THE STUDY OF FISH REMAINS
FROM
BRITISH ARCHAEOLOGICAL SITES

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Submitted for the degree of
Doctor of Philosophy
University of Sheffield
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Archaeology

September 1981

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Acknowledgements

This study was commenced in 1975 funded by a state studentship from the Department of Education and Science. The topic was proposed by Dr Paul Mellars and I am indebted to him for his support and advice as my supervisor;he also made available the archaeological material from the sites on Oronsay and provided the opportunity for me to examine the fish remains during the excavations. My thanks also go to his wife,Mrs Anny Mellars,Mr Will Peacock and everyone else who participated in the excavations in 1975,1976,1977 and 1979.

Facilities were made available to me in the Department of Prehistory & Archaeology of the University of Sheffield throughout the period of my research and I received assistance on technical points from the Departments of Geology and Zoology and the Computing Centre. Some of the identification work was carried out at the British Museum(Natural History) and I am very grateful to Mr Alwyne Wheeler for making available the collections there;also for his help in the early stages of the study as I was familiarising myself with the material and for releasing the Oronsay material that had been given to him. An earlier draft of part of Chapter Five was presented to a conference of the Association for Environmental Archaeology and subsequently published(Wilkinson 1981);my thanks to Mr Don Brothwell for arranging this.

Finally to the people of Colonsay and Oronsay for their hospitality during my visits to Scotland to collect samples of saithe. All of the processing and analysis of this data was done by myself,apart from the single 1973 sample,and I participated in the capture of some of the fish;but I am most grateful to Mr Dai Alexander,Mr Peter McAllister and Mr Dougie McGilvray for providing most of the fish.

The Study of Fish Remains from British Archaeological Sites.

Michael Rex Wilkinson.

The subject of this study falls into two parts. Firstly an examination of the methodology of the analysis of archaeological fish remains. It considers the problems of recovering and quantifying material and then the aims and difficulties of analysis. Several lines of evidence can be used to study how the fish were caught and utilised but much of it is ambiguous and natural agencies can produce similar patterns. One major use for fish remains lies in the study of seasonality;behavioural evidence is not as reliable as is often claimed but growth rings and sometimes fish size are clear indicators.

Integrated with this is a case study of a large and well-recovered assemblage of fish remains from a series of five fourth millennium bc. shell middens on the small island of Oronsay(Inner Hebrides). The fauna is dominated by the young age stages of one species,the saithe(*Pollachius virens*) but at least fifteen other fishes are represented;they are mostly found along rocky shores or in inshore waters. The size of the assemblage and the lack of selectivity,both in species and sizes,suggests a technique of mass capture such as a weir or nets;however,a combination of methods including line fishing from boats seems likely.

The behaviour of the species and evidence from the traditional fisheries demonstrates that it could be caught for most of the year,except the 'winter' quarter. Fish size and growth ring data reveal a consistent pattern of a single principal fishing season at each site and differences between them.Collectively,the period of fishing spans much of the year and,as the sites are broadly contemporary,there is a strong possibility that they functioned as part of a single economic system.

List of Abbreviations: used in appendices,tables and figures.

Abd	Abdominal vertebra
Alsp	Alisphenoid
An	Angular
Boc	Basioccipital
Brstg	Branchiostegal ray
Bsbr	Basibranchial
Bspt	Basipterygium
BW	Weight of fish:boned
Cad	Caudal vertebra
Ce	Centrum
Cerbr	Ceratobranchial
Cerhy	Ceratohyal
Cl	Cleithrum
Co	Corocoid
Dn	Dentary
Dpp	Dorsal pharyngeal plate
DW	Fish weight:dressed
Enpt	Entopterygoid
Epbr	Epibranchial
Ephy	Epihyal
Epiot	Epiotic
Ethl	Lateral ethmoid
Exo	Exoccipital
FL	Fish length:Fork length
Fr	Frontal
FW	Fish weight:whole
HA	Haemal arch
HS	Haemal spine
Hybr	Hypobranchial
Hyhy	Hypohyal
Hyom	Hyomandibular
Inhy	Interhyal
Iop	Interoperculum
La	Lacrymal
Mpt	Metapterygoid
Msth	Mesethmoid
MW	Fish meat weight
Mx	Maxilla
Na	Nasal
NA	Neural arch
NS	Neural spine
OB	Otolith breadth
OL	Otolith lrngth
Op	Operculum
Opo	Opisthotic
Pa	Parietal
Par	Parapophysis
Pcl	Postcleithrum
Pl	Palatine
Pmx	Premaxilla
Pop	Preoperculum
Pot	Posttemporal
Pto	Pterotic
Ptr	Pterygoid
Qu	Quadrate
Sc	Scapula
Scl	Supracleithrum
Soc	Supraoccipital
Sop	Suboperculum
Sors	Suborbital series
Sphot	Sphenotic
St	Supratemporal
Sym	Symplectic
Th	Thoracic vertebra
TL	Fish length;total length
Ur	Urohyal
Vo	Vomer
Vpp	Ventral pharyngeal plate

INTRODUCTION

The development of procedures for the analysis of fish remains from archaeological sites is a recent occurrence, within the last twenty years (Heizer 1960:106). Before this most reports were limited to a list of the species represented together with inferences drawn from their known behaviour; there were few attempts at a synthesis of material (Clark 1948; Ryder 1969). The growth of interest in the subject can be attributed to a combination of circumstances which have increased awareness of this class of material: particularly the introduction of techniques for recovering small-scale remains from sites and the growth of interest in ecological approaches in archaeology. Many of the developments have come from the direct involvement of archaeologists in the analysis of fish remains, building on the work of the small number of vertebrate zoologists interested in the subject-Wheeler(British Isles), Lepiksaar(Scandinavia), Follett(California) and others. These contributions to the methodology of fish analysis have come through the reappraisal of existing material (Akazawa & Watanabe 1969) and especially from the recovery of large assemblages of remains for the first time (Shawcross 1967; Parmalee et al 1972). In 1972 Casteel completed his thesis (1972a) and published the first of a series of papers devoted to aspects of the study of archaeological fish remains (1972b et seq).

This study was begun in 1975 based upon the very large quantities of fish remains that were being recovered from the excavations of a series of mesolithic shell middens in the Hebrides (see below). The existing literature at that time showed the potential of the subject but there was no adequate framework for undertaking an analysis. Therefore it was necessary to broaden the scope of the work and consider the wider field of the methodology of the subject. The main stages in the examination of assemblages (recovery, identification, quantification) and fields of interpretation (how the fish were used; nature of the fishery; seasonality) have been examined drawing principally on ideas and data from two other disciplines. Firstly, on developments in vertebrate faunal analysis particularly in the discussion of sampling and recovery, quantifying remains, taphonomy and resource use scheduling. Secondly, on techniques used in fisheries science for identification, size estimation, ageing and capture methods. More attention is given to these latter subjects as they will be less familiar to most of those interested in archaeological fish remains. In addition, a number of papers have appeared on fish analysis since this study began and they have been included in the discussion.

The work is intended primarily as a contribution to the methodology of the study of archaeological fish remains and is not a catalogue of results and site reports. However, it does pay close attention to the practicalities and limitations of archaeological material and the applicability of the procedures described in the general discussion is demonstrated in the second part of the thesis: a case study of the assemblage from the sites on the island of Oronsay. The geographical restriction (the British Isles) is simply an acknowledgement of the diversity of fish life and reduces the extent to which statements have to be qualified to take account of this. Wherever possible examples are used of species that are found in the waters of north-west Europe but most of the work should be applicable more widely.

Introduction:Oronsay

The assemblage of fish remains examined in this study comes from a group of shell middens of mesolithic date on the island of Oronsay in the Inner Hebrides (Figure 1). It is a small island, with a land area of only 6 square kilometres, and is joined at low tide to its larger neighbour, Colonsay. To the east lie Jura and Islay, both of which also have mesolithic occupation (Mercer 1970; Burgess 1976), and beyond them the Scottish mainland. Oronsay would have been even smaller (4 sq.km.) at the time of occupation as the sites lie close to the level of the maximum post-glacial marine transgression (Jardine 1977, 1978). At least five middens have been located and they are similar in their industries and composition: dominated by shellfish (limpet, periwinkle, dog whelk), with fish, bird and mammal bone, crustacea and plant remains. Radiocarbon dates from three of the sites indicate that they were occupied in the latter part of the fourth millennium b.c. (Mellars 1978, 376).

Excavations were carried out on a number of the sites on Oronsay at the end of the last century (Anderson 1898;Grieve 1883, 1885, 1923;Bishop 1913) and at related sites in Oban - hence the term 'Obanian'- and on Risga (Lacaille 1954). These Obanian sites were identified as mesolithic particularly from their fine antler and bone work and parallels were sought with the continent as there are no comparable assemblages in Britain (Clark 1956). The present investigations started in 1970 (Mellars & Payne 1971) and there have been five subsequent seasons of work. One of the sites,Cnoc Coig,has been the subject of extensive excavation (70% of the site) and sampling (Peacock 1978),and more restricted work has been carried out at four other sites (Caisteal nan Gillean I & II,Priory and Cnoc Sligeach).An interim account of the project has been published (Mellars 1978) but work is continuing on a wide range of material including the samples from Cnoc Coig,the mollusca,bird and mammal bones (Grigson 1981).

A detailed study of the fish remains appeared to be a worthwhile undertaking on a number of grounds. The assemblage must be one of the largest recovered from any archaeological site in the British Isles,with remains from thousands of fish; the standards of sampling and recovery employed were highly appropriate for the material. The size of the assemblage made it practicable to develop and test procedures of analysis and the dominance of a single species simplified this task. It was clear that the study of the fish remains could contribute to many of the questions being investigated in the project,and that it would complement the work on other aspects of the sites. Finally,the richness of the fauna from the Oronsay middens makes them exceptional among mesolithic sites in Britain and thus warrants a detailed examination of the material.

CHAPTER ONE

SAMPLING AND RECOVERY

Data from the analysis of archaeological material are directly related to past cultural activities but only through a series of intervening stages and it is impossible to use such data to reconstruct these activities without understanding the processes that separate them. This sequence can be simply represented by a flow-chart (Meadow 1976,111) which shows the processes falling into two stages. Firstly,there are those that contribute to the formation of the archaeological record including the context of deposition (Schiffer 1972) and taphonomy (Behrensmeyer 1978);some of these issues are covered in Chapter 4. The second group covers the stages of archaeological activity from survey to data analysis. The basic constraint on all subsequent investigation is the nature of the samples available for study (Payne 1975a,7). For this reason it is desirable that specialists are involved in the formulation of sampling and recovery strategies. Different sets of data are required to investigate particular questions and so the sampling and recovery should be geared to the aims of the study.

Sampling

All archaeological investigation,from regional surveys to analysis of pit-fills,is sampling (Mueller 1975;Cherry et al 1978) and the implications of this are only now being realised. These include the negative features of selectivity and bias in archaeological remains (Payne 1972a) and the advantages of the integration of sampling within research design. The production of archaeological data can be costly,with excavation,processing and analysis,and so it should be an important goal to minimise the amount of such effort. The aim of sampling is to obtain an accurate representation within determined confidence limits of the variability within a population,without examining the entire population. The relationship between sample size and level of accuracy generally takes the form of a parabolic curve;thus there exists an optimally efficient sample size in terms of work input (Cherry 1978,305). This relationship can be used experimentally to determine levels of sampling, or alternatively strategies based upon random sampling theory can be employed.

The establishment of sampling levels is normally further complicated by the use of samples to examine several parameters of a population. The most important point of this is that a sample is likely to contain different quantities of each value and so different sizes of sample are required to give equal numbers of specimens ;for example faunal samples contain more identifiable pieces than measurable ones,and so on,with the result that larger samples are necessary for each subsequent stage of analysis.However,in practice the relationship is not so straightforward as parameters can be measured by different sizes of sample. For instance,the rank order of the principal species can be determined from a small number of bones whereas the investigation of contextual variation requires a very large total sample. These points have been discussed by Gamble(1978).

