, two deposit feeding taxa which can withstand mesohaline conditions (*Capitella* and *Tubificoides*) were more abundant in the middle part of the estuary. Were they in this area because they were excluded

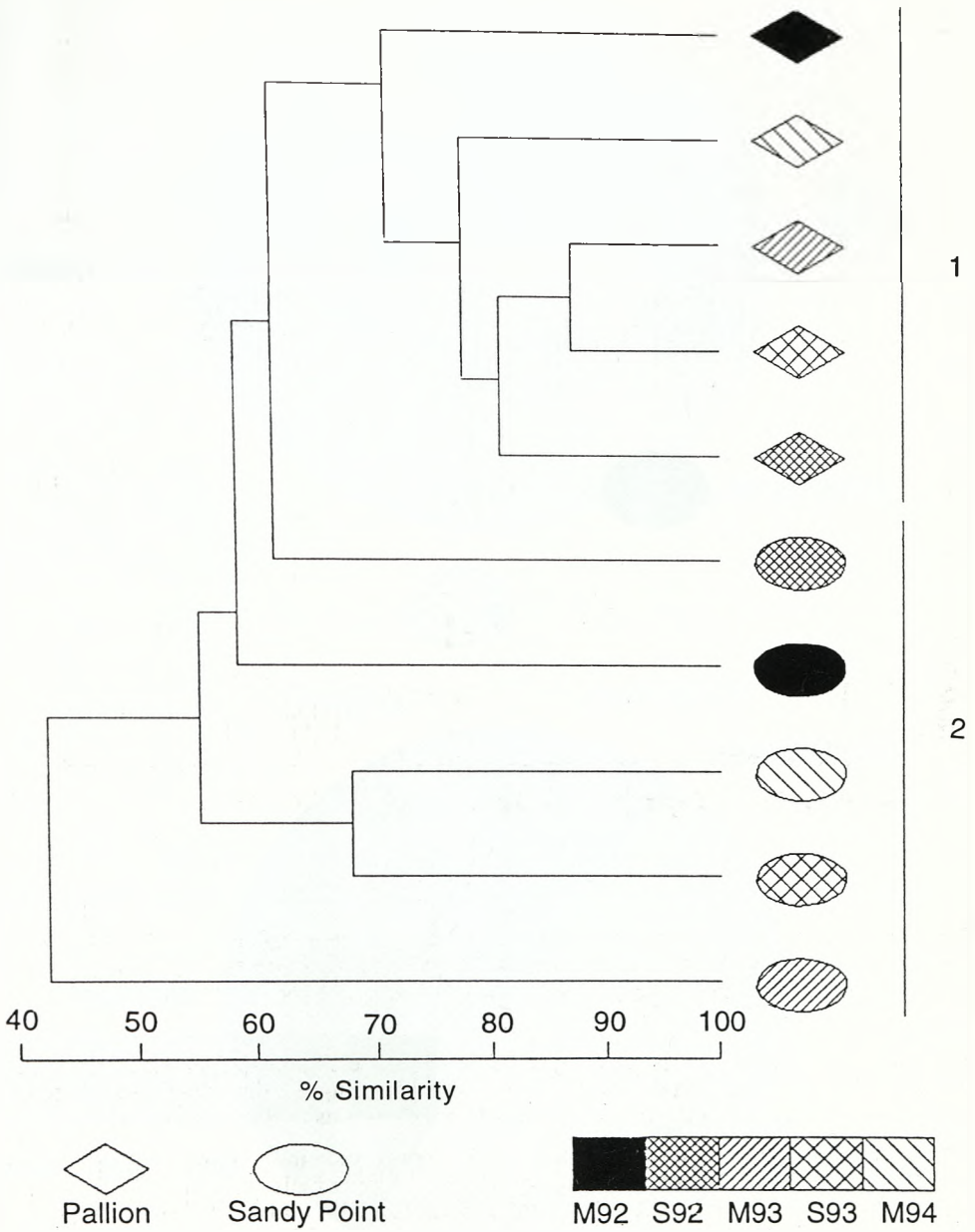

Fig. 8 Ordination of Sandy Point and Pallion stations in the Wear estuary sampled between March 1992 and March 1994. Abundances were log (x+1) transformed before Bray-Curtis analysis and the dendrogram formed by group-average sorting.

