Determination of age, sex and origin of guillemots (Uria aalge) and razorbills (Alca torda) killed in oilspills and other incidents

Thesis

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DETERMINATION OF AGE, SEX AND ORIGIN OF GUILLEMOTS *Uria aalge* AND RAZORBILLS *Alca torda* KILLED IN OILSPILLS AND OTHER INCIDENTS

A dissertation submitted to The Open University in part fulfilment of the requirements for the degree of Master of Philosophy (Science - Biology).

Peter Hope Jones

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Menai Bridge,
Gwynedd.

Date of submission: April 1985

Date of award: 1 July 1985

DECLARATION

The substance of this dissertation has not already been submitted for any degree or other qualification, either to The Open University or to any other university or institution.

Some of the data in this dissertation have been published; they are contained in Jones et al, in the Reference section, Chapter 8, of the present work.

Signed ....

(Candidate)

This is to certify that the work here submitted was carried out by the candidate himself. Due acknowledgement has been made of assistance received.

Signed ....

(Internal Supervisor)

Signed ....

(External Supervisor)

Signed ....

(Candidate)

ABSTRACT

Large numbers of auks (Alcidae) have died in recent years in a variety of mortality incidents, many of which resulted from oil pollution. This thesis explores the background to determining age, sex and origin of Guillemots Uria aalge and Razorbills Alca torda involved in such incidents, and presents data resulting from the examination of these birds.

Ageing factors considered were cloacal bursa, supra-orbital ridge, gonad size, wing and bill measurements, and bill grooves in Razorbills. Most ageing factors were mutually supportive, though as yet there were only few confirmations from known-age birds.

Sex determination was usually straight-forward, based on gonadal inspection. Especially in adults, males were on average shorter-winged and bigger-billed than females in both species; however, individual birds could not safely be sexed from external measurements. Sex ratios, from various mortality incidents, were mainly equal in Razorbills of all ages and in adult Guillemots.

Origins of Razorbills could be fixed morphometrically from size (as indicated by winglength and bill depth), which separated most birds of the form torda (breeding in Scandinavia and Russia) from those of the form islandica (breeding in France, Britain, Ireland, Faroe and Iceland). Guillemots could be fixed more closely using three parameters which increased clinally through western Europe towards the north: winglength, proportion of bridled birds, and degree of colour saturation of upperparts.

A knowledge of the age, sex and origin of auks involved in mortality incidents is important in contexts of conservation and of population ecology. Present knowledge could be particularly improved through the implementation of a minimum standard system of examination of auks killed in incidents; the storage and study of known-age (ringed) auk corpses; and the acquisition of more data on fine-grain taxonomy in European auks.

ACKNOWLEDGEMENTS

In a wide-ranging study of this nature, it is not possible for one person to collect all the necessary raw data, and I am primarily grateful to those many enthusiastic workers, in several parts of Europe, who helped me with auk examinations at mortality incidents; who facilitated my visits to museums and auk colonies; or who sent me raw data (these last are duly acknowledged in the text and tables). Although too numerous to name individually, their help and co-operation is very gratefully acknowledged.

Throughout the preparation of this thesis, the assistance of my two supervisors, Dr.T.Halliday and Dr.R.Mitchell, was invaluable, and I thank them very much for their support through my several employment and location fluctuations.

Whilst working in Aberdeen, I was helped in numerous ways by the other members of the Nature Conservancy Council's Seabirds at Sea Team: Dr.B.F.Blake, Mr. T.J.Dixon and Mr.M.L.Tasker. In Menai Bridge, Professor G.E.Fogg kindly allowed me working space in the Marine Science Laboratories, Mr.W.Wormald was very helpful with my library queries, and Mr.E.I.S.Rees helped particularly with constructive discussion on auk taxonomy. At several stages I was encouraged, and given museum access and facilities, by Mr.P.J.Morgan at the Zoology Department of the National Museum of Wales in Cardiff.

At certain of the auk mortality incidents I was provided with subsistence or facilities by the Nature Conservancy Council and the Royal Society for the Protection of Birds, and I acknowledge with thanks their contributions.

It has been a pleasure to explore this topic in great detail with three friends in particular: Trina Barrett, Ken Partridge and Tim Stowe, and I would like to record my appreciation for their interest in this work, and for their stimulating discussions.

For having typed out much of the first draft and all of the final draft, I extend my very sincere thanks to Joan Lewis.

Finally, it is most unlikely that this work would have been collated in this form without the existence of The Open University; I thank particularly Dr.H.Williams and Dr.P.R.Thomas of the Cardiff office for having set me off on the right footing, and to the Walton Hall establishment for having kept me on course thereafter.

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1. INTRODUCTION, AND OBJECTIVES

Auks affected by oilspills are a recurring phenomenon in 20th century ornithology, with numerous papers and reports attesting to the interest and concern which they have aroused. Bourne (1969) has summarised the occurrences up to 1968, since when there have been some major, and many minor incidents involving auks and oil. However, auks are also prone to 'wrecks' - arrivals of dead and dying unoiled birds on beaches, usually after storms at sea - and an incident of this kind in the Irish Sea in the autumn of 1969 was deemed serious enough to warrant a government enquiry, though with inconclusive results (Holdgate 1971).

Auks are very vulnerable to surface-borne oil pollution because most of their lives are spent at sea, and because their natural escape reaction to threats is usually to dive rather than to fly away. Guillemots and Razorbills are abundant in Britain and Ireland, with populations of breeding individuals in excess of 745,000 and 140,000 respectively (Stowe 1982). It is perhaps not surprising, therefore, that in the beached bird counts organised by the Royal Society for the Protection of Birds, these two species figure predominantly, with Guillemots second in order of abundance in the list of birds found (and 58% of them oiled) and Razorbills fourth (and 61% of them oiled).

Hence, Guillemots and Razorbills have been turning up on beaches in high numbers, and they were being oiled at a level which potentially could affect the size of their breeding populations in N.W.Europe. It was felt that at least two parameters, and possibly a third factor, could be discovered from samples of beached auks: the age and sex composition of any given sample, and some indication of the natal origin of the birds involved. Additional data would doubtless accrue on various other factors.

These three objects of investigation can be of considerable conservation significance. Guillemots and Razorbills are long-lived seabirds with the concomitant low adult mortality and low annual productivity which this strategy normally involves (Birkhead & Hudson 1977; Lloyd & Perrins 1977). In any mortality incident, it is valuable to know the age proportion in the birds involved - a high proportion of dead adults is likely to be more damaging to the population than a high percentage of immatures (some of which would have died anyway before recruitment into the breeding population). It is also valuable to know whether auks, outside the breeding season, may segregate - with sexes or age cohorts using separate areas for 'wintering' or feeding. Finally, it is essential to know the origins of stricken auks, since conservation measures for greater protection might be applied in one country if a high percentage of its breeding auks were known to be dying in winter in another country.

It might be considered that most of these points can be covered by the ringing programme organised in UK by the British Trust for Ornithology. With the increased level of auk ringing in recent years, more information is certainly emerging on the origins and ages of birds involved in wrecks, but the ringing returns are biased in that auks are ringed only at selected colonies (usually those relatively easy of access). Furthermore, ring wear has, until recently, militated against an accurate assessment of age cohort mortality patterns, and in any particular incident the number of rings found is usually too small for a confident prediction of age proportions in the incident overall. Because neither chicks nor adults can be sexed in the hand, and because finders only very rarely dissect a ringed bird, the ringing programme can contribute very little to a knowledge of sex proportions in beached birds. Auk ringing in other European countries (with high auk populations) is similarly biased, and in some instances negligible in extent. Ringing returns may not, therefore, be particularly useful in determining the proportions of birds from different natal origins involved in one winter incident. Thus in this context there is potentially a strong role for results from morphometric examination - not to duplicate the results from ringing, but to complement them, and perhaps to add significantly to the data thus collected.

The main objectives of the present study were to assess the methods for determination of age, sex and origin in Guillemots and Razorbills; and to present data for these three factors, especially by reference to examination of birds killed in oilspills and other mortality incidents.

2. RATIONALE

In dealing with auk mortality incidents, ornithologists have been slow in capitalising on knowledge from an obvious source of study material, however unfortunate its origin. The usual reaction to a wreck of beached birds has been - until recently - a survey of affected beaches, resulting in a corpse count of the various species involved, with the birds subsequently being buried or at least thrown away above the high water mark. This is considered to be a wasted opportunity, because so much more could be discovered from a short, but well-organised, examination of each corpse. Since the time of this investigator's involvement in the Amoco Cadiz oiling in Brittany in 1978, serious efforts have been directed towards establishing just such an examination system. The present thesis results from this work.

Early in this study, there emerged an obvious need for greater knowledge of the fine taxonomy of Guillemots and Razorbills in N.W. Europe. By 1940, early taxonomists had arrived at a consensus on the broad grouping of geographical forms within these two species and - give or take a few subspecies - there has been little change since that date. The emphasis, amongst active ornithologists, has changed from debating the subspecific rank of Guillemots on, for example, Helgoland (Lönnberg 1923) or Ailsa Craig (Gibson 1951), to debating the field identification of sibling auk species (van den Berg 1980), with the main objective of listing a rarity. Those few workers who tried to work to taxonomic principles with auks from mortality incidents were having to rely on the fundamental (but difficult-to-obtain) works of Salomonsen (1944) and Storer (1952), or on the highly condensed summaries in Witherby (1941) and Vaurie (1965). There was the further complication that a new generation of ornithologists, trained in field techniques, sometimes tended to apply, without the necessary caution and constraint, various conclusions from museum work to live or freshly dead birds. Hence the need, in the 1980s, for a closer and more critical look at the taxonomy of live or freshly dead birds, and a careful comparison with results from work on dried skins.

With the advent of ringing, and particularly of mistnets, small birds were more easily trapped for examination in the hand, and as a result the ageing and sexing of passerines has been developed to a very high degree (Svensson 1984). Most ringers handle seabirds only at breeding colonies, where birds are easily assigned to one of two categories: chick or adult. Of the few ageing criteria used in the 1970s for Guillemot and Razorbills, most emanated from the inspired experience and intuition (rather than from a study of known-age birds) of taxonomists of the 1930s and 1940s (Witherby et al. 1941).

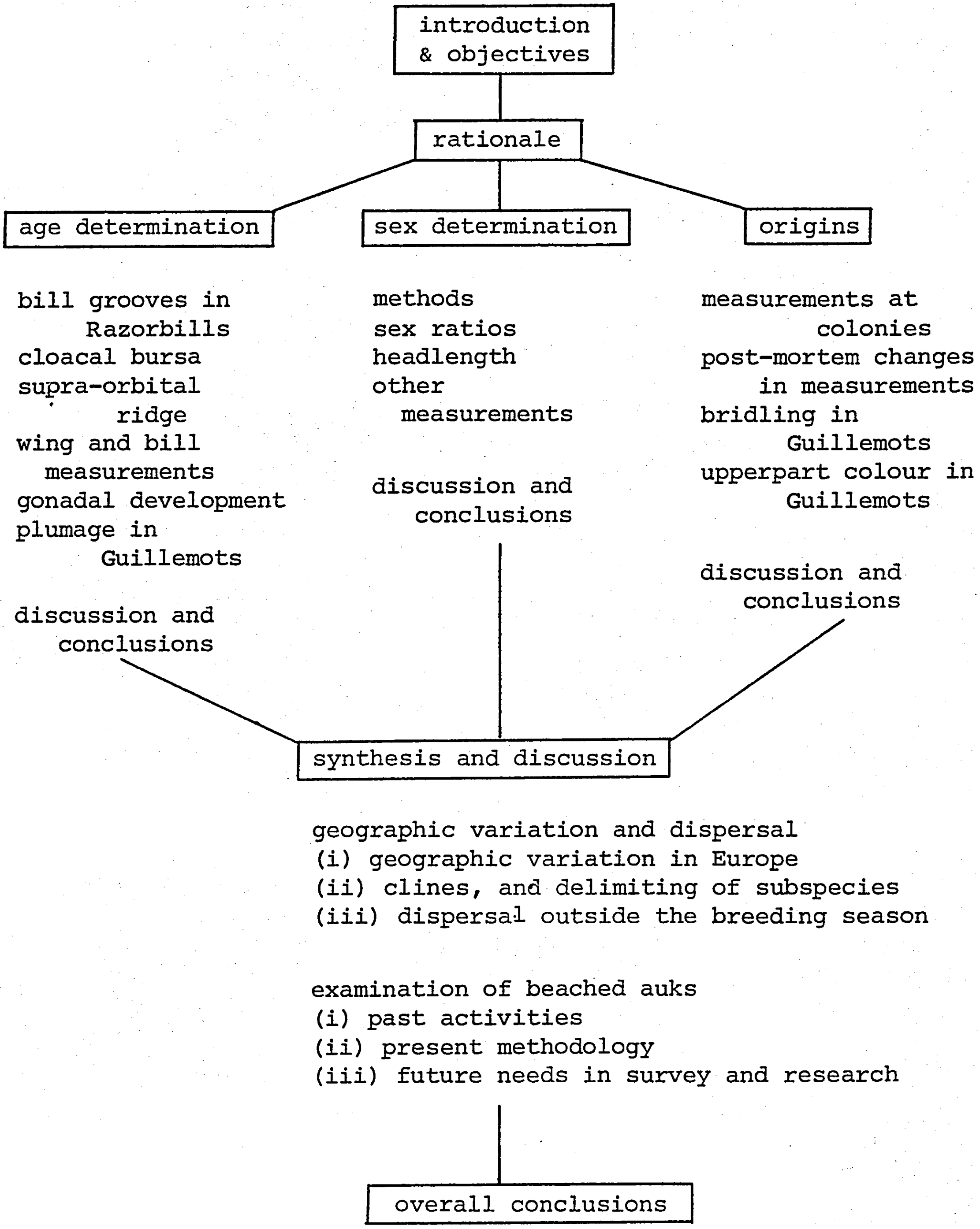
The large samples of auks emanating from mortality incidents can provide a wide range of data. There seems never to have been one person in U.K. working fulltime, or even mainly, on auk taxonomy or on collecting and assessing the results from examination of auks in mortality incidents. The inevitable consequence is an effort by amateurs, including the present investigator, in trying to salvage potentially useful information from an otherwise badly neglected topic.

In order to collect the maximum information in the shortest time, a technique was evolved for the rapid examination of corpses. This led to the production of a manual: The examination of birds killed in oilspills and other incidents (Jones et al. 1982), (Appendix I). Most of the data for dead birds reported in the present thesis were collected on forms similar to that shown on page 32 of that manual. A report was produced after each investigation. The list of reports is produced in Appendix II, and data from these are used in the appropriate sections of this thesis. The raw data are held either by the present investigator or by the Seabirds at Sea Team of the Nature Conservancy Council in Aberdeen.

Most of the results presented here were from information collected, collated, or elicited by the present investigator, but in this field it was necessary to rely on the willing assistance of large numbers of helpers, so to this extent the basic data base results from the contributions of numerous ornithologists over the past few years. The working up of results, and the conclusions, are the writer's own work and responsibility.

The subject of this thesis covers an extensive field, and in order to draw conclusions it was necessary to tackle several topics in greater depth than hitherto reported in the literature. The three topics of age, sex and origins in the auks are inter-related to varying degrees, and the complexity of these relationships and their ramifications led to the scheme of presentation shown in Fig.1. An attempt is made to deal with each major topic separately, by considering those aspects most germane to that topic; the results are then presented as a synthesis of existing knowledge, with overall conclusions and suggestions for needs in clarifying further the present position.

Fig. 1. Scheme of presentation used in the thesis.



3. AGE DETERMINATION

3.1 Bill grooves in Razorbills

The system for recording the configuration of bill grooves in Razorbills is shown in Appendix I (Section 3.2 Fig.1). Since beached birds are found throughout the year, birds with intermediate features will appear occasionally: in this study, all birds with such features have been scored in the next highest category: for example, a Razorbill showing the evident start of a second black bill groove (W + 1½) has been recorded as W + 2.

The only ringed bird examined as a museum skin had a bill of 0 + 0 in its 1st winter (October). The remaining data all stem from examination of ringed birds retrapped at breeding colonies in subsequent years.

In a series of 127 known breeders (caught whilst with egg or chick at the breeding site), 80% were W + 2, but there were also birds with w + 3 (10%) and W + 1 (10%) (Table 1). At this stage, it is not known whether the increase in proportion of W + 3 bills from 3% at Great Saltee, through 7% at Foula, to 31% in Iceland, is a true reflection of the situation or merely due to chance in small samples.Taking another approach, the known ages of a series of birds with different bill configurations are shown in Table 2. Patently, birds can reach W + 2 by their 4th summer, but some also remain at W + 1 for longer than three or four years, thus providing the small percentage of breeders with this bill type.

Table 1. Razorbill: bill grooves of known breeders (taken off egg or chick).

	nos. of birds in each bill type			
locality	W+3	W+2	W+1	authority
Great Saltee	1	28	6	PHJ
Bardsey	0	19	3	PHJ *et al.*
Shiants	0	3	0	D. Steventon
Foula	3	35	3	M.L.Tasker
Grimsey (Iceland)	8	17	1	PHJ
totals	12 (10%)	102 (80%)	13 (10%)	

Table 2. Razorbill: bill grooves and ages of birds retrapped at colonies; data from Great Saltee, Bardsey, Shiants (per D.Steventon) and Fair Isle.

Age in years: $\underline{\text{underlined}}$ = true age (ringed as pullus)
'+' = minimum age (ringed as adult)

bill grooves	age	number of birds
W + 2	12+	1
	9+	1
	8+	3
	$\underline{7}$	2
	6+	3
	$\underline{6}$	2
	5+	6
	$\underline{5}$	4
	4+	3
	$\underline{4}$	1
W + 1	7	1
	5+	1
	$\underline{4}$	4
	$\underline{3}$	5
W + 0	$\underline{2}$	1

(birds retrapped one or two years after having been ringed as adults are not included in this table)

3.2 Cloacal bursa

The cloacal bursa, or bursa of Fabricius, has been used in North America for some years as a method of separating first-year from fullgrown gamebirds (Gower 1939): the organ was well-developed in young birds but absent in sexually mature birds.

During the course of internal examination, a search was routinely made for the cloacal bursa; location and measurements are shown in Appendix I: section 4.6 and Fig.11. When present, the organ was usually fairly readily visible, and measurement normally presented few problems (length and breadth were measured to allow for the organ's inherent plasticity), though it could be difficult to detect if obscured by visceral fat. It is likely that very small bursae would have been missed for two reasons: many of the birds handled were in early stages of decomposition so the small organ may not have been easily identifiable; the necessity for rapid examination (under the pressure of time shortage and large numbers of corpses) could have led to a small bursa's being overlooked. With practice, however, these problems would have been reduced, and it is likely that the majority of bursae were found, measured, and duly recorded.

Bursa details for known-age birds are, at present, lamentably few, though more will become available with increasing numbers of ringed auks examined. Ringed birds have provided the following details so far for Guillemots: one bird two-months old had a bursa of 24 x 14 mm (index = 336), one 1st winter bird had a bursa 19 x 11 mm (index = 209), whereas none of four birds of over 5,6,8 and 10 years had a bursa. There are no reliable data for ringed Razorbills.

In Razorbills, however, there is an independent source of ageing - the bill grooves, and for one large sample collected in February 1983, it was possible to demonstrate bursal presence in relation to age (Table 3) and decreasing bursal index with increase in bill grooves, and hence of age (Table 4). All 1st-winter birds had a bursa, and none of the adults; most of the presumed younger immatures had a bursa, but very few of that group probably comprising a mixture of immatures and adults. Other data are for small numbers scattered through the year, so it is not yet possible to show bursal size linked to time of year. A very few of the adult birds (bill W + 2, W + 3) were found to have a very small bursa; although the birds' breeding status was not known, it seems likely that, in Razorbills, a very low proportion of adults (perhaps less than 0.5%) may show a visually detectable bursa.

In Guillemots there are no independent and completely validated ageing criteria against which bursal size (or even presence) can be tested, but a combination of bursa details with other facets of corpse examination (gonad development, bill depth at gonys, plumage phase, and winglength) can produce good supportive evidence to suggest that presence of bursa is an indication of immaturity and its absence an indication of adulthood. This linking of data is demonstrated later.

Table 3. Details of cloacal bursa for Razorbills examined in the east coast wreck of February 1983 - data pooled for birds from Moray Firth, N.E.England and E.Anglia (from Jones _et al_. in press).

bill grooves (and probable ages)	sample size	% of birds with bursa	mean bursal index (length x breadth in mm)
W+3, W+2 (adult)	462	0	0
W+1 (immature, possibly some adults)	74	9	38
W+0 (immature)	89	81	47
0+0 (1st winter)	109	100	98

Table 4. Bursal size index for three bill classes of Razorbill, February 1983. Data from Orkney and N.E.England (examined by PHJ) pooled with those from Moray Firth (examined by C.F.Barrett and G.P.Mudge).

bill type	male				female			
	sample size	mean (mm)	s.d.	range	sample size	mean (mm)	s.d.	range
0+0 (1st winter)	41	113.8	47.5	60-285	37	108.5	37.9	40-220
W+0 (immature)	17	49.8	24.4	20-104	50	46.8	22.9	15-98
W+1 (probably immature)	2	43.0	31.1	21-65	2	34.0	8.5	28-40

3.3 Supra-orbital ridge

In 1981 J.R.Mather (pers.comm.)pointed out the bony ridge above the eyesocket in Guillemots and Razorbills as a probably valid method of ageing these species: apparent adults had a well-developed ridge over each eye-socket, with apparent immatures and/or first-winter birds lacking the feature altogether. Mather assumed that the ridge developed with the age of the bird and that it was a consequence of increasing ossification of the cranial section of the skull. Independently, Gaston (pers.comm)had noticed the same feature, and in 1984 he produced a paper suggesting that the absence of the ridge was a feature of first-winter Brünnich's Guillemots (Gaston 1984).

Following a viewing of Mather's specimens in 1983, I checked the skins at the museum in Cardiff for this feature. The supra-orbital ridge was normally not easy to detect by finger pressure in mounted specimens, but in study skins and in fresh carcases the feature was readily detectable with only a little practice. For Razorbills, there was an independent assessment of age from the bill grooves, and comparison showed that the ridge was absent from practically all first-winter birds, and present in all of the few adults available for examination; interestingly, a number of immature birds showed intermediate characters. A very similar result was obtained for a sample of Razorbills from Orkney (Table 5).

With this success in a species where age could be independently assessed, the technique was applied to Guillemots where no such check was possible (Table 6). In study skins, there were significant differences between gonys-depth means for the three categories of supra-orbital ridge; a similar result was achieved with unskinned corpses though the samples were too small for testing. In the latter case, too, mean winglength showed a substantial rise with increasing development of the ridge.

Thus, as a technique for ageing Guillemots and Razorbills, tactile examination for the presence or absence of the supra-orbital ridge showed distinct promise, though its reliability must be checked against known-age birds before it can be validated for universal application.

Table 5. Examination of Razorbills for supra-orbital ridge.

(a) Flat study skins held at the National Museum of Wales, Cardiff; examined in May 1983.
Birds' origins: Dyfed and Cornwall, 1978 and 1979.

	supra-orbital ridge			totals
bill type	obvious	slight	absent	
W + 3	3			adult: 4
W + 2	1			
W + 1	4	1		immature: 25
W + 0	16	4		
0 + 0		2	76	1st winter: 78

(b) Corpses, unfrozen after deepfreeze storage, Aberdeen; examined in June 1983.
Birds' origins: Orkney, February 1983.

	supra-orbital ridge			totals
bill type	obvious	slight	absent	
W + 3	14			adult: 22
W + 2	8			
W + 1	4	2		immature: 13
W + 0	1	6		
0 + 0		6	19	1st winter: 25

Table 6. Measurements of Guillemots classified by presence of supra-orbital ridge.

(a) Flat study skins held at the National Museum of Wales, Cardiff; examined in May 1983.
Birds' origins: Dyfed and Cornwall, 1978 and 1979.

ridge	bill depth at gonys				
	n	mean (mm)	standard deviation	range	significance
well-developed	114	12.06[a]	0.48	11.0 - 13.1	p<0.001
slight	32	11.45[b]	0.36	10.8 - 12.3	p<0.001
absent	136	10.98	0.51	9.4 - 12.0	

(Notes: (a) 1 outlier @ 13.6 omitted; (b) outlier @ 10.3 omitted; wing length values were probably not valid because putative adults and immatures were in primary moult in many cases.

(c) means are significantly different (5% level) - Tukey-Kramer ANOVA.

(b) Corpses, unfrozen after deep freeze storage, Aberdeen; examined in June 1983.
Birds' origins: Orkney, February 1983.

ridge	bill depth at gonys			
	n	mean (mm)	standard deviation	range
well-developed	16	13.09	0.50	12.2 - 14.2
slight	8	12.39	0.63	11.6 - 13.7
absent	13	11.03	0.48	10.4 - 12.0

ridge	winglength			
	n	mean (mm)	standard deviation	range
well-developed	16	206.1	4.56	201 - 214
slight	8	205.5	3.74	202 - 212
absent	13	199.8	4.34	192 - 206

3.4 Wing and bill measurements

The method used in measuring the straightened, flattened wing is shown in Appendix I (section 3.6 and Fig.4). Of the various parameters which have been measured on birds' bills, two were chosen for this study in the belief that the length of the culmen and the depth of the bill at the gonys would adequately represent the gross size-and-shape of the bill for each individual measured. Methods of measurement are shown in Appendix I (sections 3.7 and 3.9 and Figs 5 and 6).

Measurements for adult Razorbills and for Guillemots caught in breeding colonies are shown later in Tables 32 to 36, but measurements for separated age cohorts (measured freshly dead at mortality incidents) are shown in Tables 7 and 8. As yet, the data for known-age birds are few (Table 9), but for Guillemots there are interesting indications of an emerging pattern: birds in the first few months after leaving the natal colony are small in all three parameters; one bird in the 2nd winter has adult-sized wing and culmen, but is still small in gonys depth, whereas in adults (perhaps including an older immature in its 4th winter), wing and culmen are full-sized, but there is a possibility that bill depth at gonys may increase towards the breeding season, though even in winter being on average larger than that of immatures.

In Razorbills, there is a considerable difference in measurements between the age cohorts when bill-groove configuration is taken as an indication of age. Details from samples collected in February 1983 are shown in Table 8. There are occasional significant differences within the same age group between localities (perhaps more likely a function of different measurers than of different bird population), but in the main the data are remarkably homogeneous within age classes. The very obvious difference is between 1st winter birds and older birds for all three parameters; there is also a marked increase in winglength and in bill depth between each age class ($p<0.001$ in six winglength comparisons and in six bill depth comparisons) though the culmen change, even if real, is much less convincing ($p<0.01$ two comparisons, not significant in four). The range of variation with increasing age is shown through a series of distribution polygons, for the east coast wreck data, in Fig 2. There was no overlap in measurements between 1st winter and adults, but the W + 1 group was almost entirely contained within the full adult distribution.

If the presence of cloacal bursa in Guillemots is taken as evidence of immaturity, then there is a regular difference in measurements between the two age cohorts. Details for five of the largest samples are shown in Table 7. In the four cases where a t-test is valid, there were significant differences between adults and immatures in length of wing ($p<0.001$) and in bill depth ($p<0.001$); for three comparisons of culmen length, means for adults and immatures were also significant ($p<0.002$ for Moray Firth, $p<0.001$ for N.E.England and E.Anglia). In a variety of incidents where small numbers of birds were involved, the same degree of difference between adults and immatures was envinced, even though the means could not be statistically compared.

Table 7. Guillemot: measurement differences between adults and immatures separated on the basis of absence and presence, respectively, of cloacal bursa.

locality and date	age	sample size	wing mean (mm)	s.d.	culmen mean (mm)	s.d.	gonys mean (mm)	s.d.
Buchan March 1982	ad.	193	205.1	4.3	48.4	2.4	13.6	0.5
	im.	17	199.9	4.2	46.7	2.0	11.7	0.7
Moray Firth Feb. 1983	ad.	43	205.9	5.2	47.8	2.8	12.6	0.7
	im.	59	198.2	5.4	46.1	2.4	11.7	0.6
N.E.England Feb. 1983	ad.	71	205.4	4.8	48.2	2.2	13.2	0.7
	im.	100	198.1	4.4	46.6	2.4	11.8	0.6
E.Anglia Feb. 1983	ad.	101	204.4	4.6	46.8	2.9	13.4	0.7
	im.	91	199.7	5.2	44.8	2.7	12.4	0.5
Skagerrak Jan. 1981	ad ♂	68	206.5	4.1			12.9	0.6
	ad ♀	72	208.3	5.3			12.6	0.6
	im ♂	331	200.1	4.8			11.9	0.6
	im ♀	326	200.3	4.4			11.5	0.6

Measurements for Guillemots and Razorbills in the Moray Firth (1983) were made by C.F.Barrett and G.P.Mudge, those for East Anglia by C.F.Barrett and G.Doré. These measurements are also used in some other tables.

Table 8. Measurements for three age cohorts of Razorbills from samples found in the east coast 'wreck' of February 1983.

age and bill	sample size	wing mean (mm)	s.d.	culmen mean (mm)	s.d.	gonys mean (mm)	s.d.	locality
adult (W+2, W+3)	114	197.1	4.4	32.9	1.7	19.6	1.0	(a)
	145	197.2	4.6	32.4	1.5	19.6	0.8	(b)
	193	197.1	4.1	31.7	1.6	19.9	0.8	(c)
immature and a few adults (W+0, W+1)	44	193.9	4.3	32.7	1.6	18.1	1.0	(a)
	51	193.1	3.7	32.3	1.4	18.6	1.0	(b)
	63	194.6	4.1	31.4	1.5	18.9	1.0	(c)
1st winter (0+0)	37	187.5	4.2	31.9	1.9	14.8	0.8	(a)
	36	189.0	3.9	31.3	1.5	15.0	0.7	(b)
	27	189.8	3.3	30.5	1.5	15.1	0.7	(c)

given sample size is for winglength; it varied slightly for other parameters.

Measurements:
(a) Moray Firth: C.F.Barrett & G.P.Mudge.
(b) N.E. England: PHJ
(c) E. Anglia: C.F.Barrett & G.Doré.

Table 9. Measurements of ringed, known-age birds, measured fresh when recovered away from breeding colonies.

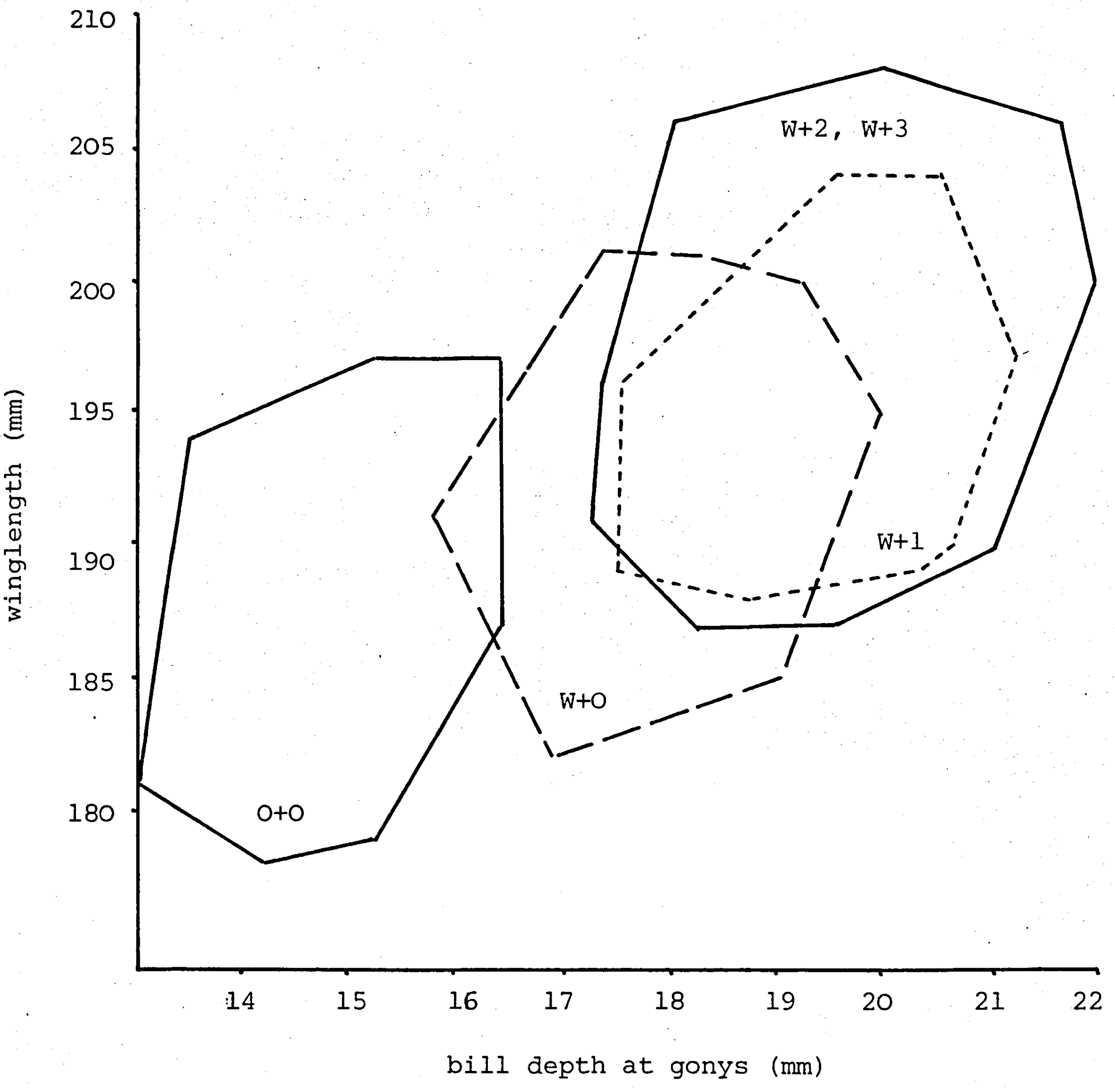
ringing locality	age when recovered	wing	culmen	gonys	recovered month	recovered locality
RAZORBILL						
Wexford	1st W	191	29	14.6	Oct.	Dyfed
GUILLEMOT						
Shetland	2 months	184	40	10.1	Aug.	Sweden
Shetland	3 months	194	39	10.3	Oct.	Orkney
Wexford	3 months	190	40	10.8	Oct.	Dyfed
Wexford	2nd W	202	47	11.6	Oct.	Dyfed
Grampian	4th W	194	45	12.5	Feb.	Devon
Dyfed	6th W	194	47	14.1	Mar.	Cornwall
Grampian	5+	205	49	13.6	Mar.	Grampian
Faroe	9+	209	46	12.9	Apr.	Berwickshire
Faroe	10+	208	44	12.4	Jan.	Oslofjord, Norway

Measurements, at Fair Isle in June 1980, of 29 ringed Guillemots known to have been at least five years old:

	n	mean	s.d.	range
winglength	25*	208.0	4.2	200-214
culmen	29	46.6	2.1	42-51
gonys	29	13.6	0.6	12.7 - 15.0

* 4 wings too abraded for accurate measurement.

Fig. 2. Distribution polygons for winglength and bill depth measurements of Razorbills _Alca torda islandica_ beached in the Moray Firth, N.E. England and E. Anglia in February 1983.



3.5 Gonadal development

Measurement of gonads was restricted to three parameters: length and width of the left testis in the male, and diameter of the largest ovarian follicle in the female. Another valuable feature in separating age cohorts is the diameter of the oviduct, but this measurement proved rather difficult to standardise, and the oviduct seemed to degenerate very quickly in decomposing birds, so this feature was not regularly checked (in an examination method where pressure of time allowed no scope for long search and investigation in individual birds). Measurement methods are described in Appendix 1 (sections 4.1 to 4.3 and Fig.10).

In males, the breadth of the testis seemed a much better indicator of the degree of development than did the length. This was tested for Guillemot in two pooled samples from February 1983 (Table 10): whereas the difference in mean testis width between adults and immatures was significant ($p<0.001$), there was no significant difference between means for testis length. However, in Razorbills (Table 11) means for both parameters were significantly different ($p<0.001$). Whilst testis length and breadth were, a priori, likely to comprise normal distributions, the small size of the latter and the relatively large steps in measurement indicated that the median was perhaps the more realistic parameter.

There was a difference between Guillemot age cohorts in the degree of gonadal development at all times of year (Tables 13 and 14, and Fig.3) except for females in autumn where the follicles of all ages were very small. The collated results, although derived from a wide variety of sources throughout Britain, are beginning to achieve a respectability of sample size for most seasons (the three periods of the year being derived from visual inspection of Table 13), and various conclusions can probably validly be drawn:

(i) in adult males, testis width varied from 1 to 6 mm in autumn and winter, and from 1 to 8 mm in spring and summer, the median value rising from 3 to 4 mm;

(ii) in immature males, testis width varied from 1 to 4 mm in autumn and from 1 to 6 mm in spring and summer, the median value remaining at 1 or 2 mm;

(iii) in adult females, diameter of largest follicle varied from less than 1 mm to 7 mm in autumn, rising to 1 to 5 mm in spring and summer, the median value rising from <1 mm to 3 mm;

(iv) in immature females, diameter of largest follicle varied from less than 1 mm to 2 mm in winter (as in adults), rising to 1 to 3 mm in spring and summer, the median value rising from <1 mm to 1 mm;

(v) at each season, and for both sexes (except for autumn females), the median value for each parameter was higher for adults than for immatures aged on absence or presence, respectively, of cloacal bursa;

(vi) the considerable spread of values at each season would not allow for safe assignment of age category to individual birds on the basis of the stated gonadal measurements, though a substantial difference between ages was evident in large samples.