Sampling for fish remains

There has been little discussion on the subject of sampling specifically for fish remains or of the quantities of material required for analysis,apart from occasional references to the existence of too much material (Wheeler 1977b,403; Casteel 1976,72). Sampling decisions can be taken during analysis or at the time of excavation. On-site there are two basic strategies for recovering material:

i.examining all the matrix,either in situ or after rapid screening;for large elements eg.mammal bone,

ii.small matrix samples,carefully sorted for micro-elements eg.seeds.

However,fish remains tend to fall between these two categories. The majority of fish bones are too small for a representative sample to be picked out during excavation and they are rarely found in such densities for small-scale sampling to be useful. The first procedure enables a large volume of matrix to be dealt with but will be biased toward the larger and more distinctive pieces,while sampling will produce an accurate representation of a small part of the site. Ideally the two should be combined to provide a check on each other. There is no single strategy for sampling archaeological sites for fish remains as the choice depends upon the nature of the site, the size range,distribution and quantity of bone,and on the assemblages required. This is dependent on the questions to be investigated;the main goals in fish bone studies have been:

i.the listing and ranking of species:can be based on only small numbers of the most diagnostic elements

ii.the number of individuals:can be calculated from small groups,but all the material must be examined to determine the most abundant element

iii.the sizes and age structure of the population:only a few elements have to be studied but larger samples are needed to cover the variability in a population

iv.frequencies of skeletal parts and context variation:large total assemblages are required to ensure adequate groups in individual contexts or of single elements.

One group of archaeological sites in which fish remains are often present and for which sampling strategies have been used for some time are shell middens. Some form of sampling is essential in their analysis because of the concentration of material in them (Bailey 1975,48),although the procedures adopted depend upon the aims of the study (Ambrose 1967). The quantitative approach attempts to reconstruct the overall composition of the site by assuming that they are homogeneous and can be studied from a small number of samples (Cook & Heizer 1951;Treganza & Cook 1948). Alternatively,the structural approach emphasises the variations within a site and seeks to understand this by extensive examination (Coutts 1971,155). Thus the aims of the excavation help determine the sampling strategy and more attention should be given to this subject on other archaeological sites.

Recovery methods

The selectivity of archaeological recovery,in sizes and classes of material,is now generally understood (Payne 1972a) and this has led to the adoption of a number of techniques to improve the quality and quantity of data recovered. Two aspects of this development deserve consideration:firstly,the ways in which they operate and then the implications of an improvement in recovery rates. The techniques fall into two groups according to the way in which they select material:

i.Sieving. Its efficiency depends upon the matrix but it can be used on-site to process large volumes of material (Payne 1972a;Barker 1975) as well as for small detailed samples. Wet sieving is generally preferable as it cleans and is less abrasive,and is effective with smaller meshes;3mm or one-eighth inch is the minimum for bulk sorting but smaller meshes can be used for more detailed work. (Cook & Treganza 1947,136-7).

ii.Flotation. A number of processes have been developed using liquids to separate classes of material,either water (Jarman et al 1972;Struever 1968;Williams 1973) or chemicals such as zinc chloride (Bodner & Rowlett 1980;Lofstrand 1972;Struever 1968). The sophistication of these techniques varies greatly, especially among water separation procedures,but all operate by floating off a lighter fraction of charcoal,seeds etc. and can handle large quantities of matrix.

The introduction of these techniques has led to improvements in the quality of data-less bias and recovery of small classes of material-and in the quantity of archaeological remains. Most accounts of such processes stress the ability to handle large bodies of material once they have been set up. The rates of operation vary considerably (Cherry 1978,298-9) but it is a fairly labour-intensive activity and more importantly produces large samples for subsequent sorting and analysis. Sorting is a 'tedious and lengthy job'(Payne 1975a,16) and takes on average twice as long as the processing (Cherry 1978, 297). The implications of this are that such work should be restricted to the level required for the questions under investigation. The most appropriate recovery procedure for the material,eg in the optimal mesh size (Casteel 1972c),should be allied to a suitable sampling strategy when work begins.

Recovery of fish remains

The paucity of fish remains from archaeological sites has long been commented upon (Ryder 1969,380)and several explanations have been offered,including difficulties in recognising them,their fragility and poor preservation (Ashbee 1974,267; Lepiksaar 1978,235),and their small size (Evans 1978,47;Limp & Reidhead 1979,74). All may play a part although size seems the major factor and so recovery procedures are of critical importance. Various studies have commented upon the relative efficiency of different techniques for recovering remains (Casteel 1975b;Clason & Prummel 1977):

i.trench recovery:this is highly variable depending on site conditions,nature of the fishbone,and manner of excavation. Occasionally all fish has been missed (Payne 1975a,13) but generally recovery is partial and biased toward the larger

and more distinctive pieces (Clason & Prummel 1977,174;Jones 1976,172) although this may be adequate for some purposes.
ii.sieving:this is now widely adopted for fish remains(Wheeler 1978a,71).Wet-sieving is preferable as it does less damage to pieces (Finlayson 1977,462) and smaller meshes can be used. A range of mesh sizes are employed but there is some general agreement that a standard field sorting screen of 3mm is too big (Garson 1980,566). Meadow proposed a 2mm mesh to recover all remains of large fish and some smaller ones (1976,116) and sieves of one-sixteenth inch and 1mm are common (Koike 1980,41;Wheeler & Jones 1976,240). In laboratory work 0.5mm is used (Casteel 1975b,3;Fitch 1967,185) and even smaller fractions have been examined (Jones 1976,171);magnification is essential for work at this level.
iii.flotation:the advantages of these procedures should include minimal abrasion and the recovery of classes of material although the latter is complicated by the differences in specific gravity of various fish remains (Calder 1977,146). Water separation as developed by Struever (1968)has been used to good effect on sites with large quantities of small fishes (Struever & Carlson 1977,99;Munson et al 1971,415;Finlayson 1977,460;Garson 1980,565) and chemicals have also recovered fish along with other materials (Lofstrand 1972,138);one extension of the latter has been to adopt it in the study of coprolites (Calder 1977).
These procedures are not mutually exclusive and can be easily combined,as in the two stage operation of water separation and wet-sieving (Struever 1968).

The choice of recovery technique will depend upon two sets of circumstances. Firstly,the properties of the site and the fish remains:type of site,matrix,volume of fill,distribution and density of fishbone,and the species and sizes of the fish. Secondly,on the aims of the study;the technique should optimise the recovery of classes of material required for analysis. Trench recovery may be adequate in some circumstances but there is no check on its accuracy. Wet-sieving is the most widespread recovery method for fish remains;the choice of mesh size will depend on individual circumstances but 0.5mm is recommended as a minimum and 2mm as the upper limit. The size selection of sieving (Casteel 1972c) may be avoided by flotation but more work is necessary to establish that other biases are not introduced. The recovery of large representative assemblages of fish remains is essential if the full potential of analysis is to be realised;the existence of too much material should not be seen as a potential problem as sampling strategies can be used to control this.

Sampling and Recovery: Oronsay

Excavation procedures

The analysis of the fish remains from Oronsay has been undertaken within the framework of the wider project and the recovery of the material has largely come through the main excavations. Therefore much of this section is an appraisal of the suitability of these procedures for recovering samples of fishbone. A number of sampling strategies and recovery methods have been used in the excavations (Mellars 1978,573-5). The total investigation of such sites is not practicable because of the volume of material involved;up to 75% of the contents of matrix samples consists of potentially recoverable economic data (Peacock 1978,179). One site,Cnoc Coig,has been extensively investigated with both area excavation and detailed sampling (23 one metre square test pits)(Peacock 1978);this will produce data on the composition and structure of this site. At the other sites-see Table 1 for details -there have been more limited trench excavations;their main purpose was to enable the collection of a series of samples through the vertical stratigraphy of the site.

The recovery procedures adopted in the excavations were:
i.trench recovery:biased toward the larger and more distinctive items and against those that are small or resemble the matrix. The rate of recovery is variable depending upon the excavator and the type of matrix(sand or shell)(Mellars 1978,389). Its advantages are that large quantities of material can be looked through,for rarer items,and that material is seen in situ; fragile pieces can be conserved,and data on location and associations recorded.
ii.one eighth inch wet-sieving:all excavated material was sieved and,except for some of the material from Cnoc Coig which was sifted in the sieve,then sorted through off-site. The sieving was a rapid procedure and all the excavated matrix could be dealt with but the sorting was much more time-consuming. Thus,

as with trench recovery only those items that are rare and of sufficient size to be found in representative quantities were collected. Complete recovery of any class of material is not likely but the assemblages are more reliable than those from the trench.

iii.column samples:dried,thoroughly sieved through 2mm and 1mm meshes and then dried before complete sorting;the 2mm fractions are sorted into all classes of material and some 1mm fractions have been sorted or searched for specific items. Samples were taken from the trench walls of the Priory,Cnoc Sligeach and CNG II,while in the sampling pits at Cnoc Coig up to four sub-samples of approximately 4kg. were taken from each stratigraphic layer (Peacock 1978,187-8). Such work is highly accurate,but it can take five hours to sort each sub-sample and so only a small quantity of material can be dealt with in this way.

Recovery of fish remains

Fish remains could have been collected from any of these excavation procedures or from samples taken specifically for fishbone analysis. The strategy adopted was determined by the composition of the fauna and by the requirements of the questions under investigation. The principal features of the fauna are the predominance of a single species of fish,the saithe;the small size of individuals of this and some other species;and a number of other species,covering a wide size range,which are present in varying frequencies. The main aims of the analysis were to determine:

i.the list of species:from the identification of a single diagnostic piece per species;the work must cover the size range necessary to recover all species and sufficient matrix to come across the rarest of them.

ii.the relative frequencies of species:can be established in several ways depending upon the precision wanted. The simplest procedure is to use data collected for other purposes(species list,numbers of fish).

iii.actual numbers of fish:once the most abundant element has been established for each species only this needs to be counted. The size of sample required for such calculations is not clearly established and the least frequent species are very difficult to quantify.

iv.size range and distribution(population structure):derived from a single well-represented and measurable element for each species;samples must not be biased or the degree of selection has to be taken into account. Assemblages must contain an adequate number of specimens and these are only attainable for more abundant species;even for these fishes a distinction might be necessary between the normal range of values and the total range of the species.

v.frequency of skeletal elements:requires detailed examination of samples recording counts of a number of elements from various parts of the body. Samples must be large enough to contain numbers of each bone;recovery should be standardised to ensure comparability between assemblages.

The choice of recovery procedures was further complicated by the different scales on which the study was conducted:these include the overall 'Oronsay' fauna,the individual sites, stratigraphic levels,sampling/excavation units,and individual samples. No single recovery method was appropriate for collecting all classes of data and so the strategy adopted combines results from all procedures.

Trench recovery: The abundance of fish and their small size prevent this technique being used to recover all fishbone. Its main use lies in the collection of less frequent items that are missing or poorly represented in small-scale sampling.Some species of large fish were only recovered in this way but the size selectivity of the method is shown by the failure to identify the smallest species (Table 2). The absence of the latter could be attributed to confusion with bones of the saithe which was not being collected here but this is refuted by their non-appearance in the lists of the earlier excavations where such selection was not practised (Table 3). The careful excavations also revealed concentrations of fish remains,which could be sampled separately,and groups of related material eg. Figure 13.

One-eighth sieving: This procedure can handle the same volume of matrix as the above method and so it is also used to recover less frequent items;recovery is enhanced,as shown by its ability to produce a complete species list (Table 2),and is more reliable than trench recovery. The mesh size appears to be adequate for the species list but not for recovering the size range of any element. Additionally, there is selection in the sorting which is illustrated by Figure 2. Two features are noteworthy. Though the samples from the one-eighth inch and the 2mm fractions are of the same size the former was collected from a much greater original sample. Thus, only a proportion of the pieces are recognised in the sorting and these are clearly biased toward the larger end of the size range.

Column samples: As these are completely sorted total recovery within a sample fraction is ensured. The main limitation on this procedure is the relatively small quantity of material that can be handled; this should be adequate for studies of the principal species but may fail to recover rarer items. The overall density of fish remains is sufficiently high that most of the column samples contain an adequate sample of fishbone although at Cnoc Coig this is complicated by the uneven distribution of material. The 2mm fraction of all the column samples is automatically sorted as part of the overall analysis and it has to be established whether this is a useful fraction for the fish remains. Following on from the one-eighth inch sampling it is adequate for establishing the list of species; limited tests with a 4mm sieve showed this to be too large a mesh to catch the smallest fishes. No new species have been identified in the 1mm fractions although the frequencies of the smaller fishes are increased.