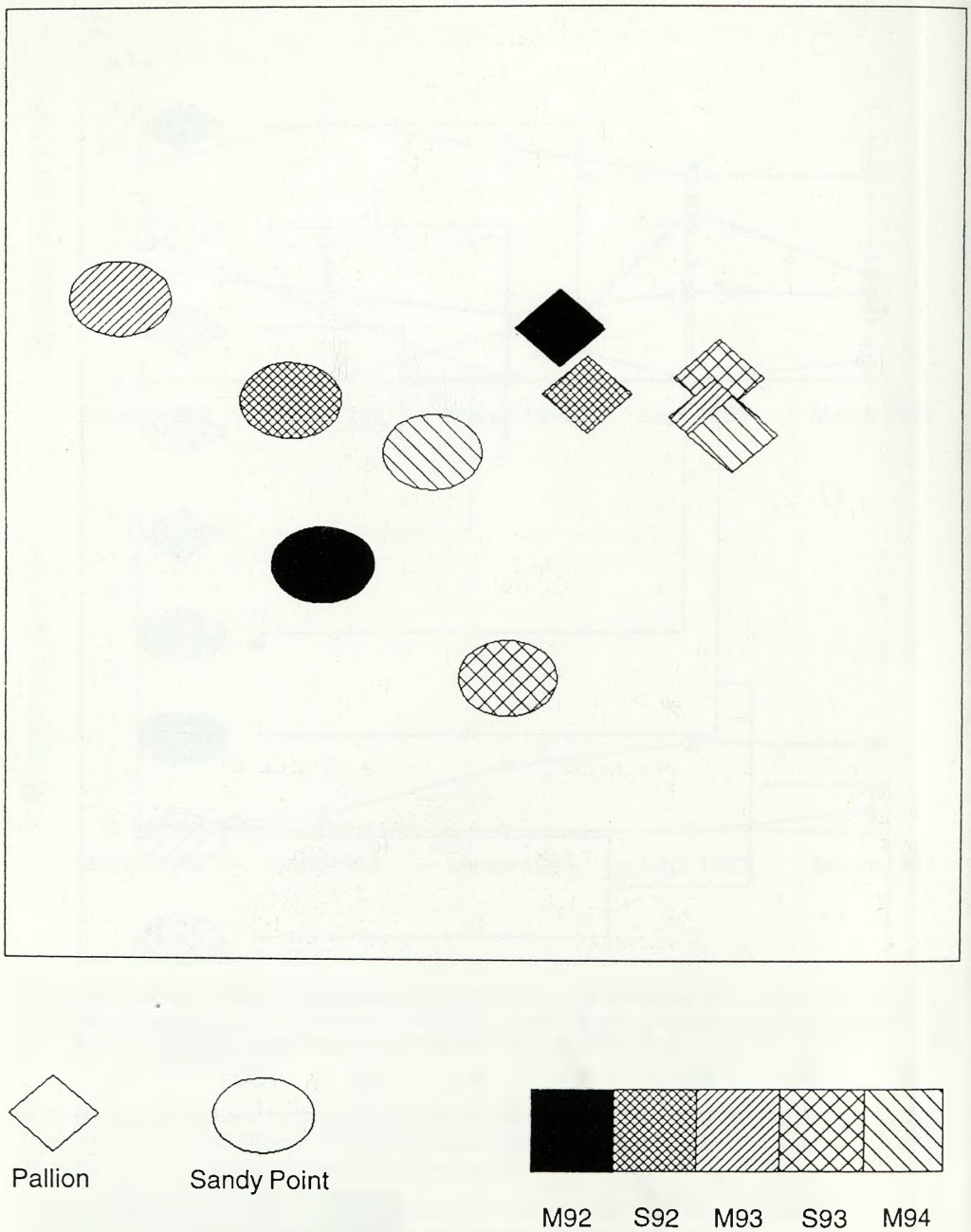

Fig. 9 Dendrogram showing classification of Sandy Point and Pallion stations in the Wear estuary sampled in the period March 1992-March 1994. Multiple Dimensional Scaling was used on the same data matrix as that used in Fig. 8.