For Razorbills, the only substantial sample was that for February 1983 (detailed in Table 12), so a similar analysis must await the collection of the relevant data.

Table 10. Guillemot: length and breadth of left testis for pooled samples from Moray Firth and N.E.England in February 1983: numbers in each 1 mm size class.

mm.	length		breadth	
	no bursa (ad.)	with bursa (im.)	no bursa (ad.)	with bursa (im.)
15		2		
14	1			
13	3	10		
12	6	17		
11	12	13		
10	15	18		
9	7	21		
8	2	17		
7	1	6	1	
6			3	
5			8	
4			20	1
3			8	4
2			6	36
1			1	63
sample size:	47	104	47	104
mean:	10.5	10.1	3.9	1.5
standard deviation:	1.4	1.9	1.2	0.6
median:	10	10	4	1

Table 11. Razorbill: length and breadth of left testis for pooled samples from Moray Firth and N.E.England in February 1983: numbers in each 1mm size class.

mm.	length		breadth	
	W+2, W+3 (ad.)	0+0 (im.)	W+2, W+3 (ad.)	0+0 (im.)
13	2			
12	6			
11	11			
10	22	3		
9	25	4		
8	21	1		
7	8	10	1	
6	3	7	3	
5	2	8	10	
4		1	44	
3			34	
2			7	14
1			1	20
sample size:	100	34	100	34
mean:	9.2	6.8	3.7	1.4
standard deviation:	1.6	1.7	1.0	0.5
median:	9	7	4	1

Table 12. Gonadal development, as indicated by two parameters, in age cohorts: percentage in each size class with median values underlined. Data from the east coast 'wreck' of February 1983.

RAZORBILLS

MALES

age (bill grooves)	testis width (mm)							sample size	significance (t-test)
	1	2	3	4	5	6	7		
adult (W+2, W+3)	1	7	37	39	13	3	1	180	
									p<0.001
imm. (W+1, W+0)	18	55	21	5	1	0	0	66	
									p<0.001
1st winter (0+0)	60	40							

FEMALES

age (bill grooves)	mean width of largest follicle (mm)				sample size	
	<1	1	2	3		
adults (W+3, W+2)	31	26	39	4	279	
						p<0.001
imm. (W+1, W+0)	71	17	10	1	101	
						p<0.001
1st winter (0+0)	100	0	0	0	47	

GUILLEMOTS

MALES

age	testis width (mm)							sample size	
	1	2	3	4	5	6	7		
adult (no bursa)	2	10	27	42	12	5	2	93	
									p<0.001
imm. (with bursa)	49	46	3	1	1	0	0	157	

FEMALES

age	mean width of largest follicle (mm)				sample size	
	<1	1	2	3		
adult (no bursa)	15	31	42	12	123	
						p<0.001
imm. (with bursa)	84	4	12	0	94	

Table 13. Guillemots: testis width measurements in males at various times of year and, for females, diameter of largest ovarian follicle. Figures show numbers of birds in each size class.

testis width (mm)	adult (no bursa)										immature (with bursa)									
	A	B	C	D	E	F	G	H	I	J	A	B	C	D	E	F	G	H	I	J
8									2	2										
7								1	1											
6		2			1			3	8	3										1
5		18			5	1	3	4	28	3										2
4		39	1		4	2	3	8	38	4		2								4
3	2	29		3	9	4	3	1	20	2	1	5								2
2	1	28				3			5		2	28	14	7	2	31			2	2
1	1	1							1			35	18	8	1	28		1	8	2
sample size:	4	117	1	3	19	10	9	17	103	14	3	70	32	15	3	59	0	1	14	13

max. follicle diam. (mm)	A	B	C	D	E	F	G	H	I	J	A	B	C	D	E	F	G	H	I	J
5								1	1	2										
4							1	7	13	3										
3					1	5	5	7	29	1										2
2		7			8	9	10	10	51	1		4				7				1
1	2	11	1		2	3	2		1			9				16			3	2
<1	8	21	3	3							5	27	2			22				
not visible												22		7			1			
sample size:	10	39	4	3	11	17	18	25	95	7	5	62	2	7	0	45	1	0	3	5

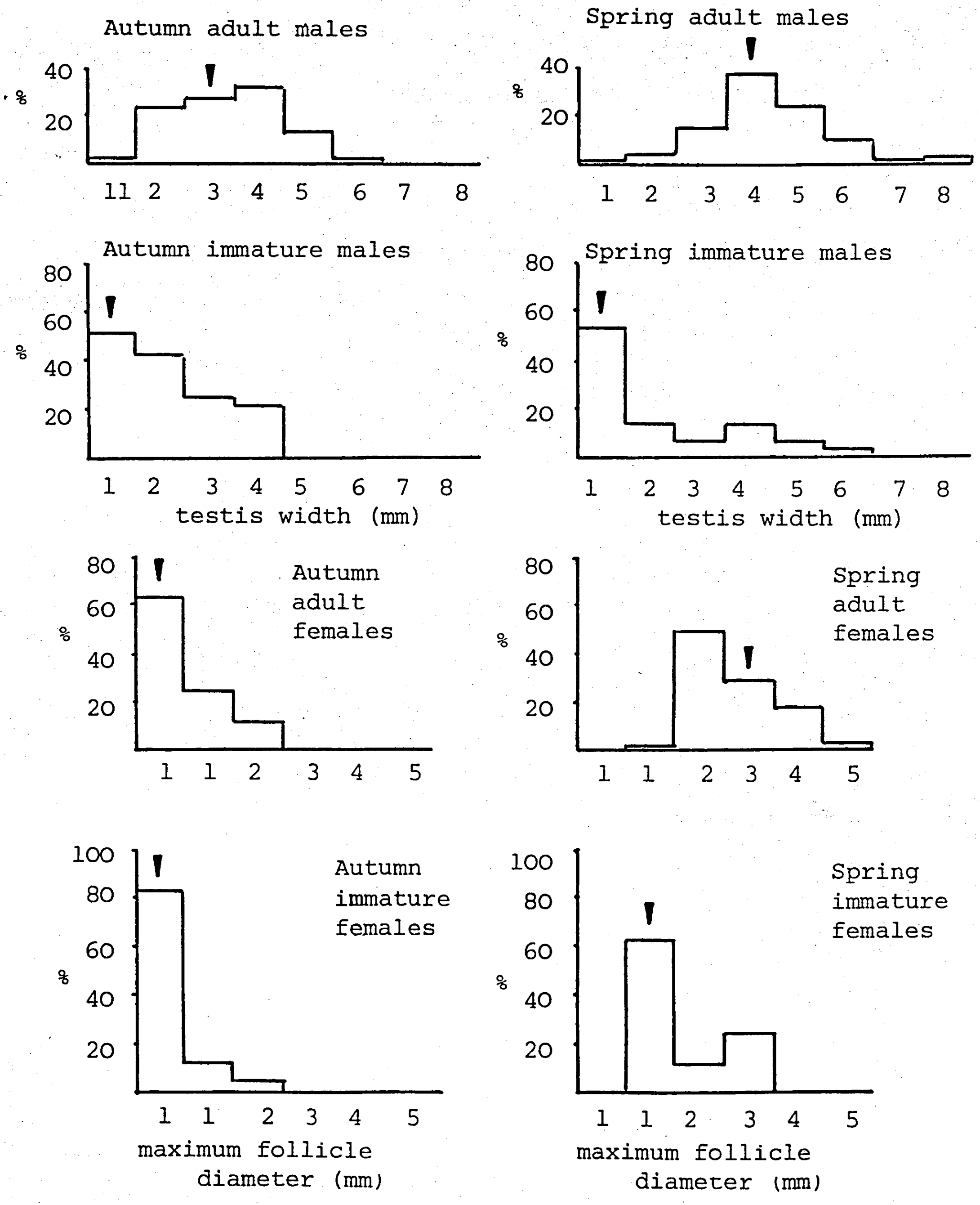
Sample localities and dates: A: Grampian, August 81;
B: Newcastle, September 81; C: Aberdeen, Sep. 81;
D: Orkney, October 81; E: Stonehaven, winter 81/82;
F: Devon, Cornwall, winter 80/81; G: Shetland, January 82;
H: Forth, March 82; I: Buchan, March 82;
J: Shetland June 81.

Table 14. Guillemots: collated results for gonad development with season. Figures are percentages for each gonad size class within the sample for that season; median values underlined.

testis width (mm)	adult (no bursa)			immature (with bursa)		
	autumn (Aug-Oct)	winter (Nov-Feb)	spring/summer (Mar-June)	autumn (Aug-Oct)	winter (Nov-Feb)	spring/ summer (Mar-June)
8			3			
7			2			
6	2	2	10			4
5	14	24	26			7
4	32	24	37	2		14
3	27	42	17	5		7
2	23	8	4	42	53	14
1	2		1	51	47	54
sample size:	125	38	134	120	62	28

max. follicle diam. (mm)						
5			3			
4		2	18			
3		24	29			25
2	12	59	49	5	15	12
1	25	15	1	12	35	63
<1	63			83	50	
sample size:	56	46	127	76	46	8

Fig. 3. Guillemots: gonad size in two seasons for the two sexes. Percentage in each size class; median value arrowed.



3.6 Plumage in Guillemots

(a) Head and neck pattern

Witherby et al. (1941) described 1st-winter plumage as (amongst other features) "like adult winter but more often with white showing across back of neck". This feature was checked on 6 adult and 66 immature Guillemots beached in winter in south Devon and north Cornwall. The heads were photographed by K.Partridge, and the plumage categories devised by PHJ: five types viewed from above, and three types viewed from the side (Fig.4).

Too few adults were available for comparison with immatures (as deduced from absence and presence, respectively, of cloacal bursa), but within the latter group two comparisons were made, especially since there seemed to be more birds with dark napes than with whitish napes (Table 15). On the nape views, 19 were in Types 1 and 2, compared with 33 in Types 4 and 5; on the side view, 10 were in Type A, compared with 26 in Type C. Differences were significant in both cases (Binomial Test, $z = 1.8$, $p=0.072$). Thus in the sample examined, immatures did not "more often" have white showing across the back of the neck. However, at that stage in the evolution of the auk examination system it was not possible to separate 1st-winter birds from older immatures, so the point still needs to be clarified since the true age composition within the Devon/Cornwall sample was not known.

(b) Wing coverts

Parrack (1967) and Kuschert et al. (1981) described the differing colours in the wing coverts as a criterion for distinguishing 1st-winter Guillemots, and both papers pointed to the likelihood that white-tipped underwing coverts were similarly diagnostic of 1st-winter birds.

Using the system of Kuschert et al., a series of 85 wings was examined for Guillemots which had died in N.E.England in the wreck of February 1983. All were from specimens known to be with cloacal bursa, and therefore almost certain to have been immatures. The Kuschert system should have separated out the 1st-winter birds (with a moult boundary) from older immatures (without a moult boundary); a corollary of this should be that measurements for winglength and bill depth at gonys should be greater in the older birds - which should also have a smaller bursal index. The results of separating the wings by eye on the moult boundary criterion were inconclusive (Table 16). Parrack's method produced varying conclusions with different replicate attempts at separation, so it was not considered further. Presumably, therefore, more experience is needed in the application of these methods.

Close examination was made of wings from nine adults (no bursa) and nine immatures (with bursa) from the Skagerrak incident of January 1981 to check on tips of greater underwing coverts. There was considerable variation (Fig.5), and although the adults' coverts were generally darker, often with grey extending right to the tips of the feathers, the feature was by no means present on all examples. Immatures, in almost all cases, showed white tips to the feathers. However, it was often difficult to distinguish pale grey central areas from dull white outer areas of the same feather, so there were problems in maintaining the same standards of objectivity when examining a series of wings.

(c) Differing stages of moult

First-summer Guillemots have been considered (by, for example, Witherby et al. 1941 and Storer 1952) to be recognisable by the later retention of winter plumage into the spring. Some Guillemots can attain 'summer' breeding plumage by the end of November, whilst other birds on egg or chick can retain some white cheek feathers through June and July (personal field observations). Table 17 has been compiled to show the plumage phases of different age cohorts at different times of year. All birds were in winter plumage in September/October, but by February up to three-quarters of the adults were back in breeding plumage, and almost all of them by March. Immatures almost all remained in winter plumage until later in the spring. However, these results are only generalisations since (a) timing may change from year to year according to, for example, temperature or food supply; (b) proportions may differ with latitude and natal origins of the birds involved; and (c) it was not possible to separate 1st-winter birds from older immatures.

In principle it seemed as if most immatures (in full winter plumage) could be separated from most adults (in full summer plumage) through the winter and spring, but more data are needed to confirm and elaborate on this outline; in any case, it would not be prudent to predict the age of an individual bird on this criterion.

Table 15. Head plumage patterns in winter Guillemots; plumage types as in Fig. 4; numbers of birds in each class: adults top right in each box, and immatures bottom left.

	1	2	3	4	5
A	5	2 5			
B		1 9	2 17	7	
C				11	1 15

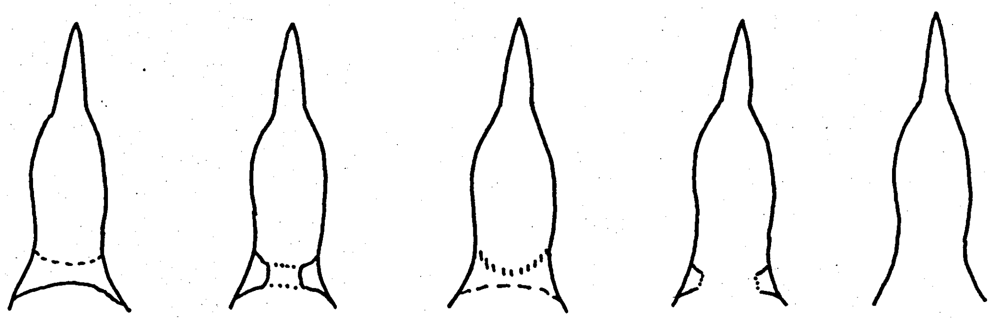
Table 16. Guillemots: comparison of wings of immatures (with bursa) according to the Kuschert (1981) system of separating out 1st-winter birds.

parameter	without moult boundary			with moult boundary			comparison of means
	i.e. older birds			i.e. 1st-winter			
	n	mean	s.d.	n	mean	s.d.	
winglength	32	199.5	4.2	53	197.6	4.0	$p < 0.05$
bill depth at gonys	32	12.0	0.5	53	11.9	0.5	n.s.
bursal index (length x breadth)	32	109.3	56.1	53	120.2	45.4	n.s.

Table 17. Guillemot: collated proportions (shown as percentages) in 'summer' and 'winter' head plumages at different times of the year; age separation effected on cloacal bursa.

period		'summer' plumage	intermediate	'winter' plumage	sample size
Sept-Oct	adult	0	0	100	60
	immature	0	0	100	113
Nov-Jan	adult	76	19	5	57
	immature	0	0	100	4
Feb	adult	57	26	17	96
	immature	0	1	99	129
Mar	adult	96	2	2	242
	immature	0	0	100	14
June	adult	100	0	0	23
	immature	78	22	0	27

Fig. 4. Head patterns in Guillemots, winter plumage, from Devon and Cornwall, 1980 and 1981.



complete band of clear white
1

clear white with nape stripe
2

speckled whitish band across
3

speckled edges with wide dark nape
4

no white visible
5

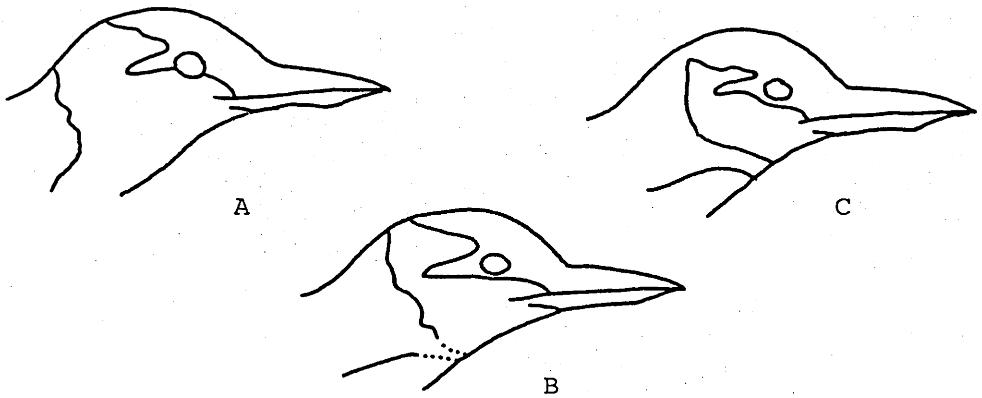
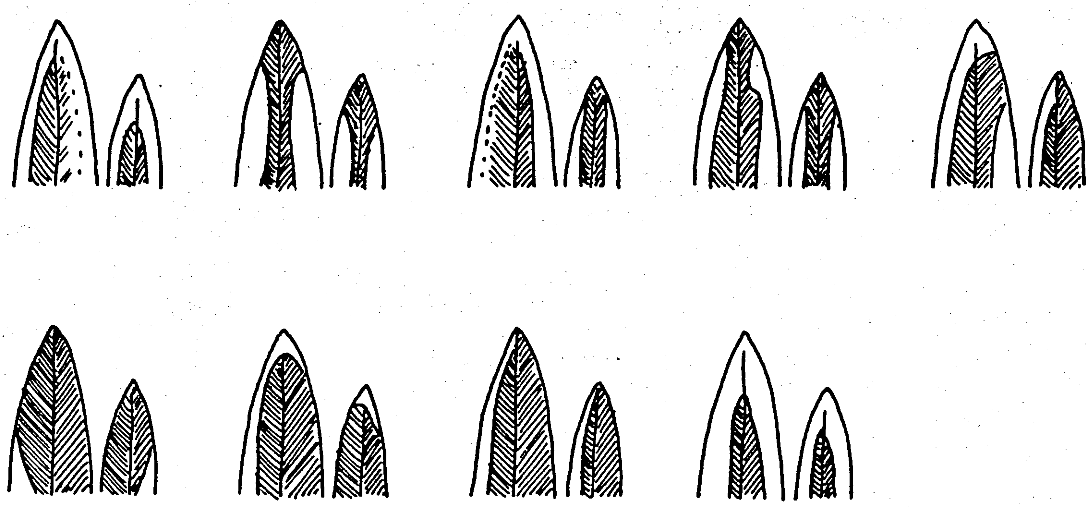
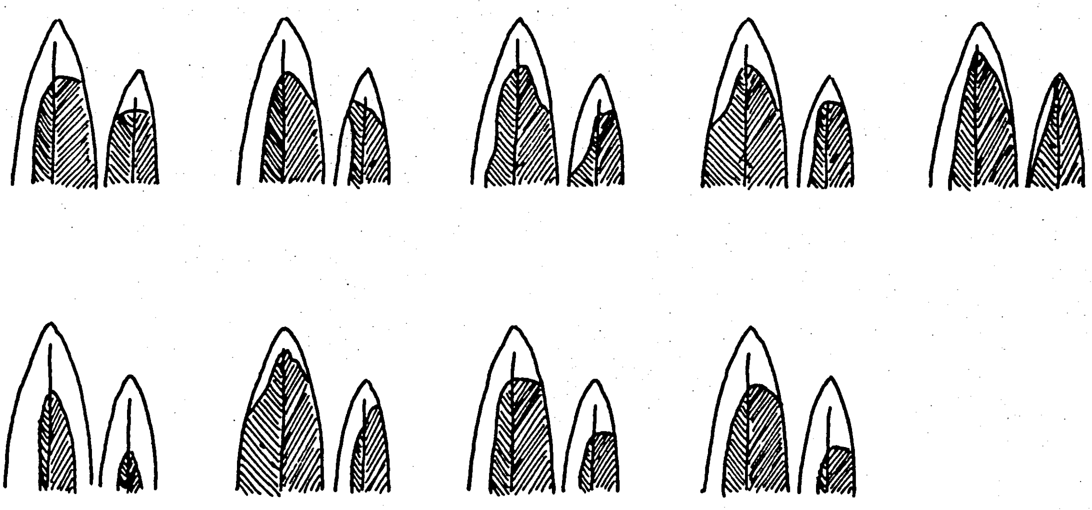


Fig. 5. Guillemot: tips of outer greater coverts in underwings of nine adult (no bursa) and nine immature (with bursa) birds from Skagerrak, January 1981.

adults



immatures



3.7 Discussion and conclusions

The cloacal bursa was first described by Fabricius (1625) but its function remained enigmatic until the middle of the twentieth century. Most work has centred on the organ's physiology, and it achieved some fame when it was found to be involved in the production of antibodies (Glick 1983). The organ (part of the bird's lymphatic system) is a dorsal diverticulum of the cloaca. In chickens it grows most rapidly between hatching and three weeks of age, remains stable for a time, then regresses before sexual maturity. General descriptions of bursae (including those in Guillemot) were given in Forbes (1877), with more recent statements on form and function in King (1981) Rose (1981) and Glick (1983).

Away from the field of medicine and poultry-rearing, the potential value of the bursa as an indicator of age in gamebirds was pointed out by Gower (1939), and by the late 1960s it had become part of the standard set of game management techniques in North America (Taber 1969). This technique seems not very prevalent in Europe, partly because it is not universally applicable through the bird families: in some waders the bursa may be used as an indicator of birds in their first autumn, but not subsequently (McNeil & Burton 1972), so that the feature (although mentioned) is not emphasised in general ageing techniques for waders (Prater et al. 1977). However, the bursal index (length and breadth) was a useful guide to age in a sample of 48 known-age (ringed) Puffins examined in Iceland (Petersen 1977): the mean index decreased from 101 mm in two-year-olds, to 24 mm in five-year-olds. Peterson was careful to add that "the presence of a bursa cannot be taken to indicate that Puffins have not bred", though 100% of his sample of 52 3 and 4 year-old birds had a bursa, whilst only 1 from a sample of eight 6-8 year-olds showed it. Data for Razorbills from the present study agree in principle with Petersen's work, but for Guillemot there are unfortunately not enough data from examinations of ringed birds.

The large variance about the mean bursal index for each age class (Peterson 1977 and Table 4 this study) implies that the exact age of an individual auk is not likely to be given by this one parameter. Moreover, the bursa is known to respond to stress (a general reaction of lymphoid tissue in vertebrates), and in an experiment with starved juvenile pigeons, the bursa had shrunk and "presented an appearance that is characteristic of birds which are approaching sexual maturity" (Dominic and Naik 1962). Since the auks beached in incidents will be under stress, it was interesting to note that the range of bursal index in Razorbills is still quite considerable, so it can be concluded that - at least in the wreck of February 1983 - the cloacal bursae of Razorbills and Guillemots did not regress dramatically. However, the stress factor must be borne in mind when considering the bursa as an invariable indicator of immaturity.

The technique of examination for the state of the supra-orbital ridge in Guillemots and Razorbills looks extremely promising as an aid in the identification of 1st-winter birds. It is potentially even more valuable in that the degree of development of this ridge can be accurately judged in less than five seconds (a vital consideration when dealing with large numbers of corpses in an incident), thus obviating the considerable time-waste necessary in checking, for example, skull pneumatisation in passerines. The extent of pneumatisation has not been checked in auk skulls; some doubt was thrown on the general principle of ageing by this method in Hogg's (1980) work which showed an impressive 'progression of ages' through a series of skulls of domestic fowls all known to be 2½ years old. Nor does any work on auks seem to have been undertaken as a follow-up to the researches of Van Soest & Van Utrecht (1971) on the layered structure of bones of birds as a possible indicator of age. These, and similar methods, would be out of the question at an auk mortality incident, but here again the value in retention, examination and curation of ringed, known-age auks is amply demonstrated.

Wing and bill measurements have long been known to differ with age in Guillemots and Razorbills (Salomonsen 1944), though the work has usually been done from skins rather than from fresh birds, with the notable exception of Verwey's (1922) researches. However a collation of measurements from the literature is probably not very meaningful since - in Guillemots particularly - the ages were often determined initially on criteria which seem rather dubious, or at least unproven. A combination of two measurements is sufficient to effect the complete separation of 1st winter from adult Razorbills, but otherwise the measurement differences between age cohorts are probably not sufficient, in themselves, to permit the ageing of individual auks on this criterion.

Gonadal development and regression is accepted as a normal function of a breeding bird's year, so it was not unexpected that adult Guillemots would show such a pattern. The choice of testis width to illustrate this in males was determined by a greater change (between seasons) in width than in length. Maximum testis development (as indicated by weight) in Brünnich's Guillemots in N.W.Russia was shown to take place in a relatively short period just at and before the beginning of laying by the females (Uspenski 1958); this cannot be deduced from the present study because of the paucity of data through the birds' breeding period. A similar short 'maximum development' period was shown by Belopol'skii (1957) for Common and Brünnich's Guillemots in N.W.Russia; it was also shown that this period could be earlier in years of favourable conditions, and that the final development and regression of ovary and follicle in females was even more condensed in time.

In the context of separating age cohorts, the main point to emerge from this study is that, in Guillemots, the chosen parameters were substantially different between adults and immatures in spring, much less so in autumn and winter, but that the degree of overlap in range did not allow the accurate ageing of an individual on this parameter.

In Razorbills, where an independent indicator of age is provided by the bill grooves, the link between age and bursal index is very evident. In Guillemots, the few data from ringed birds suggest that presence of the bursa is a valid indication of immaturity; by analogy with Puffin and Razorbill, and from the corroborative indications of wing, bill and gonadal measurements, this suggestion is raised to the level of a working hypothesis until this can be confirmed or amended by future examination of more ringed birds.

The various factors so far considered in the ageing of Razorbills are shown in Table 18, and of Guillemots in Table 19. Patently, more effort is needed in obtaining and examining corpses of ringed birds, particularly in order to check on the bursal factor and the supra-orbital ridge in both species, the bill groove factor in Razorbills, and the plumage factors in Guillemots.

Table 18. Razorbill: factors considered in ageing. Underlined values are the more reliable, though individual outliers may occur across most adjacent classes in each factor.

factor	1st winter	immature	adult
bill grooves	0+0	W+0 and most W+1	W+2, W+3 some W+1
mean bill depth at gonys (mm)	<16.5	15.5-20.0	>17.0
cloacal bursa	present	present	usually absent
bursal index (mm)	40-285	15-104	0 (21-65)
supra-orbital groove	absent	intermediate	strong
winter testis width (mm) (median)	1-2 (1)	1-5 (2)	1-7 (4)
max. follicle diam. (mm) (median)	<1 (<1)	<1-3 (<1)	1-3 (1)
mean winglength (mm) (A. t. islandica)	189	194	197

Table 19. Guillemot: factors considered in ageing. At this stage, none is completely reliable, since all depend on the not-completely-proven bursa presence or absence.

factor	immature (including 1st winter)	adult
cloacal bursa	present	absent
bursal index (mm)	? 10-300	0
winter testis width (mm)	1-5	1-7
(median)	(2)	(4)
max. follicle diam. (mm)	1-2	1-3
(median)	(< 1)	(2)

probable factors,
for further research

	1st winter	immature	adult
supra-orbital ridge	absent	intermediate	strong
covert moult boundary	present	absent	absent
mean bill depth at gonys (mm)	11	12.5	13
mean winglength (mm)	x-6	x-1	x*

* dependent upon latitude of natal origin

4. SEX DETERMINATION

In spring and summer, gonadal inspection of Guillemots and Razorbills leads almost invariably to ready identification of the two testes in males and the single ovary in females. Details of the siting and appearance of the gonands are shown in Appendix I (Section 4 and Figs. 4 and 10).

For birds found in autumn and winter, examination may need to be more careful, since in most cases the gonads are appreciably smaller than in spring (gonadal development with age and season was discussed in section 3.5).

4.1 Sex ratios

Guillemots provided good samples at a series of incidents, and the main blocks of data are shown in Table 20. In winter, adults in U.K. did not differ significantly from equality in the sex ratios, but females were predominant in the Skagerrak. By contrast, the immature sex ratio was imbalanced in all three samples: biased towards males in the U.K. and towards females in the Skagerrak. For samples taken near breeding colonies, there was no difference from equality amongst adults in summer or winter, nor for the one sample of immatures in summer. In the immediate postbreeding period, males were dominant in the N.E. England samples, though juveniles were equally distributed.

In interpreting these data, it is important to bear in mind various potential pitfalls, since the recorded data may not necessarily represent the true situation at sea. Nothing is known about the relative susceptibility of males and females to oiling (e.g. Skagerrak) or to presumed food shortage (e.g. east coast wreck) but if the sexes are equally vulnerable, then winter populations around U.K. may well comprise equal numbers of adult males and females, though with a preponderance of males amongst the immatures. The suggestion that immature females migrate preferentially out of U.K. waters (some of them to the Skagerrak) emerges as an intriguing possibility. The high proportion of males with the juveniles in the N.E. England postbreeding sample may indicate that the guardians of the juveniles, in their periods of non-flying dependence at sea, could have been mainly males in that incident; there are few data on this point, though Tuck (1960), apparently referring to Brünnich's Guillemots, stated "collection of adults accompanying chicks at sea indicated that either sex may care for the young at that stage".

Razorbill data are fewer, but two good winter samples were available from the Skagerrak and east coast incidents (Table 21). For the former there was no significant difference from equality of sexes in adults and immatures, whereas adult females predominated in the east coast wreck, even though the sex ratio in immatures was not different from equality. For a variety of combined small samples elsewhere in the U.K. in winter, there was no significant departure from equality of sexes in any of the three age groups.

Table 20. Guillemot: sex ratios for age groups in various incidents.

	MALE (%)	difference from 50:50 ratio	FEMALE (%)
WINTER			
(a) Skagerrak			
adult	47 (34)	$p<0.05$	91 (66)
immature	255 (39)	$p<0.001$	401 (61)
(b) East coast wreck			
adult	92 (43)	n.s.	123 (57)
immature	159 (65)	$p<0.01$	87 (35)
(c) other U.K.			
adult	80 (47)	n.s.	91 (53)
immature	162 (61)	$p<0.05$	105 (39)
NEAR COLONY			
(a) spring and summer			
adult	134 (51)	n.s.	127 (49)
immature	23 (70)	n.s.	10 (30)
(b) winter			
adult	28 (50)	n.s.	28 (50)
immature	0		0
POSTBREEDING			
(a) N.E.England			
adult	69 (84)	$p<0.001$	13 (16)
immature	7		3
juvenile	19 (56)	n.s.	15 (44)
(b) E.Scotland			
adult	5 (26)	n.s.	14 (74)
immature	35 (78)	$p<0.01$	10 (22)

Table 21. Razorbill: sex ratios for age groups in various incidents.

	MALE (%)	difference from 50:50 ratio	FEMALE (%)
WINTER			
(a) Skagerrak			
adult	114 (52)	n.s.	107 (48)
immature	28 (39)	n.s.	44 (61)
(b) East coast wreck			
adult	181 (39)	$p<0.05$	281 (61)
immature	66 (40)	n.s.	100 (60)
1st winter	49 (52)	n.s.	46 (48)
(c) other U.K.			
adult	30 (58)	n.s.	22 (42)
immature	26 (52)	n.s.	24 (48)
1st winter	59 (58)	n.s.	43 (42)

4.2 Sex determination from total head-and-bill length

For certain of the gull species, Coulson et al. (1983) showed that it was possible to determine the sex of a high proportion of individuals from the one parameter of head-and-bill length: 93% of Lesser Black-backed Gulls and 96% of Herring Gulls examined. The measurement was taken with a caliper specially designed for measuring the distance between back of the head and bill tip on live or freshly-dead birds: one of these tools was purchased from Durham University, and the mean head-and-bill length parameter was calculated for certain samples of Guillemots and Razorbills (Tables 22 and 23).

In large samples of adult Guillemots at three different stages in the year, neither sex showed significantly different mean values between samples, but males always had significantly higher values than females. In the one big winter sample of immatures, males were similarly larger than females in this one measurement. However, the distribution of measurements (108 - 125 mm in adult males, and 104 - 119 mm in females) was such as to preclude any useful segregation of the sexes: in adult males and females only 8% of the individual values lay outside the overlap zone (108 - 119 mm). For immatures, these values were 2% for males and 6% for females.

Razorbills from one incident were similarly grouped: significant differences between means were evident for adults, but separation was effected for only 2% of males and 6% of females. Differences in means occurred between immature and 1st w. males, but not (within each sex) between other age groups.

Figs. 6 and 7 show the headlength data plotted on arithmetic probability paper (where a straight line indicates a normal distribution and where bimodal data can be divided into the two constituent normal distributions). The 'curve' - for cumulative frequency of pooled data - hardly exists, and it is not feasible to pinpoint a meaningful point of inflexion nor, therefore, a discriminant function for the separation of sexes from this measurement.

The conclusion must be that, on the samples examined, this one parameter - although so successful in gulls - was of no real consequence in separating sexes in Guillemots and Razorbills.

Table 22. Guillemot: head + bill length measurements from samples.

	male			comparison of means	female		
	n	mean	s.d.		n	mean	s.d.
ADULTS							
(a) winter East coast wreck, Feb'83	45	115.7	3.48	$p<0.001$	68	111.5	2.90
(b) colony, spring: Buchan March '82	89	115.0	3.03	$p<0.001$	90	112.0	2.71
(c) post-breeding Newcastle, Sept. '81	91	115.0	2.80	$p<0.001$	30	110.9	2.74
IMMATURES							
(a) winter East coast wreck, Feb'83	102	111.5	2.88	$p<0.05$	51	110.3	3.36

Table 23. Razorbill: Head + bill length measurements from one sample.

	male			comparison of means	female		
winter, East coast wreck, Feb '83	n	mean	s.d.		n	mean	s.d.
adult	102	91.4	2.13	$p<0.001$	156	90.0	2.23
immature	31	92.0	1.83	$p<0.001$	62	89.6	2.38
1st winter	36	90.1	2.44	n.s.	36	89.8	2.05

Fig. 6. Guillemot: cumulative frequency of headlength measurements for a sample of 292 adults (no bursa) from the east coast wreck of February 1983, and from Buchan, March 1982.