Calculations of abundance and population structure have to be based upon complete assemblages of elements. The 2mm fraction failed to recover 100% of any element from the skeleton of the saithe; the proportion recovered varied depending upon the original size of the bone and the extent of fragmentation, and this accounts for some of the differences in the proportions of skeletal parts (Table 8). The element most widely used in the study is the otolith and while all complete specimens are caught by a 1mm mesh a proportion at the lower end of the size range are not retained in the 2mm fraction (Figure 23) . The relationship between the two fractions is not marked by a single cut-off point as might be expected. This is the result of the gentle nature of the sieving which does not rigorously separate material into size classes. However, the relationship is fairly constant between samples in terms of the proportion retained by the 2mm mesh for each size class. Where there is consistency between samples in their size range the relationship established in a few cases can be used to estimate the 1mm fraction of all assemblages;this will be most useful for Cnoc Coig where there is a large number of column samples.

Fishbone concentrations: These were sampled at Cnoc Coig as there were marked variations in the distribution of the fish remains in the site. This served two purposes:to ensure that there were a sufficient number of assemblages of some size and also because they were interesting in themselves as units of deposition. They were wet-sieved through meshes of 2 and 1mm which gives comparability with the column samples and the uses and limitations of such sizes are already established. The analysis of such samples is flexible and can be decided individually according to the interest of the sample;ranging from examination of a single element through to total sorting. The context and scale of such sampling means that they should not be regarded as equivalent to a comprehensive sampling of the site.

Most of the data used in this study is taken from the small-scale and detailed sampling procedures (column samples,fish concentrations). This was most appropriate given the nature of the material-the size and density/distribution of fish remains-and fitted in with the overall analysis of the sites. Alongside these recovery methods some use was made of more 'extensive' procedures (trench and one-eighth sieves) for specific items. The most important species could be studied from the assemblages contained in the small samples but these would not yield adequate specimens of less frequent species or size classes;the relative and absolute selectivity of the different procedures was also taken into consideration.

CHAPTER TWO
IDENTIFICATION

As identification is the first step in analysis the standard of work,in terms of the level and accuracy of determinations,is of crucial importance (Chaplin 1971,41). This subject has not been adequately considered in the field of archaeological fish remains because of the breadth of the subject;the skeleton of the fish is unlike that of other vertebrates and the number of species is enormous. These issues are discussed in the sections on taxonomy and skeletal anatomy but it must be stressed that these are only brief and simplified introductions,and reference must be made to more detailed references mentioned in the text. After this background the problems of archaeological identification are considered.

The basis of identification is comparison and there are two principal sources of material for osteological work; published descriptions and collections of comparative skeletons. Detailed accounts of skeletal anatomy come from two main sources:taxonomic studies of the relationships between species and faunal reconstruction in predation studies,palaeontology and archaeology. The former has produced some very detailed descriptions of small groups of species and wider comparisons of particular parts of the body while the second concentrates on key features for the identification of single elements. Much useful information can be gained from these studies but the coverage of both species and anatomical regions is far from complete. A further difficulty lies in the reliance there has been on relative characteristics with few absolute or quantified differences recognised and little attention to intra-specific variability.

These limitations help to emphasise the primary role of comparative skeletal collections in osteological studies. Vertebrates can be skeletonised by various techniques (Chaplin 1971,50-4) and these can be used for fishes. Points to bear in mind are the small and delicate nature of much fishbone,the preference for disarticulated elements,and the ease with which the bone and flesh can be separated (Hill 1975,217). The most common procedures are gentle boiling and the use of digestive enzymes (Casteel 1976,15-6). Before the fish is defleshed a sample of scales should be taken and mounted separately. In fisheries collections scales are sampled from 'typical' locations on the body (Tesch 1971,101-3) but for archaeological purposes it is important to collect them from across the whole body to cover the variation within the fish. It is useful to obtain the skeletons of several individuals per species to allow for variability and to provide a sample of the fish at different ages and sizes.

Classification of fish

Taxonomy attempts to describe the evolutionary relationship between species and therefore it provides a framework for the comparison of material (Budker 1971,20). There is no definitive system of classification;the results depend upon the criteria used and so many schemes have been proposed. At the same time there have been changes in nomenclature and this can cause confusion especially when early works are consulted. Fortunately many of the differences between classifications are ones of terminology and not substantive points (Lagler et al 1962,11;Norman & Greenwood 1963,331-3) and there are studies listing all the synonyms for species (Andriyashev 1964). The greatest problem in studying fishes is their diversity with some 20,000 recognised species-half the total of known vertebrates (Nelson 1976,1). The scope of this discussion is restricted to the c.400 fishes found in the waters of north-west Europe (Wheeler 1978b),of which some 200 occur regularly in British waters (Ryder 1969,379); this fauna is made up of fishes from several biogeographical complexes that converge in this region (Rass 1959;Wheeler 1978b,x). This fauna is not static and has changed through time,with climatic shifts (Lamb 1977,189,510),introduction of species,etc.;the history of the British freshwater fish fauna is discussed by Varley (1967,19-28) and Wheeler (1977a;1978c). The following account is a summary guide to the main groups of species among the three Classes of vertebrates commonly recognised as fish that occur in this area (Norman & Greenwood 1963,3). It follows the classification and terminology of Wheeler (1969),with subsequent amendments (1978b) which is based upon the system of Regan.

Marsipobranchii: These are very primitive fishes,with a cartilagenous skeleton and lacking jaws,fin rays and scales.

It includes the lampreys,elongate fish characterised by their tooth-bearing oral disc;their life histories are complex,but the smallest is a freshwater species while the other two (one reaching 600mm) spend part of their life in the sea but enter rivers to spawn(anadromous fishes).

Selachii: The second major group,also known as elasmobranchs, contains the sharks and rays. The skeleton is cartilagenous although there may be some calcification especially on the vertebral centra. They possess jaws which are armed with numerous rows of teeth,while the skin of many species is covered with dermal denticles which resemble the teeth in form and composition. Other characteristic features include the presence of several gill slits(in most species),internal fertilisation and their lack of bouyancy. All the species in these waters are exclusively marine. The two principal groups (Orders) of selachians are the:
i.Pleurotremata: the sharks and dogfishes. Over thirty species are found in these waters and they fall into three broad groups on behavioural features. A group of small sharks (up to 2m in length) that live close to the bottom (benthic or demersal fishes) in fairly shallow water;this includes the tope, dogfishes and smooth hounds. Sharks of similar size and behaviour but found in greater depths (over 100m). Thirdly, those species that are found nearer the surface (pelagic fish) and occur principally offshore;these include the larger sharks, like the basking and greenland sharks which reach over 6m.
ii.Hypotremata: the skates and rays. Most of the c.20 species belong to a single genus (Raja sp) and so display many common features. These fish differ.from the sharks in their adaptation to life on the seabed:flattened bodies,broad pectoral fins and the ventral position of the mouth and gill slits. The majority attain lengths of one to two metres,of which half consists of the tail. They can be divided into species of shallow waters,like the thornback ray,and those of greater depths eg.the skate.

Pisces: The true fishes,or teleosts,have a bony skeleton, although the degree of calcification varies markedly. There are several hundred species with a wide range in form and adaptations,and can be divided into two groups or Classes.The first contains only the sturgeons which are large anadromous fish with poorly ossified skeletons although the head and body are protected by large bony plates or scutes. The more advanced group includes a number of Orders of fishes,of which the most important numerically and commercially are:

i.Isopondyli: One of the two main orders of the less 'developed' fishes. Characterising skeletal features include cycloid scales, a mesocoracoid,single dorsal and anal fins with soft,jointed fin rays and both the premaxilla and maxilla form part of the gape. The most important groups of fishes in this Order are the Clupeoidea(herring-like fishes) and the Salmonoidea(salmon -like fishes). The former belong to a single family(Clupeidae) and are all small pelagic shoaling fishes(maximum size 600mm); apart from the herring their distribution is southerly and they are mostly marine although the shads are anadromous. The second group is more varied and includes several families (salmonids,charrs,whitefishes and grayling). These are medium to large fishes(0.5-1.25m) with complex life histories;some are freshwater and others anadromous,with species like the trout occurring in both forms. They can be identified from the small dorsal adipose fin and most have well-developed teeth in the mouth.

ii.Ostariophysi: The other major group of generalised fishes. Most species belong to the carp family(Cyprinidae),some of which are recent introductions to Britain. All are freshwater fishes and they dominate this fauna,particularly in the middle and lower parts of river systems. They spawn in spring-early summer and many congregate in large shoals at this time but at other times they are more widely dispersed and may become inactive in cold weather. Their distinguishing characteristics include cycloid scales,toothless jaws but with teeth on the pharyngeal plates,and modification of the first four vertebrae to form the Weberian apparatus. Species range in size between 100mm and 1m;hybridisation is known to occur between many of the cyprinids(Maitland 1972,11;Wheeler 1976).

iii.Apodes: The eels are immediately recognisable by their very elongate form and single continuous median fin. They have only minute scales or lack them altogether,and have no spines in their fins. Two species are common:the eel which reaches 1m in length and spends most of its life in freshwater but returns to the sea to spawn(catadromous),and the conger eel which is larger and exclusively marine.

iv.Anacanthini: Most of these fishes belong to the cod family (Gadidae) and are mostly marine fishes of the continental shelf in cooler waters;one species,the burbot,is found in freshwater. The depth of water occupied varies between species, from the shore down to several hundred metres,with the smaller fishes mostly found closer to the coast(maximum lengths range from 200mm to 2m). Their anatomy shares many features with the previous groups,including soft fin rays,cycloid scales and a well-developed swim bladder,but others resemble those of the following orders eg.in the exclusion of the maxilla from the gape.

v.Percomorphi: The largest Order containing several dozen families,distinguished by the ctenoid scales,the presence of some spiny fin rays,a ligamentary connection between the paired fins,and a gape containing only the premaxilla. A very diverse group including freshwater species(perch etc.),small shore fish(blennies,gobies),larger marine forms(wrasses,sea breams etc) and pelagic species(mackerel,tunny etc.) ranging in size from the smallest goby(50mm)through to the tunny which can reach over four metres.

vi.Scleroparei: The 'mail-cheeked'fishes differ from the percomorphs in the elongation of the second suborbital bone across the cheek to articulate with the preoperculum. Many members of this group have very distinctive forms of certain cranial elements or bony plates along the body. They are mostly marine and cover a range of habitats;members include the gurnards,bullheads and sticklebacks.

vii.Heterosomata: The flatfishes are immediately recognisable from their flattened body form. This has been achieved by the lateral compression of the body so that the fish is lying on its side;there is marked asymmetry in many species in some parts of the body such as jaws. Most species lie on their left side (plaice,halibut,soles etc.) but this is reversed in one group of the flatfishes(turbot etc). They are all sea fish although the flounder can tolerate freshwater,and are mostly small to medium sized(200-600mm)with the halibut reaching 2.5m.Many species live in shallow water near the shore but there are some deeper water ones.

Skeletal anatomy of fishes

This section lists the main elements of the fish skeleton and describes their position within the body. Most textbooks on ichthyology include a section on the skeleton (Günther 1880, 51-92;Lagler et al 1962,59-73) and there are some more detailed references. These include works on particular parts of the body eg.the skull(Gregory 1933),vertebral column(Ford 1937) and otoliths(Frost 1925-30) and accounts of individual species (Knorr 1974,1975a,b,c,1977). There are descriptions of groups of fishes including the salmonids(Norden 1961),eels(Tesch 1977), sticklebacks(Wootten 1976),mail-cheeked fishes(Allis 1910) and the gadoids(Mujib 1967;Svetovidov 1962;Williamson 1902). Some differences exist in the terminology of these authors(Mujib 1967,1317-20;Harrington 1955) but most elements have a single common name. The description here is based upon the skeleton of the bony fishes but reference is also made to elements of the selachians. One further point to note is the distinction made between cartilage and dermal bone;this is based upon the evolutionary origin of the ossification and has no bearing on their function or appearance.