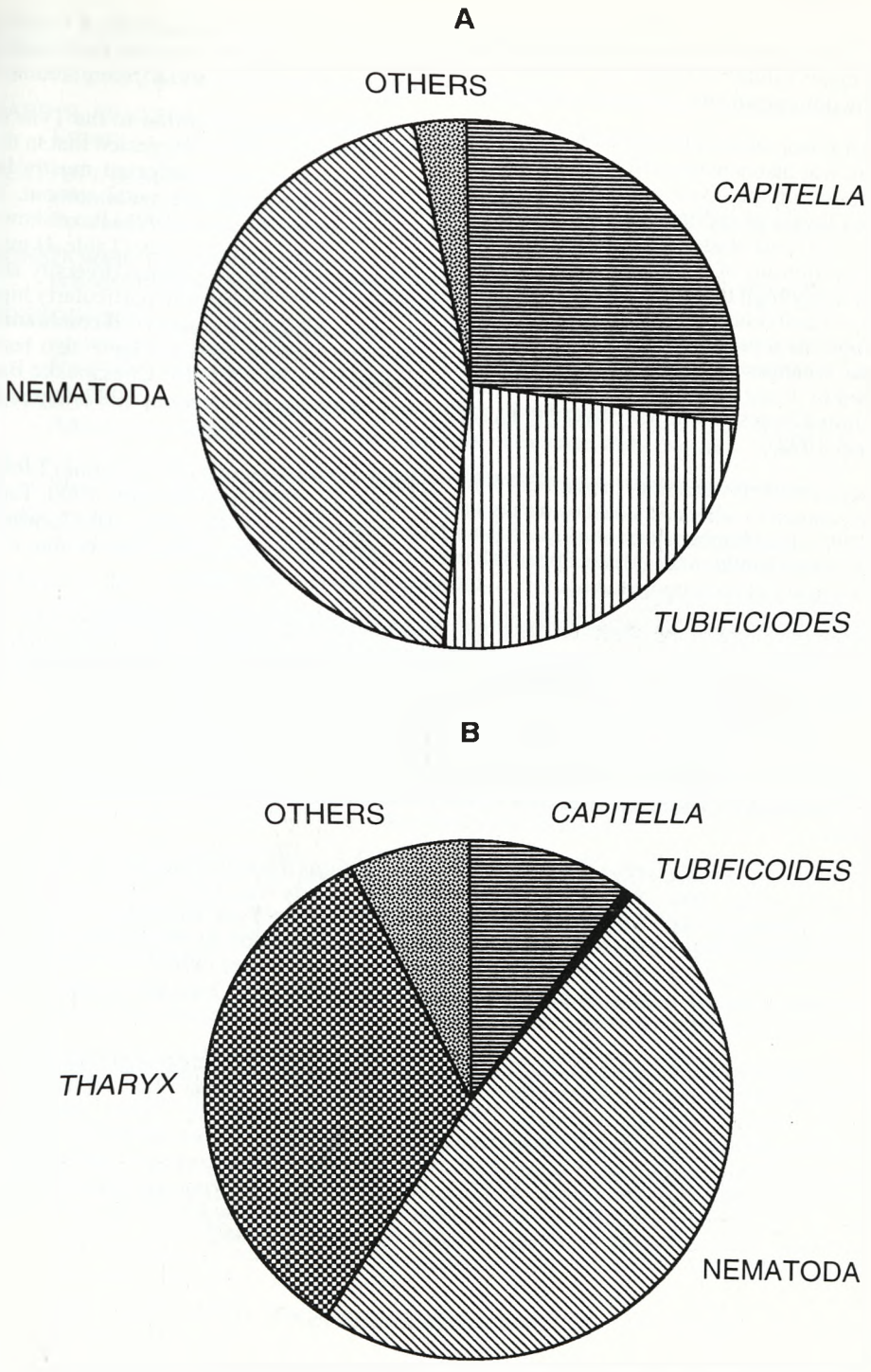

Fig. 10 Pie diagram to show mean faunal composition at all sites on A) Tyne and B) Wear estuaries, March 1992-March 1994.

from the lower estuary as a result of competitive interaction and predation (ecological factors), and the upper estuary by pollution (toxicity factors)? Or alternatively, was the food supply from Howdon causing the great abundances of these opportunists at this, and adjacent stations?