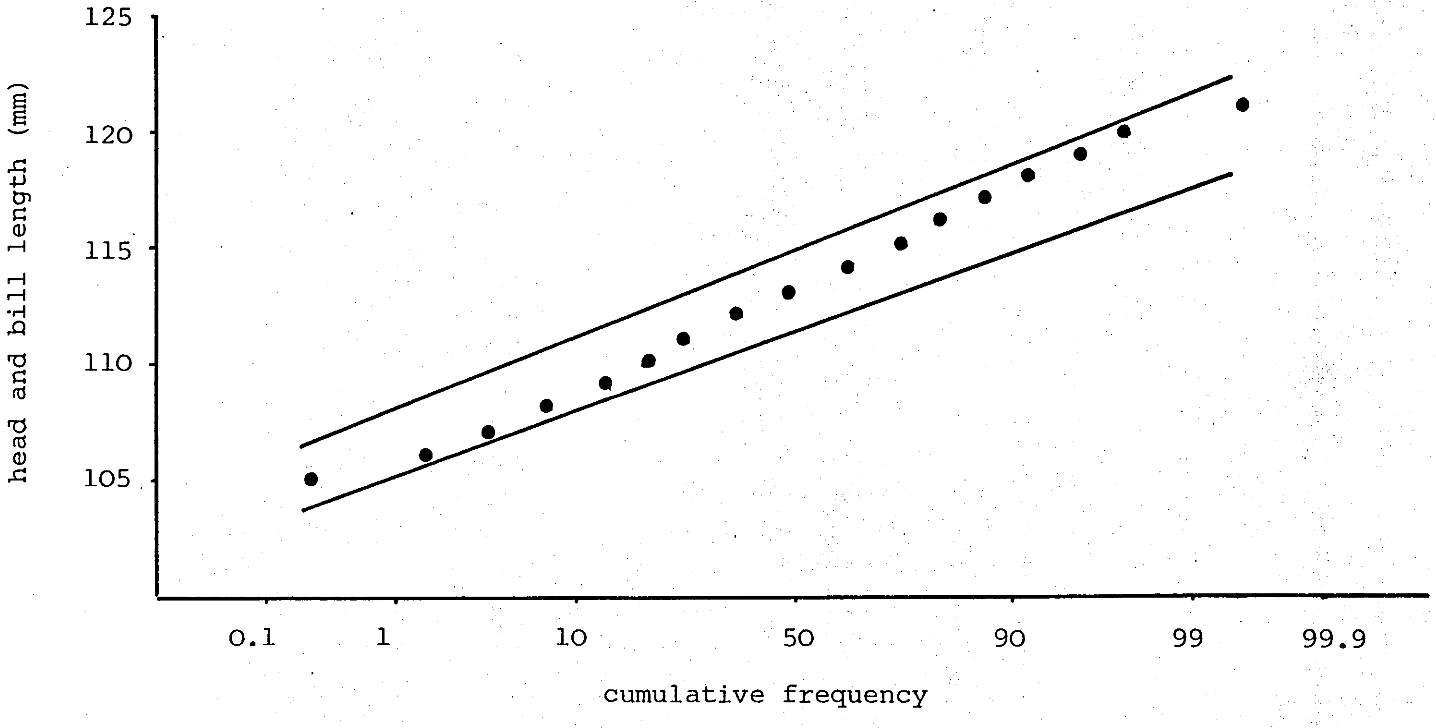
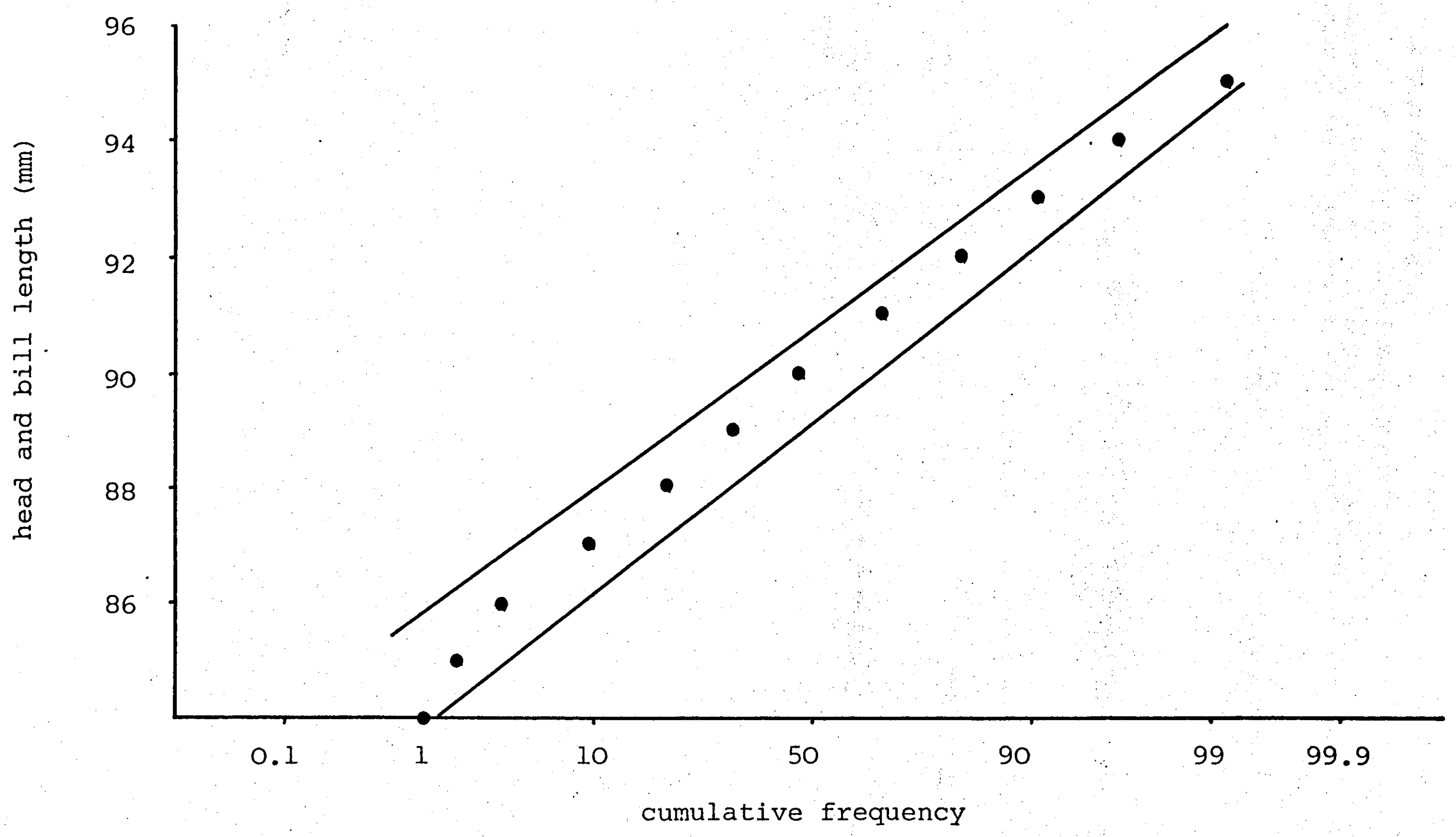


Fig. 7. Razorbill: cumulative frequency of headlength measurements for a sample of 258 adults from the east coast wreck of February 1983.



4.3 Sex determination from other measurements

Results from sets of three other body measurements are shown for Guillemots in Tables 24 to 26, and for Razorbills in Tables 27 to 29.

For Guillemots, winglength means were significantly different for only two of the nine groups tested (t test), but in adults the male mean wing lengths were almost always 0.4 - 2.0 mm shorter than those for females. In comparing nine sets of data, this difference was significant ($\rho<0.05$, sign test) for adults, but not for immatures. Culmen length showed a stronger distinction between sexes, with significant difference being evident in all six comparisons of means in adults, and in three out of four in immatures. The sign test indicated that this parameter is of significance for adults and immatures. An exactly similar conclusion applies in the case of measurements of bill depth at gonys.

For Razorbills, the results were not quite as conclusive. Although winglength means were rarely different between sexes, the indications are that females had marginally longer wings. Culmen length and gonys depth for adults tended to be greater in males, though the results were equivocal in immatures.

From the above analyses, there is ample evidence for significant differences between sexes in means of various of the parameters, but none of the measurements was, in itself, adequate for effecting the separation of more than a very small percentage of males from females. The overlap zone was invariably very extensive, and usually included well over 90% of the measurements from any one sample.

The use of two measurements combined is illustrated for Guillemots in Fig. 8. The distribution polygons had partially separated (females tending to have bigger wings and small headlength), allowing an identification of 40% of the males (36 outside the overlap zone in a total sample of 91) and 22% of the females (20 in a total sample of 89). In both sexes there is evidence for allometric size increases from significant linear regressions of winglength on head and bill length:

males : $n = 91$ $r = 0.2896$ $\rho < 0.01$ (89 d.f.)
females: $n = 89$ $r = 0.3016$ $\rho < 0.01$ (87 d.f.)

However, not even the use of two parameters is satisfactory as a method for discriminating sexes on measurements, so it is safest to conclude that - from the measurements examined - it is not possible safely to separate the sexes of individual Guillemots.

Table 24. Guillemot: sex differences in winglength.

	n	male mean	s.d.	comparison of means	n	female mean	s.d.	difference of male mean (mm)
ADULTS								
winter								
Moray Firth	21	205.4	5.3	-	22	206.4	5.1	- 1.0
N.E.England	27	204.4	5.1	n.s.	44	206.0	4.6	- 1.6
E.Anglia	45	204.9	4.8	n.s.	57	203.9	4.4	+ 1.0
Skagerrak	68	206.5	4.1	$p<0.05$	72	208.3	5.3	- 1.8
N.Cornwall	40	199.6	4.3	n.s.	45	200.0	4.2	- 0.4
colony, spring								
Buchan	99	204.1	4.0	$p<0.01$	94	206.1	4.5	- 2.0
Forth	17	203.3	3.2	-	24	204.6	3.2	- 1.3
colony, winter								
Noss	9	207.6	2.4	-	18	209.4	3.1	- 1.8
Fowlsheugh	19	206.5	4.2	-	11	208.5	3.4	- 2.0
IMMATURES								
winter								
Moray Firth	40	198.4	5.7	-	19	197.9	4.8	+ 0.5
N.E.England	64	198.1	4.0	n.s.	36	198.0	4.6	+ 0.1
E.Anglia	53	199.3	5.2	n.s.	36	199.5	4.3	- 0.2
Skagerrak	331	200.1	4.8	n.s.	326	200.3	4.4	- 0.2
N.Cornwall	55	196.9	4.4	n.s.	31	197.6	4.5	- 0.7

Table 25. Guillemot: sex differences in culmen length.

	n	male mean	s.d.	comparison of means	n	female mean	s.d.	difference of male mean (mm)
<u>ADULTS</u>								
<u>winter</u>								
Moray Firth	19	49.1	2.5	-	22	46.7	2.6	+ 2.4
N.E.England	26	49.2	2.1	p<0.01	43	47.6	2.1	+ 1.6
E.Anglia	42	48.1	2.3	p<0.001	56	45.9	2.9	+ 2.2
Skagerrak	61	49.6	2.1	p<0.001	72	47.6	2.4	+ 2.0
N.Cornwall	50	47.5	2.0	p<0.01	59	46.3	1.9	+ 1.2
<u>colony, spring</u>								
Buchan	98	49.2	2.4	p<0.001	94	47.6	2.1	+ 1.6
Forth	14	49.8	2.6	-	24	48.3	2.2	+ 1.5
<u>colony, winter</u>								
Noss	9	50.7	2.1	-	16	48.3	2.9	+ 2.4
Fowlsheugh	19	50.1	2.4	-	10	47.7	2.3	+ 2.4
<u>postbreeding</u>								
Newcastle	76	49.5	2.0	p<0.001	29	47.0	2.3	+ 2.5
<u>IMMATURE</u>								
<u>winter</u>								
Moray Firth	38	46.7	2.2	-	19	44.9	2.2	+ 1.8
N.E.England	64	47.1	2.4	p<0.01	35	45.7	2.3	+ 1.4
E.Anglia	53	45.2	2.7	n.s.	37	44.3	2.5	+ 0.9
Skagerrak	305	48.0	2.6	p<0.001	308	46.1	2.4	+ 1.9
N.Cornwall	71	47.3	2.1	p<0.001	42	45.8	1.9	+ 1.5

Table 26. Guillemot: sex differences in bill depth at gonys.

	n	male mean	s.d.	comparison of means	n	female mean	s.d.	difference of male mean (mm)
ADULTS								
winter								
Moray Firth	20	12.8	0.7	-	21	12.5	0.7	+ 0.3
N.E.England	27	13.4	0.7	$p<0.05$	44	13.0	0.6	+ 0.4
E.Anglia	44	13.8	0.6	$p<0.001$	57	13.2	0.7	+ 0.6
Skagerrak	64	12.9	0.6	$p<0.01$	68	12.6	0.6	+ 0.3
N.Cornwall	54	12.4	0.7	$p<0.05$	58	12.1	0.6	+ 0.3
colony,spring								
Buchan	98	13.9	0.5	$p<0.001$	94	13.5	0.5	+ 0.4
Forth	16	13.8	0.4	-	24	13.3	0.6	+ 0.5
colony,winter								
Noss	9	13.0	0.5	-	18	12.6	0.5	+ 0.4
Fowlsheugh	19	13.5	0.6	-	10	13.0	0.5	+ 0.5
postbreeding								
Newcastle	76	12.8	0.5	$p<0.001$	29	12.2	0.6	+ 0.4
IMMATURE								
winter								
Moray Firth	34	11.7	0.5	-	18	11.4	0.5	+ 0.3
N.E.England	64	12.0	0.5	$p<0.001$	37	11.5	0.6	+ 0.5
E.Anglia	49	12.4	0.5	n.s.	42	12.3	0.6	+ 0.1
Skagerrak	297	11.9	0.6	$p<0.001$	326	11.5	0.6	+ 0.4
N.Cornwall	73	12.0	0.5	$p<0.01$	42	11.7	0.6	+ 0.3

Table 27. Razorbill: sex differences in winglength (all measurements made in winter).

	n	male mean	s.d.	comparison of means	n	female mean	s.d.	difference of male mean (mm)
ADULTS								
Moray Firth	50	196.4	4.5	n.s.	64	197.6	4.4	- 1.2
N.E.England	49	196.1	4.5	n.s.	96	197.7	4.7	- 1.6
E.Anglia	79	196.8	3.9	n.s.	110	196.9	3.8	- 0.1
other U.K.	11	196.6	4.9	-	25	196.8	4.6	- 0.2
IMMATURES								
Moray Firth N.E.England E.Anglia	63	193.4	4.0	n.s.	91	194.2	4.0	- 0.8
other U.K.	12	191.5	4.9	-	11	195.5	4.5	- 4.0
1st WINTER								
Moray Firth N.E.England E.Anglia	46	187.7	4.1	$p<0.05$	48	189.5	3.6	- 1.8
other U.K.	9	182.6	4.2	-	7	189.9	6.1	- 7.3

Table 28. Razorbill: sex differences in culmen length (all measurements made in winter).

	n	male mean	s.d.	comparison of means	n	female mean	s.d.	difference of male mean (mm)
ADULTS								
Moray Firth	52	33.1	1.7	n.s.	68	32.7	1.7	+ 0.4
N.E.England	49	32.9	1.3	p<0.01	96	32.2	1.5	+ 0.7
E.Anglia	80	32.3	1.6	p<0.001	114	31.2	1.4	+ 1.1
other U.K.	15	32.8	2.0	-	28	31.9	1.6	+ 0.9
IMMATURES								
Moray Firth N.E.England E.Anglia	67	32.7	1.3	p<0.01	98	32.0	1.5	+ 0.7
other U.K.	13	31.5	1.8	-	12	32.2	1.5	- 0.7
1st WINTER								
Moray Firth N.E.England E.Anglia	48	31.5	1.7	n.s.	45	31.5	1.6	0
other U.K.	11	30.2	2.9	-	9	31.3	2.7	- 1.1

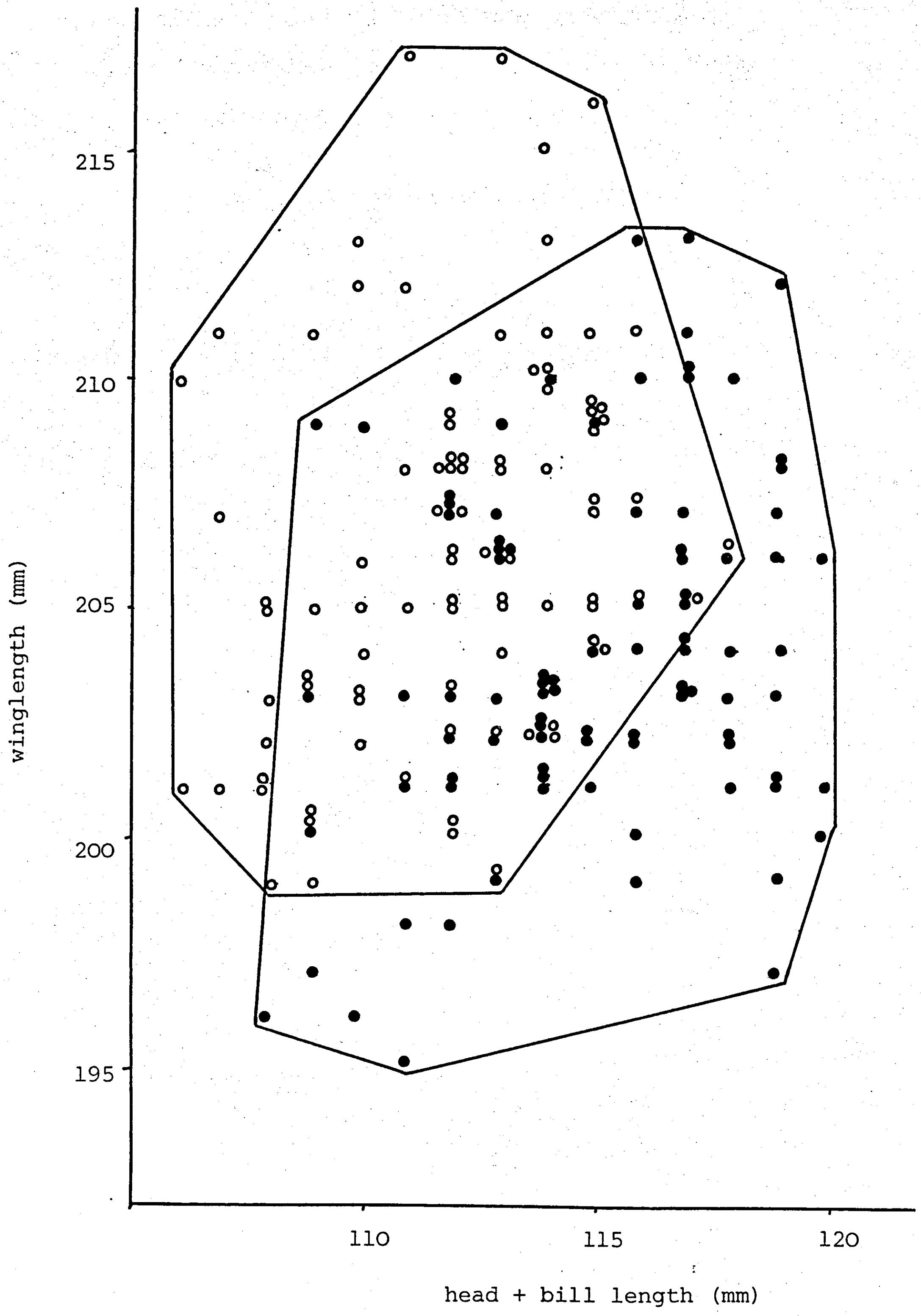
Table 29. Razorbill: sex differences in bill depth at gonys (all measurements made in winter).

	n	male mean	s.d.	comparison of means	n	female mean	s.d.	difference of male mean (mm)
<u>ADULTS</u>								
Moray Firth	51	20.0	0.8	p<0.001	68	19.4	1.1	+ 0.6
N.E.England	49	20.0	0.8	p<0.001	96	19.5	0.8	+ 0.5
E.Anglia	115	19.6	0.7	n.s.	80	19.8	0.8	- 0.2
other U.K.	15	19.6	0.8	-	29	19.3	0.7	+ 0.3
<u>IMMATURES</u>								
Moray Firth N.E.England E.Anglia	70	18.7	0.8	p<0.05	95	18.4	1.1	+ 0.3
other U.K.	13	18.8	1.0	-	12	17.9	0.9	+ 0.9
<u>1st WINTER</u>								
Moray Firth N.E.England E.Anglia	37	15.0	0.8	n.s.	36	14.8	0.7	+ 0.2
other U.K.	13	14.6	0.9	-	9	14.6	0.6	0

Fig. 8. Guillemots, Buchan, March 1982: plot of two parameters by sex. (One outlier male omitted: 213 x 125).

● male

o female



4.4 Discussion and conclusions

Sex determination by gonadal inspection of dead birds normally presents no problems, except occasionally in first-winter individuals - particularly Razorbills. For those inexperienced in the work, it is also necessary to consider the need for care in distinguishing between undeveloped ovary (usually granular) and adrenal gland or part of the kidney (both usually smooth-textured). In fresh specimens, the contrasting (usually yellowish) colour of the gonads, and of the testes in particular, makes the organs stand out against this background, but with the onset of decomposition they can fade to a brownish-grey, making them much less readily visible.

There are few data on sex ratios in Guillemot and Razorbill populations. "In fact, the sex ratio in murres is not clearly understood" (Tuck 1960), and this statement still stands; it is almost unknown in Razorbills. Tuck himself recorded no significant disparity in sex ratio amongst 1400 murres examined in winter in Newfoundland, but the context does not clarify whether the species was U.aalge or U.lomvia, or perhaps both, since the two species are present off Newfoundland at that season. Most of our knowledge for Guillemots comes from the work of Uspenski (1958) during the birds' breeding season in N.W. Russia: in Novaya Zemlya 56% males ($n = 34$), and in Seven Islands 59% males ($n = 36$) (Kaftanovski 1951). Uspenski points to the greater participation of males in incubation and in feeding of the young (and hence the greater chances of their being found on the sea) as the reason for the apparently greater proportions of males in the three samples. Belopol'skii (1957), working in the Barents Sea, recorded a similar higher proportion of males when presenting data on mean weights: 56% males ($n = 375$).

For British waters, Beer (1968) found 52% males in a sample of 84 Guillemots oiled in the Torrey Canyon incident of March 1967, whilst in

Newfoundland Threlfall and Mahoney (1980) found 51% males in a sample of 238 taken in the period May - July 1966-68. However, in neither case was a separation of age cohorts made. For the Netherlands coast in one autumn, Verwey (1922) found 56% males amongst 34 adults, and 73% males amongst 63 immatures.

Data from the present study indicate, for adult Guillemots near the breeding colony, equality of sexes in summer and winter, and equality in U.K. winter incidents, though a predominance of females in one winter incident in the Skagerrak and of males in one autumn incident off N.E. England. The immature sex ratio in winter was biased towards males in U.K. and towards females in the Skagerrak incident. Razorbill data in the present study were all obtained from winter incidents: equality of sexes for adults and immatures in one Skagerrak incident and various small U.K. incidents, but a bias towards adult females in the East coast wreck of 1983. If other data exist in the literature on Razorbill sex ratios, they are very elusive.

The existing information on sex ratios is therefore scanty in the extreme, especially for Razorbills, and the continued examination of kills from incidents is obviously valuable and necessary. This paucity of information lends added importance to the quest for the sexing of live birds from measurements or plumage examination.

Sex determination from total head-and-bill length, although very successful in gulls (Coulson et al. 1983), did not give helpful results when tested for either Guillemot or Razorbill, adults or immatures. Certainly, for the reasonably large samples of Guillemots and Razorbills examined by this method, the parameter was probably of no great help in separating the sexes even when, as in Razorbill, the age cohorts could be well defined. Further examinations should be made to extend the sample size and range for each species, but the auguries are not good.

For European populations of Guillemot, Witherby (1941) noted negligible differences between sexes in measurements made on small samples, whilst Salomonsen (1944), with larger samples, concluded similarly. Storer (1952) concluded that "there is no significant sexual difference in wing and tarsal measurement" for Uria species, though his tests were conducted on measurements from the Pacific and Atlantic forms of North American Guillemots. However, he found that the figures for culmen length and bill depth were consistently greater in males than in females: the point had previously been demonstrated for bill depth in European specimens by Verwey (1922). Threlfall and Mahoney (1980) were specifically researching the use of measurements in sexing Guillemots taken in Newfoundland waters; despite fairly sophisticated statistical treatment of the data from a sample of 238 birds, "it proved impossible to sex this species on the basis of measurements with any degree of certainty". Parameters examined were weight, winglength, culmen length and bill depth, tarsus length and tail length. There was no comment on ageing, and there are indications (from quoted bill depth measurements) that immature (possibly first-year) birds were included in the sample; if this were so, then perhaps the increased variance would have been sufficient to mask any sex difference within each age cohort. Nevertheless, mean values for female winglengths were higher than those for males, with the reverse applying in culmen length and bill depth. A similar explanation (failure to segregate age classes) may have lain behind Beer's (1968) finding of "no significant differences between body measurements of the two sexes" in a sample of 84 Guillemots from the Torrey Canyon disaster (though neither the parameters nor their mean values were stated).

Table 30 shows sexes separated in series of measurements from various regions through the range of the species; coupled with measurements from this study (Table 24 to 29), they indicate the almost universal findings that, in adults from the same region, females have longer mean winglengths than males, and males have longer and deeper bills than females.

For Razorbills, neither Witherby (1941) nor Salomonsen (1944) commented on sex differences in measurements, and data elsewhere in the literature are few. Table 31 shows measurements for the two sexes in series of measurements from the North Atlantic; coupled with measurements from this study, they indicate that, in adults from the same region, females usually (though perhaps not invariably) have longer mean winglengths than males, and males have longer and deeper bills than females.

The wing loading of both species is already close to a critical level, and perhaps the females need the extra lift when carrying the egg which averages, according to Uspenski (1958), about 11% of the weight of the parent bird. Indications are that males in general are heavier than females: 2.5% in a Guillemot sample of 375 spread over a summer season, and 4.6% in a similar Razorbill sample of 142 (Belopol'skii 1957), thus the slightly larger female wing length (and possibly area, though this is not confirmed) assumes even greater importance. Other reasons for the evolution of slightly longer wings might be adduced if females migrated further than males, or if a larger wing conferred an enhanced hunting ability when the egg protein was being laid down. The number and spread of samples in Guillemots, less so in Razorbills, does indicate that the difference - though slight - is real, but the evolutionary implications of small differences in measurements between males and females is beyond the scope of this thesis.

Table 30. Guillemot measurements: some quoted values. Slight difference in methods of measurement are not important in this table which demonstrates - for each set of uniformly-measured data - the differences between sexes.

sample size		winglength		culmen length		bill depth		authority & locality
♂	♀	♂	♀	♂	♀	♂	♀	
121	117	200.9	202.3	44.3	42.4	14.3	14.1	Threlfall & Mahoney (1980) Newfoundland
91*	61	208.5	209.2	49.2	47.1	13.7	13.6	California (Storer 1952)
12	23	214.4	214.6	49.0	47.0	14.4	14.0	British Columbia (Storer)
45	25	217.8	216.7	47.7	45.8	14.5	14.0	Alaska (Storer)
38	41	207.3	208.9	44.6	43.2	13.8	13.3	Eastern N.America (Storer)
19	15					14.0	12.8	Verwey (1922) Netherlands
17	7	201.4	204.1	48.2	46.3	14.9	14.4	Salomonsen (1944) Norway, Sweden, Iceland
125 (wing) 51 (bill)	94 41	210.8	211.5	48.7	46.6			Belopol'skii (1957) East Murman
34 (wing) 48 (bill)	37 46	208	209	49.3	47.2	14.9	14.5	Smail et al. (1972) California

* Storer's sample size varied slightly between parameters.

Table 31. Razorbill measurements: some quoted values. Slight differences in methods of measurement are not important in this table which demonstrates - for each set of uniformly-measured data - the difference between sexes.

sample size		winglength		culmen length		bill depth		authority & locality
♂	♀	♂	♀	♂	♀	♂	♀	
10	15	209.4	205.8	35.1	33.9	24.6	23.8	Sweden (Salomonsen (1944)
7	6	212.3	211.5	36.5	35.9	25.1	23.6	Greenland (Salomonsen)
15	11	210.3	211.5	35.2	33.4	23.5	22.8	Norway & Sweden (Salomonsen)
73	51	207.5	208.5	34.6	33.6	-	-	Belopol'skii (1957) East Murman
18	15	-	-	33.4	32.0	21.9	20.5	Lloyd (1976) various localities represented in two museums.

most sample sizes varied slightly between parameters.

5. ORIGINS

5.1 Measurements at colonies

Between 1979 and 1983 Guillemots and Razorbills caught at several breeding colonies were measured using the methods detailed in Appendix 1. Practically all the Razorbills were breeding adults, taken individually out of rock crevices where they were guarding egg or chick; the great majority were of bill types W + 2 and W + 3. The true status of the Guillemots is less certain because the colonies at the chick-rearing period may be visited by older immatures (3 - 4 year olds) which might have been amongst the sample, with birds inseparably mixed together on breeding ledges. However, these non-breeders are likely to comprise only a very small minority within the samples - which can probably safely be used as representative of the breeding population for each locality. Any birds with badly worn tips to the outer primary feathers have been omitted in calculation of mean winglength values.

For Guillemot, winglength means are shown for thirteen sample sites in Fig.9, whilst details of winglength, culmen length and gonys depth are shown in Tables 32 to 34 respectively. Details for Razorbill winglengths are shown in Fig. 10 and Table 35, with gonys data in Table 36. Weights for both species are shown in Table 37.

Mean winglength values are plotted against latitude in Figs. 11 and 12. For Razorbills, the regression of winglength on latitude is not significant for the form islandica ($r = -0.1147$, 5 d.f.). An interesting situation emerges in Guillemot: although a regression analysis using all 13 points is significant ($r = 0.9242$, $\rho<0.001$, 11 d.f.), visual inspection indicates two sections to the cline, with Shetland in pivotal position (the three sets of data from Shetland are included in both analyses below).

Skomer to Shetland $r = 0.9559$ $\rho<0.001$ 7 d.f.

Shetland to Vardø $r = 0.8819$ $\rho<0.01$ 5 d.f.

The two regression lines indicated by these results are shown in Fig. 11.

Thus, for Guillemots, the link of winglength with latitude is strong within the British Isles, and present, though slightly weaker, in the sector Shetland/N.Norway. There was relatively little variation in culmen length and gonys depth from Guillemot samples, though the birds from Finmark were generally bigger overall.

Table 32. Guillemot: winglength measurements of fullgrown birds in breeding colonies. Numbers correspond with those in Fig.9.

country	colony	date	sample size	mean (mm)	s.d.	range	authority
(1) Wales	Skomer	c.1975	84	197.6	4.75	185-210	T.R.Birkhead
(2) Ireland	Gt.Saltee	1982	35	199.5	3.67	194-209	PHJ
(3) Scotland	I. of May	1982	83	200.0	4.83	192-212[a]	M.P.Harris
(4) Denmark	Graesholm	1983	46	201.2	4.43	193-210	P.Lyngs
(5) Scotland	Canna	79/81	91	203.8	4.81	193-215	R.L.Swann & A.D.K.Ramsay
(6) Scotland	Troup Hd & Whinnyfold	1979	39	203.6	3.64	195-210	J.Hardey & R.Rae
(7) Scotland	Fair Isle	1980	252	206.6	4.30	196-219	PHJ
(8) Scotland	Foula	1980	38	207.3	3.96	198-214	M.L.Tasker
(9) Scotland	Noss	1980	65	207.3	4.71	196-217	B.F.Blake & T.J.Dixon
(10) Faroe	Esturoy	1977	19	207.0	3.03	200-212	S.Prendergast
(11) Iceland	Grimsey	1981	60	207.2	3.49	199-216	PHJ
(12) Norway	Røst	1981	45	209.6	5.50	[b]202-223	T.Anker-Nilssen & O.W.Røstad
(13) Norway	Vardø	1980	95	210.5	5.50	199-223	R.Barrett

a outlier of 217

b outlier of 196

Table 33. Guillemot: culmen-length measurements of fullgrown birds in breeding colonies. Numbers correspond with those in Fig. 9.

country	colony	date	sample size	mean (mm)	s.d.	range	authority
(2) Ireland	Gt.Saltee	1982	35	45.3	2.06	40-49	PHJ
(4) Denmark	Graesholm	1983	46	45.5	2.08	42-53	P.Lyngs
(5) Scotland	Canna	79/81	37	46.6	2.55	42-54	R.L.Swann & A.D.K.Ramsay
(7) Scotland	Fair Isle	1980	98	46.5	2.39	39-52	PHJ
(8) Scotland	Foula	1980	66	47.1	2.31	42-52	M.L.Tasker
(9) Scotland	Noss	1980	65	48.6	2.07	44-53	B.F.Blake & T.J.Dixon
(11) Iceland	Grimsey	1981	61	45.6	1.84	42-49	PHJ
(12) Norway	Røst	1981	45	45.2	2.15	41-49	T.Anker-Nilssen & O.W.Røstad
(13) Norway	Vardø	1980	95	47.0	3.10	39-56	R.Barrett

Table 34. Guillemot: gonys depth measurements of fullgrown birds in breeding colonies. Numbers correspond with those in Fig.9.

country	colony	date	sample size	mean (mm)	s.d.	range	authority
(1) Wales	Skomer	c.1975	84	13.1	0.64	12.0-14.5	T.R.Birkhead
(2) Ireland	Gt.Saltee	1982	35	13.0	0.60	12.0-14.3	PHJ
(4) Denmark	Graesholm	1983	46	14.1	0.60	13.0-15.2	P.Lyngs
(7) Scotland	Fair Isle	1980	98	13.5	0.64	12.2-14.9	PHJ
(8) Scotland	Foula	1980	67	13.5	0.66	12.0-15.0	M.L.Tasker
(9) Scotland	Noss	1980	67	13.3	0.70	11.9-14.8	B.F.Blake & T.J.Dixon
(11) Iceland	Grimsey	1981	61	13.3	0.51	12.1-14.4	PHJ
(12) Norway	Røst	1981	45	13.5	0.58	12.6-14.8	T.Anker-Nilssen & O.W.Røstad
(13) Norway	Vardø	1980	96	14.1	0.60	12.5-15.5	R.Barrett

Table 35. Razorbill: winglength measurements of adults in breeding colonies. Numbers correspond with those in Fig.10.

country	colony	date	sample size	mean (mm)	s.d.	range	authority
(1) Ireland	Kerry Is.	66/73	27	194.2	4.87	187-203	P.G.H.Evans
(2) Ireland	Gt.Saltee	1982	34	198.3	4.23	188-206	PHJ
(3) Wales	Bardsey	81/83	24	196.1	3.92	191-205	P.J.Roberts & M.Sutherland
(4) Scotland	I. of May	1982	25	194.2	5.63	186-205	M.P.Harris
(5) Scotland	Canna	79/81	31	198.9	4.11	190-206	R.L.Swann & A.D.K.Ramsay
(6) Scotland	Shiants	1982	31	197.2	4.34	189-206	D.L.Steventon
(7) Scotland	Foula	1980	62	197.8	4.04	189-206	M.L.Tasker*
(8) Iceland	Grimsey	1981	36	196.1	4.06	187-203	PHJ
(9) Norway	Røst	1981	32	207.8	6.20	198-217	T.Anker-Nilssen & O.W.Røstad
(10) Norway	Hornøy	81/82	73	211.6	5.90	187-220	R.Barrett

*subsequently published in Furness (1983)

Table 36. Razorbill: gonys depth measurements of adults in breeding colonies. Numbers correspond with those in Fig. 10.

country	colony	date	sample size	mean (mm)	s.d.	range	authority
(2) Ireland	Gt.Saltee	1982	36	20.7	0.71	19.6-21.9	PHJ
(7) Scotland	Foula	1980	70	20.6	1.01	*18.4-22.7	M.L.Tasker
(8) Iceland	Grimsey	1981	37	20.9	0.91	19.5-23.3	PHJ
(9) Norway	Røst	1981	32	22.2	1.52	19.5-25.0	T.Anker-Nilssen & O.W.Røstad
(10) Norway	Hornøy	81/82	74	22.9	1.30	-	J.Barrett

*2 low outliers @ 16.8 and 17.7

Table 37. Guillemot and Razorbill: weights of birds at or near breeding colonies at two seasons.

colony*	sample size	mean (gm)	s.d.	range	authority
GUILLEMOT					
(a) breeding season					
Great Saltee	3	923.3	106.9	830-1040	PHJ
Isle of May	80	942.0	52.9	820-1050	M.P.Harris
Canna	34	926.7	46.4	850-1010	R.L.Swann & A.D.K.Ramsay
Troup Head	27	926.3	50.2	830-1020	J.Hardey
Fair Isle	22	986.8	87.1	840-1200	PHJ
Grimsey	10	1007.0	58.3	930-1090	PHJ
Vardø	96	1039.2	82.5	850-1240	R.Barrett
E.Murman	375	1053	-	825-1285	Belopol'skii (1957)
(b) winter					
Forth estuary	43	1094.0	114.8	850-1310	B.F.Blake & T.J.Dixon
Fowlsheugh	32	1122.2	64.2	1020-1300	B.F.Blake & T.J.Dixon
Noss	27	1087.8	86.3	930-1280	B.F.Blake
RAZORBILL					
(a) breeding season					
Kerry islands	27	610.0	31.3	550-670	P.G.H.Evans
Great Saltee	32	630.0	49.4	570-710	PHJ
Isle of May	24	625.0	40.8	560-720	M.P.Harris
Grimsey	37	631.1	37.8	560-740	PHJ

* localities as in previous tables; Fowlsheugh is in E. Scotland between Troup Head and Isle of May.

Fig. 9. Guillemot: winglength means for samples of fullgrown birds in breeding colonies (numbers in brackets correspond with details given in Table 32).