The Head: This appears to be covered entirely by bone(Figure 3) but it is made up of a large number of individual elements; most of these are paired bones and,with the exception of the flatfishes,the fish skull is broadly symmetrical. This account follows the terminology of Mujib(1967) who lists the synonyms of other authors;the bones are grouped according to their position and relationships within the skull:
i.Neurocranium:(figure 4). A single unit of closely sutured bones that encase the brain and sense capsules,which can be divided into three parts. At the front of the skull there is the olfactory region which consists of the ethmoid bones and the vomer,a median bone that forms the roof of the mouth and is often tooth-bearing. The eye socket(orbital region) is formed by the frontal and sphenoid bones,including the parasphenoid which is attached to the vomer. The otic region, at the rear of the skull,protects the brain and is the most highly ossified part of the neurocranium;the elements in this region are the parietal and otic/occipital bones,with the basioccipital articulating with the vertebral column.

The otic sense organ somewhat resembles the inner ear of other groups of vertebrates;there is a labyrinth of three chambers and interconnecting canals,each of which contains a small calcareous body or otolith. The three otoliths,of which the sagitta is generally much larger than the other two,assist the hearing and balance of the fish. They vary tremendously in size and form and in the selachians and other primitive fishes their place is taken by crystals of calcium carbonate; the terminology of the otolith is given by Frizzel & Dante(1965, 692)(Figure 7a).

ii.Branchiocranium:(Figures 5,6a). This is made up of a series of interconnected 'arches' or groups of elements suspended from the neurocranium. At the anterior margin of the skull lie the jaws;the upper jaw consists of the maxilla and premaxilla,and in most species either both bones border the mouth or the maxilla is excluded from the gape. The tooth bearing element of the lower jaw is the dentary and behind this lies the angular(often termed articular)which articulates with the quadrate. Behind the jaws there is the palatoquadrate arch with the palatine,quadrate and the pterygoid bones. The rear elements of this are linked to the hyoid arch which consists of the hyomandibular,symplectic and hyal bones; ventrally,attached to the epi- and ceratohyal,are the branchiostegal rays which partially enclose the throat region. Much of the form of the head is provided by a series of flattish dermal bones covering these arches;these are the circumorbitals (lacrymal,suborbitals)which surround the eye ventrally,the preoperculum,and the opercular series(sub-,inter- and operculum) which protect the gill opening. The gills are supported on five branchial arches made up of rings of rod-like elements (-branchials),some of which have become modified in certain groups of fishes to bear teeth(pharyngeals).

The Body: The trunk also contains large numbers of bones but the majority of these belong to series of median elements so the actual number of bone types is fairly small. They can be divided between those associated with the backbone and those of the fins:

i.Vertebral column:(Figure 8). The basic structural components of a vertebra are the centrum and the processes attached to it(Figure 7c). Fish centra are distinguished by their amphicoelus form,with concave anterior and posterior articulating surfaces;the lateral surfaces are sculpted for the attachment of body muscles and the dorsal and ventral margins are channelled to carry nerves and blood vessels. Dorsally all vertebrae bear processes(neurapophyses)which form the neural arch and spine. Ventrally,a distinction can be made between vertebrae of the caudal or tail region with haemapophyses forming a haemal arch and spine analogous to the neural arrangement,and those of the anterior precaudal or trunk region which bear transverse processes(parapophyses). These two groups can then be subdivided;the first few precaudal vertebrae are modified to articulate with the basioccipital, and in the Cyprinidae to carry the Weberian apparatus,(thoracic vertebrae),and the tail elements(final vertebra is the urostyle) are variously adapted to support the caudal fin principally by expansion of the neural and haemal spines into plates (epural and hypural respectively). Other appendages to the centra include lateral processes(apophyses)and pre- and post-zygapophyses which serve to articulate the centra with each other;in some cases these processes are not fused to the centrum and so become detached when the flesh is removed. Finally there are separate elements associated with the vertebral column and these include the ribs and intermuscular bones(epineurals).

ii.Fins & fin supports:(Figure 8). Most fins contain internal bony supports or fin rays;most of these are 'soft rays' which are biserial and often branched or segmented,but in some fins of certain groups of fishes there are also 'spines' which are uniserial and more massive. The form of support within the body for the fins varies between the paired(pelvic,pectoral) and the median(dorsal,anal,caudal)fins.The main elements in the latter are the pterygiophores,rod-like bones that articulate with the rays and interdigitate with the vertebral spines;the rays of the caudal fin are carried on the expanded plates of the final vertebrae but the form of this varies between groups of fishes. The position of the pelvic fin is variable and this influences the form of the support but in general it consists of a single paired element(basipterygium). The pectoral fin is attached to the pectoral girdle,an arch of bones that articulate dorsally with the cranium(posttemporal, supra-,post- and cleithrum,coracoid,scapula,radials)(Figure 6b).

iii.Squamation: Most fishes possess some form of exoskeleton, with elements covering part or all of the body. The most common form among the Pisces is the 'bony ridge' scale, so-called from the pattern of concentric rings of ridges or circuli. There are two basic forms,cycloid and ctenoid scales, with the latter distinguished by the presence of tooth-like projections on the posterior margin. Other superficial elements include the scutes of fishes like the sturgeons and sticklebacks. The dermal denticles of the selachians consist of a base embedded in the skin and a projecting enamel point; they vary greatly in size and form but generally resemble the teeth,with some obvious exceptions like the dorsal fin spines of the Squalidae(spur-dog etc.).

Identification of archaeological material

Keys developed for the identification of fishes employ several types of information and skeletal features are only used when other lines of evidence prove inadequate. In such cases dentition is the most widely used characteristic(Günther 1880,124). There have been few attempts to produce atlases of fish bones for archaeologists(Olsen 1968;Desse & de Buit 1970-1)or in related disciplines;there are some accounts in predation studies(Stephens 1957)while palaeontological work is mainly concerned with extinct forms. Thus the basis of archaeological studies is comparison with modern skeletons. This raises problems as to the accuracy of such work as there is no standardisation of criteria between workers. Little has been published on this subject and as few absolute differences can be recognised between closely related species there is much scope for the development of quantifiable relative features. Until a greater understanding is reached between workers in this field it is essential to publish the criteria used in determinations. Illustrations provide the best check on the accuracy of identifications(Wheeler 1978a,74) but are not practicable in most reports(Lepiksaar & Heinrich 1977).

Two aspects of identification have to be considered:the level of taxonomic resolution that can be achieved with material and the level that is required for archaeological purposes. The first of these can be approached in two ways. Each bone can be studied in isolation independent of all other information. However,all material has a context(location,age,associated fauna)and this can be used to reduce the range of species that has to be considered. For instance,virtually all remains from sites in Britain will belong to the c.350 species found in these waters,and of these only some 50 species have any commercial importance(Wheeler 1978a,70).

All bone is potentially identifiable(Wheeler 1978a,70) but this must be qualified in various ways. The standard procedure in identification is to group bones according to element and then to sort them taxonomically(Leach & Davidson 1977,166). All complete bones and a proportion of broken pieces can be recognised to bone type but the level of taxonomic resolution depends upon the intrinsic properties of the bone(number of diagnostic features,variability within the type)and on the systematic position of the species(fishes with few closely related species can be more readily identified). Most complete bones and some fragments can be assigned to Orders but less can be identified to the level of genus or species. Before such work is undertaken however the second aspect of the subject should be considered. Identification is a costly procedure and so should be restricted to the work necessary to provide the results for analysis. It is rarely necessary to have a complete identification of all the bones in a sample(Wheeler 1978a,70);a species list can be compiled from the identification of a single element per species and numbers and sizes of fish from the most common bone type. In some instances a fuller analysis is justifiable but for most purposes adequate data can be obtained by concentrating on a small group of diagnostic and well-represented elements, together with more selective examination of some specific bones that may be indicative of particular fishes or which can be used for detailed studies of age etc.(Leach & Davidson 1977,166;Wheeler 1978a,70).

The Head: The most useful bones for identification are the paired elements of the jaws,including the dentary,premaxilla, maxilla,angular and quadrate(Leach & Davidson 1977,166; Poggenpoel nd.,2). These are generally well-preserved and bear many distinctive features especially in the teeth borne on the first three elements. Dentition varies greatly between species in the location,arrangement,number,size and form of teeth(Lowe-McConnell 1971,58)although there are also variations within species depending upon age and sex,and within the mouth of individuals. The teeth are not always firmly attached to the bones but some of the features can be recognised from the tooth sockets(alveolae);individual teeth of some fishes can be placed in families(pike,sea breams,wrasses etc)while this is the only form in which the teeth of the selachians occur. Many tooth-bearing bones(dentary,premaxilla,maxilla, vomer,palatine,pharyngeals)can be identified to the species level,and may even be used in classification studies as with the pharyngeals of the Cyprinidae(Wheeler 1969,172)and the premaxilla/dentary of the Sparidae(ibid. 347). A number of other branchiocranial elements are diagnostic for certain groups of fish eg.the preoperculum and operculum of the wrasses and some families of Scleroperei(Kennedy 1969,165-173). Most branchiocranial elements can be assigned to the Family,and often the genus or species using supporting evidence,although some have almost no diagnostic value(ceratobranchials,branchiostegal rays). The neurocranium is rarely found intact and the separate paired elements are usually fragmented;the value of these bones for identification is thus limited. However,the median elements,and in particular the vomer and parasphenoid,are species diagnostic for some groups of fishes. Otoliths are among the most useful of elements and can generally be identified to the species or genus level(Frost 1925-30;Chaine & Duvergier 1934;Chaine 1935-8;Schmidt 1968);unfortunately because of their composition they are rare in archaeological contexts(Wheeler 1978a,71).

The Body: Vertebrae are among the most common of archaeological fish remains(Ryder 1969,380)and although complete specimens possess many features by which they can be identified(Desse & de Buit 1970-1)most archaeological pieces consist of broken centra and can only be assigned to families(Wheeler 1977b, 404). The level of identification that can be achieved also depends upon access to an adequate comparative collection to take account of variability within species. Most of the other body elements have little diagnostic value,apart from the supports for the paired fins especially the cleithrum.Elements of the exoskeleton have considerable potential in identification studies although there are problems in the preservation and recovery of such remains(Pennington & Frost 1961,189). Denticles,along with the teeth,are the only common elements of the <u>Selachii</u> recovered and they are often diagnostic;many species of <u>Pisces</u> possess scales and these can generally be identified to the Order or even down to species level(Maitland 1972,73-7).The more specialised forms of certain species can usually be readily identified.

The identification of archaeological fish remains is still in its infancy and there is much scope for further development. At present only a few elements can be attributed with confidence to particular species,although many more are identifiable at some level with varying confidence and by using supporting evidence. More bones could be identified with the greater use of quantifiable features and more extensive comparative collections. As the first stage in analysis it is essential to consider the basis and limits of the identifications(Lawrence 1973,397);the criteria used must be explained.Secondly,it should be a goal to match the extent of identifications to the needs of the subsequent stages of analysis,in terms of the quantity of material and level of determination. Present standards of work are adequate for the more basic aspects of the subject,as a few key elements can provide a species list or numbers of individuals,but more detailed examinations will be necessary when intra-site patterning,taphonomy etc. are under investigation.

Identification: Oronsay

The list of species from the Oronsay sites must be divided into two groups,separating those found in the present series of excavations from those of the earlier work(Table 3). The list of the latter,including the other 'Obanian' sites for comparison,is taken from Lacaille(1954,240). The material from Grieve's excavations at CNG I was examined by Dr Traquair in Edinburgh(Grieve 1885,50)and in the absence of supporting evidence they must be treated with caution. The fish bones from Cnoc Sligeach were identified by Tate Regan of the British Museum(Natural History) and should therefore be reliable(Bishop 1913,105). However as none of this early material has been re-examined,the species recorded from them will not be used directly in this study and so can be discussed in less detail.