Although fewer sites were visited in the Wear estuary, this estuary is similar to the Tyne in that there was also a major discharge of sewage to the mid-estuary. It is suggested that in the mid-sections of the Tyne and Wear estuaries, the communities were affected mostly by enhanced levels of sediment organic matter, rather than a high sediment metal content. In bioassay tests and observations on benthic community structure, NOAA (1991) have shown that concentrations of metals similar to those found at the upper estuary sites (Table 4) may be sufficiently high to affect benthic community structures, by reducing faunal diversity and numbers of individuals of even tolerant species. Lead and zinc are present in particularly high concentrations at the upper estuary stations. These may be leading to the observed community structure. Changes in community composition as a result of metal toxicity have also been described by Rygg (1985) in Norwegian Fjords, by Dauer *et al.* (1993) for Chesapeake Bay in the United States and for the River Fal in south-west England (Bryan *et al.*, 1987; Bryan & Langston, 1992).

There was a marked variability in numbers of individuals between sampling occasions (Tables 5, 6), in contrast to other east coast estuaries such as the Tees (Shillabeer & Tapp, 1990; Tapp *et al.*, 1993), the Humber (Barr *et al.*, 1990), and the Forth (Elliott & Kingston, 1990), where populations of benthic individuals appear to remain relatively stable. This may be due to a higher intensity of anthropogenic activity at the stations used in this study.

Identifying the cause of the observed distribution and composition of the benthos is difficult (Clarke & Warwick, 1994). If there were less intense anthropogenic impacts on the benthos, the benthic communities would be expected to contain a wider range of species, and increased populations of crustaceans and molluscs in particular (Gray *et al.*, 1992). A greater diversity of species is found in the Forth (Elliott & Kingston, 1990), Humber (NRA, 1993) and even the Tees estuary (Shillabeer & Tapp, 1990), most notably the greater occurrence of molluscs. However, the actual cause of the impoverished community structure cannot be fully identified, and only inferred by taking an overview of the contaminants that have been identified and quantified.

It is possible to infer cause-effect relationships by observations through time (Gray *et al*, 1992; Clarke & Warwick, 1994). The timescale over which this study was carried out means that it represents a series of snapshots of the benthos and metals in the Tyne and Wear estuaries in the period March 1992-March 1994. High variability in the benthos, as observed in the case of *Ophryotrocha* and *Capitella* in the Wear estuary means that longer periods of observation, and possibly a greater degree of sampling effort, are required to increase confidence in describing any long term, or widespread trends.

In future studies of the changes in the Tyne and Wear estuaries it is suggested that the best way to determine the impact of the contaminants present in the Tyne and Wear estuaries is to follow the benthos through recovery. This could be carried out by firstly gaining an understanding of existing fluctuations in benthic populations by establishing a time-series of populations of benthic infauna. This could be carried out by making bi-annual observations, as in this study. Then by monitoring the benthos more intensely following remediation works, such as the forthcoming installation of secondary treatment at Howdon STW on the Tyne estuary (NRA, 1994 a), the effects of such projects can be ascertained.