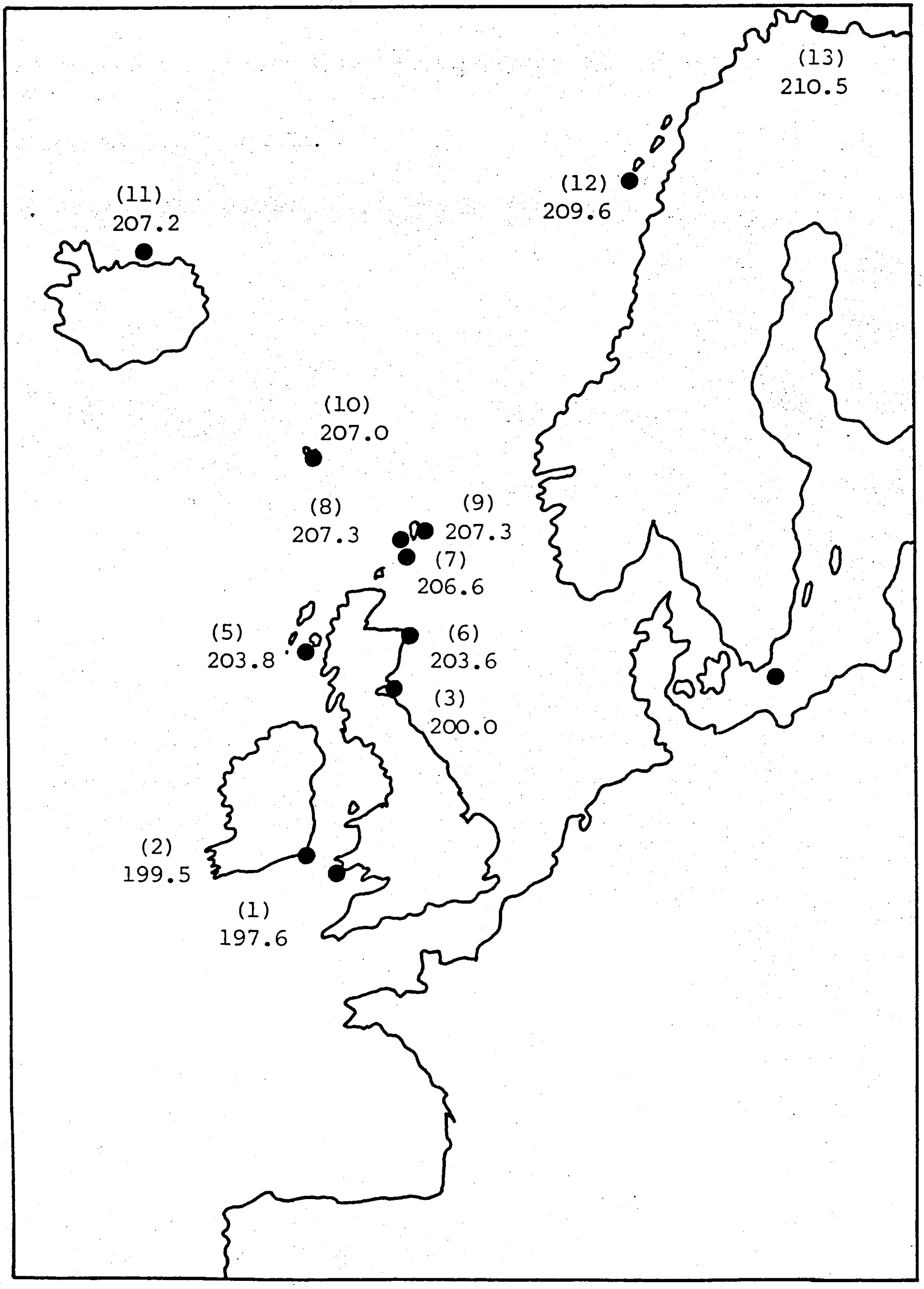


Fig. 10. Razorbill: winglength means for samples of adults from breeding colonies (numbers in brackets correspond with details given in Table 35).

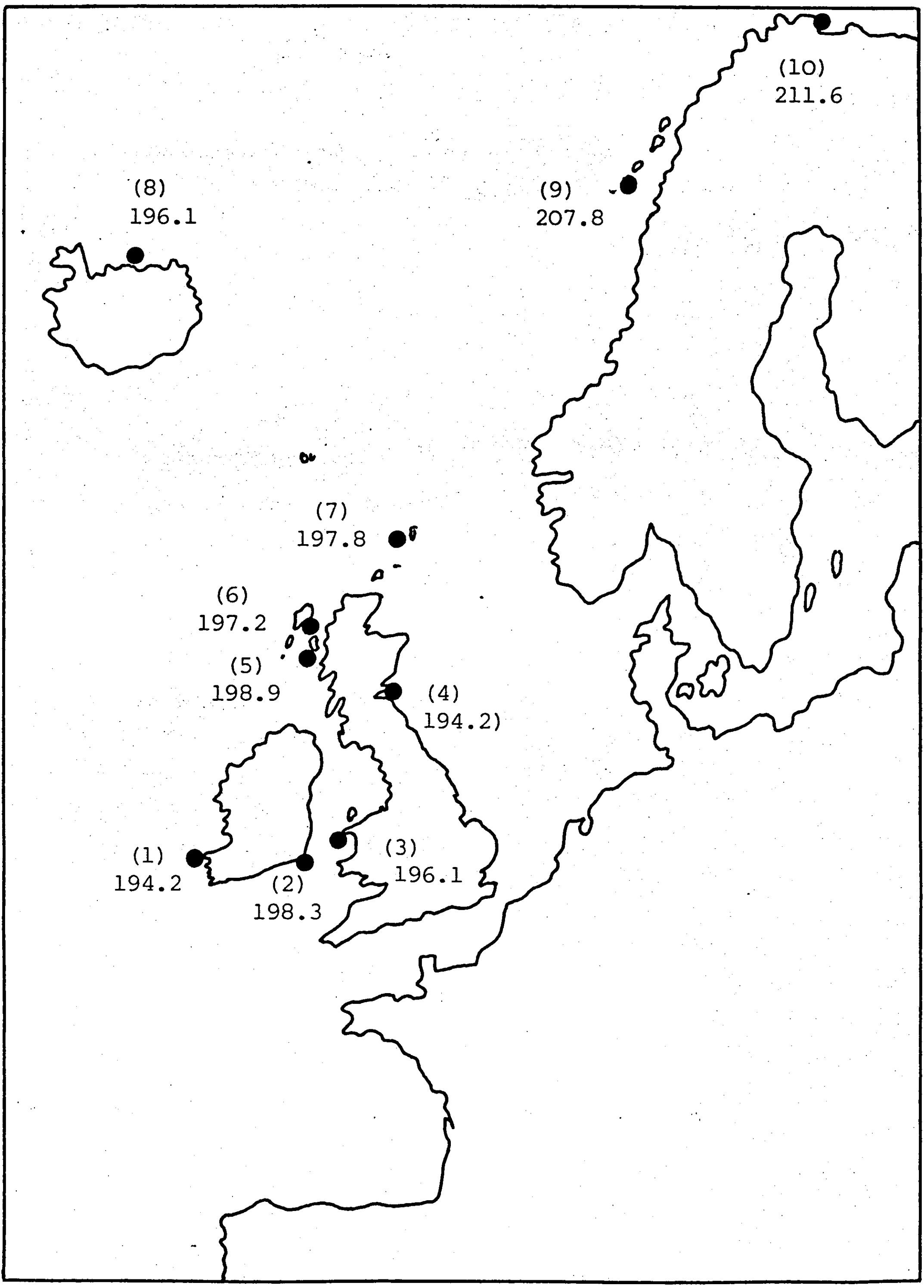


Fig. 11. Guillemot: mean winglength of colony birds by latitude in N.W. Europe.

Skomer to Shetland: $y = 1.0906x + 141.27$ $r = 0.9559$

Shetland to Vardø : $y = 0.3096x + 188.24$ $r = 0.8819$

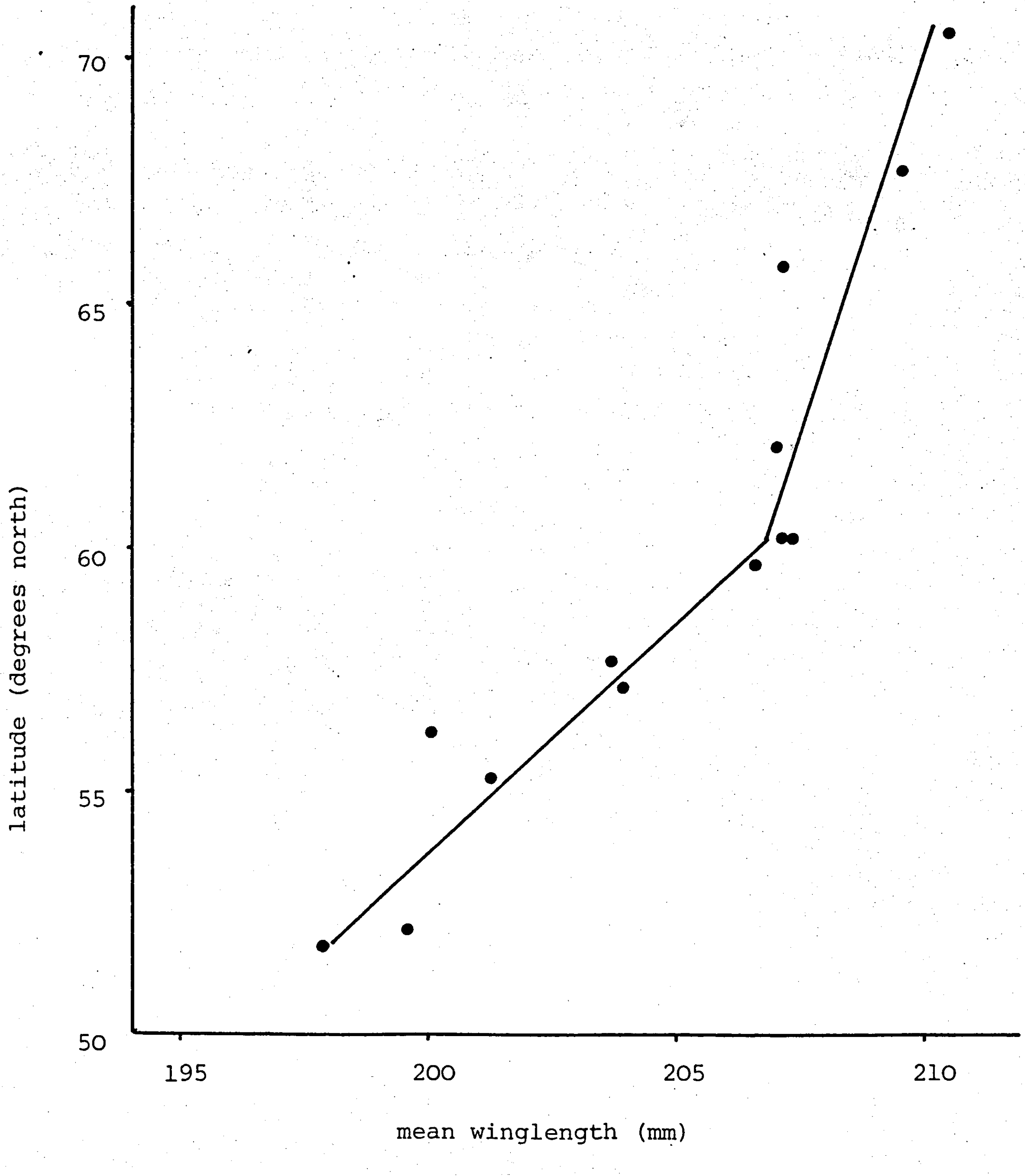
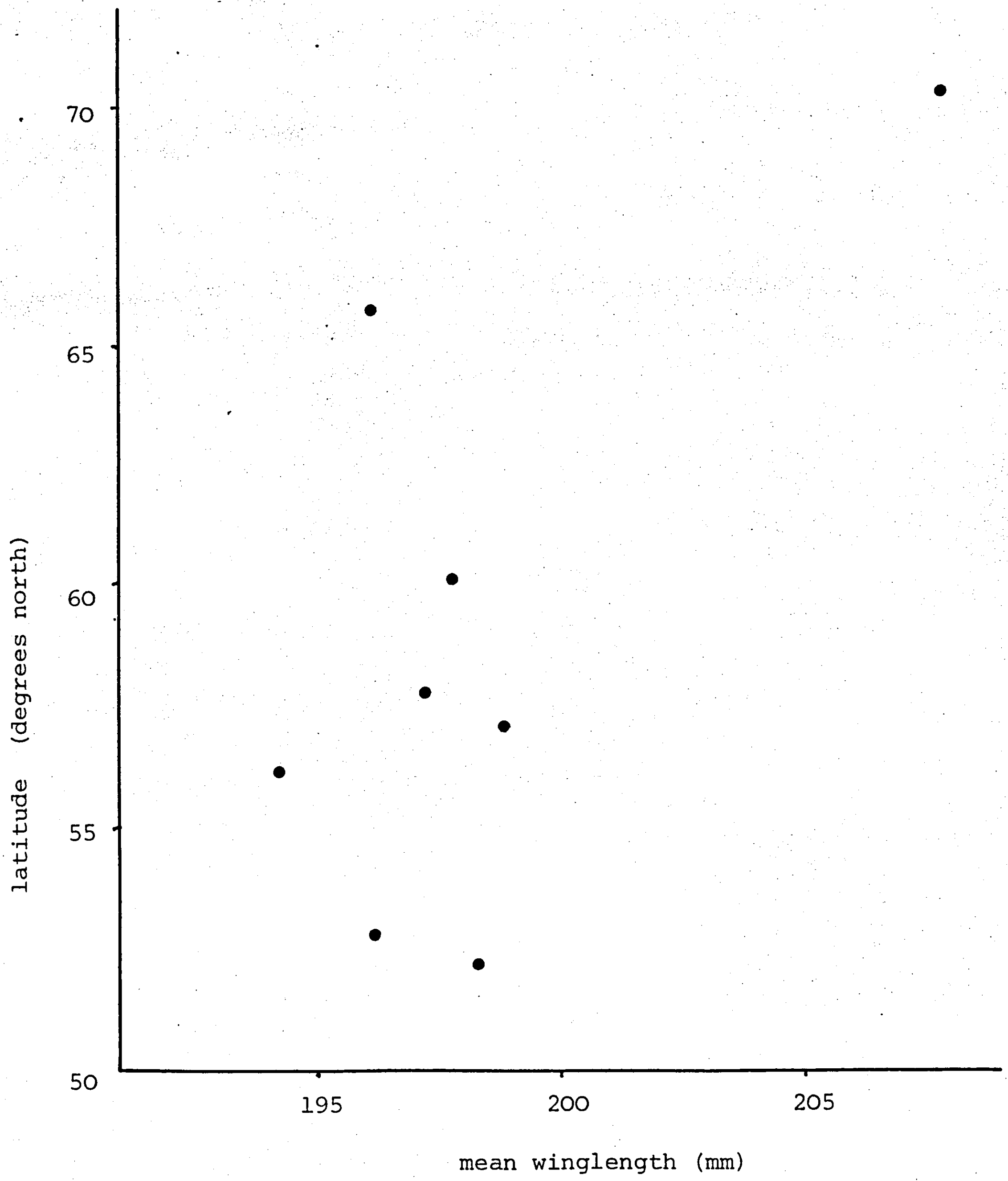


Fig. 12. Razorbill: mean winglength of adult breeders by latitude in N.W. Europe.



5.2 Post-mortem changes in measurements

In 1978, an oilspill from the tanker 'Christos Bitas' resulted in a carnage of Guillemots and Razorbills off the coast of Dyfed. Skins were made from corpses of both species collected at that time; these specimens were prepared and curated by the National Museum of Wales (Morgan 1980), and this was the collection of flat skins examined in the present study.

Four measurements were taken from each skin: winglength, culmen length and bill depth at gonys (described in Appendix I, and illustrated there in Figs. 4 - 6), together with the measurement between bill tip and the distal end of the nostril groove. For each individually-numbered skin, measurements were taken soon after the birds were dead (November 1978) and on three occasions subsequently: all measurements were made by PHJ.

Personal variation in skin measurement

In order to be sure that any changes were not due to too much personal variation, two of the sets of measurements were made in May and October 1983: sufficiently close together that there was little chance of shrinkage between times (skins were almost five years old by this stage), and sufficiently far apart to preclude any memory, on the part of the measurer, of means and variances. Both sets of measurements were made fairly rapidly in order to simulate the rushed conditions which are normal at the examination of birds during an oilspill: the collated results are shown in Table 38.

Consistency in winglength measurement was high in both species, though mistakes had obviously been made, indicating the need to check potential outlier values very carefully during initial examination of a sample of birds. For both species, there was no significant difference between means of the two sets of winglength measurements. Bill length measurements indicated that a higher consistency was obtained from nostril-to-tip measurements, perhaps because the proximal point of measurement was rather difficult to ascertain on the culmen specimens. Measurement of bill depth at gonys - whilst an important parameter - is notoriously difficult and variable, and patently a greater variability must be expected, since

(a) it is an inherently short measurement;

(b) more mistakes are likely when reading the vernier scale on the caliper;

(c) the curvature of the rhamphotheca can produce problems in measurement replication (see Appendix I, Fig.6, central diagram).

Measurement changes over a period of five years

Collated and summarised results for two sets of measurements (made after the curation of the study skins) are shown in Table 39. Basically, it was evident that most of the shrinkage occurred within two months of skinning and drying - there was only little change subsequently. The effect is further demonstrated in Table 40, showing a significant change in sample mean between measurements of freshly dead birds and the same individuals two months after skinning. No significant change occurred subsequently.

These data, and the principles which they illustrate, are fundamental when considering any comparison of museum study skins with live birds or with fresh, unskinned, corpses.

Measurements of skins and live birds

A long series of measurements was made in various European museums, using skins of Guillemots collected at, or very near, breeding colonies during the breeding season. The results, when compared with measurements from live birds (Fig. 13) indicate that

(a) for any given latitude, the museum measurements for mean winglength are likely to be 3-5 mm shorter than for live birds (1.5-2.5% decrease);

(b) there is clinal variation in three steps through Europe.

Table 38. Personal variation in skin measurements: collation of results.

parameter	% within 1 mm of previous measurement	% within 2 mm of previous measurement	approximate relationship with the mean
<u>winglength</u>			
Guillemot	89.2	96.1	1 mm = 0.5% of the mean 2 mm = 1.0%
Razorbill	87.5	99.1	
<u>culmen length</u>			
Guillemot	81.1	96.1	1 mm = 2% of the mean 2 mm = 4%
Razorbill	96.2	98.1	
<u>nostril to tip</u>			
Guillemot	95.0	98.6	1 mm = 2% of the mean 2 mm = 4%
Razorbill	97.1	100	
	% within 0.1 mm of previous measurement	% within 0.5 mm of previous measurement	
<u>depth at gonys</u>			
Guillemot	65.8	96.7	0.1 mm = 1% of the mean 0.5 mm = 5%
Razorbill	51.0	97.0	0.1 mm = 1% of the mean 0.5 mm = 4%

Table 39. Guillemot and Razorbill: postmortem changes in measurements in a sample at the National Museum of Wales, first measured in November 1978.

	after 2 months (Jan.'79)			after 5 years (Oct.'83)		
	n	median change (mm)	range of change	n	median change (mm)	range of change
WINGLENGTH						
Guillemot	104	- 2	+1 to -7	101	- 2	+1 to -7
Razorbill	59	- 2	+1 to -6	57	- 2	+1 to -6
CULMEN LENGTH						
Guillemot	103	0	+2 to -4	101	- 1	+2 to -5
Razorbill	59	- 1	+1 to -4	57	- 1	+1 to -5
NOSTRIL TO TIP						
Guillemot	104	0	+2 to -2	100	0	+3 to -2
Razorbill	59	0	+2 to -2	57	0	+1 to -2
GONYS DEPTH						
Guillemot	104	- 0.5	+0.3 to -1.5	101	- 0.5	+0.3 to -1.5
Razorbill	59	- 0.6	+0.2 to -1.7	57	- 0.4	+0.3 to -1.7

Table 40. Comparison of winglength measurements for two sets of skins.

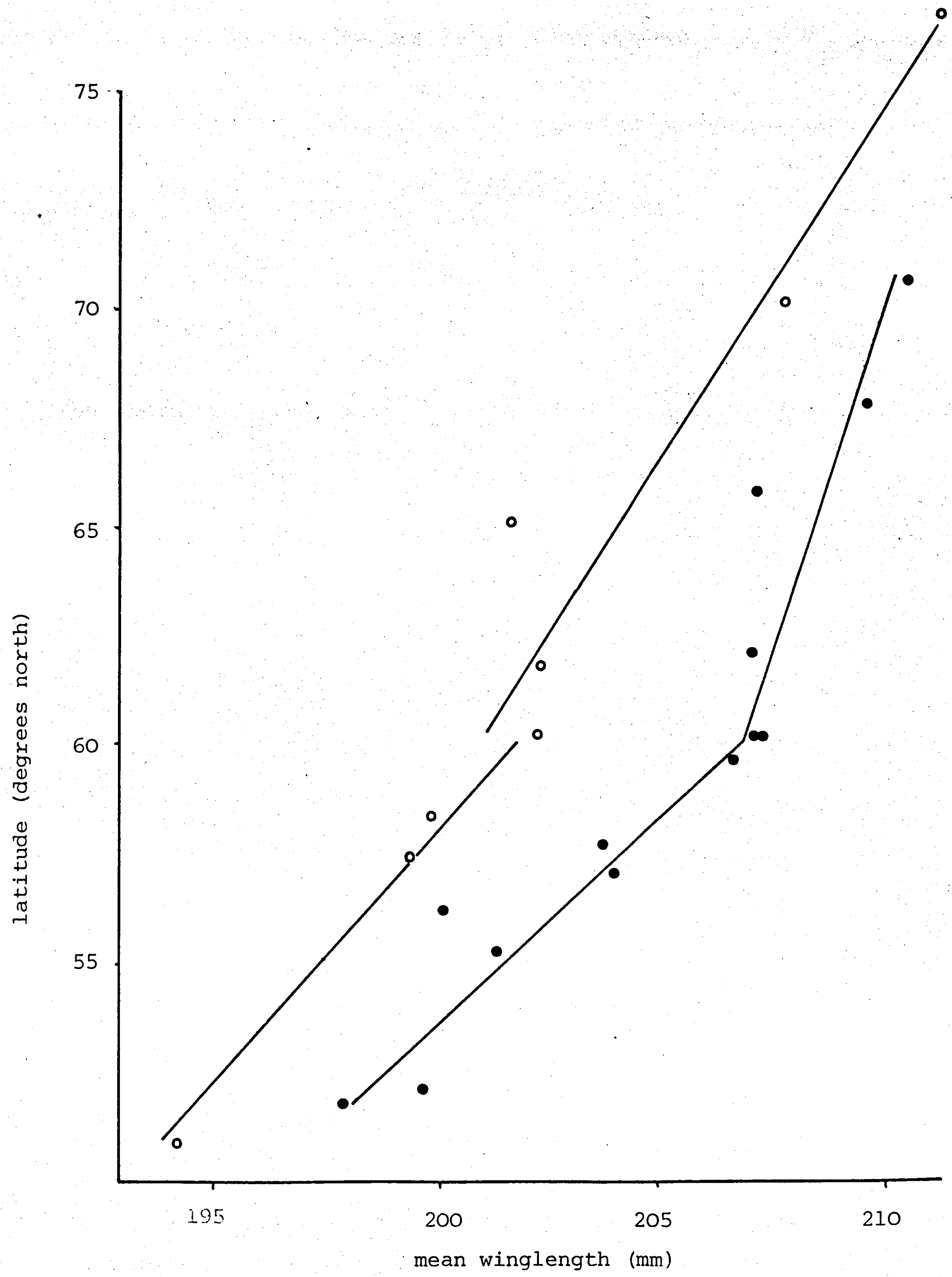
	sample size	mean (mm)	standard deviation	range
GUILLEMOT				
freshly dead	83	192.9	5.1	180 - 205
$p<0.002$				
after 2 months	83	190.4	4.9	176 - 202
n.s				
after 5 years	83	190.2	5.7	177 - 202
RAZORBILL				
freshly dead	58	190.1	4.4	179 - 201
$p<0.01$				
after 2 months	58	187.6	4.3	177 - 198
n.s				
after 5 years	57	188.5	4.5	178 - 198

N.B. Fewer Guillemots than in Table 39 because birds with initial winglength of less than 180 mm were mainly moulting, and these specimens were excluded in calculation of means.

Fig. 13. Guillemot: mean winglength of colony birds by latitude in N.W. Europe.

Closed dots = live birds; open dots = museum skins.

Omitted is one set of skin values from Berlengas, Portugal: mean winglength = 195.5 at latitude 39.5° N.



5.3 Bridling proportions in Guillemots

The two forms of Guillemot - bridled and non-bridled - are normally readily identifiable at close to medium range when birds are in breeding plumage. Researches summarised by Southern (1939) confirmed the existence of a cline between N.W. France and northern Norway in a gradually increasing proportion of bridled birds from south to north. Following on from these surveys made by predecessors between 1938 and 1960, Birkhead (1984) instituted a fourth in 1981/82, so it was superfluous for PHJ to undertake additional survey work in the field.

The main emphasis in this study was therefore centred on recording the proportions of bridled birds during examination of Guillemots killed in incidents. Data for clean birds in breeding plumage were easy to collect, but samples at other times of year proved more problematical, on two counts:

(a) birds were often fouled with oil and dirt,

(b) the 'bridle' was often less easy to discern when the bird was in 'winter' plumage (additionally, Jefferies and Parslow (1976) stated that, in first winter birds, the winter plumage tended to encroach on the bridle, and that the orbital ring became less distinct).

Details for birds examined at breeding colonies are shown in Table 41. The sample from Grimsey was collected as a series of freshly-dead birds having been killed by falling stones following an earth tremor; the bridling proportion of 5.4% was not significantly different from that of 7.7% obtained by counting 1035 live birds from the cliff top in that area ($\chi^2 = 1.03$). However, the proportion of bridled birds may change locally. Counts made for Grimsey are shown in Fig. 14; differences in the proportions of bridled birds in the two north-eastern sectors are significant ($\chi^2 = 5.909$, $\rho<0.05$), so it is obviously preferable to have high numbers in samples both of live birds at colonies and of dead birds at incidents.

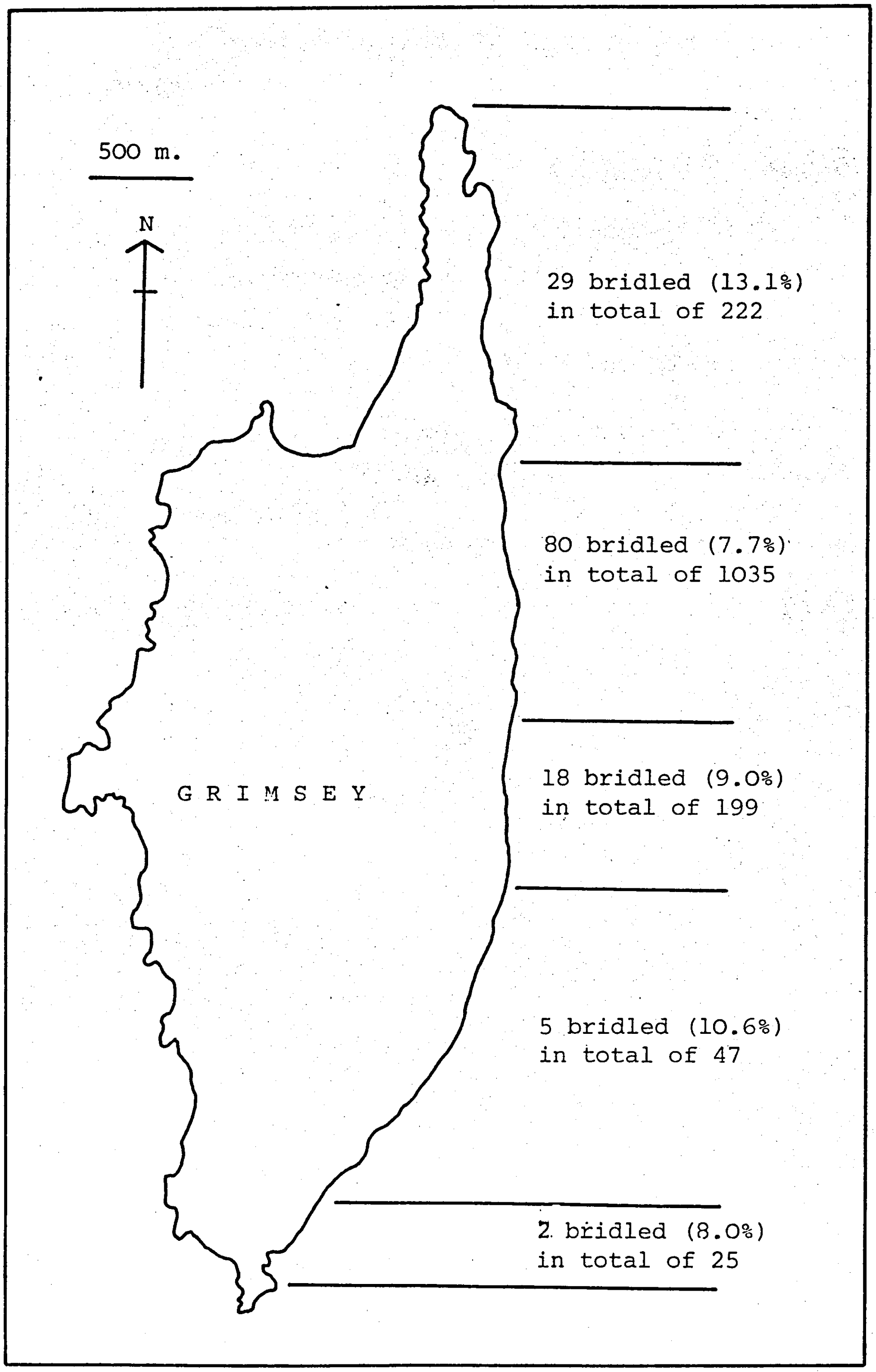
In all six samples in Table 41, the bridling proportions for birds examined in the hand were lower than in the relevant field counts ($\rho<0.05$ sign test), but the samples were comparatively small. If this proved to be a general principle, it would have to be borne in mind when comparing this parameter between mortality samples and field counts.

In view of the paucity of information on birds showing intermediate characters between bridled and non-bridled forms, it is worth noting such an individual caught at the Fair Isle, Shetland, in June 1980: there was a semi-bridle on the left side, but no sign of any bridling on the right. Because of the speed of operation necessary in dealing with Guillemot corpses in a mortality incident, it was not possible to produce accurate figures on the proportions of intermediate types, but at least three other specimens were noted in the period 1980-83.

Table 41. Guillemot: comparison of bridling proportions for samples examined in the hand at breeding colonies and counts of live birds at that site.

site	proportion bridled in samples at colonies		proportion bridled at or near that site - in Birkhead (1984)	
	n	%	n	%
Great Saltee, Ireland	35	0	8202	0.8
Fair Isle, Scotland	283	17.3	2983	23.0
Foula, Scotland	66	19.7	1225	27.4
Noss, Scotland	66	21.2	2000	22.9
Grimsey, Iceland	149	5.4	1394	9.6
Røst, Norway	46	6.5	1180	17.0

Fig. 14. Counts to establish proportions of bridled Guillemots at Grimsey, off northern Iceland, on 17 July 1981.



5.4 Upperpart colour in Guillemot

With a cline in increasing colour saturation of Guillemot upperparts from south to north (Vaurie 1968), it was important to classify specimens from particular colonies and incidents. Two approaches initially seemed practicable: a comparison of clean feathers with a known standard series of specimens (paper or feather), or the measurement of the colour by means of a calibrated instrument.

The latter approach seemed much the best but it quickly proved to be too expensive - reflection densitometers of various makes usually costing well over £800. However, it was possible to use a machine in the British Museum's Department of Palaeontology for examination of one sample of wings. The machine's small viewing cell was first calibrated against a chalk white block of magnesium carbonate, then placed directly onto the outer secondary coverts of each of the wings tested. There is known to be the possibility of systematic errors between calibration and measurement, if, for these operations, the applicator head is held in different planes (Beerens 1980), so calibration and measurement were both done with the machine head facing vertically downward.

At a more practical level, three methods emerged for consideration: a relatively inexpensive book with colour samples selected for wildlife application (Smithe 1978); neutral value scales, ranging from white, through varying degrees of greyness, to black (Munsell 1971 and Eastman Kodak 1977); and a series of specimen Guillemot wings, (graded and chosen from specimens available) to cover the range of darkness of colour shown in N.W. Europe. Wings, taken from various Guillemot corpses, were cleaned, dried, and stored in the dark before being compared with these sets of standards, under 'daylight' fluorescent lighting.

(a) Reflection densitometer

The machine was first tested using two wings of obviously different colour, with light passed through various colour filters ranging from violet (4260 Angstrom units wavelength) to deep red (6840 A), giving an abridged spectrophotometric curve for each specimen. The latter filter produced the greatest difference between samples as well as the highest values (which were therefore less subject to error). It was not possible to have white (unfiltered) light on this particular model.

Using this dark red filter, the variation in readings around the same spot on the wing coverts were tested on three wing specimens, moving from one to the other between each reading to give, eventually, ten readings per wing; the whole test was repeated once (Table 42). Readings ranged between 4% and 11% of mean values, and it seemed as though PHJ had learned to use the machine more efficiently by the second test. The upperwing coverts of Guillemot, although fairly uniform at a distance, are nowhere near homogenous in colour when viewed very closely, and the variation in the placing of the machine's light-emitting aperture was obviously showing up this range of colour. In moving the machine head over the wing of bird no. 83, the range of variation on the coverts was mainly between 11 and 13 deflection units, rising to 17 on the pale feathers near the carpal joint, and dropping to 10 on the darker inner primaries. Table 43 was constructed following examination of a series of specimens chosen by eye.

The use of an apparently objective machine was in no way a panacea to the problem of standardisation and repeatability, though perhaps an observer could improve with experience in use of the machine. However, problems with the interpretation of results from the machine, and the cost of acquiring one in order to obtain the necessary experience in its use, led to consideration of other methods of grading the wing colours.

(b) Colour guides

The comprehensive Munsellcolour guide(showing 1500 colours, and selling at £400 in 1981) was too complex for this work, but an excellent small guide was purchased from the American Museum of Natural History: Naturalist's Color Guide by F.B.Smithe at ca. £9. Not unexpectedly, the range of grey-browns was extensive, and the time necessary for matching one wing made the calibration of a long series of wings very time-consuming and tiring to the eyes. The Guide's capacity for facilitating a colour match was good, but the system was eventually adjudged impractical on the time factor.

(c) Neutral value scales

The exact colour value of each specimen wing was considered not as important as the intensity of saturation (or degree of darkness), so various series of wings were examined using only grey scales without consideration of colour. The standards used were the Munsell Neutral Value Scale (£19 in 1982) and the Kodak Reflection Density Guide (£4 in 1982). Being each on one sheet of card, these were more satisfactory than the colour charts (which necessitated flicking through several pages) and for the darker wings they worked very well. However, the paler wings proved problematical since brown took over from black and made comparison with shades of grey rather difficult, so this system also had drawbacks. Comparison of calibration by this system and by reflection densitometer is shown in Table 43.

(d) Specimen wings

Having experience of the range of colour values shown by Guillemots throughout their European cline, it was possible to divide this range into eight steps, each one just separable by eye from the adjacent step. From a long series of cleaned specimen wings obtained in recent mortality incidents, samples were chosen to represent these steps; these were labelled as standard types from 2 (palest available) to 8 (darkest available). The colour range was from a pale warm brown through to black, and the reflectance of white light decreased from 6% for the palest wing to 1.5% for the darkest (Table 43). Various sets of cleaned and dried wings were calibrated against the standards under 'daylight' lighting, and the method proved easy and quick.

The one major drawback to this system is the fact that dark plumage colours tend to fade after death, so the 'standard' wings would become non-standard after an unknown period - possibly three or four years - even though carefully stored in the dark after each session of use. It is known (J.Dyck pers. comm.) that black wings from male Common Scoters will show a measureable change in degree of darkness within one year, even when stored in the dark.

Results

Distribution of shade of upperwing is shown for three samples in Table 44. Difference between birds from colonies in S.E.Ireland and N.E. Scotland are well-marked, though there was an overlap of 22% (31 birds in types 4 + 5 with the remaining 110 outside this range). The winter sample showed that 24% at least were likely to have been from outside the range of birds breeding in southern Britain - that is, 26 of the Devon/ Cornwall samples of 110 were darker than the range of colour shown by breeders from near that latitude (Great Saltee). However, the colour of upperparts almost certainly fades with time after the autumn moult, so that winter birds may anyway be slightly darker than the same population in summer.

Table 42. Variation in readings of reflection densitometer on Guillemot upperwing coverts (dark red filter used).

wing number	no. of tests	mean reading	standard deviation	range of readings	coefficient of variation (%)
1st series					
83 (pale)	10	11.8	0.92	10 - 13	7.8
210	10	11.4	0.70	10 - 12	6.1
55 (dark)	10	6.6	0.70	5 - 7	10.6
2nd series					
83	10	12.1	0.74	11 - 13	6.1
210	10	11.7	0.48	11 - 12	4.1
55	10	6.8	0.42	6 - 7	6.2

Table 43. 'Calibration', by reflection densitometer and dark red filter, of the series of Guillemot wings chosen by eye as representing a graded series of colour intensity.

wing number	type number	% deflection on machine*	approximate % reflectance of white light †
83	2 (palest)	12	6
82	3	11	5.5
191	4	10	5
210	5	9	4
84	6	7	3
90	7	6	2
55	8 (darkest)	5	1.5

* this value should (according to the manufacturer) be halved to give the reflectance of white light.

† wings compared directly with Munsell grey scale.

Table 44. Guillemot upperwing colour for three samples (medium values underlined).

locality and time	colour code								sample size
	2 (pale)	3	4	5	6	7	8	9 (dark)	
Great Saltee (in colony, July)	3	21	9	2	0	0	0	0	35
Buchan (near colony, March)	0	0	1	19	42	30	14	0	106
S. Devon & Cornwall (winter)									
adult	0	1	8	5	5	1	0	0	20
immature	3	18	26	23	20	0	0	0	90

5.5 Discussion and conclusions

Measurements of Guillemots and Razorbills at breeding colonies confirmed - for the former - presence of a cline of increasing winglength with latitude in N.W.Europe and - for the latter - the homogeneity of measurements for populations between Wales/Ireland and Iceland. This is believed to be the first collation of measurements taken on live birds in this region.