The material from the current series includes samples from the 1970 season at Cnoc Sligeach which were analysed by Alwyne Wheeler at the British Museum(Natural History)(Wheeler 1970;Mellars & Payne 1971),and he has given assistance with the subsequent work. The identifications are based upon the comparative collections established by myself and at the British Museum(Natural History). Unfortunately these do not provide a comprehensive coverage of the British fauna and so a small proportion of the material remains to be identified. This includes some elements belonging to selachians and a small number of vertebrae;the latter are all small and could belong either to species of shore fishes or could be from young individuals of larger fish. It is also possible that species of fish remain to be discovered in the unexcavated parts of the sites. However,such fishes would be infrequent and thus are unlikely to significantly alter the interpretations of the fauna which is heavily dominated by a single species,the saithe.

Species identified 1970-1979

Saithe.Pollachius virens(L):Reinsch(1976),Wheeler(1969,274-5;
1978b,159-60),Kennedy(1969,311-24).(Figure 9a).

This fish probably has more common names than any other species (Couch 1878,84;Smith & Hardy 1971,2);many of these are regional terms for the young fish,including cuddy,sillock,piltock etc. (Day 1880-4,294),while the adult fish are most widely known as saithe or coalfish(Macleod 1956). The saithe is a member of the cod family(Gadidae)and at one time was placed in the same genus(Gadus virens)but is now regarded as forming a separate genus(Pollachius sp)together with the lythe(Pollachius pollachius).

Like other gadoids the saithe is a cold-water fish of Arctic/sub-Arctic distribution(Kennedy 1969,313)although its range is more southerly than that of the cod. It is found on both sides of the North Atlantic,with a continuous distribution along the eastern side from Spitzbergen and the Barents Sea down to the Bay of Biscay(Figure 9b). It is most abundant in the central part of this range between southern Norway,the British Isles and Iceland. Saithe occur throughout British waters except the eastern Channel and southern North Sea,but are particularly common in the north and west:from the west of Ireland through the west coast of Scotland to the Shetlands and Orkneys(Cunningham 1896,293). It is the object of major commercial fisheries by several European countries(Reinsch 1976,118-24;Smith & Hardy 1971);this effort is concentrated on the subadult and adult fish that live in offshore waters although there were once considerable fisheries for the younger fish inshore(see Chapter 6).

The life cycle of the saithe can be divided into several distinct periods. Spawning is recorded throughout its range with the principal grounds off southern Iceland,the Faroes and southern Norway;the northern North Sea and the west of Scotland are also important areas(Reinsch 1976,63).It takes place in depths of 100-200m where there is high salinity and at temperatures between 5.5 and 10°C(Reinsch 1976,62). The spawning season is spread over some four months(January-April)but is more restricted in any locality,becoming later in the year from the southern to the northern part of the range. The eggs and larvae remain near the surface of the water and drift with the currents for some 3-4 months(Baranenkova 1959,4);many are carried toward the coast and begin to actively move toward the shore from May-June onwards. The littoral stage saithe are found very close to the shore in their first year,often in depths of only 1-2 metres. They swim in large shoals in sheltered waters,preferring weed-covered rocky ground,but are also found widely in sandy bays where there is extensive weed growth(Baranenkova 1959,9).

The fry stay close to the shore through the summer and autumn but then move away during the winter months;this movement is not well documented but they appear to move out to the shallow reefs and in British waters it has been suggested that the distance is greater on the Atlantic than on sheltered east-facing coasts(Kennedy 1969,315). The fish return to the coast in the spring where they range in shoals until the autumn,in greater depths than the first year fish. Once again they retire from the coast for the winter and reappear in the spring. These fish,now in their third year,range widely in the coastal waters and when they move away in the autumn the inshore phase is completed. After this the fish,still immature, progress into deeper water and within one or two years join the adult stocks. Saithe mature at around five years,and at this age are found mainly in midwater over depths of 200-250m (Reinsch 1968a,259).

The saithe is of typical gadoid form,with a streamlined body,three dorsal and two anal fins and a forked caudal fin, and a colouration that is dark dorsally(green-black) and light ventrally(silver-white)(Figure 9a). It can reach a length of 1.3m and a maximum weight of 14kg(Wheeler 1978b159). The saithe can be confused with the lythe but there are a number of small differences(Kennedy 1969,311). The key features are the position of the first anal fin,the shape of the lateral line,the presence of a barbel,the relative size of the jaws, and the number of gill rakers(Wheeler 1969,157-9).Other points that are mentioned include body shape,scale size and the fork in the tail. These comparisons are all based on adult fish and juveniles are more difficult to tell apart as many of the features are not fully developed.

The skeletons of the two species are quite similar (Svetovidov 1962,156-7,280-1)and a detailed comparison of the skulls showed that most differences were ones of degree and that a similar range of variation existed within each species (Williamson 1902). Thus,while most bones can be identified to the genus it is difficult to establish the species involved. The exceptions to this are:

i.dentition: small conical teeth are borne on the vomer,dentary and premaxilla. Those of the saithe are relatively smaller but occur in larger numbers in the jaws;the maximum number of tooth rows on the premaxilla of the saithe was 12 and only 6 for the lythe. The distinction is clearer on the dentary with only a single row of teeth together with some additional small teeth near the symphysis of the lythe against two clear rows on the dentary of the saithe(Smitt 1892-5,501,505).

ii.vertebrae: there are some differences in the form of the vertebrae (Desse & de Buit 1970-1)and in the total number of elements per fish. The range of the saithe(53-6)and that of the lythe(50-5)only partially overlap,and the difference is caused by variations in the number of precaudal vertebrae(Schmidt 1909,35).

iii.otoliths: these are fairly similar but there are differences in the sculpting of the outer surface and in the overall shape(Frost 1926,485-6). The otoliths of the saithe are relatively narrower,as demonstrated by length:breadth:thickness ratios of 1:0.32:0.16(saithe)and 1:0.40:0.20(lythe)(Schmidt 1968,15). These criteria may be open to question as they are based upon small samples of fish and only adult individuals have been compared. The possibility of changes in otolith form through life is clearly supported by an examination of those belonging to juvenile saithe which are more slender and pointed than the adult forms.

For archaeological material the most useful criteria are the number of tooth rows on the dentary and the shape of the otolith as they are clear quantifiable features. However, the reservations expressed above on the existing studies necessitated further examination of comparative material. The dentaries of a small number of lythe of various ages(5 fish) all possessed a single row of teeth while those of the saithe (25 fish),all from small individuals,appeared to have two rows although it was not always easy to establish this for the smallest fishes. The length-breadth ratios of a large sample of young saithe together with a smaller number of lythe are shown in Figure 10,with best-fit lines of the relationship for the two age groups of saithe represented calculated by least squares. This demonstrates that there is a wide range of values for each species with a considerable area of overlap between them. Thus the relationship cannot be used to identify the species of all individual otoliths but can be used to determine the relative frequency of the two species within a sample.

Dentaries were examined in a number of samples from each site and only a couple of specimens clearly showed a single row of teeth out of a couple of hundred pieces;thus the bulk of the dentaries appeared to belong to the saithe. The length-breadth ratio of the otolith does not provide such a diagnostic feature but larger samples are available for analysis. Several samples from CNG II and the Priory have been plotted and all show a distribution that agrees with that obtained for the modern saithe. In the samples for the Priory(Figure 11)only half a dozen values lie outside this range and can be ascribed to lythe with some confidence,although further values may also belong to this species;the important point is that the bulk of values are coincident with the spread obtained for the saithe. The conclusion drawn from this study is that almost all the fish identifed from the sites and assigned to Pollachius sp. belong to the saithe(P.virens). To simplify the discussion all this material will be described as saithe throughout this work,but the presence of some lythe should be noted and will be mentioned where it is likely to affect the interpretation.

Lythe.Pollachius pollachius(L):Reinsch(1976),Wheeler(1969, 272-3;1978b,158-9),Kennedy(1969,299-311).

This species is the poor relation of the genus,with few names -pollack,lythe(Scotland)-,little commercial importance and no detailed studies of its natural history. Its distribution in the eastern Atlantic is similar to that of the saithe,from Iceland and north Norway to the west of Iberia,but with a more southerly bias;in British waters it is common to the south and west but less so to the north.

Within its range spawning has been recorded in waters from the North Sea to the Bay of Biscay and occurs along all of the Atlantic coast of Britain. It takes place between January and May(maximum intensity in March) in depths of 100m and temperatures of 8-10°C. The early life of the lythe,for the first two or three years,closely resembles that of the saithe(Meek 1916,215).The eggs and larvae drift inshore and the fry arrive at the coast from April-May onwards. They remain very close to the shore throughout the summer and autumn and grow rapidly reaching 150mm by the end of the growing season;they prefer rocky ground but are found over all types of bottom and are less gregarious than the saithe at this stage(Lie 1961,5). Their behaviour over winter is not fully documented but they appear to move away from the shore at some point(Kennedy 1969,308).From the following spring they are found in the vicinity of the shallower reefs(up to 9m) but range widely in schools. During their second winter they retire to deeper waters,having reached 260-310mm in length,but return inshore in the spring. After their third year they assume the adult lifestyle and are found in depths of 40-100m.

The adult lythe,unlike the saithe,is an inshore fish and is found within the 200m line over rocks and rough ground. It is mainly a solitary fish although numbers may be found in the vicinity of reefs. Lythe may grow to 1.3m and 11kg, but more usually to 0.5m and 4kg,with the larger fish found further offshore although they may come near the coast in summer. Its diet consists principally of fish and it is found mainly in midwater or near the bottom.(The identification of this species in the Oronsay sites was considered above.)

Ling.Molva sp.:Wheeler(1969,284-7;1978b,167),Kennedy(1969,325 -328).

The most common species of the genus is the ling(Molva molva) but two other species also occur in European waters. The ling is a common fish in the seas off north-west Europe from Norway and Iceland to the Bay of Biscay,with major fisheries in the Norwegian Sea,off Iceland and the west of Scotland. It is found throughout British waters wherever sufficient depths occur particularly to the north and west. Mainly a deepwater fish in depths of 300-400m although some are found shallower and occasionally come close inshore. Spawning takes place from March to July at 200m mostly to the north of the British Isles. The young are bottom-living fish found in shallow depths (15-47m)but from the third year,at lengths of over 300mm,they move to deeper water. The maximum size of the ling is 2m and 35kg,with fish up to 1-1.5m occurring in inshore waters.

The ling is one of the largest members of the cod family with a long narrow body and two dorsal and a single anal fin. The skeleton is of gadoid type but most elements can be identified to the genus;no attempt appears to have been made to distinguish between species(Wheeler 1977b). Ling is represented in the Oronsay sites by several vertebrae which are easily recognised by the form of the lateral sculpting and the deep hollows on the haemal surface of the centra(Desse & de Buit 1970). Wheeler(1970) tentatively identified a broken portion of an otolith as ling;these are of gadoid form but more flattened(Schmidt 1968,17).

Hake.Merluccius merluccius(L): Wheeler(1969,281-2;1978b,171-2) Kennedy(1969,332-6),Hickling(1935).

The hake is the only member of this family of cod-like fishes that occurs in European waters;its distribution extends from Norway to the Mediterranean and it is found all around Britain except in the south-east. It occurs mainly in depths of 165-550m but enters shallower water during the summer;before stocks were subject to overfishing it was probably much more common in inshore waters(Wheeler 1978a,74). The spawning season extends through the spring and summer with the principal grounds lying off the south and west of the British Isles. It is an important commercial species with a maximum size of 1.8m but has been affected seriously by overfishing.

The hake resembles the ling in general form with its elongated body and fin arrangement. The skeleton is of gadoid type but most elements are diagnostic The species has been identified in the Oronsay material by the presence of a number of precaudal vertebral centra with the characteristic arrangement of channels on the haemal surface and other features (Desse & de Buit 1970).

Eel.Anguilla anguilla(L):Tesch(1977),Wheeler(1969,227-8;1978b, 62),Kennedy(1969,342-50).

The eel has a very interesting life history;starting from the breeding grounds in the central Atlantic the larvae take two to three years to reach the coasts of Europe at which point they undergo metamorphosis into their characteristic form. They are found through most of Europe,and in all parts of Britain;most enter estuaries and ascend into freshwater but some remain near the coast especially along rocky shores. They spend at least seven years in freshwater before returning to the sea for the migration to the spawning grounds;at this time they have reached lengths of 400-600mm with females of 1m recorded. It is a valuable food fish and is taken at most stages of its freshwater life.