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Appendix

Taxa found at stations in the Tyne and Wear estuaries in the study period March 1992 - March 1994

Species	St Peter's Quay	Willington Quay	Howdon	Whitehill Point	Fish Quay	Lloyd's Hailing Station	Pallion	Sandy Point
Abra alba (W. Wood)		✓	✓	✓	✓	✓	✓	✓
Angulus tenuis (da Costa)								
Arenicola marina (L.)	✓							
Capitella								
Carcinus maenas (L.)								
Chaetozone setosa Malmgren								
Chamelea gallina (L.)								
Cirratulus cirratus (O. F. Muller)								
Cirratulus filiformis Keferstein								
Cirriformia tentaculata (Montagu)								
Corophium volutator (Pallas)								
Crangon crangon (L.)	✓							
Diastylis bradyii Norman								
Diastylis rugosa G. O. Sars								
Eteone longa (Fabricius)								
Fabulina fabula (Gmelin)								
Gammarus indet.	✓							
Glycera rouxii (Audouin & Milne-Edwards)								
Harmothoe spp.								
Iphinoe trispinosa (Goodsir)								
Logis korenii (Malmgren)								
Macoma balthica (L.)								

Appendix continued

Species	St Peter's Quay	Willington Quay	Howdon	Whitehill Point	Fish Quay	Lloyd's Haling Station	Pallion	Sandy Point
Malacoceros fuliginosus (Claparede)	✓	✓	✓	✓	✓	✓		
Mediomastus fragilis Rasmussen		✓		✓	✓			
Modiolula phaseolina (Phillippi)		✓	✓	✓	✓	✓	✓	✓
Naididae	✓	✓	✓				✓	✓
Nematodes	✓	✓	✓	✓	✓	✓	✓	✓
Nemertines					✓			
Nephtys caeca (Fabricius)								✓
Nereis (Hediste) diversicolor (Muller)	✓			✓			✓	✓
Nereis (Neanthes) virens (M. Sars)		✓						
Nucula nucleus (L.)			✓	✓				
Nuculoma tenuis (Montagu)			✓	✓	✓	✓		✓
Ophelina ecuminata Oersted								✓
Ophiothrix						✓		
Ophryotrocha hartmanni (Huth)	✓	✓	✓	✓	✓	✓	✓	✓
Paranais litoralis (O.F.Muller)			✓					
Parathalestris clausi (Norman)		✓	✓	✓	✓	✓	✓	
Phyllodoce maculata (L.)			✓		✓	✓		
Pseudocuma longcornis (Bate)						✓		
Pygospio elegans Claparede								✓
Spio martinensis Mesnil						✓		
Spiophanes bombyx (Claparede)			✓					
Spisula solida (L.)						✓		
Tharyx vivipara (Webster & Benedict)					✓	✓		✓
Tubificoides	✓		✓	✓	✓			✓

SHORT COMMUNICATION

HARP SEAL: A NEW MAMMAL FOR THE NORTHUMBERLAND FAUNA

Plate 1: Harp Seal *Phoca groenlandica* photographed on Holy Island by P. R. Davey

In the late afternoon of 10 September 1995, G. Q. A. Anderson and M. Denny noticed a seal lying on the saltmarsh on Holy Island Snook, at grid reference NU 102 432. It had apparently been stranded on the saltmarsh by the spring high tide earlier that afternoon. They noted that it was diseased, lying still and only giving a brief growl when approached. GQAA and MD contacted the Lindisfarne NNR senior warden (P. R. Davey), who inspected it in the evening, but was not able to identify it in the very poor light then. An attempt to take it into captivity then failed, as it became more aggressive, trying to bite on close approach. The next morning, M. P. Frankis, with E. Nicholson and P. McHugh and unaware of the previous night's discovery, saw a strikingly white seal in the distance. Knowing that despite their variability, neither the Common Seal *Phoca vitulina* L. nor the Grey Seal *Halichoerus grypus* (Fabricius) are anything like as white as this seal was, MPF decided to make a closer study. On reaching it, he realized that its striking body pattern answered only to the Harp Seal *Phoca groenlandica* Erxleben. The following description was taken:

A small, earless typical seal (Phocidae) about 155-170cm (5′-5′ 6″) long (nose to tip of rear flippers), with a head shape similar to that of a Common Seal, without the 'Roman nose' shape of a Grey Seal. Most of the body was creamy white (soiled greyer by mud in places), with a dark chocolate brown horse-shoe shaped marking extending from the base of the tail, along the right flank, over across the shoulders, and back down the left flank to near the base of the tail (slightly asymmetrically). The edge of the brown was wavy and irregular, with one or two lobes and separate spots of brown extending into the white area. The head was also dark chocolate brown, forming a hood from the muzzle to just behind the ear cavities. All four flippers were white, stained grey, with five stout claws on each fore-flipper. The tail was about 12-15cm long, flattened, brown at the base and whitish at the tip. The fur was about 2cm long, dense, stiff and velvety; when dry standing stiffly out, when wet lying flat. A few small patches had lost their fur showing the skin beneath, black below the brown fur and grey-white below the white fur. Vibrissae numerous on the muzzle, whitish, the longest at the rear of the muzzle about 12cm long. The eyes were pinkish-purple, oozing fluid and appearing diseased. The seal

was lying on its belly and slightly tilted to one side in typical seal manner. On closest approach, it reared its head up in a threat display, growling and baring its teeth.

MPF, EN and PM then met PRD to discuss the seal's identity. PRD left to consult an identification guide (Corbet & Harris, 1991), returning to confirm its identity as a Harp Seal and to take photographs (Plate 1). The reference showed it to be an adult male animal. The press were also informed by journalist B. Unwin.

Following PRD's telephone discussion with the Fife Seal Research Unit, the seal was moved to the tidal mud, where it was hoped it would return to sea on the next high tide. It however went back to its previous position above the high water mark, so a veterinary inspection was made. The seal was found to have an eye infection and it was taken into care, being moved to the RSPCA wildlife hospital at East Winch, Norfolk, on 13 September. It fed well there for several days but failed to put on weight. On 3 October it suffered a sudden relapse and the decision was taken to put it to sleep to end its suffering. A *post mortem* by Mr. I. Robinson M.R.C.V.S. (*pers. comm.* to MPF) showed it to have been very old, with heavily worn teeth and very poor general internal condition (including liver failure) associated with its age, and old age was considered to be the underlying cause of death.

A photograph of the seal was published in *The Journal* (Newcastle), 12 September 1995, p.3, and it was also filmed for *BBC Look North* on 12 September.

The Harp Seal is a rare vagrant to Great Britain, with 31 recorded between 1800 and 1988 (Corbet & Harris, 1991). Searches by E. Morton and D. Noble-Rollin at the Hancock Museum in Newcastle revealed no previous county records. This is therefore the first record of Harp Seal for Northumberland.

Adult male Harp Seals are readily identified by their striking white and dark brown body pattern. Females have a similar pattern but with less contrast, the brown being paler and greyer. Immature animals up to 2-3 years old are more easily confused with Common Seals, because they do not show the bicoloured adult pattern. Structurally it is closely similar to the Common Seal, and is now normally included in the same genus *Phoca* (Ronald & Healey, 1981; King, 1993), rather than being given its own monotypic generic status as *Pagophilus groenlandicus* as often done in older texts.

Harp Seals breed in late winter on sea ice in arctic and subarctic waters, with three main breeding areas: in the Gulf of St Lawrence, Canada; around Jan Mayen, off N. Iceland; and in the White Sea, N. W. Russia. These populations are to a large degree separate but some mixing and interbreeding does occur and no infraspecific taxa are recognized. They are morphologically indistinguishable (Ronald & Healey, 1981). All the populations are highly migratory, with the St Lawrence herd regularly moving up to 4000km north-east out of the breeding season (Ronald & Healey, 1981). A tagged individual of this population has been recorded at sea off the north Norwegian coast, 4640km east-north-east of its breeding area (Sergeant, 1973).

Holy Island is within this range of the species' normal migration distances from any of the populations, but is in a direction not normally taken. The navigational accuracy of Harp Seals is noted as being exceptionally good, with eyesight being among the senses suggested as being used (Ronald & Healey, 1981; King, 1993). It is likely that this individual may have had its navigational abilities impaired by its eye infection, resulting in vagrancy in an unusual direction. The disease may also have been responsible for its seeking land in the first place and for its returning to land after being taken back to the tidal area, to avoid the likely discomfort of salt water on its inflamed eyes.

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