Two other sets of measurements (both of Guillemots) need evaluation: those of Grandjean (1977) made in Iceland, and those of Threlfall and Mahoney (1980) made in Newfoundland. Grandjean's observations were made on a set of 150 Guillemots "captured with fowlers net" between 6 and 13 July 1969, with winglength measured "on the flattened wing", and bill depth "as the maximum vertical depth of the closed bill" - methodologies similar to those utilised in the present study. Grandjean comments on the fact that "the wing length is small compared to that of other populations of the nominate subspecies", it is even smaller when considering that comparison was made with other measurements taken from study skins which had presumably shrunk in winglength measurement. A reason for this anomaly can be suggested, as follows: it seems likely that Grandjean's sample included an unknown percentage of immature birds since the bill-depth measurements ranged from 11.2 mm - a most unlikely value for a breeding bird - even though the mean for the sample was 13.8 mm. If plotted on the regression of mean winglength on latitude (Fig. 11), Grandjean's data (198.5 mm at 63.5°) are so far displaced as to suggest either some extraordinary local anomaly in the cline or, perhaps more likely, a large difference in wing measurement methodology and/or the inclusion of a considerable number of immature (shorter-winged) birds in the sample. These results were therefore not included in Fig. 11.

The sample measured by Threlfall and Mahoney (1980) was taken in the spring and summer period May - July, 1966-1968, with measurements taken "using the methods outlined in Witherby et al. (1965)" (a reprinting of Witherby et al. 1941). Here again, the sample is likely to include some immature birds, since bill depth minima are 11.5 mm, and the standard deviations for both sexes (1.0 for males and 0.9 for females in this parameter) are considerably higher than those in Table 26 of the present study. Their second conclusion - that the winglength range of the subspecies aalge should be expanded from Witherby's 195-210 for males to their own 180-213 and from Witherby's 195-207 for females to their own 188-217 - can be criticised on two grounds: the comparison of fresh measurements with those from skins, and the possible inclusion of immature birds in the large (= 238) Newfoundland sample, when comparing with Witherby's small (= 17) sample.

The measurement of live birds in breeding colonies is a vitally important aid in 'calibrating' or 'typing' birds killed in incidents which occur outside the breeding season. However, the sample variance at any given site is quite high for those parameters measured so far: the coefficient of variation for winglength varied between 1.5% and 2.6% for Guillemots at the 13 sites in Table 32, whilst for Razorbill winglengths the coefficient ranged between 2.0% and 2.9% for the eight sites in Table 35. The range of winglengths at each site made it imperative that, in any attempt at inferring the origins of 'incident birds', a large sample be measured; it is obviously a hopeless proposition to infer precise origins from individual birds or very small samples, especially since outlier values may perhaps occur as a feature in a range of measurements at breeding colonies. At the same time it is important that the 'colony measurements' be taken from birds which should, wherever possible, be proven breeders - reasonably easy to establish for Razorbills (birds with 'adult' bills sitting on one egg or chick at an individual nestsite), but more difficult for Guillemots (no morphological 'adulthood' feature, and often large numbers mixed together on cliff ledges). The colony measurements presented in this study are probably open to further refinement and a higher degree of 'quality control' in this respect.

The major taxonomic works on Guillemots (Salomonsen 1944 and Storer 1982) and on Razorbills (Salomonsen 1944) used measurements from museum skins, and some subsequent studies have continued this well-established tradition (e.g. Vaurie 1965, Pethon 1967). However, the interest in ecological fieldwork since the 1950s has produced sets of measurements for live birds, usually collected incidentally to detailed work on population dynamics and movements, feeding ecology or chick development (Barrett, *in press*; Birkhead, *in litt.* following 1976; Swann and Ramsay, *in litt.* following 1983), though some workers have set out deliberately to take body and weight measurements for taxonomic purposes, (Corkhill 1972, Harris 1979, Furness & Baillie 1981).

Some of the efforts made in comparing measurements from beached birds with those from museum skins were rather uncritical (e.g. Bourne 1967, 1968, Parrack 1967) and although the latter referred to the problem of skin shrinkage, the conclusions of both authors - in respect of auks' origins - are open to considerable doubt. In particular, Guillemots with reported winglengths of 215 (apparently measured fresh) and of 212 and 213 (apparently measured on skins) are referred to the far northern form *U.a. hyperborea* whereas, in fact, any of these birds could have been bred in Shetland or even further south. However, these were early studies in field taxonomy on auks, and these efforts stimulated a more critical approach in subsequent reporting.

Meanwhile, the subject of post-mortem shrinkage in skinned birds was being examined in grebes (Fjeldså 1980), Lapwing (Vepsäläinen 1968), Dunlin (Greenwood 1979), Ringed Plover and Dunlin (Green 1980), waders (Engelmoer et al. 1983), gulls (Barth 1967), and Puffin (Harris 1980). The picture which emerged was that the degree of shrinkage in winglength was often statistically significant and usually representing 1-3% of the mean, that gains might occur as well as losses, and that there was considerable individual variation in the amount of shrinkage. Harris (1980) further reported that the change in his sample occurred during the first two months after death but not subsequently, and Engelmoer et al. (1983) found that longer wings had greater percentage shrinkage, but none of the authors tested his own variation in measurements of the same individual wings. In searching for the mechanism of shrinkage, Knox (1980) found from X-ray photographs that considerable differences could occur (even between the two wings of the same bird) in "the angles at which the bones of the hand become set after death". This could account for much of the recorded variation in the amount of shrinkage. The problem, therefore was well-attested and a probable explanation had emerged.

In considering shrinkage values for other measurements, Greenwood concluded that tail length in his Dunlin sample had decreased significantly, whereas bill length and tarsus length showed no significant change; Harris showed a significant decrease in Puffin bill length but not in bill depth; Engelmoer et al. found, in the main, no changes in wader bill and tarsus lengths; Fjeldså demonstrated marked changes in bill dimensions of grebes but only little change in tarsus measurements. Fjeldså also produced a correction factor: "the factor by which the measurement of a skinned specimen should be multiplied to get the fresh measurement".

Results from the present study are thus in close agreement with those of most other workers; in a large sample of Razorbills and Guillemots:

(a) most change occurred within two months of death, and was insignificant thereafter;

(b) median winglength shrinkage in Razorbills and Guillemots represented about 1% of the mean winglength, a significant change;

(c) median shrinkage in culmen length and nostril-to-tip length was negligible for both species,

(d) median shrinkage in bill depth at gonys represented about 5% of the mean, a highly significant change;

(e) individual variation in degree of shrinkage was considerable;

(f) in both species and for all parameters there were a few increases in postmortem measurement as well as the more usual decreases;

Additionally, it was shown that

(g) personal variation in replicate measurements resulted in a few obvious errors; however, there was zero modal difference between measurement sets, and high consistency between original and repeat winglength measurements (96% within 1% of first measurement) a greater variability in repeat measurements of bill dimensions (c. 97% within 4%).

In any comparison, therefore, between measurements from live birds or fresh bodies and museum skins, these results indicate that - for Guillemots and Razorbills - culmen length might be validly compared without need for correction factors; mean winglength for a large homogeneous museum sample is likely to be about 1-2% less than that for a similar sample of live or freshly dead birds, whilst mean bill depth at gonys is likely to be 5% less. However, these factors must be used with great caution because nothing is known about long-term shrinkage, or effects of different skin preparation methods. Alexander (1960) has shown that relative humidity levels can alter skull measurements of Muskrat specimens, so there may be many unsuspected factors operating. As a general principle it is safest to compare fresh measurements with fresh measurements and skin measurements with skin measurements, in both cases with the measurements made by the same individuals using the same method of measuring.

The bridled form of the Guillemot caused considerable controversy in the 19th century debate over whether or not Uria ringvia Brünnich comprised a true species, and even as late as 1926 the two-species case was still being championed (Krassovskii 1936). However, by the 1930s in Europe and North America, it was generally accepted that "the Bridled Guillemot is beyond all reasonable doubt only a variety of the common species", and that "a general trend in the proportion of bridled birds" occurred (Southern 1939). An inquiry of the British Trust for Ornithology was instigated, with the result that this trend was mapped for the British Isles, showing the existence of a cline from <1% bridling in southern Britain to 26% in Shetland. Counts abroad indicated proportions of over 40% in S. Iceland, Bear Island, N.Norway and N.W.Russia (Southern 1939, Southern & Reeve 1941). The survey was repeated in 1948-50 (Southern 1951), in 1959-60 (Southern 1962), and in 1981-82 (Birkhead 1984). Major conclusions were that the cline had remained fairly stable over that period though with a few marked local changes.

The explanation of the cline is still in debate, though there is a link with minimum air temperature during the breeding season. The genetic basis for the bridled form has been discussed by Huxley (1939), Southern (loc.cit), and by Jefferies and Parslow (1976), these last using breeding experiments with captive birds and concluding that the results were "compatible with bridling being a recession variant from the normal, carried by a single gene on one of the autosomes". Other intensive surveys of selected regions have been reported for Norway by Brun (1970), for Iceland by Einarsson (1979), and for N. Labrador by Birkhead & Lock (1980), whilst the intra-colony distribution of bridled birds has also been examined (Birkhead et al,1980).

For the purposes of aiding in identifying the origin of a sample of beached birds, it is sufficient to know the proportion of bridled birds in a region, and one map is fundamental to this aim. Data in Birkhead (1984) indicated that bridling proportions rise from <1% in southern Britain to nearly 30% in Shetland (Fig. 15). Elsewhere in Europe an even steeper section of the cline shows a reversal in Iceland with 52% at one site on the south coast and about 5% on the north coast. Faroe has about 28% bridled birds, Bear Island 50% and Norway from 12% in the south to 26% in the north-east, rising to 50% in N. Russia. The bridling proportion is between 7 and 27% in E. Canada but bridling is unknown in the Pacific populations of the Guillemot. The firm establishment of the existence of the cline south to north through Britain provides a valuable tool in 'typing' a sample of beached birds to their natal origins.

Shade of colour has long been a fundamental factor in the array of parameters used by ornithological taxonomists, particularly in the separation of contiguous or geographically-close subspecies. However, two factors militate against the unequivocal use of this particular parameter, particularly in examination of museum specimens: the difficulty involved in conveying, between taxonomists, the precise value of colour implied in any statement; and the change of colour which can occur in museum skins held for a period of time. The first point can be resolved through the use of reflection spectrophotometry (Dyck 1966) which, when carefully used, can produce repeatable results, but problems remain since the heterogeneous structure (and often colour) of, for example, a Guillemot upperwing can still produce an embarrasingly high variance about a mean value. The semi-quantitative approach adopted in this study was also used by Monaghan et al. (1983) in comparing shades of pale grey on upperwings of Herring Gulls: five populations from within Britain were demonstrably paler than one from northern Norway. One major advantage of gulls and - to a lesser extent - of Guillemots is that overall colour is not as important as the shade of darkness, so there is no need for the greater complications necessary when considering, for example, the "plain grayish olive-green plumage of the midback" of Red-eyed Vireos (Barlow & Williams 1971).

The second point (change of colour with storage) is especially relevant in Guillemots, where so much energy has been expended upon considering the importance of minute differences of colour in order to establish a taxonomic point (usually at subspecies level). Wagstaffe (1949) mentioned "perplexing and vexatious post-mortem" changes in colour of museum gull specimens, and the problem of 'foxing' was well known both to taxidermists and taxonomists: the change from a dark brown colour of plumage to a reddish brown. Foxing seemed to occur most quickly if the specimen were subjected to sunlight, but this change also occurred in museum specimens kept in the dark. Many of the Guillemot skins examined in museums had foxed badly, and they bore no colour resemblance whatsoever to live birds. The concept of carefully comparing the back colour of a freshly dead Guillemot with, say, the type specimen of <u>albionis</u>, in order to ascertain the subspecies, becomes of highly dubious value. Particularly impressive was the case where early in this study, five specimens of <u>albionis</u> and five of <u>aalge</u> were borrowed from a museum for comparison with freshly-dead Guillemots: none of the ten was remotely similar in colour to the fresh specimens. The rate of foxing, the individual variation involved, the mechanics of the process: all seem very poorly researched, so that at present there is no hope in applying any sort of correction factor to museum skins in order to ascertain their true original colour.

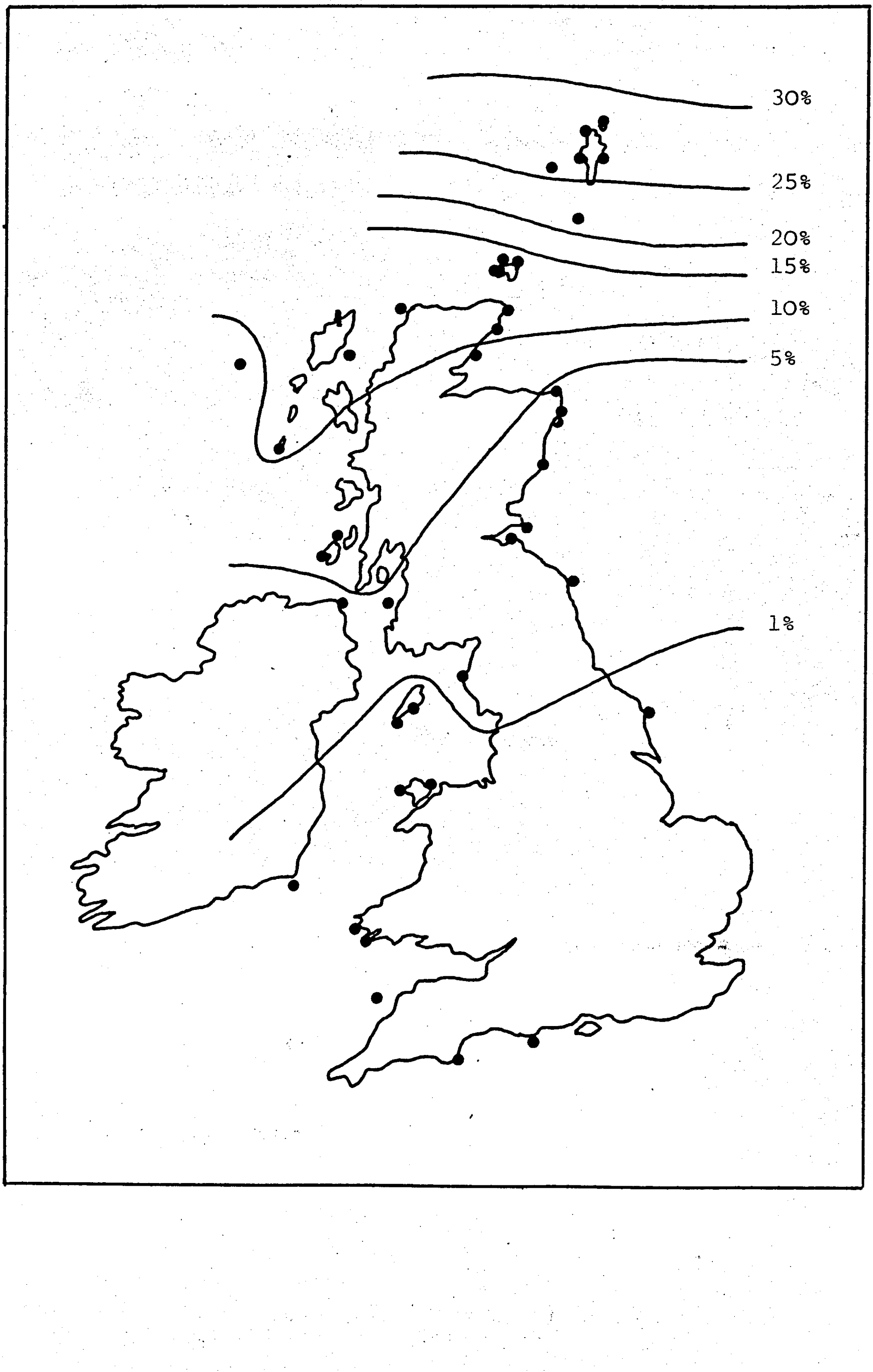
One further aspect needs consideration. There is clearly a fading of back colour in Guillemots with time from the main autumn moult. With birds examined in summer, there is often a paler edge to the flight feathers, with darker areas on those sections of the feathers protected from light when the wing is folded. It would thus seem that, over a period of time, exposed feathers fade much more quickly than those which are usually covered. This was very obvious in moulting fullgrown birds examined in September and

October where there was a very considerable difference between old (pale brown) and new (slaty-brown) feathers; this difference was also evident in moulting captive birds (Birkhead & Taylor 1977).

Since back colour is clearly an important parameter in 'typing' Guillemots to their origins, there is clearly need for more research on three prime topics: (a) the determination of 'mean colour' and range for a variety of breeding sites; (b) the invention of a relatively inexpensive portable reflection densitometer for use in this work, and (c) the establishment of the rate of change of colour in Guillemot back plumage over the course of the year between moults.

Thus the three parameters - wing measurement, proportion of bridled birds in Guillemots, and upperpart colour in Guillemots - all have various problems associated with methods and comparison of measurements, but when used in combination (and with an awareness of potential problems) they can provide a most valuable guide for the typing of Guillemots into an area of natal origin. The greater homogeneity amongst Razorbills over a wide area militates against the value of winglength and back colour, but at least the winglength can separate out many birds from the Scandinavian/Russian populations in comparison with those from the Iceland/Faroe/Britain/Ireland/France complex.

Fig. 15. Contoured proportions of bridled Guillemots at breeding colonies in Britain and Ireland, 1981-82 (from raw data in Birkhead 1984). Dots show the sites where counts were made.



6. SYNTHESIS AND DISCUSSION

6.1 Geographic variation and dispersal

6.1.1 Geographic variation, in Europe, of Guillemot and Razorbill

The generic name Uria was coined for Guillemot by Brisson in 1760 and the specific name by Pontoppidan in 1763 as his Colymbus Aalge. The two main subspecies, apart from the nominate form, are U.a.albionis Witherby 1923 and U.a.hyperborea Salomonsen 1932. Other subspecies which have had periodic currency have been U.intermedia Nilsson 1835, U.a.spiloptera Salomonsen 1932, and U.a.ibericus Bernis 1949. The geographical distribution of all the named forms is shown in Fig.16, and that of the three forms accepted by Vaurie (1965) in Fig.17.

The major criteria used in the separation of these forms are winglength and colour of the back - albionis being shorter-winged and paler than aalge, and hyperborea being longer-winged and darker. Other criteria mentioned by various authors have been strong underwing markings ('spiloptera') and shorter, deeper bill (hyperborea). Storer (1952) and Vaurie (1965) describe the geographic variation in Guillemot as mainly clinal, and it is evident, in the N.W.European sector of the world distribution of this species, that three factors increase with latitude: (a) winglength; (b) proportion of bridled birds; and (c) saturation of colour of upperparts. This is shown, for three subspecies, in Table 45.

The name Alca Torda was given to Razorbill by Linnaeus in 1758, and a British form Alca torda britannica was separated off by Ticehurst in 1936. The range of this subspecies was extended by Salomonsen to include Faroe in 1942, and Iceland in 1944. Salomonsen also erected the subspecies A.t.pica in 1944 for northern Norway and Russia, western Greenland and eastern Canada. However, Vaurie (1965) restricted the nomenclature to two subspecies, torda and islandica (= britannica above) with the breeding distributions shown broadly in Fig.18. Separation of torda and islandica is effected on winglength and depth of bill (Salomonsen 1944 and Vaurie 1965) (Table 46).

Table 45. Guillemot: generalised differences between three subspecies (data from various sources):

Birkhead (1984), Salomonsen (1944), Vaurie (1965), Witherby et al. (1941).

	albionis	aalge	hyperborea
winglength range in adults (skins)	190-204	195-210	204-227
proportions of bridled birds (%)	0-5	5-50	20-60
colour of upperparts	pale grey-brown	blackish-brown	brownish-black
latitude (degrees N.) of breeding colonies	39-56	55-70	68-75

Table 46. Razorbill: separation of the two subspecies on measurement of adults as museum skins.

subspecies	sex	sample size (mm)	winglength range (mm)	bill depth range (mm)	authority
torda	♂	18	202 - 218	23 - 26.5	Vaurie 1965
torda	♂+♀	29	201 - 218	22 - 26	Salomonsen 1944
islandica	♂	22	181 - 202	19 - 22.5	Vaurie 1965
islandica	♂	?	185 - 203*	21 - 23	Salomonsen 1944 following Witherby 1941
	♀	?	185 - 200	20 - 22	

* one outlier at 207

Fig. 16. Guillemot: breeding distribution of the named forms in the North Atlantic (Pacific distribution not shown).

data: Salomonsen (1944) and Vaurie (1965).

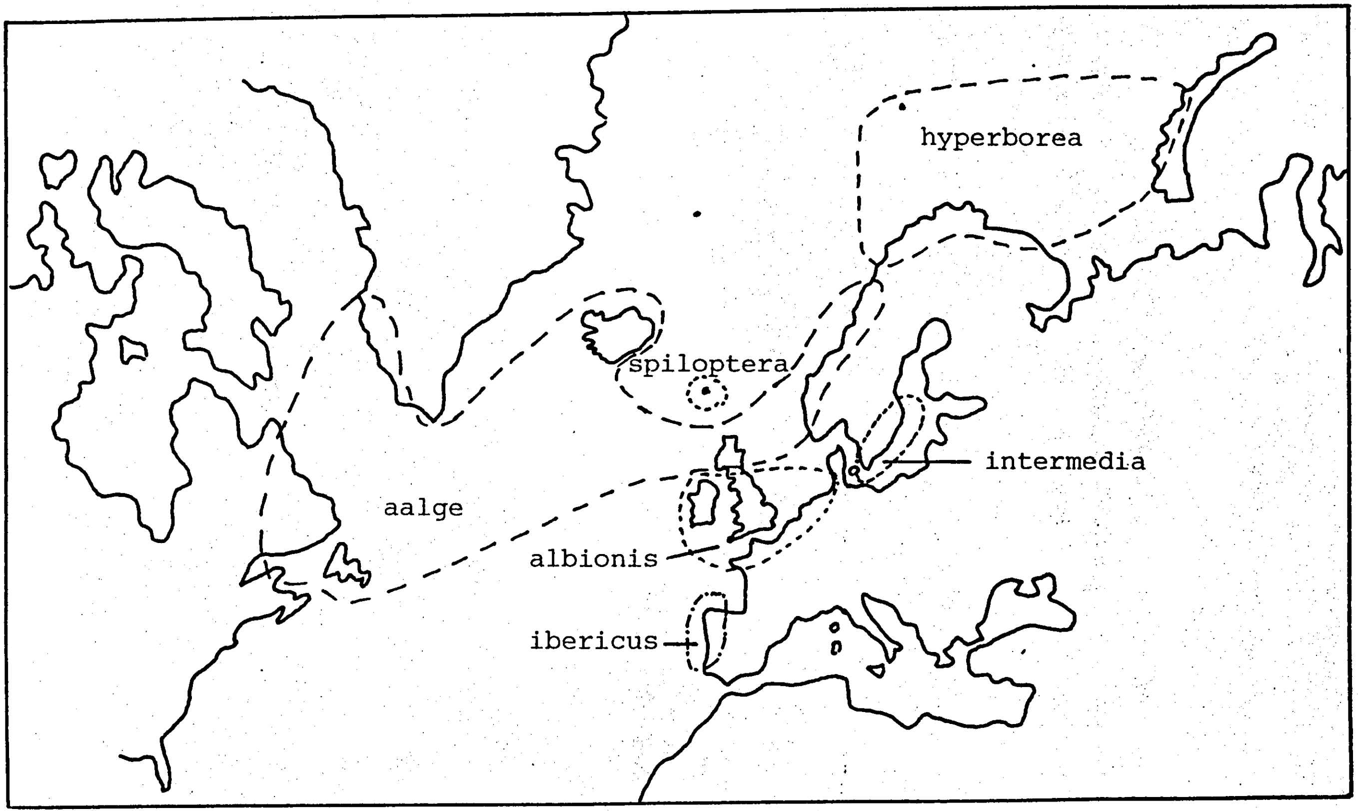


Fig. 17. Guillemot: Breeding distribution of the three forms accepted by Vaurie (1965) for the North Atlantic.

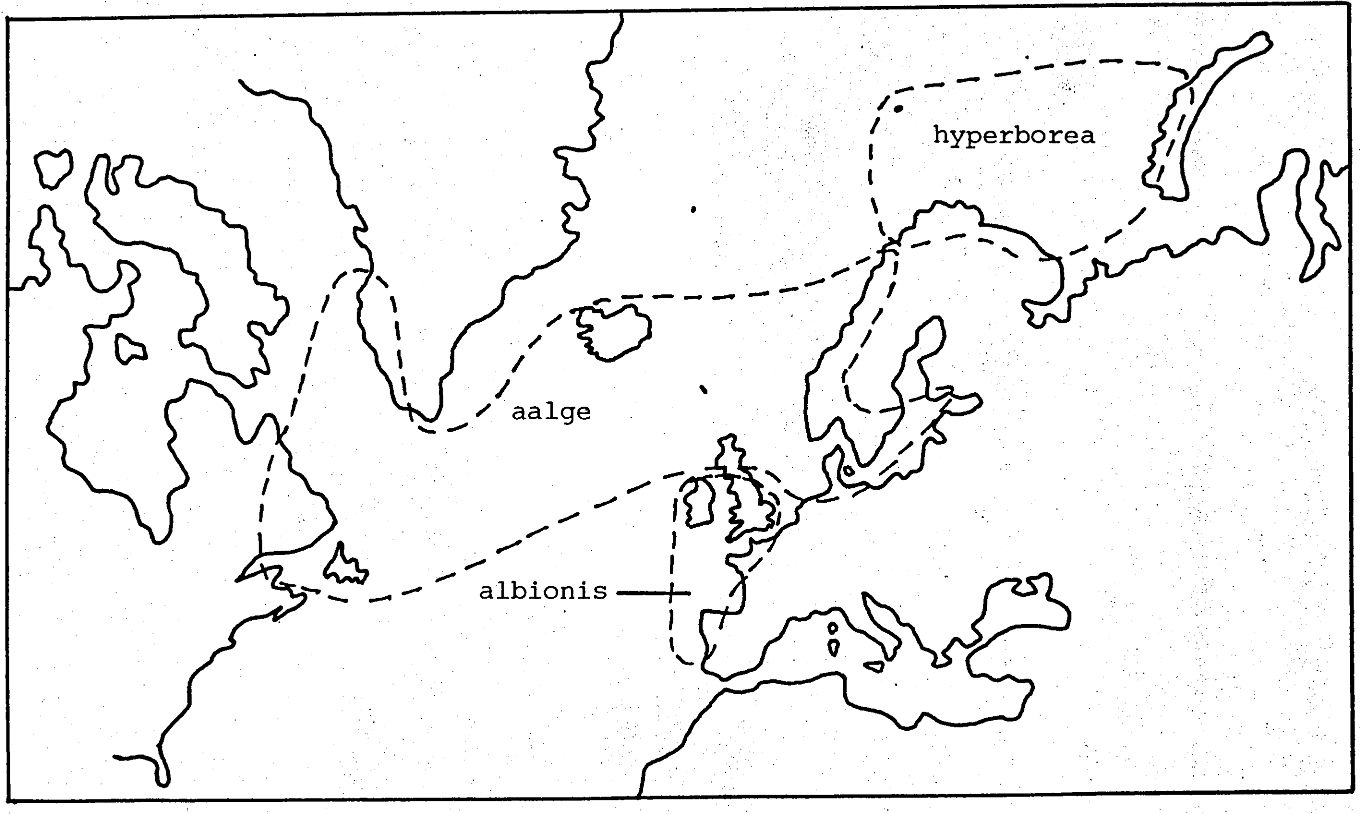
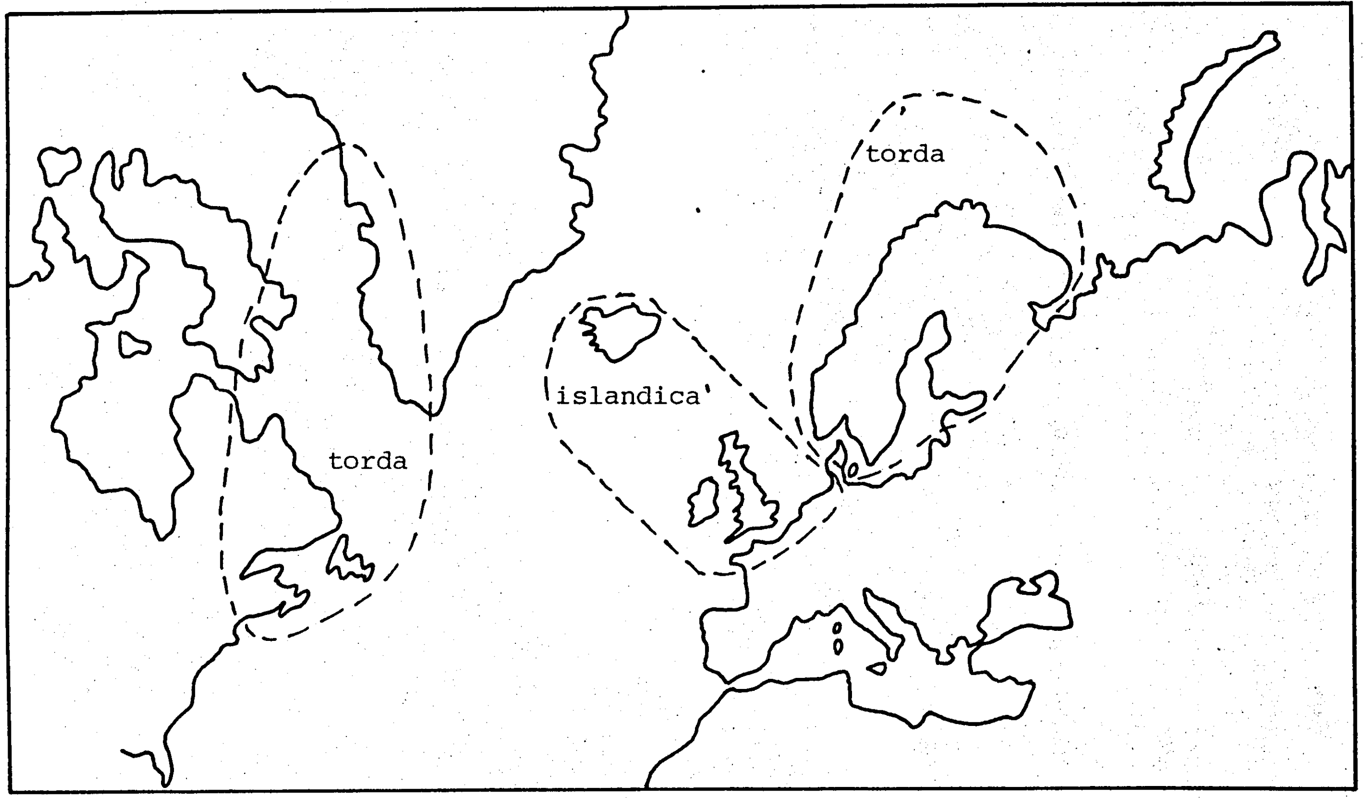


Fig. 18. Razorbill: world breeding distribution of the two forms accepted by Vaurie (1965).



6.1.2 Clines, and the delimiting of subspecies

Morphological variation within a bird species had been rationalised by the mid-19th century into the concepts of subspecies and trinomial nomenclature. In the first half of the 20th century, Guillemot and Razorbill were split into numerous such forms; subsequently, a reaction to this over-zealous splitting led to their being lumped into a smaller number of subspecies. The validity of subspecies in birds seems to have been largely a matter of personal opinion (and frequent acrimonious dissention), especially when somewhat arbitrary points were assigned names along what proved to be a continuous gradient in one or more taxonomic characters. Although the auks tended to have disjunct rather than continuous distributions, they still produced embarrassing complications (as when, for example, the Guillemots of Shetland (supposedly aalge) were found to resemble those of Faroe (spiloptera) rather than those of mainland Scotland (aalge)) (Salomonsen 1944).

The word 'cline' was coined by Huxley (1938) to describe a gradient in a measurable character, and the theoretical mathematical basis for clines was set out by Haldane (1948). This commonsense approach came as a mixed blessing to taxonomists, and something of a confusion to the postwar generation of field (rather than museum) birdwatchers who were weaned through Witherby's (1941) Handbook on the concept of clearly separable subspecies. At this time too, Lack (1946) in discussing the taxonomy of the Robin, felt it "both simpler and more accurate to describe subspecies variations in terms of geographical trends, and to omit altogether the tyranny of subspecific names". Meanwhile, Amadon (1949) was wrestling with a definition of a subspecies as a standard whereby 75% of a population must be separable from all (99+%) of the members of overlapping populations (equivalent to the statement that 97% of one of two overlapping populations must be separable from 97% of the other).

Sibley (1954) indicated that "ornithologists have been concerned for some time with the problem of the taxonomic treatment of clines" and concluded that, since clinal variation was especially difficult to express in terms of the trinomial, clines might be better described than named; however, trinomial nomenclature was still valuable, and clines were an addition to the present system, not a substitute or replacement. Hubbell (1954) made the point that clines could not be taxonomic units, and where two or more non-coincident clines existed it was inadvisable to try to separate out subspecies. Nor had discussion been restricted to the zoological world: Böcher (1967) was concerned over plant ecotypes and 'varieties', and concluded that parts of clines 'sometimes ought to be described either as subspecies or as varieties" though conceding that the exact line between them may often not be possible to define.

In the light of these, and many other, discussions in the literature, I had long been of the opinion that the plethora of subspecific names for minor geographic variates in Guillemots were not justified, especially since many were based on relatively small differences between relatively small samples; for this reason, the use of trinomial nomenclature was minimal in the section of this thesis dealing with the main presentation of results.

Razorbills and Guillemots show interesting differences in the pattern of geographical variation; the following section considers this variation in more detail, and discusses the validity of the currently-accepted delimitation of subspecies.

Within Europe, breeding Razorbills divide into two supposedly discrete forms, though Salomonsen (1944) did suggest that birds from Norway and Russia were "on an average slightly larger" than breeders from the Baltic. Data from the present study suggest a homogeneity of size (as manifested in wing and bill measurements) through most of the range of *islandica* - though there are as yet no data from live breeders in France, Helgoland or Faroe. However, there are distinct anomalies in the Scandinavian/Russian populations. In the first place, there are statistically significant differences between means of winglength and bill depth for live Razorbills from N.W. and N.E. Norway; unfortunately, there are no known measurements for live birds from S.W.Norway (Runde *in litt.*), so the possibility of a cline of increasing winglength up the Norwegian coast cannot yet be validly postulated. Secondly, the mean wing length for 84 adult *torda* Razorbills killed in an oiling incident in the Skagerrak in January 1981 was 214.5 mm (compared with 211.6 for adults from N.E.Norway and 207.8 for N.W.Norway); at least some of these birds may have come from the White Sea since birds ringed in that region had been recovered in some numbers in the Skagerrak (Bianki 1967). However, the mean winglength of live breeding birds from the White Sea colonies is apparently not known. If there *is* a cline of increasing size between southern Norway/Sweden and northern Norway/Murmansk, this would provide the interesting scene of one subspecies homogeneous throughout its range, and an adjacent subspecies clinal with increasing winglength from S.W. to N.E.. However, confirmation of this possibility awaits further fieldwork.

Razorbills therefore demonstrate categorical variation - distinct differences between adjacent subspecies. This makes the nomenclature in N.W. Europe fairly straightforward (*islandica* in France, Britain, Ireland, Faroe and Iceland, and *torda* in Norway, Sweden and Russia) and - allowing for some overlap - makes division into two major regions of origin a valid possibility on the basis of wing and bill measurements.

Clinal variation in Guillemots produces a more complex taxonomic situation, especially since data are few or lacking for many critical points along the clines. At the present stage of knowledge (and following

Vaurie 1965), names are given to the two extremes of the clines of back colour and winglength: the pale, short-winged *albionis* in the south, and the dark, long-winged *hyperborea* in the north; the remainder, comprising the middle sections of these clines, are lumped into the nominate form *aalge* despite minor local variations. It is usually assumed that steps in a cline are associated with some fairly rapid environmental change unless there is some evidence for secondary intergradation (the coming together of two forms after a period of separation) (Endler 1977), and in Europe there is evidence for such steps in the north of Scotland, with a rapid increase in the proportion of bridled birds, and on the English/ Scottish border, where there is a rapid change from pale to dark in the colour of the upperparts (Witherby et al. 1941). The steepness of the cline in winglength apparently slows north of Shetland, and it may be that the zone between South Wales and Shetland is a long steep step between two less steep sections; however, for this character there is nothing like the short steep zones illustrated by back colour and bridling proportion. The separation zone between *aalge* and *albionis* is regarded as southern Scotland (Vaurie 1965) or as Northumberland/Berwickshire on the east side of Britain and Clyde/Islay in the west (Witherby 1926 and 1941). Witherby (1941) carefully separated the Farnes and Ailsa Craig (*albionis*) from St. Abbs and Islay (*aalge*) - the pairs on east and west being less than 75 km apart. However, there does not seem to have been a critical inspection of birds from these four sites since the concept of clines gained acceptance and, until this is done, it seems pointless to debate the issue further. The line between *hyperborea* and *aalge* was defined by Salomonsen (1944) as Lofoten (*aalge*) / Tromsø (*hyperborea*), with a gap of about 100 km between them; this judgement was accepted by Vaurie (1965), but Pethon (1967) concluded that the birds of northern Norway were *aalge* and that *hyperborea* did not breed at all in Norway. Pethon went to the nub of the problem in suggesting that the subspecies concept might be replaced by designating the clinally-variable Guillemots of Europe as *Uria aalge* cl. ibericus/hyperborea (Pont.), especially since none of the described subspecies could validly be accepted if the 75% rule were applied. Since this time the debate has lapsed, though Guillemot subspecies are often referred to in the modern literature, and in trying to answer the question of whether these subspecies are valid, one is reminded of Einstein's comment in Scientific American of April 1950: "the answer is 'yes' or 'no' depending on the interpretation".