Anatomically the eels are distinctive with their long thin body,arrangement of fins etc.. Their skeletal elements are easily recognised and most bones can be identified as to the two species of eel found in European waters(Anguilla and Conger). The Oronsay material consists of a large number of small vertebrae which can be attributed to the eel on a number of grounds(Ford 1937;Tesch 1977,6-7).

Conger.Conger conger(L): Wheeler(1969,229-30;1978b63), Kennedy(1969,350-6).

The conger is a large marine eel that can reach a size of 1.83m,and occasionally 2.74m,and weights of 65kg. From the spawning grounds in the tropical Atlantic the larvae spread north and are thus most common to the south and west of Britain. Young congers are found close to the shore,in deep shore pools and lower down among the rocks;larger ones of up to 1.22m are also found inshore but are more common on rough ground offshore.

The skeleton of the conger is distinctive;some elements may be confused with the eel but any 'eel' bones of above a certain size must belong to the conger. It is represented in the Oronsay fauna by vertebrae and a number of cranial elements(dentary,premaxilla,vomerine,articular etc.).

Ballan wrasse.Labrus bergylta L: Wheeler(1969,368-9;1978b, 276-8),Kennedy(1969,160-5).

The ballan wrasse is the largest and one of the most common wrasses in British waters especially on southern and western coasts. It is an inshore fish largely confined to rocky ground and lays its eggs in 'nests' built in rock crevices in June-July. The young fish(up to 130mm) are found between and just below the tidemarks while larger individuals keep to somewhat deeper water(2-20m)except for spawning. Ballan wrasse occur singly or in small schools and there may be an offshore movement in winter as the fish is very susceptible to cold. The maximum recorded size is 600mm and 3.5kg,with 300-400mm more common. The other species of wrasse are also mainly inshore fish of rocky ground,with similar diets of molluscs and crustacea.

The wrasses(Labridae) are most easily distinguished by their 'massive' dentition and in particular by their pharyngeal plates(Wheeler 1969,371). The various species can be separated by the form and dentition of the jaws and also on other cranial elements(preoperculum etc.). There are various bones of the wrasses in the Oronsay samples including vertebrae,jaws,pharyngeals and cleithra;only one species has been identified from these-the ballan wrasse-on the basis of the dentition and large size of some of the pieces;however it is possible that other species are also present.

Red sea-bream.Pagellus bogaraveo(Brunnich): Wheeler(1969,354-5;1978b,258-60),Kennedy(1969,100-5).

The sea breams(Sparidae) are a large and systematically complex family but only two species are at all common in British waters. The red sea bream is fairly common in the south and west and appears regularly on other coasts;most of the fish in northern seas are summer migrants and are found here mainly between June and September. It is a schooling species,with the young fish found over rough ground in inshore waters while the larger ones(over 130mm) are generally found further offshore. The maximum size for the species is 510mm and 4,5kg,with 350mm the more usual size.

The sea breams are fairly distinctive skeletally as a family;species can be determined from several bones and in particular the jaws(shape of the bone and form of dentition).

Sparid fishes are represented in the Oronsay fauna by vertebrae, posttemporals and jaw bones, and the identification of the red sea bream is based upon the presence of a number of otoliths; these can be identified at the species level(Chaine 1937,131).

Shanny. Lipophrys pholis: Wheeler(1969,436;1978b,286-8).
The shanny is found on all British coasts and is one of the most common shore fishes. It prefers rocky shores and is most abundant below the low-tide level;its range is from inter-tidal rock-pools down to 30m. In winter there appears to be an offshore movement by most fish. The shanny is small with a maximum length of 160mm.

The bones identified in the Oronsay samples include the jaw bones and vertebrae. It is possible that at least some of these belong to other species of blenny for which comparative skeletons were not available. However, the present day frequency of the shanny and the close matching of the archaeological material with the bones of a shanny obtained on Colonsay gives confidence in the interpretation.

Viviparous blenny. Zoarces viviparus(L): Wheeler(1969,447-8; 1978b,174).
The viviparous blenny is the only species of the Eelpouts (Zoarcidae) to occur around the British Isles;it is restricted to North Sea and Scottish coasts. It is fairly common in shallow waters, down to 40m, on rocky weed-covered shores. They grow to 500mm, generally reaching 330mm. Its most interesting feature is that it gives birth to live young which is not common among fishes.

The identification of the viviparous blenny in the Oronsay fauna is based only upon vertebrae. This is not the most diagnostic of elements but the identification followed detailed checks of other groups of fish. Comparative material for other parts of the skeleton was not available and so it has not been possible to confirm the presence of the species on other grounds.

Sea scorpion. Taurulus bubalis(Euphrasen): Wheeler(1969,496; 1978b,220-2).
The sea scorpion is a small shore fish with a maximum length of 175mm. It is found on all British coasts, on the shore and sublittorally(down to 30m) but only where there are rocks and weed cover.

It has been identified in the Oronsay samples by its distinctive four-spined preoperculum;no other elements have been recognised as comparative material was not available.

Salmonid.Salmo sp.: Mills(1971),Wheeler(1969,150-4;1978b,78-80),Kennedy(1969,357-87).

The genus Salmo contains two species,the salmon(S.salar) and the trout(S.trutta),which share many biological features and are similar in appearance. The skeletons of the two fishes are also difficult to tell apart and the difficulty is made greater by the poor preservation of salmonid bones;a few elements may be diagnostic(eg.ceratohyal) and it should be possible to recognise the freshwater and marine phases of life by studies of the growth rings on elements(see Chapter 5). The Oronsay material consists of a few vertebral centra and these cannot be identified to the species level;on the basis of their small size it can be inferred that they come from the initial freshwater stage of either species.

The salmon is an anadromous species,spawning in freshwater but passing much of its life in the sea;it is found throughout the British Isles,both in the rivers and in the surrounding seas. The eggs are laid in autumn and hatch the following spring;the young salmon spend a year or more in the parent stream before moving to the sea at a length of 100-200mm. In the sea they grow rapidly and then return to spawn after 1-4 years;most fish die at this stage but some get back to the sea and make further spawning migrations. The size of the fish vary greatly according to the length of time in the sea but salmon can reach 1.5m and 36kg.

The sea trout has a similar life history but is usually smaller. The brown trout is a non-migratory form although it undertakes movements within freshwater systems;it is very widespread and is found in a range of conditions which helps to account for the variability in form,colour,growth,and size(reaching only 230mm in small streams but up to 1m in large rivers).

Flatfish(Heterosomata).

Only a few of the bones of the flatfishes are species diagnostic particularly the jaw bones;others can be attributed to family or groups of fish based upon size. The couple of elements found in the Oronsay samples-vertebrae,first anal pterygiophore-could not be used to determine the species involved other than that it is one of the small flatfishes.

The bones probably come from the flounder(Platichthys flesus) which is a common inshore fish found from the tide-line down to 55m on sand and muddy bottoms. Spawning takes place in spring in the deeper part of its range and then the fish move inshore in early summer. It is the only species of flatfish to enter freshwater and it is common in estuaries and other ares of low salinity. The flounder is one of the smaller species,reaching 510mm and 3kg. The bones could also belong to several other species of flatfish,eg.the plaice, which are similar in size and also found in inshore waters over soft bottoms.

Thornback ray.Raja clavata L: Wheeler(1969,100-1;1978b,36-8), Kennedy(1969,452-4).

The thornback is the most common species of ray in British inshore waters,and is found mostly between 10 and 60m. The adult fish move into shallow water in the spring to lay their eggs and remain through the summer months. Like other rays it lives on the bottom on soft grounds and lives off a diet of crustaceans. The maximum size reached by the species is 0.85m and a weight of 17.25kg.

The thornback is immediately recognisable by the presence of some denticles with enlarged bases(bucklers) along the back and tail of mature fish. The remaining denticles,of varying form,and the teeth(pointed in the male and flat in the female) resemble those of other species of rays;the cartilagenous skeleton will not be preserved in archaeological contexts except for the vertebrae which may be partially calcified-the pattern of calcification may be a key to the species(Desse & de Buit 1971) but otherwise the vertebral centra are not diagnostic. A range of teeth,denticles and vertebrae have been recovered from the Oronsay sites;there are a few bucklers in the assemblage and all the remaining elements could belong to the thornback,but the presence of other species of ray is a possibility.

Dogfish.Scyliorhinus canicula(L): Wheeler(1969,45-6;1978b, 13-4),Kennedy(1969,437-9).

The dogfish is one of the smallest sharks,reaching 0.6-0.7m with a maximum recorded size of 1m and 1.72kg. It is very common on all British coasts,often occurring in large single-sex shoals. It lives near the bottom over soft ground in a wide range of depths(3-110m),with the young found closest to the shore. The eggs are laid mainly below the tide-level from November to July,with the fish moving away from the coast in late summer.

The problems of preservation and the absence of a comprehensive comparative reference collection make the identification of shark remains difficult. The presence of the dogfish in the Oronsay fauna has been based upon the recognition ofthe small conical teeth;various small vertebrae may also belong to this species.

Monkfish.Squatina squatina(L): Wheeler(1969,75;1978b,31),
Kennedy(1969,446-7).

The monkfish is another species of shark ;it is found on all British coasts but is more common to the south and west and appears in greater numbers in summer as the result of a northward and shoreward migration at this time. It lives on soft bottoms in depths of 5-90m,and can reach a size of 1.83m 32.6kg.

As with the other sharks there are few diagnostic elements that survive archaeologically;the identification of the monkfish was based upon its small pointed teeth,and a number of small denticles may also come from this species.

Early Identifications

Many of the species recovered during the present excavations were identified in the early work,including the saithe, conger,ballan wrasse,red sea bream,thornback and monkfish. However,a further five species are also listed and as these have not been verified they will only be considered briefly.

Spurdog.Squalus acanthias(L): Wheeler(1969,67-8;1978b,24-5),
Kennedy(1969,441-4).

The spurdog is a very common small shark throughout the North Atlantic,attaining sizes of 1m and 7kg(maximum 1.22m and 9kg). It is found in depths ranging from less than 11m to 200m, mainly near to the seabed over soft ground. The species is highly mobile and occurs in large schools;the only clear annual movement undertaken is into shallow waters for the birth of the young from August to January.

The most distinctive feature of the spurdog is the presence of a spine in front of the two dorsal fins. This diagnostic element is found in archaeological contexts and both the early excavations refer to the spines of this fish.

Tope.Galeorhinus galeus(L): Wheeler(1969,60;1978b,17-8), Kennedy(1969,431-3).

The tope is a shallow water shark found on all British coasts, with young fish close inshore and larger individuals down to 200m. It is a bottom-living fish,occurring singly or in small shoals on soft ground. There is an offshore migration during the winter,so they are more commonly encountered in the summer months. They are fairly small,growing to 1.2m and occasionally 1.67m and 33.9kg.

The teeth of the tope are quite distinctive,with a triangular shape,sharply pointed and fine serrations on the cutting surfaces. The species was identified at Cnoc Sligeach but the criteria used are not recorded.

Skate.Raja batis L: Wheeler(1969,89-90;1978b,42-4),Kennedy (1969,458-60).

The skate is a relatively common species,found in depths of 30-600m with young fish mainly in the shallower part of the range and adults mostly between 90 and 220m;there is probably an inshore migration during the summer. The skate occurs on all British coasts over a range of seabed conditions.It is the largest and heaviest of the rays,with females up to 2.85m and 113kg recorded.

The identification of this species at CNG I is based upon 'tubercles from the back'(Grieve 1923,51) ie. denticles,and while it is conceivable that these have been identified at the species level it is much more likely that the attribution is only to the genus(Raja sp).

Black sea-bream.Spondyliosoma cantharus(L): Wheeler(1969,357-8; 1978b,258),Kennedy(1969,108-10).

The black sea bream is a relatively common summer migrant in British waters,although its biology is not well known. It prefers rocks and wrecks,and in the eastern Channel it makes an inshore movement in April-May. They reach 350mm and occasionally 510mm and 3kg.

As with the red sea bream the most distinctive feature is the dentition. Both species are listed at Cnoc Sligeach so that although the criteria of identification are not given it seems likely that two species of sea bream are represented.

Thin-lipped grey mullet. Liza ramada(Risso):Wheeler(1969,465-6; 1978b,274),Kennedy(1969,185-6).

The thin-lipped grey mullet is uncommon in British waters except as a summer visitor to southern coasts. They are found in shoals close to the shore or in estuaries;they reach 600mm and 2.5kg. More common is the larger thick-lipped grey mullet which is found on all British coasts especially in sandy bays and estuaries.

The identification of the three species of grey mullet that occur in British waters is not easy and so the particular one listed here may be dubious. The identification of the fish at CNG I may also be open to question;the only elements mentioned are scales and it is quite possible that these have been confused with other species.

A high proportion of the Oronsay material has been identified,although a few problems remain over the unidentified pieces and the level of resolution of some elements. The species list contains 16 fishes with an additional five species in the early excavations. The problem of using these latter fish in the study without corroborative evidence can be illustrated by the separate examination of some remains from Cnoc Sligeach by Newton(Bishop 1913,107-8);the identification of young haddock otoliths and perch? scales seem most unlikely and the material has probably been confused with otoliths of the saithe and scales from either wrasse or sea bream.

Confidence in the species list for the Oronsay sites is increased by the measure of agreement with the contemporary fauna of Hebridean waters(McNeill 1910;Darling 1947;Harvie-Brown & Buckley 1892). The descriptions of the species are only intended as brief introductions to their biology and relevant points will be considered in more detail as appropriate. Even so,it should be apparent that a range of fish species,in terms of size,habitat etc. are present in the sites and that interpretations of fishing methods,season of capture, food values and patterns of consumption must take account of this variability.

CHAPTER THREE
QUANTIFICATION

Quantification is taken here to cover two separate aspects of faunal analysis:estimation of the quantities of animals and the reconstruction of their size. They are used in combination to calculate the food values of assemblages but also have other applications which are considered below. There are several methodologies available for investigating each subject and their different levels of precision,complexity and data requirements are also considered;detailed descriptions of the procedures are not included as they are given elsewhere.

Measures of abundance in faunal studies

This is one of the most controversial areas of faunal analysis;for a recent account of the developments in the arguments see Grayson(1979). Three main techniques for measuring abundance have been proposed(Chaplin 1971,63-75) and there is no general agreement on which is the most appropriate;the choice depends upon individual preferences,and the particular aims of the study. The procedures vary in the type of data they require,the sophistication of the analysis and the form of results and so should be matched to the samples available and the values being sought;the latter includes the form of data needed(numbers of individuals,volumes,meat weights etc.) and how it is expressed(absolute quantities or relative order or proportions).

Weight method: This is a very simple procedure which takes the weight of bone as the unit of quantity. It has been used to compare the amount of animal bone to other classes of material in such sites as shell middens and to calculate the total quantity of meat from assemblages. Its usefulness rests on the assumption that bone weight is a relevant parameter because it is directly related to meat values;a ratio of 6:100 has been used(Cook & Treganza 1947,138). However there are many problems with the technique and it is only suitable for very gross calculations. For instance there is no allowance for variations in the bone weight:flesh weight ratio either within species or between taxa;although Cook & Treganza did modify their ratio to 5:100 where there was a high volume of fishbone(1950,245).

Number of identified specimens(NISP) or fragments method:This is based upon counts of the number of identifiable pieces of bone in different taxa. Its main limitation is that it can only be used to compare the relative importance of taxa, because the fragment count is not directly related to any other variable such as number of animals or meat weights. There are also practical problems in the operation of the method(Payne 1972b,68-9)and these are discussed by Grayson who concludes that most of them can be resolved either by detailed studies of taphonomy(differential preservation, butchery and breakage patterns) or the application of statistical and collection procedures to ensure comparability of material(against biases in collection,numbers of pieces and whole skeletons);the remaining problem,that the results are not suitable for statistical treatment as such tests assume that the data are independent,cannot be resolved at present as there is no way of determining the extent to which fragments come from the same individual(1979,201-2).

Minimum number of individuals(MNI or MIND): The calculation of the minimum number of animals necessary to account for all the remains in an assemblage is the most intensive of the measures of abundance;the basic procedure is relatively straightforward but differing degrees of sophistication are possible. There are two main sources of difficulty with the method. Firstly,the relationship between the MNI estimate and the actual number of individuals is unknown;MNI figures can vary depending upon how they are calculated with,at one extreme, the possibility that each piece belongs to a separate animal in which case the MNI count is equal to the NISP.

The other problems are related to sample sizes. A certain number of bones are required to provide a representative sample for each taxon;Payne gives Gejvall's estimate of 300 pieces(1972b,69). A second aspect of this question depends upon the aggregates in which samples are analysed;a large number of small units will produce a higher number of individuals than if these units are combined,unless all the remains (both elements and taxa) are evenly distributed through the units.

Thus the MNI count is not to be taken as a record of the actual numbers of animals in a sample but standardised results can be achieved by careful examination of samples and choice of sampling units. The principal advantage of this technique is that it is the only method for obtaining some form of count of the absolute number of individuals,which is essential for investigating additional questions about the fauna. However,as itrequires more data than the other procedures which are equally capable of representing the relative proportions of the taxa,it need not be used unless this consideration is involved.

Fish remains and measures of abundance

The subject has not attracted much interest in studies of fish remains and where the work is undertaken as part of a wider faunal study the same method is usually adopted.Three measures of abundance are in use,and often more than one is presented in a report. The number of identifiable specimens is sometimes used to represent the frequency of fish relative to other resources and of different taxa(Ekman 1974). It has been proposed that the relative importance of species can be obtained in some circumstances from the proportion of sampling units in which each taxon occurs(Wilkinson 1979). The most widespread procedure is a calculation of the minimum number of individuals but there are few instances where the methodology has been elaborated(Parmalee et al 1972;Leach & Davidson 1977,167). Akazawa employed two sets of calculations;from counts of the jaw bones he produced an estimated minimum number of individuals(est Min NI) and a maximum number of individuals(est Max NI) which is equivalent to NISP(1980,328).

Measures of the abundance of fish remains are faced with all the problems encountered in general faunal studies with two particular sources of difficulty. Firstly,there is the frequency of elements in the skeleton;most bones occur singly or in pairs(with'expected frequencies'therefore of 1 or 2) but a few are present in larger numbers. These include ribs etc., which are not used in any calculations as they are not diagnostic,but also vertebrae and scales which can be identified to species and may be abundant in assemblages. The problem with vertebrae can be partially resolved by recognising individual elements(basioccipital,urostyle etc) or small groups of them. However,incomplete vertebrae are often not suitable for identification at this level and for any species there is a range in the total number of vertebrae per fish and in the numbers of elements within parts of the backbone. For scales a total count is not practicable, although some attempts have been made(Casteel 1976,62);his alternative is to reconstruct the size of individuals represented by the scales and the difficulties in this are discussed below.

The second problem area arises because all elements are not identifiable at the same taxonomic level. Unfortunately, only a small proportion of bones are diagnostic to species level and where these are not the most abundant of elements it follows that a higher number of individuals can be obtained at other taxonomic levels(genus,family etc.)(Poggenpoel nd.,3). One system for dealing with this is to calculate the number of individuals for each element and use these to produce counts for each taxonomic level;by subtracting the number of individuals in each species from the total for the genus this gives the number of individuals only identified to that genus and so on(Parmalee et al 1972,11-13).

A comparison of the various methods of calculating abundance reveals points in favour of each. Ranking based upon the number of units is obviously very crude and limited in its uses,but it is easily calculated as a rough index. The count of identified specimens tends to give an impression of spurious accuracy as they appear to be absolute values;this takes no account of the distortions introduced by variations in the recovery,preservation,identification and anatomical frequencies of different species. The data is easily collected and so the technique is useful,but only for estimating the relative importance of taxa. The minimum number of individuals is probably the most useful index,but it is more complicated to calculate and has greater data requirements than the other procedures. Therefore,it is not recommended if the only aim is the relative frequency of species;if an approximation of the actual numbers of fish is needed,to calculate meat weights, capture units etc.,then this is the only appropriate measure and at the same time it will give information on the proportions of taxa.

Reconstructing the sizes of individuals

The principle involved in this work is that if a relationship can be demonstrated between the size of individuals and the size of their bones,then the size of animals can be reconstructed from bone measurements. Although measurement is one of the main aspects of faunal studies(Dreisch 1974) the results have been used principally in studying sex structure,breeds etc. and less for establishing animal sizes in their own right(Chaplin 1972,91-2). Because of this little attention has been given to the methodology of size reconstruction and various techniques,including direct proportionality and regression analysis have been applied. One of the applications of size reconstruction is in the calculation of the meat yield of a fauna. This has generally been calculated from the number of individuals times an average weight for the species; this may be adequate where the animal rapidly attains its ultimate size,but if individuals of varying size occur in the assemblage this should be allowed for,either by reconstructing individual sizes or at least by using average values for size/age groups(Smith 1975,100).

The reconstruction of size has been one of the main fields of interest in the study of fish remains and the techniques have been considered at length by Casteel(1976,93-123). Part of the reason for this interest derives from the work that has been done in this field in fisheries research where the estimation of size has two main functions. The first of these closely resembles its application in archaeology,in the study of prey fishes found in the stomachs and faeces of predators;the same criteria apply in that the element must be commonly preserved and identifiable at the genus or species level(Popova 1967,363). The second procedure is more elaborate but employs the same principle to reconstruct the size of fish through their life. This 'back calculation' of growth uses the annuli,or growth marks,laid down at the end of each year(see Chapter 5) and the known relationship between bone size and the size of the fish(Chugunova 1963,68-109;Tesch 1971,115-20). The advantages of this technique are that the growth pattern of single fish can be studied and that the growth rate of populations established from a smaller sample of fish.

The earliest studies assumed that the relationship between bone size and fish size was linear and directly proportional but it soon became apparent that other forms existed including: linear but not directly proportional($y=a+bx$);curvilinear,which can be transformed logarithmically into a straight line($y=ax^b$ into $\log y = \log a + b \log x$);and S-shaped with the various stages of life described by different equations(Nikolsky 1963,197-200). The values of the constant(a) and the regression coefficient(b) can be obtained in various ways,from a line fitted by eye to regression analysis by least squares. The different forms of relationship are not the only problem in attempting to back-calculate growth and this is one of the more complex areas of fisheries science. Scales are the most widely used element(Kipling 1962) but other bones that have clear annuli including otoliths and operculae are also suitable(Frost & Kipling 1959).

In the majority of fisheries work length is taken as the size parameter. There are various measures of length(Ricker 1979,678-9) of which three are commonly adopted:standard length (SL),fork length(FL) and total length(TL)(Figure 8). The most common ways of recording the weight of fishes are total weight and gutted weight;the first is easier to record but is subject to greater variability as it includes the contents of the stomach etc.,while the latter excludes potentially important data on the state of the gonads,fat content etc..The relationship between fish weight and length can be expressed in the form $w=al^b$ with the exponent(b) approximating to 3(Tesch 1971, 121-4). One application of this relationship is in calculations of the Condition factor(K) which is designed to record the'well-being' of fishes in terms of their fat content($K=w/l^b$)(Weatherley & Rodgers 1978,63-4).

Size reconstruction of archaeological fish

With this background the reconstruction of the size of archaeological fishes is not a difficult subject(Wheeler 1978a, 72). Such calculations can be made using various procedures and used for a number of purposes:

i.calculation of meat values; as fish growth is indeterminate and continues through life(see Chapter 5) the adoption of a standard weight for a species cannot be justified.

ii.an indicator of age; to infer the stage of life and hence behaviour patterns of fish,to reconstruct the age structure of populations(Shawcross 1975,57-9),and as a check on other ageing techniques(Ekman 1973,57-8).

iii.to study fish growth; back-calculation of growth(Casteel 1976,138-41) raises problems as there is no independent value for fish size,but the technique can be used to consider the average and maximum sizes of earlier populations(Brinkhuizen 1978;Ekman 1974,211).

iv.to suggest methods of capture; as most fishing methods are size selective(see Chapter 6) size bias in catches may indicate the method of capture.

v.calculation of MNI; size can be used as one criterion for comparisons(Casteel 1976,62-4) and conversion to fish size is the only way to compare different elements.

vi.seasonality studies; by size-related behaviour or comparison of sizes with the rate of growth(see Chapter 5).