The evolution of these forms within Europe makes a fascinating field for conjecture. It has been bravely tackled by de Wijs (1978), but is considered beyond the scope of this present thesis.

Despite the best efforts of the 'numerical taxonomists', classification remains, in many areas, a somewhat subjective field. In the present case, I consider that it would not be justified to make categorical pronouncements on Guillemot subspecies and on the precise range of each, because:

(a) the variation is clinal throughout the European range;

(b) relatively little is known about morphometric differences between geographically-close colonies;

(c) there are few sets of means and ranges of measurements for adequate samples at various points along the clines.

Therefore, for practical purposes, it may be best to ignore subspecies, and to describe groups of birds (measured to agreed standards by agreed methods) according to mean winglength, proportions of bridled birds, and colour of upperparts; a possible format is shown in Table 47.

Table 47. Possibility of a 'clinal index' as a measure to replace subspecies nomenclature in European Guillemots.

cline:	mean adult winglength	% bridled	mean adult back colour
approx. range in Europe:	? 195-215	0 - 60	pale brown - black (PHJ scale 2-9) *
index			
9	> 214	51 - 60	9
8	212-214	41 - 50	8
7	209-211	31 - 40	7
6	206-208	21 - 30	6
5	203-205	11 - 20	5
4	200-202	6 - 10	4
3	197-199	1.1 - 5	3
2	194-196	0.1 - 1.0	2
1	< 194	0	1

* eventually to be replaced by % reflectance of white light

clinal index examples:

breeders from South Wales:	wing 198 (index 3) , bridling 0.5% (index 2), back colour 3 (index 3). Full index: 323
Shetland:	wing 207 (index 6), bridling 25% (index 6), back colour 7 (index 7). Full index: 667
N. Norway:	wing 210 (index 7), bridling 26% (index 6), back colour 9 (index 9). Full index: 769

6.1.3 Dispersal outside the breeding season

The taxonomy of birds is usually based on descriptions of breeding birds in their habitual breeding area. These areas were discussed in the previous section, and mapped there as non-overlapping (even though occasionally contiguous) distributions. Outside the breeding season, the position becomes more complicated by the dispersal of birds away from their natal and/or breeding areas.

After the breeding season, full-grown Guillemots and Razorbills move away from their colonies to moult at sea, and at the same time the juveniles of that year develop their flight feathers and presumably become independent of their parents or guardians. From October (in some British cases) onwards, birds visit the breeding colonies, usually for periods of 2-3 days with longer intervals between visits, but their location at this time of year is very poorly understood and in many cases not known.

Results from ringing many thousands of auks in W.Europe during this century have permitted analysis into patterns of dispersal, mortality and winter distribution. Movements and mortality of British Razorbills were described by Lloyd (1974) and North (1980) and of British Guillemots by Birkhead (1974) but the major mapping of recoveries from ringing in Britain and Ireland was by Mead (1974). The natural extension of this work onto a European basis is being tackled by Baillie (1982).

Generalised dispersal patterns are shown for European Guillemots in Fig. 19, and for some British and Irish Guillemots in Fig. 20 and Razorbills in Fig. 21. The main point is to demonstrate that, outside the breeding season, an auk incident of high mortality may involve birds from a wide variety of natal origins: for example, in the Skagerrak, Guillemots could have emanated from Norway, Helgoland, England, Scotland, Faroe, and possibly Sweden and Denmark, whilst the English Channel could hold Guillemots from Ireland, Wales, England, France, Helgoland, Scotland and possibly Norway.

The generalised pictures cannot demonstrate one major complication which has already been proved to occur: different age cohorts can have different dispersal and wintering patterns. This factor underlines the importance, at any mortality incident, of establishing the age as well as the origins of the birds involved. In winter especially, there is need for careful analysis and interpretation of the amassed data since auks are very likely, at that season, to comprise a heterogeneous collection of both sexes, all ages, and a possibly wide diversity of natal origins.

Fig. 19. Guillemots: indications of movement towards mid-winter recovery zones for birds ringed in nine selected areas (from descriptive data in Baillie 1982).

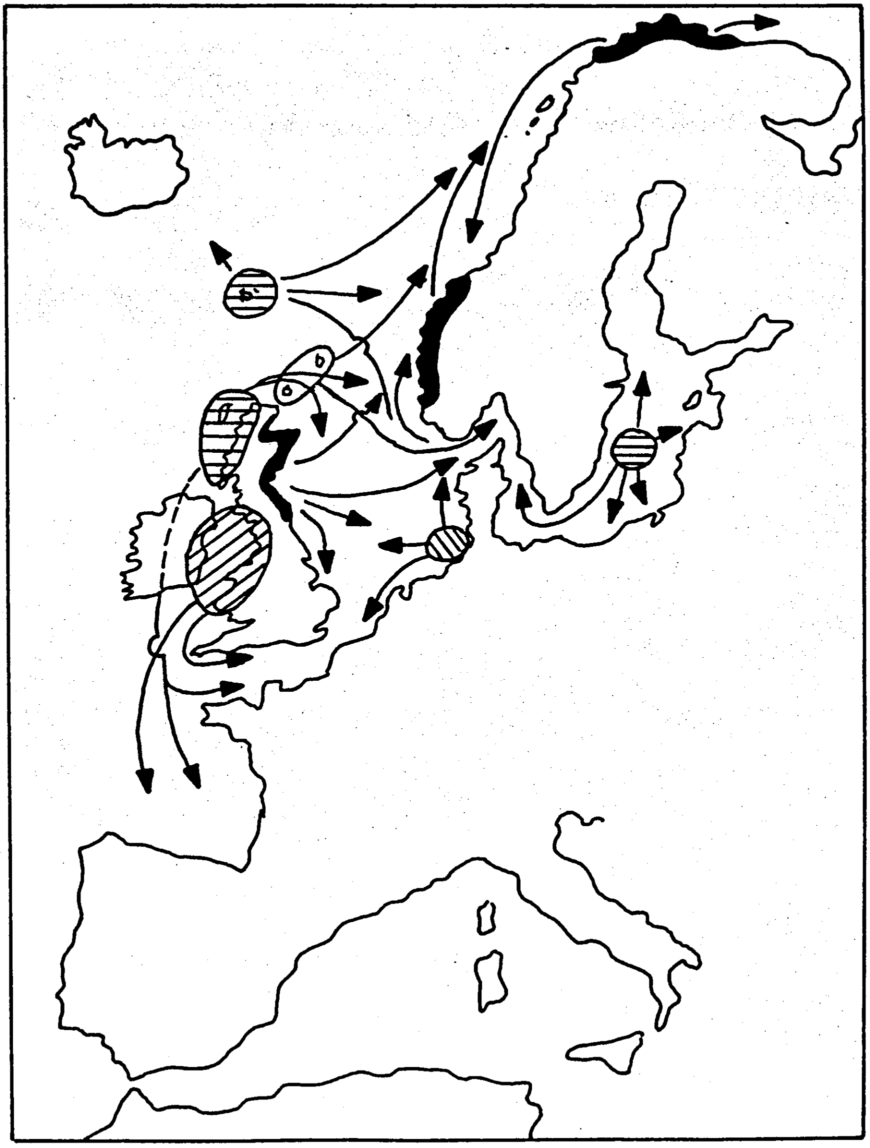


Fig. 20. Guillemots: indications of movement towards main recovery zones for birds ringed in the two hatched areas (from maps in Mead 1974).

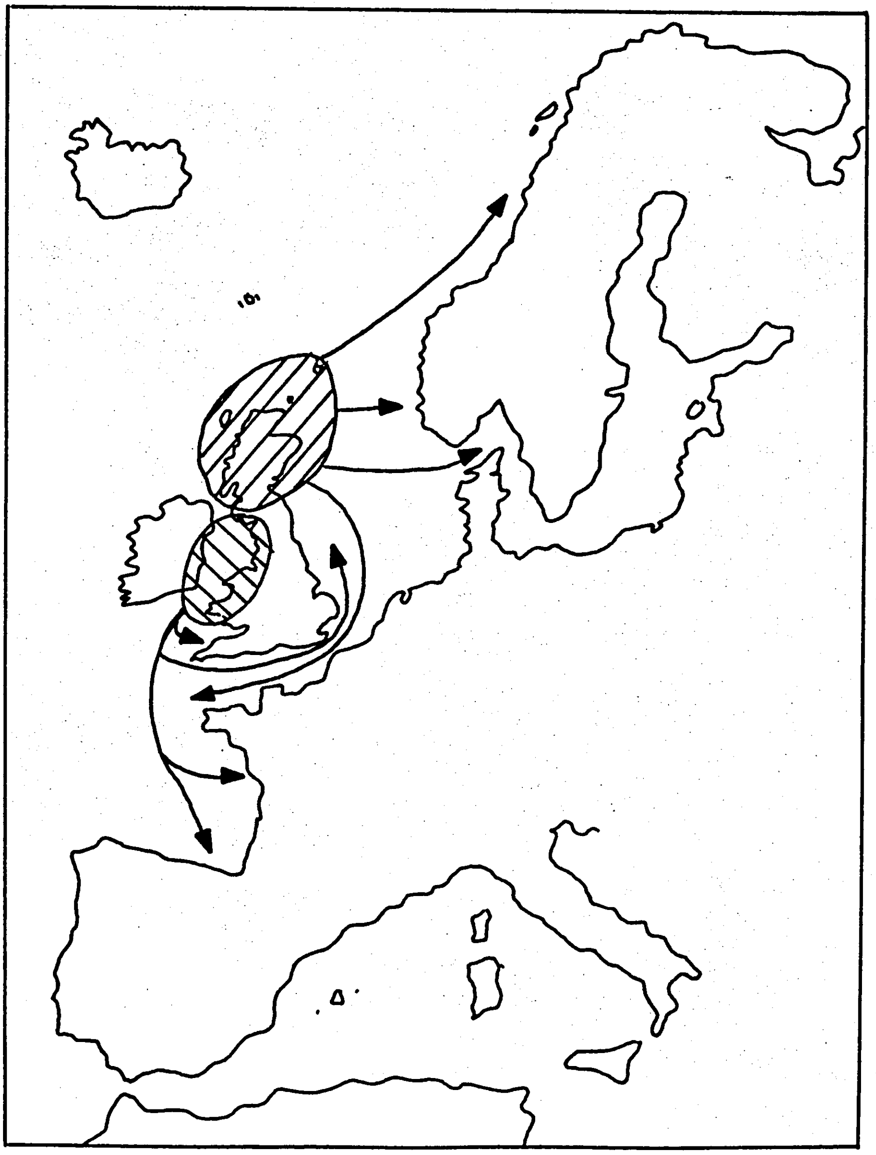
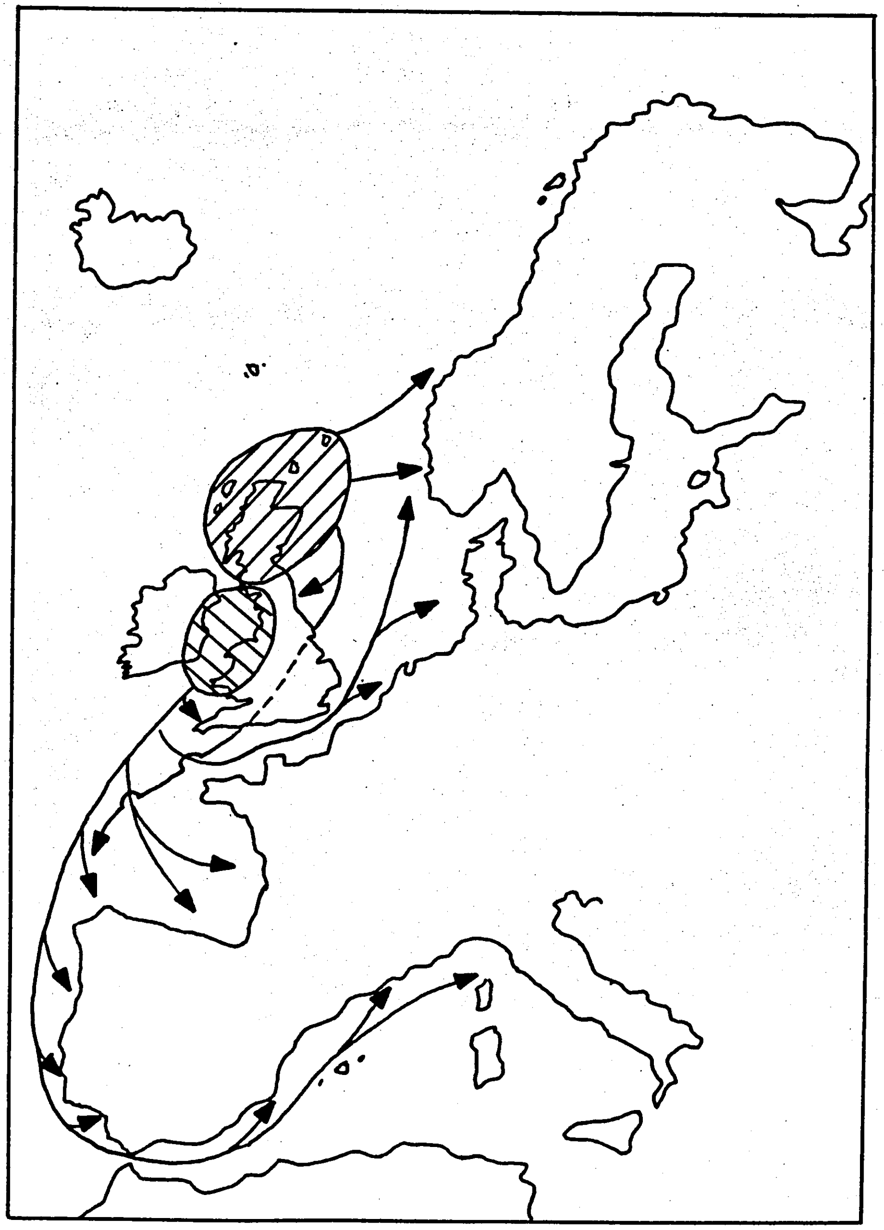


Fig. 21. Razorbills: indications of movement towards main recovery zones for birds ringed in the two hatched areas (from maps in Mead 1974).



6.2 Examination of beached auks

6.2.1 Past activities

Several efforts have been made to extract information from dead auks on beaches. Usually this process consists of an assessment of the numbers of birds per unit length of beach, the total numbers of birds involved the degree of oiling (of birds and of beach), and the proportions of species. Results from British work of this nature have been collated and analysed by Stowe (1982), so this present section will be concerned with examinations which extended beyond the parameters outlined above.

As early as 1920-22, Verwey (1922) examined about 700 Guillemots and 130 Razorbills "furnished by the destructions of seabirds on our [Dutch] coast by stormy weather and oil on the water", and established the patterns of moult in the two species. In 1948 an attempt was made by Voous (1948) to determine, from skins of such auk casualties, the subspecific rank of Guillemots appearing on the Dutch shore. From the mid-1960s onwards, various papers appeared, dealing with a variety of topics: toxic chemical analysis was particularly prominent in the seventies, but also the origins of affected birds were regularly suggested - often from interpretations which, though made with confidence, lacked due regard for the complexities of the topic.

Table 48 has been prepared from known results of auk corpse examination. However, it may not be comprehensive because there are likely to be a number of papers, particularly in regional journals, which have not yet been found. Nevertheless it does indicate the strong interest in the topic, the range of examination carried out, and the numerous locations involved.

Apparently there has neither been a synthesis of existing information, nor a unified approach to collecting data other than numbers of individual birds. This was probably due both to the lack of any standardised system of data-collecting, and to the fact that, at the majority of incidents, all available interested people were involved either in checking the beaches or in caring for the live bird victims. The few professional ornithologists were usually so involved with logistics of pollution control, site and species protection, and mortality monitoring, that they were usually unable to contribute more than moral support to the examination of auk corpses. Amongst other things, there was clearly a need for a standard data-collection methodology, so a 'Manual of suggested procedure' in 'the examination of birds killed in oilspills and other incidents' was duly prepared through the collaboration of British and Norwegian workers (Appendix I). This solved one of the main problems, and the document was welcomed, and used, by a variety of interested and involved parties in Britain and Europe.

Table 48. Published examinations of auks involved in mortality incidents.

publication date	authority	species		examination for:						location
		Guill.	Raz.	age	weight	sex	origin	toxics	cause of death	
1922	Verwey	+	+	+		+				Netherlands
1948	Voous	+					+			Netherlands
1966	Mather	+					+			Yorkshire
1967	Bourne +	+	+	+			+			S.W.Britain
1967	Parrack	+	+	+			+			N.E.England
1968	Beer	+	+		+	+			+	Cornwall
1968	Bourne	+	+				+			Scotland
1969	Bourne	+					+			U.K.
1970	Holdgate	+		+	+		+	+	+	Irish Sea
1970	Jones +	+		+			+			N.Wales
1971	Jones	+					+			Merioneth
1972	Bailey +	+			+			+	+	Alaska
1972	Smail +	+		+		+	+	+		California

.../...

Table 48 (contd.) Published examinations of auks involved in mortality incidents.

publication date	authority	species		examination for:						location
		Guill.	Raz.	age	weight	sex	origin	toxics	cause of death	
1972	Grandjean	+					+			Iceland
1973	Brown +	+					+			E. Canada
1974	Lloyd +	+			+			+	+	Irish Sea/Clyde
1975	Scott +	+		+	+			+		Oregon
1977	Lambert	+	+	+			+			Germany
1979	Whilde	+	+	+	+				+	Ireland
1981	Anker-Nilssen+	+	+	+		+	+			Skagerrak
1981	Kuschert+	+	+	+						Germany
1982	Stowe	+					+			Yorkshire
1982	Jones +	+	+	+		+	+			Brittany
1983	Jones +	+		+	+	+	+			S.W.England

6.2.2 Present methodology

The Manual (Appendix I) has been used at most recent incidents where morphometric data have been collected. In its use at several such incidents, only a few minor modifications have been found necessary, but additions will need to be made as knowledge improves. For example, sections are needed on the supra-orbital ridge, on ageing Guillemots by wing-covert colours, and perhaps ageing on convolutions at the distal end of the oviduct. At the present state of lack of manpower and resources, the principles will need to remain as earlier: the collection of the most valuable bits of information in the least possible time. The present system, using a team of three experienced workers (one on external examination, one on internal, one writing) can cope with about 15-20 auk corpses per hour - four minutes or less per bird.

If the birds are not too badly decomposed, sexing is reasonably straightforward except in first-winter Razorbills where the gonads can be difficult to find, and harder to identify. Ageing in Razorbills is also easy (if bill grooves are accepted as classifying criteria), but one of the greatest needs is for the identification of first-winter Guillemots - supra-orbital grooves appear to be the best character for advancement here, and maybe the wing-covert criteria can be confirmed. Large bursa and thin bills are good indicators, but at this stage it is usually impossible to separate first-winter Guillemots from older immatures. Weight and fat content are usually linked, and it is an easy job to remove and label each stomach for storage and subsequent examination. Analysis of the data has evolved into a format for each species, as indicated in Table 49.

From nature conservation agencies needing information, the main requests are for the age and sex composition of the kill (once the proportion of species has been established); these are easy to present in the form of a table, the only caveat being from the competence of the corpse-examiner in sexing the birds and from the criteria used in ageing. The other main request is for the origin of the birds involved; this is very much dependent on a knowledge of the type of information presented earlier in this thesis, but essentially the interpretation (for Guillemots) is based on mean winglengths for adults and for immatures; proportion of bridled birds; and back colour. The presence of ringed birds can often help, but it can also assume an unwarranted importance: for example, at an oilspill off the Forth estuary in April 1979, a sample of 23 Guillemots contained one bird ringed in Faroe; examination showed this individual to be darker-backed than the other Guillemots which were adjudged - on winglength, 5% bridling, and paler backs - to be of local stock. Hence the ringed bird was completely unrepresentative of the majority of birds involved in that incident. Obviously, at other times, ringed birds can be a most valuable indication of the origin of the sample, but there is still need for careful evaluation and interpretation of all the data before a considered opinion can be put forward.

I consider that the present situation in this field is a great improvement over that which obtained five years ago, but there is also much scope for continued survey and research if the present methodology is to improve and if it is to become standard procedure at any bird mortality incident.

Table 49. Presentation format for analysed results from auks examined by use of the Manual in Appendix I.

Guillemot

1. Sample size.

2. Age and sex composition, e.g.

age	male	female	totals	(%)
adult (no bursa)	27	44	71	(43)
immature (with bursa)	66	30	96	(57)

3. Plumage (summer, intermediate, winter) by age, and plumage by sex for adults; proportion bridled, by age.

4. Oiling: proportions in the different categories of oiling: no oil, 10% of plumage oil-covered, 20% ... etc.

5. Winglength: sample size, mean, standard deviation, range - separated for adult and immature, and for sex if the sample is large.

6. Culmen length (as in 5 above).

7. Bill depth at gonys (as in 5 above).

8. Headlength (as in 5 above).

9. Weight (as in 5 above).

10. Fat content: numbers of birds, or percentage, in each fat category, divided by age.

11. Gonads: numbers of birds, or percentage, in each 1 mm category for testis width in males, and for females in categories (for diameter of largest follicle) of < 0.5 mm 0.5, 1, 2, etc.

12. Bursa: bursal index by testis width or follicle diameter.

Razorbill : essentially similar, but age is divided into three categories on bill morphology: 1st winter (0+0 bill), immature (W+0 and W+1), and adult (W+2 and W+3).

Where samples size allows, t-tests are made to compare parameters between age cohorts or between sexes, and X^2 tests are made to compare the deviations of, e.g., sex ratios from 50:50.

Subsequent examination can give an upperpart colour index from the dried wings, and food spectrum from stomach contents.

6.2.3 Future needs in survey and research

In this study, one of the basic aims - that of establishing the sex of beached Guillemots and Razorbills - was relatively easy to attain. For the factors of age and origin, the basic standards were initially rather dubious, whilst the interpretation of the data were beset by uncertainties in a variety of allied fields. Many of these problems could be resolved through (i) identification of data needs, (ii) collection of the relevant data, and (iii) application of extensive knowledge and experience in their analysis, interpretation and presentation. The eventual document would be a completion of the work which has been started in this thesis, and it would comprise an important advance in the study of age, sex and origin in European Guillemots and Razorbills.

Table 50 indicates, in four categories, the data requirement and the necessary analysis. Apart from the first-priority crucial point of collection of ringed birds, the items are not ranked in any particular order.

Table 50. Needs in furthering knowledge on aspects of age, sex and origin in European Guillemots and Razorbills.

A. DATA COLLECTION

Aa. ringed birds: systems for collection, storage, curation.

Ab. data on age in relation to skull pneumatisation and layered structure of bones.

Ac. weights for fit birds away from the colonies and throughout the year.

Ad. measurements of Russian birds from Russian museums.

Ae. blood protein analyses for separation of populations.

Af. colour photographs and measurements of normal (and of stressed or diseased) internal organs.

Ag. information on bridling in winter-plumaged Guillemots.

Ah. complete inspection (PHJ system) of more birds in summer and early autumn.

Ai. data on supra-orbital ridge, headlength, and oviduct convolutions.

Aj. data on wing coverts and winter head pattern in relation to age.

Ak. measurements (and colour) for breeding Guillemots at colonies throughout the range of the species.

Al. measurements for breeding Razorbills at colonies in Norway, Sweden and Russia.

B. INVENTION

Ba. cheap, reliable, portable reflectometer for Guillemot back colour; mains-powered for laboratory use, battery-powered for field use.

C. COLLATION AND ANALYSIS

Ca. bursa regression with age in Guillemot.

Cb. separation of ages and sexes by multivariate analyses.

Cc. changes, through the year, in colour of upperparts.

Cd. changes, through the year, in weight and fat in different age groups.

Ce. development of wing and bill with age in Guillemot.

(Table 50 continued)

Cf. gonadal development through the season, and through the pre-breeding years.

Cg. confirmation of Razorbill age/bill groove relationship.

Ch. identification of first-winter Guillemots.

Ci. colour comparisons for fresh Guillemot wings.

D. INTERPRETATION AND PRESENTATION

Da. examination of freshly-dead birds in the light of results from known-age ringed birds.

Db. review of ageing and sexing criteria for both species.

Dc. review of taxonomy of European Guillemots and Razorbills.

Dd. conservation-oriented review of the show so far.

7. GENERAL CONCLUSIONS

The project originated as an exercise to find a means of providing information of value in assessing the conservation implications of oil-spills and other mortality incidents; in particular, to establish the genders, ages, and natal origins of Guillemots and Razorbills involved. This assumed, as a major premise, that there were standard and valid criteria by which sex, age and origin could be determined, but it quickly became clear that this was neither true nor straight-forward. Consequently, this study concentrated on attempting to find means by which the age and origin could be validly and reliably determined.

Several reports on mortality incidents have been prepared (Appendix II), but since it is considered that the age and origin criteria have still not been comprehensively confirmed, it is therefore perhaps premature to present collated results from all the auk incidents investigated to date.

After assessment of methods for determining age, sex and origin in Guillemot and Razorbill, a complex web of interconnected factors emerged, and the linkages are shown in Fig.22. The general conclusions from the assessment are set out below, underlined (the conclusions apply to both species, except where only one is mentioned).

7.1 Age

7.1.1 Bill grooves in Razorbill have long been considered as indicators of age. It has been shown in this study that the winglength and bill depth parameters increase considerably with age (as indicated by bill grooves), and that birds caught in colonies as breeders always show at least one black groove (and usually two) in front of the white groove.

Bill grooves in Razorbills are linked with measurement differences, birds with most grooves having the largest measurements.

7.1.2 The cloacal bursa, part of a bird's lymphatic system and involved in the production of antibodies, has been shown to decrease in size with increasing age of Razorbills (as shown by bill grooves). The presence of a bursa (in Guillemots as well as Razorbills) is usually linked with smaller measurements of winglength, bill depth and gonad dimensions, whilst the absence of a bursa is usually a feature of birds with larger morphological measurements.

The bursa is linked with age (from bill-grooves) in Razorbills, and the presence/absence of this organ is linked with measurement differences both in Guillemots and in Razorbills.

7.1.3 The supra-orbital ridge, a protruding ridge above the eye-socket, presumably develops with increasing cranial ossification. Tests on flat study skins and unfrozen corpses of Razorbills indicated that the ridge was very obvious on adult Razorbills (aged by bill grooves) and absent or only very slightly developed in first-winter birds.

The supra-orbital ridge is linked with age (from bill grooves) in Razorbills and the absence of this ridge is probably an indication of a first-winter bird.

7.1.4 Gonad size, as indicated by testis width in males and diameter of the largest ovarian follicle in females, was larger - for one substantial Razorbill sample - in adults than in immatures (aged by bill grooves). In Guillemots (aged on cloacal bursa) the same conclusions obtained, and in addition it was found that in a series of samples taken throughout the year, the gonads of adults increased gradually throughout the period from autumn to spring/summer whereas those of immatures did not show such changes.

Gonads, of both species, are bigger in adults than in immatures; gonads develop through the year in adult Guillemots but not in immatures.

7.1.5 One of the major difficulties in the study was the paucity of known-age specimens against which the conclusions for ageing criteria could be tested. Additionally the differences between putative ages, whilst often significant as mean values of large samples, were not always adequate in ageing individuals. Until good samples of ringed (known-age) auks have been collected from mortality incidents, and examined in the ways detailed in this study, the range of variation between same-age individuals and within a sample of one age cohort cannot be ascertained.

Overall, most ageing factors were mutually supportive, though not yet firmly linked to known-age birds; various parameters were significantly different between ages in a big sample, but not adequate for ageing of individuals.

7.2 Sex

7.2.1 Sex determination was usually straightforward, from gonadal inspection, though first-winter birds (particularly Razorbills) sometimes had very small gonads which were difficult to see or which degenerated quickly in the early stages of corpse decomposition.

Sex determination, from gonadal inspection of fresh corpses, was usually straightforward.

7.2.2 Sex ratios were determined for samples in mortality incidents: from a variety of incidents in Britain (and one in the Skagerrak), Razorbills showed usually equal numbers of males and females in all age cohorts, whereas Guillemots usually showed equality of sexes in adults but some distinct sex ratio biases among immatures in winter.

Sex ratios were mainly equal in Razorbills of all ages and in adult Guillemots, though with biases among immature Guillemots in winter.

7.2.3 Differences in mean values for morphological measurements were shown when comparing males and females of the same age cohort. In adult Guillemots from the same region, and adult Razorbills from the same subspecies, females usually (though not invariably) showed longer mean winglengths than males, whilst males showed longer and deeper bills than females. Results for immatures were not so clear-cut, though similar tendencies were evident - more so in the Guillemot than in the Razorbill.

Especially in adults, males were shorter-winged but bigger-billed than females.

7.2.4. Birds sexed by gonadal inspection were measured: winglength, headlength, culmen length and bill depth. Whilst in a large sample there was often a significant difference between mean values for the two sexes, there was invariably a large overlap zone which included a high proportion of both sexes. Individuals therefore could not safely be sexed by use of those measurements.

Sexing of individual birds by external measurement was precluded by large overlap between the sexes.

7.3 Origins

7.3.1 'Within-species' size variation in European Guillemots is quite complex but is less marked in Razorbills. Measurements of Guillemots in breeding colonies showed that the cline of increasing size (exemplified by wing-length) extended northwards through Europe, being steepest within the British Isles. Razorbill winglengths were similar throughout the British Isles to Iceland, with larger birds from Norway to Russia. It became obvious that 'field taxonomy' in Europe needs much more work in data-collection.

Mean winglength of Guillemot increased clinally through Europe, being steepest within the British Isles, whereas in Razorbill, winglength was similar from the British Isles to Iceland, and larger in Norway/Russia.

7.3.2 Post-mortem shrinkage of auk skins can be considerable, with most change occurring in the first two months after skinning; there can be wide individual variation in the degree of shrinkage, but in the Razorbills and Guillemots sampled, there was a 1% reduction in measured winglength and 5% in bill depth compared with freshly-dead specimens. The cline in Guillemot winglength was equally apparent from museum specimens, but with slightly reduced mean measurements for each latitude.

Post-mortem shrinkage of auk skins resulted in 1% reduction in measurements of winglength and 5% in bill depth.

7.3.3 Razorbills in mortality incidents may be 'typed' morphometrically to only two main areas of origin relating directly to the subspecies range: the smaller *islandica* with similar measurements throughout the area British Isles to Iceland, and the larger *torda* of Norway, Sweden and Russia. The latter may perhaps clinally increase in size northwards through its breeding range, though this is not yet confirmed. Guillemots may be 'typed' to finer areas of origin, using three criteria which all increase clinally to the north: winglength, proportion of bridled birds, and colour saturation of upperparts. In the present context at least, the subspecies concept in the Guillemot could perhaps be better replaced by a clinal index incorporating these three parameters.

Origins of Razorbills could only be fixed morphometrically from size (winglength and bill depth) related to the two subspecies, whereas Guillemots could be fixed more closely using the three clinal parameters of winglength, bridling proportion and upperpart colour.

7.4 Overall

In considering the age, sex and origins of Guillemots and

Razorbills involved in mortality incidents, it is evident that the complex relationships between the interacting factors need clarification. However, several of the present problems are soluble given the collection, storage and examination of known-age (ringed) birds. Fieldwork (some of it reported here) has demonstrated that considerable progress has been made, and it is believed that a continuation of this study would lead to further refinement of information of significant conservation and biological importance.

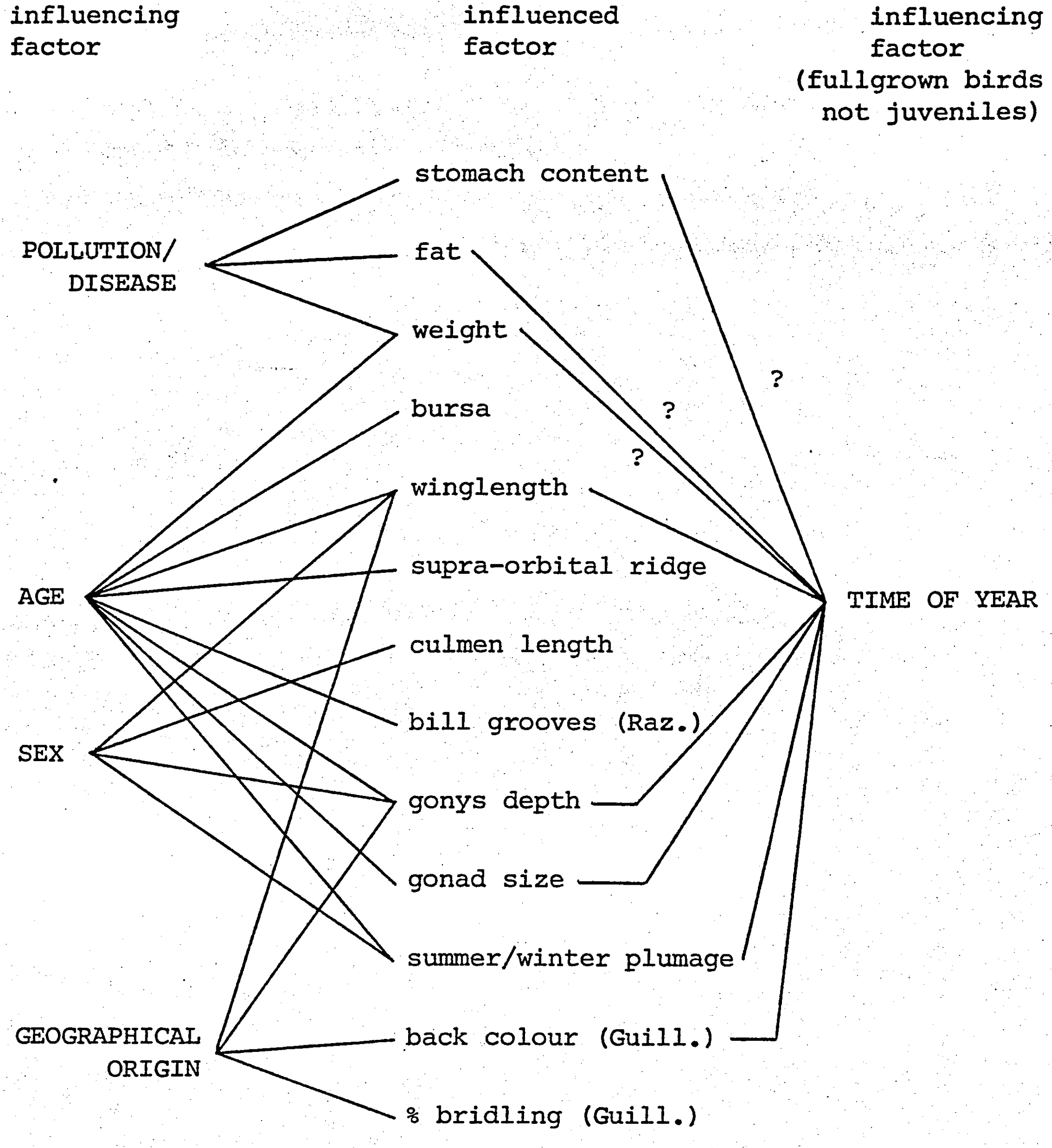
Age determination was hampered by empirical difficulties, mainly the paucity of specimens of known-age birds for certain identification and confirmation of ageing criteria. However, cloacal bursa, supra-orbital ridge, gonad size, and selected morphological measurements, were mutually supportive of putative age determinations, including those based more firmly on bill grooves in Razorbills.

Sex determination, from gonadal inspection of fresh corpses, was usually straightforward, but for neither species could the sex of an individual bird be determined by external measurement.

Origins of Razorbills could be tied, for most individuals, to the zones occupied by one or other of the two subspecies. Guillemots, in a sizeable sample, could be tied to finer areas of origin by pinpointing their position on the clines of winglength, bridling proportions and upperpart colour.

It is believed that this investigation has advanced knowledge on the subject in producing useful, though sometimes tentative, conclusions.

Fig. 22. Interaction of factors involved in the examination of Guillemots and Razorbills.



8. REFERENCES

Alexander, M.M. (1960) Shrinkage of muskrat skulls in relation to aging. *J.Wildl.Mgmt* 24: 326-329.

Amadon,D. (1949) The seventy-five per cent rule for subspecies. *Condor* 51: 250-258.

Anker-Nilssen,T. & Røstad,O.W. (1981) Undersøkelser av oljeskadede sjøfugler i forbindelse med oljekatastrofen i Skagerak, Desember 1980/ Januar 1981. *Viltrapport* 16: 1-41.

Bailey,E.P. & Davenport,G.E. (1972) Die-off of Common Murres on the Alaska Peninsula and Unimak Island. *Condor* 74: 215-219.

Baillie,S.R. (1982) Guillemot ringing recoveries: a European perspective. *Proc. 1982 Seabird Group Conf.*: 17-19.

Barlow,J.C. & Williams,N. (1971) Colorimetric analysis of the dorsal plumage of the red-eyed vireo (Aves: Vireonidae) in Canada. *Can.J.Zool.* 49: 417-419.

Barrett,R.T. (in press) Comparative notes on eggs, chick growth and fledging of the Razorbill *Alca torda* in North Norway. *Seabird.*

Barth,E.K. (1967) Standard body measurements in *Larus argentatus*, *L.fuscus*, *L.canus* and *L.marinus*. *Nytt Mag.Zool.* 14: 7-83.

Beer,J.V. (1968) Post-mortem findings in oiled auks dying during attempted rehabilitation. *Field Studies* 2,suppl.: 123-129.

Beerens,E.G.J. (1980) Possible systematic errors in measurements of skin colour using EEL reflectance spectrophotometer. *Ann.hum.Biol.*7: 555-563.

Belopol'skii, L.O. (1957) Ecology of sea colony birds of the Barents Sea. (Israel Program for Scientific Translations, Jerusalem 1961).

van den Berg,A.B. (1980) On field identification of Brünnich's Guillemot *Uria lomvia* *Dutch Birding* 2: 19-21.

Bianki,V.V. (1967) Gulls, shorebirds and alciids of Kandalaksha Bay (Murmansk). Proceedings of the Kandalaksha State Reservation No.6 (Israel Program for Scientific Translations, Jerusalem 1977).

Birkhead,T.R. (1976) Breeding ecology and survival of Guillemots (Uria aalge). D.Phil thesis, Oxford.

Birkhead,T.R. (1974) Movements and mortality rates of British Guillemots. Bird Study 21: 241-254.

Birkhead,T.R. (1984) Distribution of the bridled form of the Common Guillemot Uria aalge in the North Atlantic. J.Zool.,Lond. 202:165-176.

Birkhead,T.R., Biggins,J.D. & Nettleship,D.N. (1980) Non-random, intra-colony distribution of bridled Guillemots Uria aalge. J.Zool.,Lond. 192: 9-16.

Birkhead, T.R. & Hudson,P.J. (1977) Polulation parameters for the Common Guillemot Uria aalge. Ornis Scand. 8: 145-154.

Birkhead,T.R. & Lock,A.R. (1980) Changes in the proportion of bridled murres in northern Labrador. Condor 82: 473-474.

Birkhead, T.R. & Taylor,A.M. (1977) Moult of the Guillemot Uria aalge. Ibis 119: 80-85.

Böcher,T.W. (1967) Continuous variation and taxonomy. Taxon 16:255-258.

Bourne,W.R.P. (1968) Arctic auks on the Scottish coast. Scot. Birds 5: 104-107.

Bourne,W.R.P. (1969) Chronological list of ornithological oil-pollution incidents. Seabird Bull. 7: 3-8.

Bourne,W.R.P. (1969) Beached birds: preliminary list of wings collected, 1966-68. Seabird Bull. 7: 9.

Bourne,W.R.P., Parrack,J.D. & Potts,G.R. (1967) Birds killed in the Torrey Canyon disaster. Nature 215: 1123-1125.

Brown,R.G.B., Gillespie,D.I., Lock,A.R., Pearce,F.A. & Watson,G.H. (1973) Bird mortality from oil slicks off eastern Canada, February-April 1970, Can. Fld Nat. 87: 225-234.

Brun,E. (1970) Dimorph-ratio cline of bridled Guillemots (*Uria aalge*) in Norway, *Astarte* 3: 45-50.

Corkhill,P. (1972) Measurements of Puffins as criteria of age and sex. *Bird Study* 19: 193-201.

Coulson,J.C., Thomas,C.S., Butterfield,J.E.L., Duncan,N., Monaghan,P. & Shedden,C. (1983) The use of head and bill length to sex live gulls Laridae. *Ibis* 125: 549-557.

Dominic,C.F. & Naik,D.R. (1962) Effect of starvation on the bursa of Fabricius of juvenile pigeons. *Sci.Cult.* 28: 291-292.

Dyck,J. (1966) Determination of plumage colours, feather pigments and structures by means of reflection spectrophotometry. *Dansk orn. Foren.Tidsskr.* 60: 49-76.

Eastman Kodak Company (1977) *Reflection Density Guide*, New York.

Einarsson,T. (1979) (Numbers of Brünnich's (*Uris lomvia*) and Common Guillemots (*Uria aalge*) at Icelandic breeding stations.) *Náttúrufraedingurinn* 49: 221-228.

Endler,J.A. (1977) *Geographic variation, speciation, and clines.* Princeton University Press, Princeton, New Jersey.

Engelmoer,M., Roselaar,K. Boare,G.C. & Nieboer,E. (1983) Post-mortem changes in measurements of some waders. *Ringing & Migration* 4: 245-248.

Evans,P.G.H. (1977) Results of ringing seabirds on the Kerry Islands. *Irish Birds* 1: 46-56.

*Fjeldså,J. (1980) Post-mortem changes in measurements of grebes. *Bull. Br. Orn. Club* 100: 151-154.

Forbes,W.A. (1877) On the bursa Fabricii in birds. *Proc.zool. Soc. Lond.* 1877: 304-318.

Furness,R.W. (1983) *Foula, Shetland, vol 4: The birds of Foula.* Brathay Hall Trust, Ambleside.

Furness,R.W. & Baillie,S.R. (1981) Age ratios, wing length and moult as indicators of the population structure of Redshank wintering on British estuaries, *Ringing & Migration* 3: 123-131.

*Fabricius - see page 155.

Furness,R.W. & Baillie,S.R. (1981) Factors affecting capture rate and biometrics of Storm Petrels on St. Kilda. Ringing & Migration 3: 137-148.

Gaston,A.J. (1984) How to distinguish first-year murres, Uria spp., from older birds in winter. Can. Fld Nat. 98: 52-55.

Gibson,J.A. (1951) The Northern Guillemot on Ailsa Craig. Br. Birds 44: 70-71.

Glick,B. (1983) Bursa of Fabricius. Avian Biology vol. 7: 443-500. (in Farner,D.S., King,J.B. & Parkes,K.C. (eds.) Avian Biology Academic Press, New York).

Gower,W.C. (1939) The use of the bursa of Fabricius as an indicator of age in gamebirds. Trans. N. Amer. Wildl. Conf. 4: 426-430.

Grandjean,P. (1972) Some morphological observations on the Guillemot (Uria aalge aalge Pont.) on Ellidaey, Westmann Islands. Dansk orn. Foren. 66: 51-56.

Green,G.H. (1980) Decrease in wing length of skins of Ringed Plover and Dunlin. Ringing & Migration 3: 27-28.

Greenwood,J.G. (1979) Post-mortem shrinkage of Dunlin Calidris alpina skins. Bull. B.O.C. 99: 143-145.

Haldane,J.B.S. (1948) The theory of a cline. J.Genet. 48: 277-284.

Harris,M.P. (1979) Measurements and weights of British Puffins. Bird Study 26: 179-186.

Harris,M.P.(1980) Post-mortem shrinkage of wing and bill of Puffins. Ringing & Migration 3: 60-61.

Hogg,D.A. (1980) A comparative evaluation of methods for identification of pneumatization in the avian skeleton. Ibis 122: 359-363.

Holdgate,M.W. (ed.) (1970) The seabird wreck of 1969 in the Irish Sea. N.E.R.C. Report, 45pp.

Holdgate,M.W. (ed.) (1971) The sea bird wreck in the Irish Sea autumn 1969. N.E.R.C. Ser. C, No. 4, 17pp.

Hubbell,T.H. (1954) Subspecies and clines: the naming of geographically variant populations. *Syst. Zool.* 3: 113-121.

Huxley,J.S. (1938) Clines: an auxiliary taxonomic principle. *Nature* 142 (3857): 219-220.

Huxley,J.S. (1939) Notes on the percentages of bridled Guillemots. *Br. Birds* 33: 174-183.

Jefferies, D.J. & Parslow,J.L.F. (1976) The genetics of bridling in Guillemots from a study of hand-reared birds. *J.Zool., Lond.* 179: 411-420.

Jones,P.H. (1971) Ornithological beachcombing in Merioneth. *Nature Wales* 12: 203-206.

Jones,P.H., Barrett,C.F., Mudge,G.P. & Harris,M.P. (in press) Examination of corpses of auks *Alcidae* beached on Scottish and English east coasts in February 1983. *Seabird.*

Jones,P.H., Blake,B.F., Anker-Nilssen,T. & Røstad,O.W. (1982) The examination of birds killed in oilspills and other incidents - a manual of suggested procedure. Nature Conservancy Council, Aberdeen. 32pp.

Jones,P.H., Howells,G., Rees,E.I.S., & Wilson,J. (1970) Effect of 'Hamilton Trader' oil on birds in the Irish Sea in May 1969. *Br. Birds* 63: 97-110.

Jones,P.H., Monnat,J. & Harris,M.P. (1982) Origins, age and sex of auks (Alcidae) killed in the 'Amoco Cadiz' oiling incident in Brittany, March 1978. *Seabird Report* 6: 122-130.

Jones,P.H. & Partridge,K.E. (1982) Examination of Guillemots killed by oil off the coasts of south Devon and north Cornwall in 1981. *Devon Birds* 36: 10-14.

Kaftanovski,Y.M. (1951) not seen, but quoted in Uspenski 1958.

King,A.S. (1981) Proctodeum. pp. 86-90 in King,A.S. & McLelland (eds.) *Form and function in birds*, vol. 2, Academic Press, London.

Knox,A. (1980) Post-mortem changes in wing-lengths and wing-formulae. *Ringing & Migration* 3: 29-31.

Krassovskii,S.K. (1936) (Kraniologische Besonderheiten der europäischen Arten der Gattung Uria) Bull. de l'inst. Sci. Lesshaft 19: not seen, but quoted in Salomonsen 1944.

Kuschert,H., Ekelöf,O. & Fleet,D.W. (1981) Neue Kriterien zur Altersbestimmung der Trottellumme (*Uria aalge*) und des Tordalken (*Alca torda*). Seevögel 2: 58-62.

Lack,D. (1946) The taxonomy of the Robin Erithacus rubecula (Linn.) Bull. Br. Orn. Club 66: 55-65.

Lambert,K. (1977) Die Rassenzugehörigkeit mecklenburgischer Alkenvögel. Falke 24: 11-15.

Lloyd,C. (1974) Movement and survival of British Razorbills. Bird Study 21: 102-116.

Lloyd,C.S. (1976) The breeding biology and survival of the Razorbill *Alca torda*. D.Phil thesis, Oxford.

Lloyd,C., Bogan,J.A., Bourne,W.R.P., Dawson,P., Parslow,J.L.F & Stewart,A.G. (1974) Seabird mortality in the North Irish Sea and Firth of Clyde early in 1974. Mar.Pollut.Bull. 5: 136-140.

Lloyd,C.S. & Perrins,C.M. (1977) Survival and age at first breeding in the Razorbill *Alca torda*. Bird Banding 48: 239-252.

Lönnberg,E. (1923) Nagra ord om Sillgrisslorna. Fauna och Flora 18 not seen, but reviewed in Salomonsen 1944.

Mather,J.R. (1966) The occurrence of the northern Guillemot (*Uria aalge aalge*) in Yorkshire waters. Naturalist 902: 81-84.

McNeil,R. & Burton,J. (1972) Cranial pneumatisation patterns and bursa Fabricius in North American shorebirds. Wilson Bull. 84:329-339.

Mead,C.J. (1974) The results of ringing auks in Britain and Ireland. Bird Study 21: 45-86.

Monaghan,P., Coulson,J.C., Duncan,N., Furness,R.W., Shedden,C.B. & Thomas,C. (1983) The geographical variation of the Herring Gull *Larus argentatus* within Britain and in northern Europe; a biometrical approach. Ibis 125: 412-417.

Munsell (1971) Munsell Neutral Value Scale. Munsell Color, Baltimore, Maryland.

North,P.M. (1980) An analysis of Razorbill movements away from the breeding colony. Bird Study 27: 11-20.

Parrack,J.D. (1967) The wreck of oiled birds in the north-east early in 1966. Seabird Bull. 3: 12-17.

Petersen,A. (1977) Age of first breeding in Puffin Fratercula arctica (L.). Astarte 9: 43-50.

Pethon,P. (1967) The systematic position of the Norwegian Common Murre (Uria aalge) and Puffin (Fratercula arctica). Nytt Mag. Zool. 14: 84-95.

Prater,A.J., Marchant,J.H. & Vuorinen,J. (1977) Guide to the identification and ageing of Holarctic waders. BTO Field Guide No. 17, Tring.

Rose,M.E. (1981) Lymphatic system. pp.341-384 in King,A.S. & McLelland,J. (eds.) Form and function in birds vol. 2, Academic Press, London.

Salomonsen,F. (1944) The Atlantic Alcidae. The seasonal and geographic variation of the auks inhabiting the Atlantic Ocean and the adjacent waters. Göteborgs K.Vetensk. O. Vitterh. Samh. Handl. Ser. B. Band 3. 138pp.

Scott,J.M., Wiens,J.A. & Claeys,R.R. (1975) Organochloride levels associated with a Common Murre die-off in Oregon. J. Wildl. Mgmt 39: 310-320.

Sibley,C.G. (1954) Subspecies and clines: the contribution of avian taxonomy. Syst. Zool. 3: 105-110, 125.

Smail,J., Ainley,D.G. & Strong,H. (1972) Notes on birds killed in the 1971 San Francisco oil spill. Calif. Birds 3: 25-32.

Smithe,F.B. (1975) Naturalist's Color Guide. American Museum of Natural History, New York. (amended 1981).

van Soest,R.W.M., & van Utrecht,W.L. (1971) The layered structure of bones of birds as a possible indication of age. Bijdr. Dierk. 41: 61-66.

Southern,H.N. (1939) The status and problem of the bridled Guillemot. Proc. Zool. Soc. Lond. A(3): 31-41.

Southern,H.N. (1951) Change in status of the bridled Guillemot after ten years. Proc. Zool. Soc. Lond. A 121: 657-671.

Southern,H.N. (1962) Survey of bridled Guillemots, 1959-1960. Proc. Zool. Soc. Lond. A 138: 455-472.

Southern, H.N. & Reeve, E.C.R. (1941) Quantitative studies in the geographical variation of birds - the Common Guillemot (Uria aalge Pont.). Proc. Zool. Soc. Lond. A 111: 255-276.

Storer, R.W. (1952) A comparison of variation, behavior, and evolution in the sea bird genera Uria and Cepphus. U. Calif. Publ. Zool. 52(2): 121-222.

Stowe,T.J. (1982) An oil spillage at a Guillemot colony. Mar. Pollut. Bull. 13: 237-239.

Stowe,T.J. (1982) Beached bird surveys and surveillance of cliff-breeding seabirds. RSPB Report to NCC. 207 pp.

Svensson,L. (1984) Identification guide to European passerines. Svensson, Stockholm.

Swann,R.L. & Ramsay,A.D.K. (1983) Movements from and age of return to an expanding Scottish Guillemot colony. Bird Study 30: 207-214.

Taber,R.D. (1969) Criteria of age and sex. In Giles,R.H. (ed.) Wildlife Management Techniques, Washington.

Threlfall,W. & Mahoney,S.P. (1980) The use of measurements in sexing Common Murres from Newfoundland. Wilson Bull. 92: 266-268.

Tuck,L.M. (1960). The Murres. Canadian Wildlife Service, Ottawa.

Uspenski,S.W. (1958) The bird bazaars of Novaya Zemlya. Russian Game Reports vol. 4: 8-159. (translation by J.M.MacLennan, Canadian Dept.

of Northern Affairs and National Resources).

Vaurie,C. (1965) The birds of Palearctic Fauna. London.

Vepsäläinen,K. (1968) Wing length of Lapwing (Vanellus vanellus) before and after skinning, with remarks on measuring methods. Ornis fenn. 45: 124-126.

Verwey,J. (1922) The moult of Uria troille (L.) and Alca torda L. Ardea 11: 99-116.

Voous,K.H. (1948) Notes on the races of Uria aalge (Pont.) occurring along the Dutch North Sea coast. Limosa 21: 12-14.

Wagstaffe,R. (1949) Scandinavian Herring-Gull in Yorkshire. Br. Birds 42: 398-399.

Whilde,A. (1979) Auks trapped in salmon drift nets. Irish Birds 1: 370-376.

de Wijs,W.J.R. (1978) (The geographical variation of the Guillemot) unpublished thesis, University of Amsterdam.

Witherby,H.F. (1926) Notes on the Common Guillemot - a new British from. Br. Birds 16: 323-324.

Witherby,H.F., Jourdain,F.C.R., Ticehurst,N.F. & Tucker,B.W. (1941) The Handbook of British Birds vol. 5. Witherby, London.

Fabricius, H. (1625) Hieronymi Fabricii ab Aquapendente opera anatomica. (not seen, but quoted in Forbes 1877).

Appendix I.

THE EXAMINATION OF BIRDS KILLED IN OILSPILLS AND OTHER INCIDENTS - A MANUAL OF SUGGESTED PROCEDURE

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The examination of birds killed in oilspills and other incidents - a manual of suggested procedure

by

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Pages

1. INTRODUCTION

There have been many incidents in the past few decades where oil pollution has caused the deaths of large numbers of seabirds and seaducks, and occasionally of divers and grebes. Other incidents have caused extensive mortality, such as dinoflagellate poisoning, and in sum, many tens of thousands of bird corpses have been found on the shores of N.W. Europe and other parts of the world.

These incidents are of sufficient concern for the numbers and species of affected birds to be recorded, but until recently there has been little effort made to retrieve more information from these samples. It is felt that much more use could be made of the available material, or at least from samples of it. This manual suggests a procedure which has been evolved at various oilspills since 1977, with a view to collecting information towards answering questions of conservation importance and biological value. For each incident:

(i) What are the proportions of ages and sexes in each species?

(ii) What is the geographical origin of the birds involved?

(iii) Are there other details which can be of value, e.g. the physiological state (as indicated by weight, fat levels and gonad size); the food (as indicated by stomach contents); the state of moult?

This manual has evolved mainly for work on Guillemots Uria aalge and Razorbills Alca torda in N.W. Europe, with less experience on Puffins Fratercula arctica, Little Auks Alle alle and Black Guillemots Cepphus grylle, but it could probably be adapted for use with a wide variety of species world-wide, with special categories added to cater for local requirements.

We are grateful to the following for their helpful comments on early drafts of this manual: Rob Barrett, Bill Bourne, Tim Dixon, Derek Langslow, Peter Morgan, Nils Røv, Tim Stowe, Mark Tasker, Trina Tyson and Tony Williams.

2. EXAMINATION PROCEDURE - INITIAL COMMENTS

In most incidents it is likely that corpses will be collected on the beaches in plastic sacks before transportation to the examination centre. Thought should be given to the location of this centre, preferably with adequate outside space for car parking and for the initial storage and sorting of carcasses; it should have a hot and cold water supply and preferably a telephone, together with ample table- and bench-space.

If corpses are to be cleaned and made into museum skins, this calls for refrigerated space, cleaning materials, etc. and the specialised work involved in one incident in Wales has been described by MORGAN, P.J. (1980): "The collection, storage, cleaning and research of oiled auk corpses" The National Museum of Wales, Cardiff. However, this present manual deals only with the examination of corpses which will subsequently be destroyed, though if numbers of corpses are large, it would be valuable to have excess corpses stored in deep-freeze facilities until required. The size of an 'adequate' sample cannot easily be gauged since, by the time the birds have been divided into categories of age, sex, origin, etc., there need to be at least 30 in each category for ready statistical comparison. Field experience has shown that a total sample of about 300 birds per species can often satisfy the statistical requirements without causing too many problems in, initially, the collection of the data, and subsequently, the computation of results. The optimum solution is to examine as many birds as possible.

In corpse examination, a working team should comprise not more than three persons - one to make external measurements, one to make internal examination and measurements, and one to record the data. The writing work is most important, and the team should be allowed to work without the constant movement and chatter of people not connected with the examination process. If there are sufficient competent persons, two or more teams could be set up to work on different species, or else time could be made during the first day or two to instruct people in the system. It is vital that each worker knows exactly what and how to measure; all measurements must be standardised between individuals.

Hygiene is important, and the examiners should wear rubber gloves and should be aware of the dangers from cuts caused by, for example, jagged ends of a bird's ribcage, or from aspergillosis in a bird's lungs. Medical advice must be sought rapidly if, after such dissections, a worker develops an infected cut or high temperature.

Data are best collected on sheets prepared as shown in Appendix II. In an oilspill incident, samples coming from different localities are usually kept in separate sacks, and locality details should be noted for each sample of birds. It is vital that each bird be given a number just prior to examination, and that this number be used on any specimens to be stored subsequently, e.g. wings, stomachs, or other organs for chemical testing. Each record sheet should be headed with species, the locality of the incident, and preferably the date of finding, and the examiners' initials. The sequence and abbreviations in the next two sections are those shown on the record sheets in Appendix II.

3. EXTERNAL EXAMINATION

3.1 No. (= specimen number). This is the important unique number which must be given to each bird, and which must be used on labels for all specimens from that individual, e.g. wing or stomach. The system of consecutive numbering can be devised by the operating team, but at each incident the risk of confusion is lessened if the digits are preceded by a letter corresponding to the species name: G = Guillemot, R = Razorbill, P = Puffin, etc. A code is also needed to identify each incident.

3.2 Br/B.g. (= bridled ? /bill grooves). Guillemots are checked for the presence or absence of a bridle (white eye-ring and stripe) and noted "yes" or "no". This feature may be difficult to see in birds in full winter plumage, and it is wiser to put "?" if the head plumage is too soiled for accurate assessment.

For Razorbills, the numbers of bill grooves are noted using the formula aW + b, where a = number of white (W) grooves, and b = number of black grooves (Fig. 1). Thus 2W + 3 means 2 white and 3 black grooves.

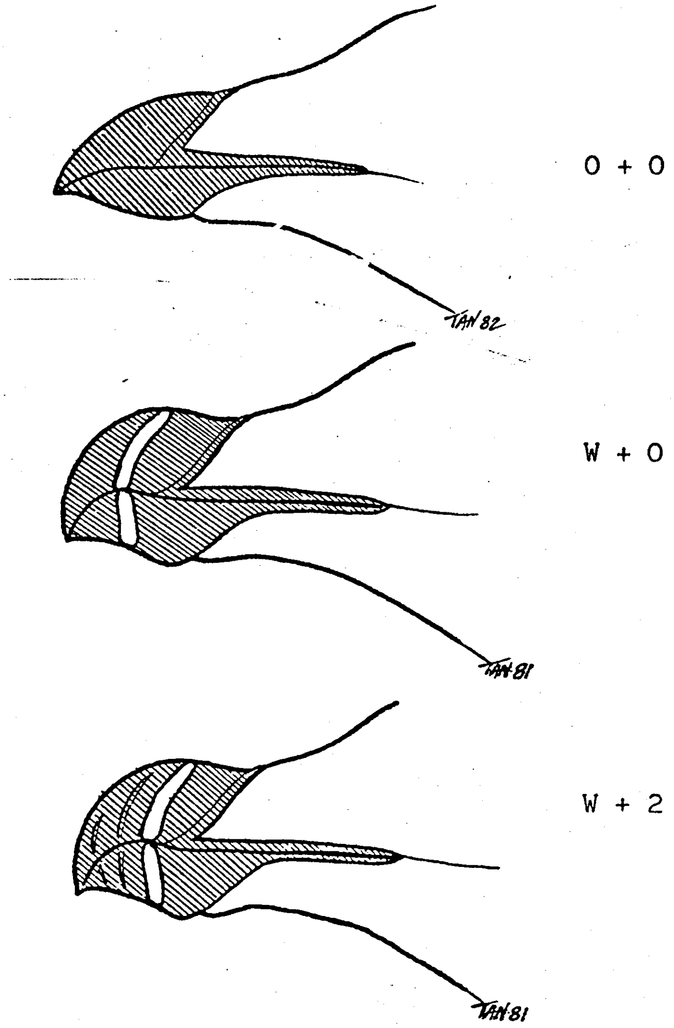


Fig. 1

Bill grooves in

Razorbills

3.3 % oil (= % of body area covered by oil). Only those areas completely covered by oil are considered, not areas which are only smudged. The bird is laid on the table with its wings extended, first on its back and then on its belly. The percentage area oiled is rounded off to the nearest 10%; dorsal and central sides are each considered as 50%, with the body 30% and each wing being scored 10%.

Fig. 2 Extent of Oiling. When estimating the percentage of the corpse covered by oil, the dorsal side and the ventral side are regarded as 50% each, one wing-side as 10%.

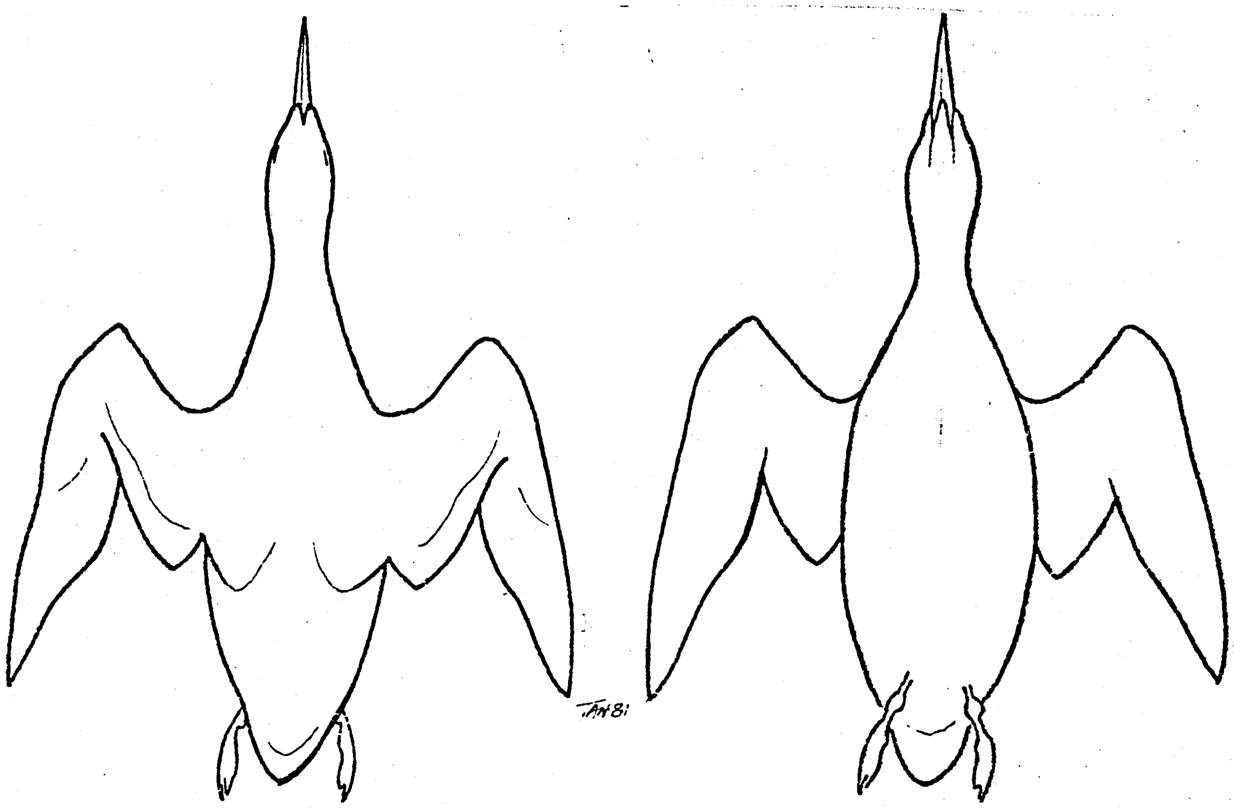
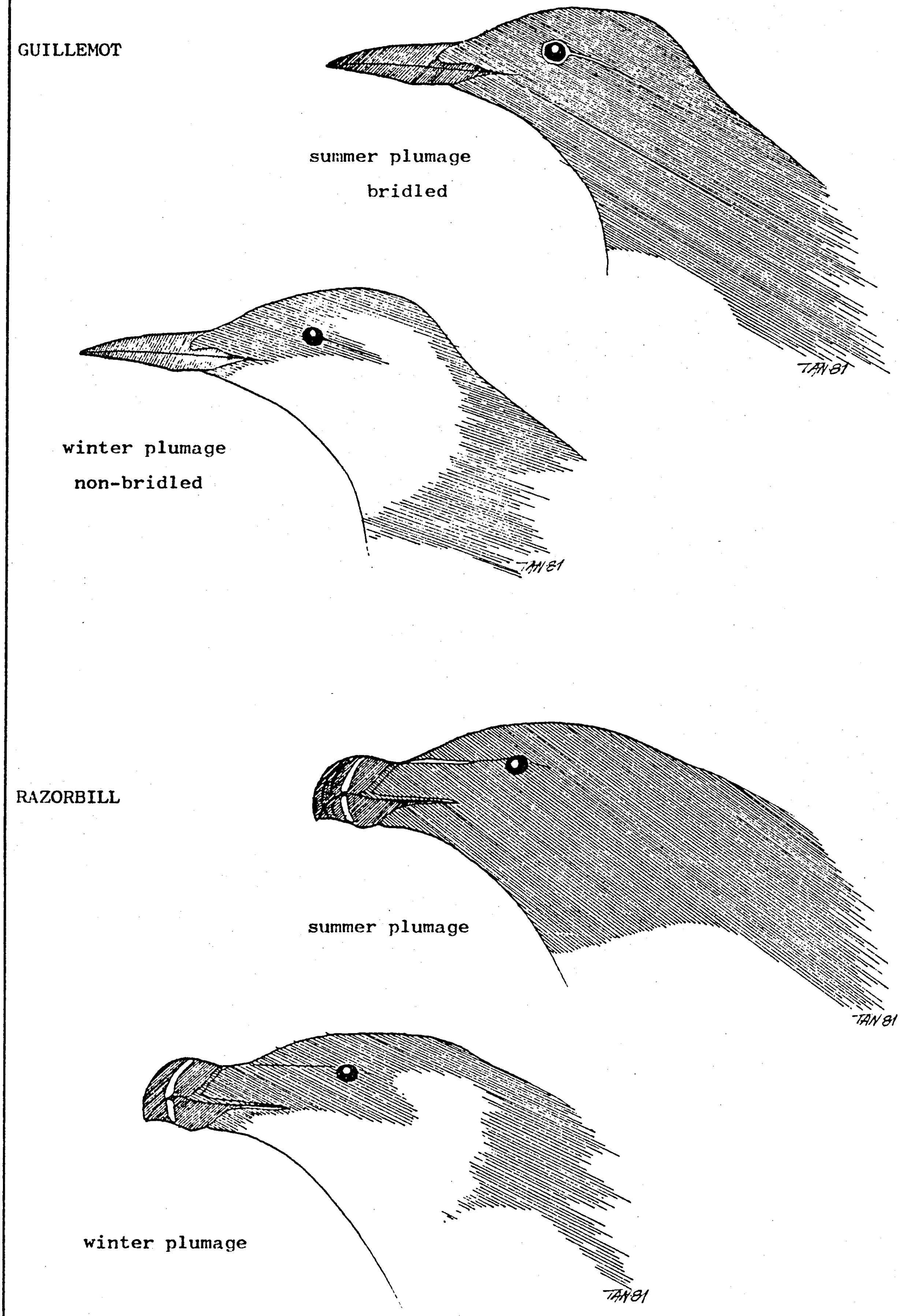


Fig. 3 Summer and winter plumages of Guillemot and Razorbill



3.4 Wt. (= *weight*). If any parts of the body have been eaten by predators or are missing, e.g. head, wing, intestines, the bird should not be weighed, but birds with oil on the plumage should still be weighed. Weight is measured to the nearest 10 gm.

3.5 Plu. (= *plumage*). Winter head plumage is noted as "W", summer plumage as "S". Transitions between the two are noted with the dominant plumage first, e.g. "W/S" = winter plumage with traces of summer plumage. N.B. A bird in full summer plumage can have, amongst the brown or black feathers, some white ones which are not necessarily remnants of the winter plumage.

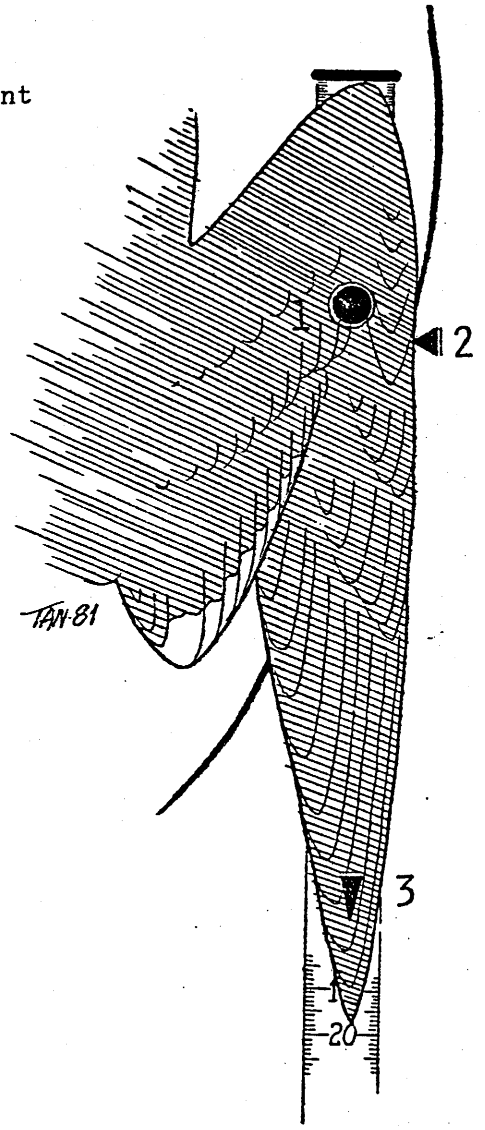
3.6 Wing (= winglength - maximum flattened chord). Having checked that the longest primary feather is intact, the wing is held close in to the body and the ruler inserted between wing and body. The joints in the alula region are straightened by pushing the leading edge of the wing so that it lies along the edge of the ruler (Fig. 4). Wing length is measured to the nearest 1 mm.

Fig. 4 Wing Measurement

1: press down

2: push in

3: stretch out



3.7 Culm. (= culmen = bill length). Measured, using vernier calipers, from the proximal edge of the horny sheath of the upper mandible (Fig. 5); this is often concealed by feathers. Culmen length is measured to the nearest 1 mm. but to the nearest 0.1 mm in Little Auks.

3.8 Head + B. (= head plus bill = total head length). The distance from the tip of the bill to the back of the head. Check that the head is bent forward so that it forms an acute angle with the throat. Measured to the nearest 1 mm. This measurement is at present experimental, but it is known to be of value in sexing Herring Gulls Larus argentatus, and Kittiwakes Rissa tridactyla.

3.9 Gonys (= bill depth at the gonys). Measured (making sure that the bill is fully closed) using vernier calipers, as the vertical depth of the bill at the gonys, and at right angles to the cutting edges of the mandibles (Fig. 6). Note that this does not necessarily correspond to the maximum height of the bill in Razorbills. The measurement may also be difficult to take on Little Auk and Black Guillemot but, at the present state of our knowledge, it should be taken nevertheless. Note the three measurements for Puffins (Fig. 7). Gonys measurements are given to the nearest 0.1 mm.

Fig. 5 Culmen measurement in Guillemot

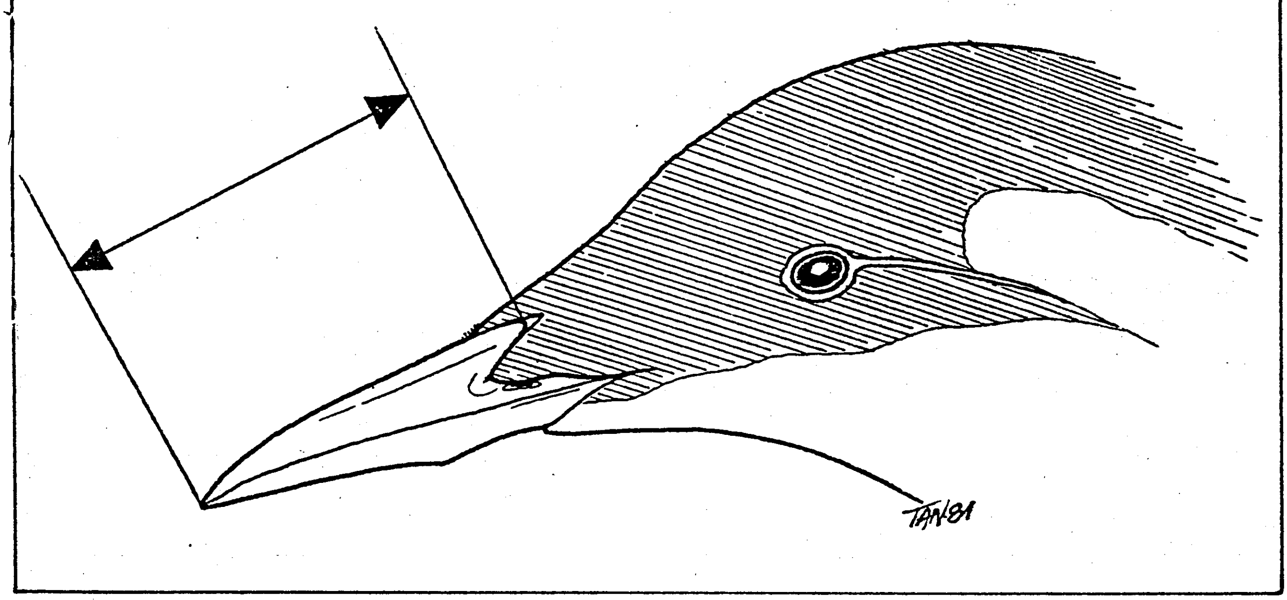
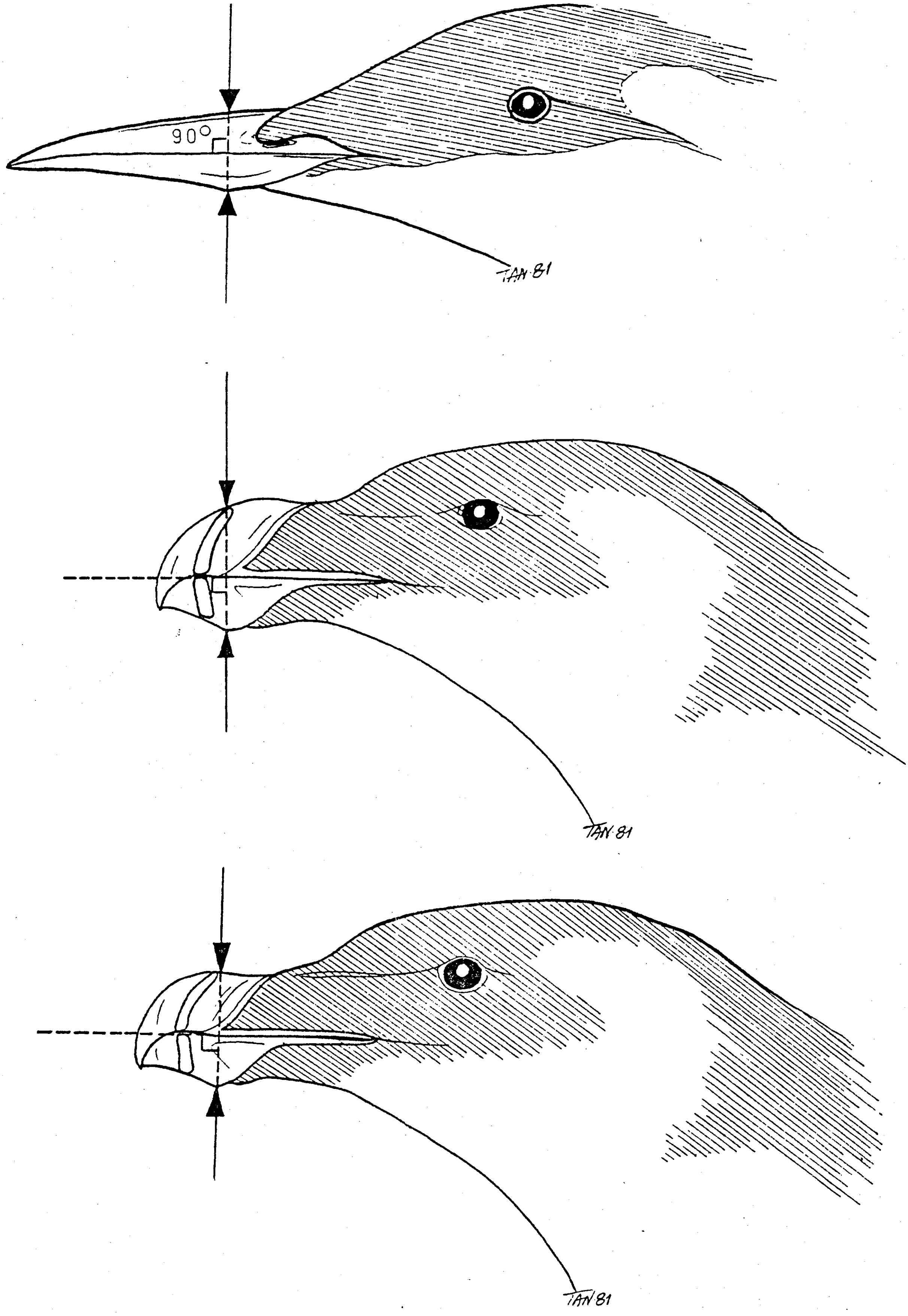


Fig. 6 Gonys measurement in Guillemot and Razorbill



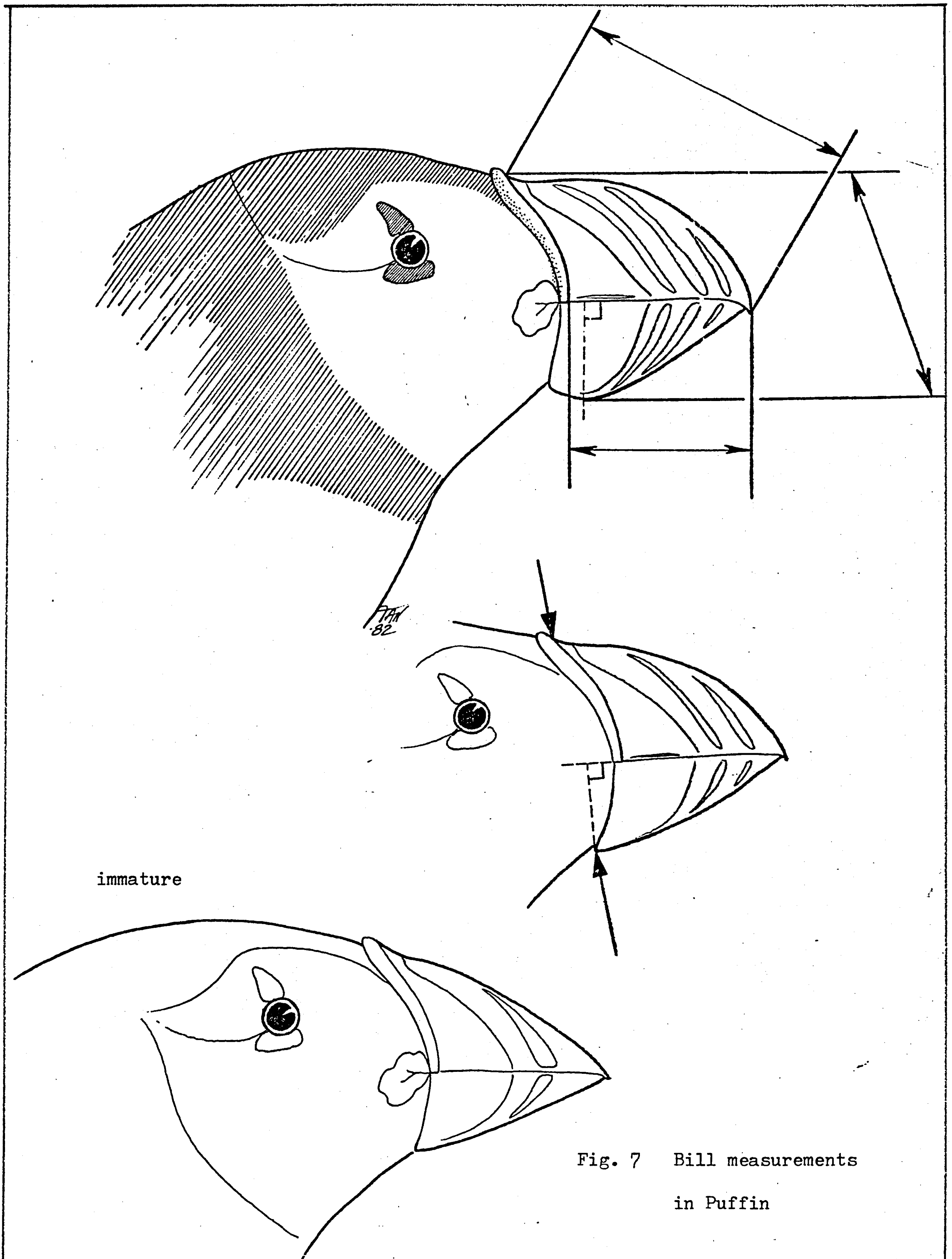
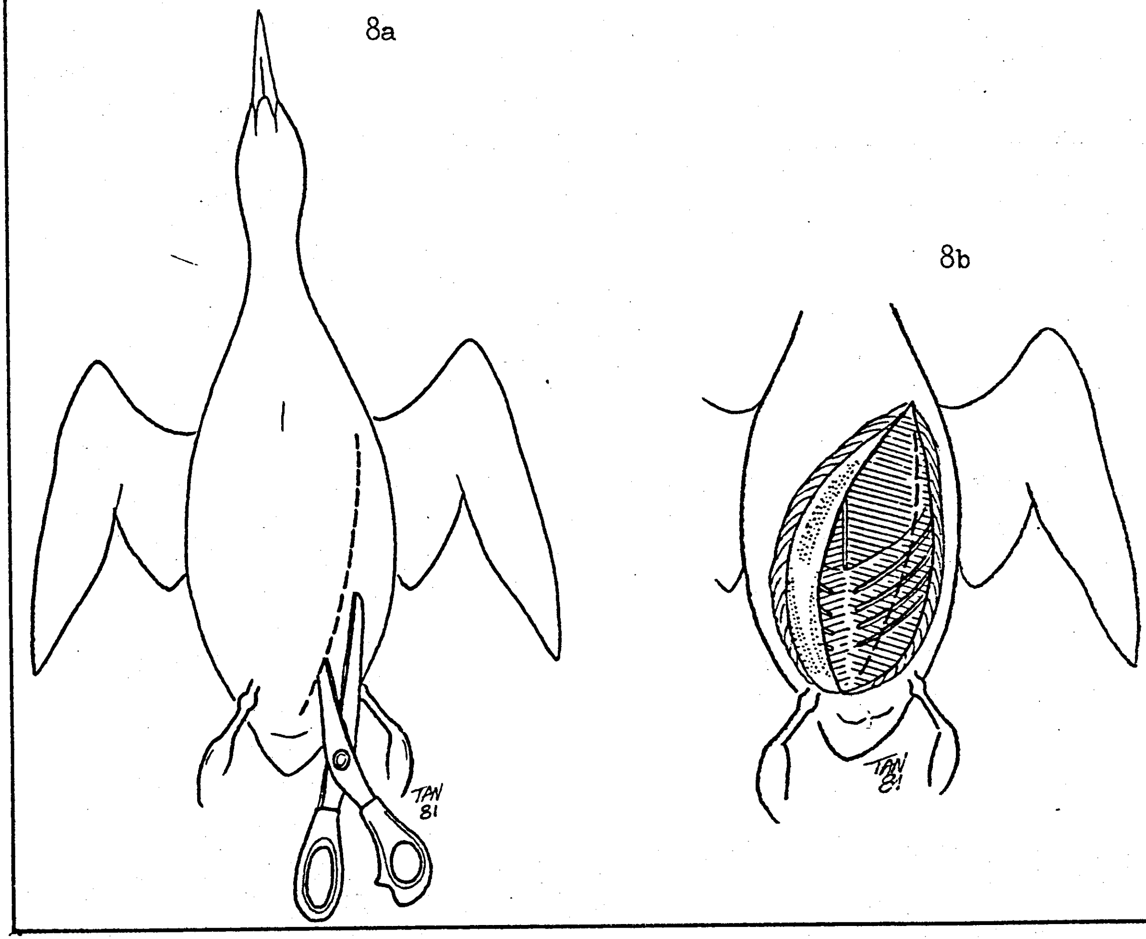


Fig. 7 Bill measurements in Puffin

4. INTERNAL EXAMINATION

The easiest way to open up a bird is to put it on its back with the head pointing away from the observer. Using strong scissors, a first cut is made through the skin on the bird's left dorso-ventral side. The skin can be peeled back to reveal the abdominal wall (Fig. 8a). Then a cut is made through the wall, ribs and sternum from just in front of the cloaca forward towards the bird's left wing (Fig. 8b). Sharply-pointed scissors should not be used (or at least they should be used with great care) since these may easily puncture well-filled stomachs.

Fig. 8 Initial opening of the body cavity



4.1 Sex The bird's sex is determined by inspection of the gonads. These lie exposed on top of the kidneys well forward in the body cavity (Fig. 9), and it is often necessary - for good viewing and measuring - to push the intestines to one side. The males have two sausage- or bean-shaped testes (Fig. 10) which are often pale in colour, though they tend to darken in specimens in the early stages of decomposition. The bird's right testis may be hidden by a membrane between the kidneys. Females (in auks) have only one ovary, more club-shaped, positioned on the bird's left side. Care must be taken not to mistake the left adrenal gland (which is not granular) for the ovary. The size of the gonads varies greatly with the stage of the reproductive cycle (Fig. 10).

4.2 ♂-testes (= length and breadth of the bird's left-side testis). Measured using vernier calipers, and noted to the nearest 0.1 mm.

4.3 ♀-foll. (= diameter of the largest follicle). The ovary normally has a granular structure due to developing eggs (follicles). The diameter of the largest follicle is measured using vernier calipers: if under

Fig. 9 Internal organs of Guillemot

1. Breast muscle
2. Sternum
3. Adrenal
4. Testis
5. Kidney
6. Stomach
7. Intestine
8. Caeca
9. "Dep. fat"
10. Bursa
11. Cloaca
12. Underside of skin
13. Ribs
14. Cloacal opening

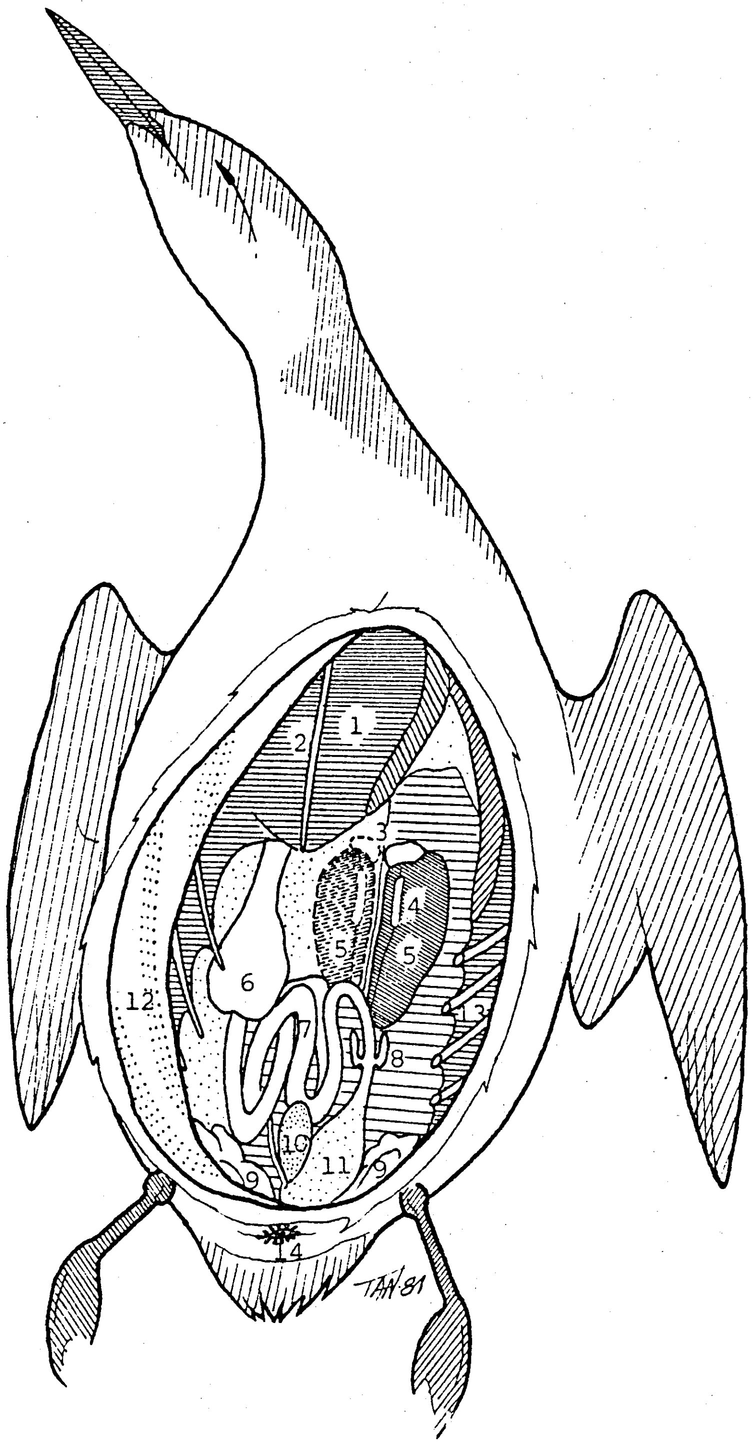
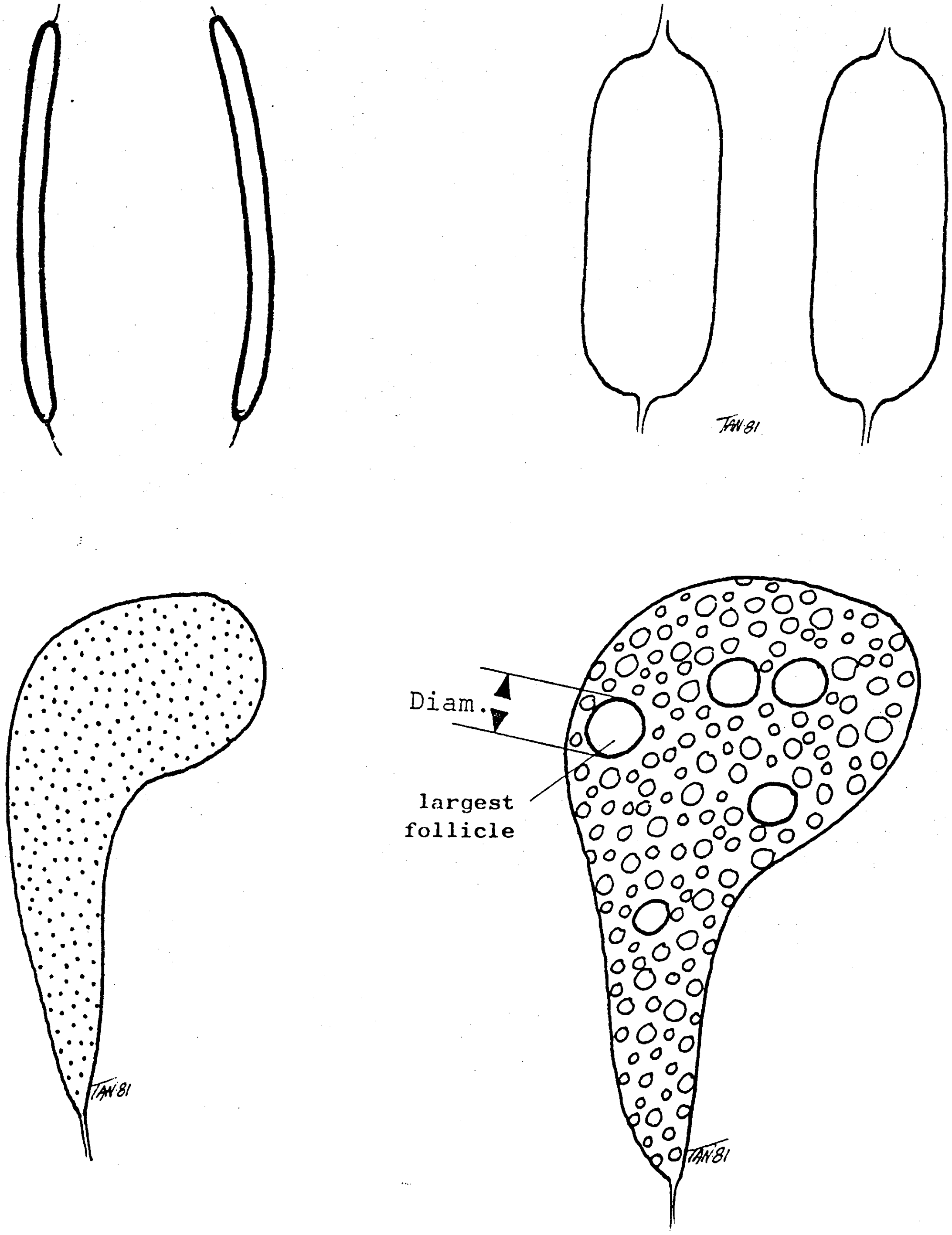


Fig. 10 Poorly-developed (left) and well-developed (right) testes and ovaries in Guillemot and Razorbill



0.5 mm it is difficult to measure and is noted as 0 on the data form; otherwise, measurements are noted to the nearest 0.1 mm.

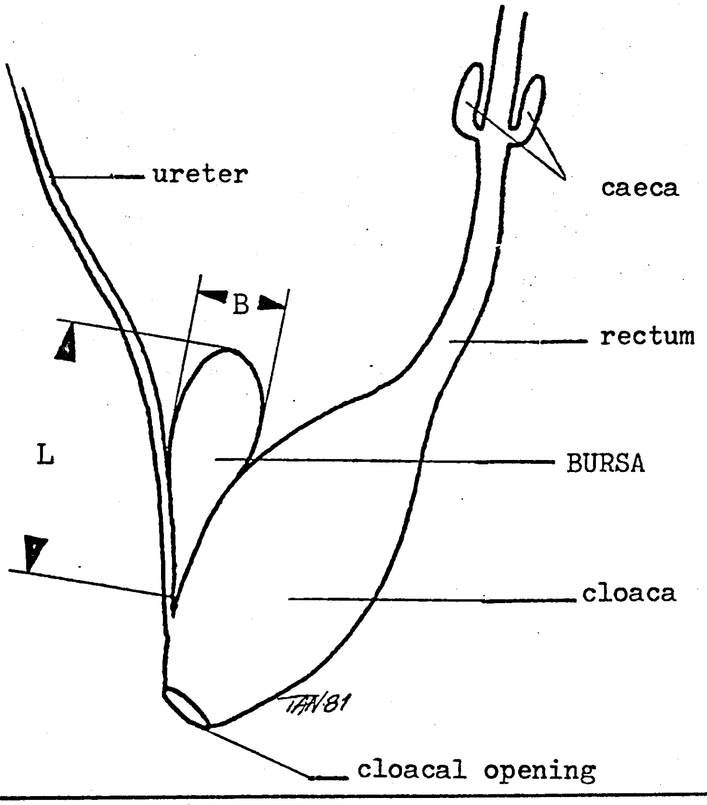
(The state of the oviduct is often a good guide to whether or not a female has previously laid an egg (and hence in deciding whether or not the bird is adult): normally it is very thin and thread-like along its whole length in birds which have not laid, and much wider in birds which have laid, often in this case with a series of convolutions at the distal end. The diameter of the oviduct varies along its length, and it is a measurement which is difficult to make for a consistent comparison between birds, but a record of, e.g. "wide convoluted oviduct" or "threadlike oviduct" could be a useful item for the Notes column.)

4.4 Sub. fat (= subcutaneous fat). Scale 0-3. This is the fat lying under the abdominal skin, and the amount is estimated as follows: if the feather papillae are not visible through a thick layer of fat, the value 3 is given; if the whole area of the skin is covered by a thin layer of fat and the feather papillae are visible, the value given is 2; if the fat lies in thin strips, concentrated around the papillae, the value given is 1; and if there is no fat at all, the value given is 0.

4.5 Dep. fat (= <u>deposition fat</u>). Scale 0-3. This is the fat within the hind end of the body cavity, (generally concentrated around the cloaca), graded 0-3. The figure 3 is noted when large clumps of fat are found around the cloaca and the small intestine, 0 when no fat is seen. The gradation is subjective and difficult to standardise.

4.6 Bursa (= <u>length and breadth of the cloacal bursa</u>, or bursa Fabricius). The bursa is a rather plastic sack-like organ which opens into the cloaca on the bird's right side (Figs. 9 & 11). If there is much deposition fat the bursa is often concealed and difficult to find. If absent the figure 0 is noted otherwise the bursa's length and breadth are measured to the nearest 1 mm.

Fig. 11 Measurement of length (L) and breadth (B) of bursa



5. NOTES, AND ROUTINE SPECIMEN COLLECTION

5.1 Notes

In this column on the data form, notes can be made of any relevant information which is not accommodated in the preceding columns. Important details such as ring number should be entered here, or details of any plumage peculiarities or internal abnormalities. This, too, is the place to explain, or elaborate on, unusual items in the data, e.g. "unusual culmen length due to greatly extended bill-tip; photograph taken". Other points to note are the presence of brood patches or an egg in the uterus. Overall moult studies are perhaps best made from prepared cleaned skins, but it is always valuable to check for sheathing at the bases of the outer primaries since the mean winglength of a sample can be considerably altered by the inclusion of birds with outer primaries not completely grown. A note must always be made for birds which have been cleaned or kept in captivity, since these treatments can have important effects on some aspects of the data.

Another important task for the data-writing recorder is to ask for confirmation when an extreme or unlikely measurement is called. If the figure is confirmed upon checking and re-measurement, then it should be underlined on the data form. When a specific piece of information is missing or uncertain, a dash or question-mark should be entered in the form; the space should never be left blank.

5.2 Specimens

In the work of the Seabirds at Sea Team in Aberdeen, PHJ and BFB have routinely removed stomachs from all auks (at the end of the internal examination) and wings from Guillemots (after external examination and weighing). Although stomachs of oiled auks normally contain relatively few identifiable food remains, this is not invariably the case, and some very valuable data have been forthcoming from such specimens. However, the subsequent identification work is rather specialised, and not quickly or easily learned by an ornithologist untrained in marine biology, so if stomachs are removed, it is important to ensure that there is a specialist available, and willing to examine them!

The treatment of specimens is discussed in more detail in Section 6.

6. PRESERVATION OF WHOLE BIRDS AND SELECTED ORGANS

6.1 Whole birds

If time and storage space permit, it could be valuable to store a few of the freshest whole carcasses deepfrozen from an incident. If any particular feature of environmental pollution is suspected, advice should be sought from an appropriate specialist on the numbers of specimens needed.

6.2 Ringed birds

These specimens are especially valuable, and if ringed as chicks they represent known-aged birds from specific localities, with consequently important information on morphometrics and other factors. They should be examined according to the standard procedure, taking care to do as little damage as possible whilst opening the skin and body cavity, and ensuring that the ring number is entered in the 'Notes' column, and that the ring is left in place on the tarsus. The corpse should then be deep-frozen prior to transfer for curation in an appropriate museum (e.g. the National Museum of Wales, in Cardiff, has begun a collection of skins and carcasses of ringed auks found dead around British coasts).

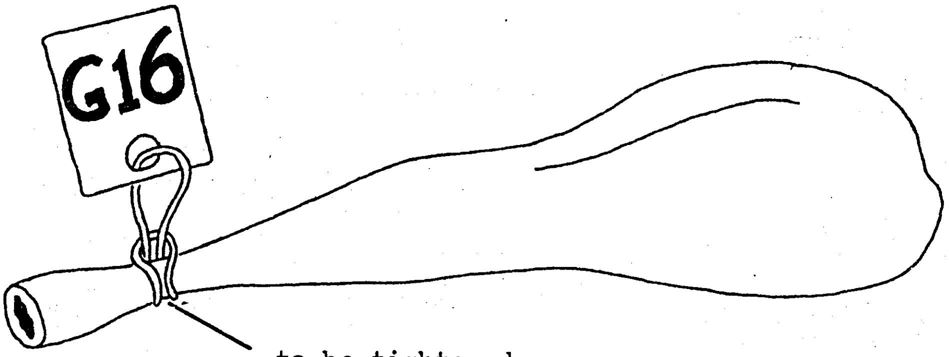
6.3 Stomachs

A stomach sample can easily be collected by lifting the whole forward end of a bird's alimentary tract and cutting posterior of the gizzard to remove that organ together with the forward end of the stomach (which, in auks, grades into the oesophagus); the second cut should be made as far forward into the body cavity as can comfortably be reached with the point of the scissors.

The method of stomach preservation depends on circumstances. When dealing with fresh-killed birds, the ideal treatment is injection of buffered formalin or the immediate opening and flushing of contents with industrial methylated spirits (c. 70% alcohol). In handling oilspill victims however, the necessity of arresting post-mortem deterioration of contents is less important and, after removal, the whole stomach may be tied off with the string of a label and stored in a jar of c.70% alcohol with other samples. The sample number must be clearly written on the label using pencil since ink or ballpoint will become illegible in alcohol.

It is important to note that alcohol is not a fixative, and if samples are to be stored for long periods before examination, then buffered formalin should be used. The acidity of non-buffered formalin rapidly erodes the identifiable characteristics of fish otoliths and should not be used unless absolutely unavoidable.

Fig. 12 Removed stomach with label



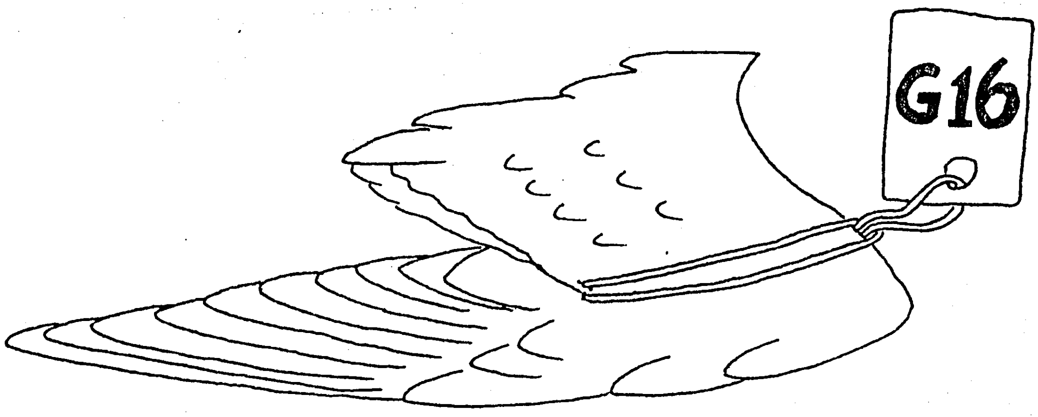
6.4 Other selected internal organs

If samples are to be kept for heavy metal analysis or for quantification of pesticide and PCB residues, the best procedure is to put whole sample birds into deepfreeze. However, individual organs can also produce valuable results; kidney and liver are best in this context. The whole liver, and samples of the kidney, should be kept in glass pots (not plastic) and deepfrozen; the brain is also a key organ, and in this case the best procedure is to cut off the bird's head, and keep it deepfrozen in a plastic bag. In all cases, specimens must be taken from fresh carcasses, and each pot or bag must be clearly labelled with the specimen number, the incident and its date.

6.5 Wings

It could be useful to keep one wing from each Guillemot. This species, in Europe, varies considerably in the colour of the upperwing, the degree of spotting on the underwing, and winglength. These features are usually linked to the individual bird's geographical origin, and a wing specimen could help in providing confirmatory evidence in this context and also as a check on one of the most importamt morphometric parameters - winglength. The wing should be broken acorss the humerus, with pliers, quite close to the body, and the skin cut with scissors to remove the whole wing including all the secondaries. Wings can be dried in warm air, and stored for future examination, preferably in the dark to reduce 'foxing' (colour change in brown and black plumage). The numbered label can be tied between primaries and secondaries, and tightened over the 'forearm' and <u>not</u> over the primaries - or the label will fall off.

Fig. 13 Removed wing with label



Appendix I. List of equipment used in the examination procedure

1. Safety

1.1 Thin rubber gloves

1.2 Antiseptic liquid (for use on cuts and grazes)

2. Recording

2.1 Prepared record sheets (data forms)

2.2 Pens, pencils and erasers

2.3 Notebooks and spare paper

3. Measuring

3.1 Stopped wing rules (up to 300 mm for European auks)

3.2 Vernier calipers

3.3 Spring balance (up to 1500 gm for European auks). A dial weighing balance is preferable, being easier and quicker to use, but not often available.

4. Dissection

4.1 Large scissors

4.2 Small scissors

4.3 Forceps

4.4 Seekers

4.5 Scalpels

4.6 Pliers (for wing removal)

(Appendix I continued)

5. Storage

5.1 Plastic, wide-mouth, screw-top containers (for stomachs)

5.2 70% industrial methylated spirit (alcohol) (for stomachs)

5.3 Sticky labels (outside of storage containers)

5.4 Tie-on tags (for wings and stomachs)

5.5 Deepfreeze unit (or ready access to one nearby)

5.6 Cardboard boxes

5.7 Polythene bags

5.8 Glass pots or jars (samples for pesticide analysis etc.)

6. Disposal

6.1 Large plastic sacks

7. General

7.1 Newspapers (as floor- and table-covering)

7.2 Paper tissues (for cleaning hands, dissection instruments, wingrules, etc.)

7.3 Detergent and disinfectant (for cleaning tables, sinks, floors)

7.4 Thin lubricating oil (for cleaning and protecting calipers, wingrules and pliers)

Appendix II. Example of data form (next page)

The proforma is best prepared across lined sheets of A4 paper; copies can then be made as needed.

SPECIES: URIA AALGE LOCALITY: FARSUND, Norway FINDING DATE: 11.01.81 Ex. by: TAN Date: 27.01.81

No.	Br./B.g.	%oil	Wt.	Plu.	Wing	Culm.	Head+b.	Gonys	Sex	♂-testes	♀-foll.	Sub.fat.	Dep.fat.	Bursa	Notes
G505	No	10	920	W/S	200	44	–	12.4	♂	7.6x1.2		1	1	22x13	
06	Yes	10	920	W/S	207	43	–	11.5	♀		0	1	1	23x12	
07	No	30	860	W	200	48	–	11.3	♂	11.3x1.8		1	1	26x11	
08	No	30	710	W	198	46	–	11.6	♂	10.5x1.4		1	1	?	
09	No	30	950	W	197	48	–	12.1	♀		0.8	2	2	24x12	Wet !
10	?	30	–	–	201	–	–	–	♂	9.4x4.7		2	2	0	Headless
11	No	10	700	S	210	48	–	12.9	♂	14.5x3.1		1	1	0	
12	No	50	830	W	197	–	–	10.9	♀		0	2	2	23x13	
13	No	10	730	W	221	46	–	12.0	♀		1.9	1	1	0	
14	No	20	890	W	207	51	–	12.7	♂	9.7x1.7		2	2	21x10	
15	Yes	40	760	W	214	46	–	11.7	♀		1.7	1	1	0	
16	No	0	750	W	207	45	–	11.4	♂	10.4x1.3		2	1	15x7	
17	No	20	810	W	197	47	–	11.6	♂	11.6x1.7		1	2	24x9	
18	?	10	660	W	200	–	–	–	♀		0	1	1	?	
19	No	10	780	W	212	48	–	12.3	♀		1.3	1	1	0	
20	No	50	–	W	203	46	–	13.7	?			1	?	?	Partly eaten
21	No	10	790	W	202	47	–	12.4	♀		0.8	1	1	19x8	
22	No	10	–	W	212	44	–	12.1	♀		1.3	1	1	?	Partly eaten
23	No	10	740	W	205	45	–	10.8	♀		0	1	1	25x12	

Appendix II. List of reports produced, since 1979, on auk examination (date of report in brackets)

1. (9.1.80) Guillemots examined at Little Creech on 7 January 1980.
2. (30.10.80) Work on Guillemots and Razorbills in Shetland, summer 1980.
3. (4.11.80) Corpses of Guillemots oiled in N.E. England in March 1980.
4. (4.12.80) Guillemots killed in an oilspill off the Forth estuary in April 1979.
5. (20. 3.81) Guillemots found ashore oiled in Norfolk, February 1981.
6. (-. 4.81) Auks found dead in the Cruden Bay/Collieston area near Aberdeen in June 1980.
7. (21. 9.81) Measurements of the larger auks *Uria aalge*, *U. lomvia*, and *Alca torda* at Grimsey, Iceland, in July 1981.
8. (24.10.81) Examination of corpses of Guillemots killed by oil off Tyneside in September 1981.
9. (16.11.81) Auks found oiled at Rattray Head, Grampian, mid-August 1981.
10. (14.12.81) Auks found in salmon nets at Downie Bay, Troup Head, Grampian, 12 June 1981.
11. n.d. (=1982) Examination of Guillemots killed by oil off the coasts of South Devon and North Cornwall in 1981.
12. (13. 1.82) Auks found dead in Orkney, early October 1981.
13. (28. 1.82) Guillemots found dead on the coast near Aberdeen in late September 1981.
14. (28. 3.82) Examination of auks killed in an oilspill off the Buchan coast in March 1982.
15. (1. 4.82) Examination of Guillemots shot in the Firth of Forth on 5 March 1982.
16. (8. 5.82) Examination of Guillemots shot off the Fair Isle, Shetland in June 1981.
17. (25. 5.82) Examination of Guillemots shot at Noss, Shetland, 25 January 1982.

18.(16. 7.82) Age, sex and origins of auks *Alcidae* killed in the Skagerrak oiling incident of January 1981.

19.(17. 8.82) Measurements of Guillemots and Razorbills at Great Saltee, S.E. Ireland, in June 1982.

20.(2. 4.83) Examination of dead Razorbills and Guillemots in N.E. England, March 1983.

21.(23.11.83) Examination of Guillemots shot near Fowlsheugh, Stonehaven, winter 1981/82.