Most of these aims employ fish length as the size variable and only the estimation of meat values relies upon fish weight; the latter can be calculated directly from the bone size or at a second stage from fish length. Bone size has to be expressed by a measure of length,unlike in fisheries work where weight is sometimes employed,because the weight of archaeological specimens is subject to many influences. The measurements adopted must satisfy several conditions and this has not been followed in some studies(Casteel 1976;Morales & Rosenlund 1979); the elements must be capable of identification,preferably to the species level;the measured portion of the element should occur regularly in assemblages and not be subject to a high level of breakages or poor preservation;measures must be easily replicable and margins of error can be established for this (Ekman 1973,14);and most important the measurement needs to be strongly correlated with some parameter of fish size. The bones used most frequently in such studies have been those of the jaws which meet the criteria of preservation and diagnostic value(Akazawa & Watanabe 1969,193);a range of other elements are also suitable(Wheeler 1978a,70)including otoliths(Witt 1960) and pharyngeals(Wheeler 1979,147).

Several methods of calculating sizes of fish are in use (Casteel 1976). The simplest is direct comparison with the bones of fish of known size but this requires large comparative collections and individual cross-checking. Two procedures employ a calculation of the relatioship between bone size and the size of fish. One assumes a simple linear relationship that can be expressed in a single ratio;this is adequate when the relationship is of this form but otherwise it introduces errors especially when applied to fish from outside the range for which it was calculated(Casteel 1977,131). The alternative is to fit a best-fit line empirically to the data,either drawn by eye(Wheeler & Jones 1976,213-5) or fitted more exactly by regression analysis. Such calculations do not make assumptions about the form of the relationship and curvilinear as well as linear forms can be dealt with(Casteel 1976,95-102). Regression analysis is the most accurate of the available techniques and is now widely used,but its precision does raise the question as to whether it is unnecessarily exact for many of the purposes to which the results are put.

Quantification: Oronsay

In the absence of a widely accepted procedure for quantifying fish remains the methodology adopted here was devised to meet the aims of the analysis and handle the material available. The main quantities being sought included:the number of species of fish(see Chapter 2);the relative importance of different species;absolute numbers of fish;the range and distribution of fish size;and potential meat yields(see Chapter 4). As some of the results were to be compared with other classes of material it was necessary to adopt fairly standardised techniques,particularly for calculating the numbers and meat weights of the fish. The results presented here all relate to the column samples from Cnoc Coig,Cnoc Sligeach,CNG II and the Priory.

Relative frequencies of species

There are a number of problems that must be considered in using the assemblage of archaeological material to reconstruct the original frequencies of the different species. Allowance has to be made for the differences in the number of elements in each species;both in terms of the total number of bones,as considerable variations exist in the numbers of vertebrae for example(53-6 in the saithe,112-7 in the eel)(Wheeler 1969,227, 274),and in the numbers of elements that can be identified to the species level. The latter is influenced by the intrinsic qualities of the bones and by the availability of comparative material. Differences in preservation are likely to introduce biases in the frequency of species;the most obvious example of this is the absence of most of the skeleton of the selachians. Biases will also be introduced by the recovery procedures which select by size(pieces over 2mm)rather than by class of material;small bones and species of small fish will be underrepresented. Finally,there are other potential sources of variability if different species were being processed or disposed of in different ways.

Of the generally used methods for estimating relative abundance MNI counts seemed unnecessarily elaborate and could not adequately represent the small quantities of material that existed for the rarer species. Weight of bone was not considered because of the small quantities involved and the problems of comparability between species outlined above. The latter point applies equally to counts of NISP;in addition to which the number,rather than the weight,of pieces of bone was very high and much of the material would have been interrelated. It was decided to aim at a fairly crude representation of the relative frequency of species given all these limitations;the subsequent calculations of absolute abundance would provide more detailed results if they were required. The method chosen made use of the large number of individual sampling units that had been analysed,with a simple count of the proportion of units in which each species had been identified. If all species were to be evenly distributed through the units then this method would accurately represent the relative abundance of species;this assumption is not accepted but the procedure should still be able to produce a rank order for species.

The results of the analysis are presented in Table 4;some differences are apparent between the sites but there is a sufficient level of similarity for the results to be considered together. The overwhelming importance of the saithe,which includes a small percentage of lythe(see Chapter 2),is obvious as it occurs in every sample(80). Next in rank order is the shanny which is present in 50% of units(40),followed by the eel in 27.5%(22). The remaining species,and groups of fishes, are found in less than 15% of the samples and details of their rank order are of dubious value with such small numbers represented;taking them in groups of decreasing abundance they are the eelpout,shark or ray,and wrasse,then the sea scorpion,sea bream and monkfish,and finally species of ray,conger and flatfish.

Calculation of absolute abundance

The estimation of absolute values for numbers of individuals raises many problems that have not been satisfactorily resolved and so in most circumstances such calculations would not be attempted. However, there is a greater measure of control over the sources of variability in the material in samples from shell middens and standard units of quantity are required for the comparison of values for different classes of economic resources. Therefore, such estimates have been undertaken but it must be stressed that the results are not counts of the actual numbers of fishes represented in samples but are values for the minimum number of individuals necessary to account for the material in the samples. The method of quantification adopted was devised to deal with the type of assemblages that were available and does not follow any of the procedures outlined above; thus comparability with other studies is not guaranteed and it is possible that the results will not meet the needs of anyone else looking at this material, but in the absence of an agreed methodology this was unavoidable.

The main problems that were faced in producing the procedurewere the assessment of whether bones belonged to the same fish; the degree of interrelationship, in the extent to which bones from one fish could occur in more than one sample; and the units of analysis in respect of the size of samples and degree to which samples could be aggregated together. The context of deposition in middens makes it likely that associated material will be deposited together and will remain in that position, but remains can be dispersed either before of after deposition and soelements from one individual could occur in two or more samples; in such circumstances it would be inaccurate to regard the samples as independent. This is most likely to affect adjacent units, especially where these are arbitrary divisions of larger stratigraphic units, and this problem was resolved by Parmalee et al. by amalgamating samples from adjacent units of the same chronological phase(1972, 11). But such dispersal could also take place over wider areas of the site and there is no way of assessing its impact; such assessments are possible with certain types of data(Koike 1979) but could not be made in this instance(see Chapter 4). It is essential for standard MNI counts that units are regarded as independent and thus contain numbers of whole fish,which is not appropriate in this case. Furthermore this argument can be extended as the sampling units are a part of the site as a whole;parts of a fish may occur in a sample and also in the rest of the site and again it would be inaccurate to count these bones as representing a whole individual in the samples.

If the samples cannot be accepted as independent and if they may contain only parts of some individuals this raises two problems in making the calculations. The first of these, that the same fish might be counted in two samples,is avoidable if the same feature is used in all samples from a site. This should be the most common element overall and for the saithe this proved to be the sagittal otolith at all the sites(Table 8). This is fortunate as the element is identifiable at the species level,the recovery is easily controlled and it is used for other aspects of the study. In practice,this choice does not depart much from standard MNI procedure as the otolith is the most abundant element(allowing for its frequency in the skeleton) in most of the samples. The choice of a particular feature of the otolith on which to make the count is based on the same principle. Otoliths tend to fracture into either two or three pieces (anterior,posterior and sometimes central portion);there is a tendency for the extremes of the element to be underrepresented as they may be on very small fragments and the most common feature is the more robust central piece as recognised by the point of interruption in the sulcus acusticus on the internal surface(Figure 7a).

The next problem is to consider how the presence of two otoliths in each fish can be taken into account. The pairing of left and right specimens does not solve the problem,as it does not indicate how unpaired bones should be counted,and this leaves aside the basic question of whether such elements can be successfully matched;the differences in size recorded in the modern fish between the left and right otoliths,of up to 0.45mm over a length of 10mm,suggest that pairing on size grounds is not an exact procedure. An alternative would be to count only the left or the right sided specimens but this could lead to further complications as an additional source of variability is introduced. The method adopted here attempts to get around the problem of using one otolith to represent each fish and also of assuming that a number of whole fish are present in each sample which provided the second source of difficulty. The system counts elements according to their frequency in the skeleton;as there are two sagittal otoliths each is taken to represent one half of a fish,so that the 'number of individuals' is equal to the number of otoliths divided by two. Further advantages of this method are its simplicity,its suitability for calculating meat yields directly from each bone,and the fact that it will not be affected by sample size or grouping of samples.

The calculations are presented in Table 5 and again it should be explained that these figures do not necessarily reflect the actual numbers of fish involved. Alongside these figures a second set of results are included. These were calculated using the same principle of counting each bone according to its expected frequency but were based upon the most common element in each separate sample;where no figure is given then the saggital otolith produced the highest total. This applied in the majority of units and where a second figure is available the margin of difference is usually small. The elements that provided these results were mainly the basioccipital(one per fish) and thoracic vertebrae(four);where a greater differential exists special circumstances are involved eg CNG II sample R (see Chapter 4).

The remaining species of fish present a more difficult problem as no method of quantification can adequately deal with such small quantities of material. To maintain comparability the same procedure is therefore used,but for these species the most common element for all the sites combined is used to simplify the calculations;in practical terms the same applies to the saithe as the same bone(the otolith) is most abundant in each case but this was checked individually for each site. For some species this was again a paired bone:shanny (quadrate),wrasse(dentary),sea bream(posttemporal) and the sea scorpion(preoperculum). Only multiple elements(teeth,denticles,vertebrae) have been identified for the remaining fishes and only small numbers of any of these are present in the samples;if all the pieces from the samples at each site are combined the totals are not even equivalent to one half of a fish and so only the presence of such species is recorded with no attempt at quantification.

One final complication that may affect all species is that they are calculated on recovered fractions of material which may not coincide with complete classes of elements. It is obviously difficult to take account of remains that have not been preserved but the effects of recovery procedures are more easily quantified. Size is the main factor and one solution would be to adopt methods that recovered all fishbone.For the saithe it was established that all complete,and almost all central portions of otoliths could be recovered by sieves with a 1mm mesh;therefore all material of over 1mm has been sorted in the main samples from Cnoc Sligeach,the Priory and CNG II .This has not been possible for Cnoc Coig because of the large number of units,but here the quantities of missing otoliths can be estimated(Chapter 1).

There is no data on the proportion of pieces of counted elements belonging to the remaining species that have been missed and so the influence of this can only be guessed;clearly for the smaller species at least a proportion of material has been missed. In overall terms however the effects of this will only be marginal as the fauna is overwhelmingly dominated by a single species,the saithe. This fish accounts for over 95% of counted individuals and if the 1-2mm fractions of samples were to be included the figure would be higher. There are some differences between the sites,with only 3% of the fauna from other species at Cnoc Coig and CNG II up to 10% at Cnoc Sligeach and the Priory,but the overall similarity of the faunas is again apparent. The rank order of species is similar to that produced by the estimates of relative abundance,with the shanny and then the eel following the saithe in importance but the dominance of the latter is emphasised by the absolute values for numbers of individuals.

Size reconstruction of the saithe

The study of the relationship between the size of fish and bone size has concentrated on the saithe because of the overwhelming dominance of this one species. The two variables of fish size,length and weight,were both investigated;the former could be used in the study of seasonality(Chapter 5) and of fishing methods(Chapter 6) and the latter for estimatimg meat values(Chapter 4). The measures employed and the samples for the analysis are described in Appendix 2. Interest was concentrated on the sagittal otolith as the element is abundant and easily identified in the archaeological assemblages,there is a simple and replicable measurement(maximum length),and the collection of comparative material is straightforward. Otoliths are widely used in fisheries work for size estimation and there have been a few studies on the saithe:Rojo Lucio established a relationship between otolith length and fish length(1967,15),and Cieglewicz & Draganik plotted the longer radius of the otolith against fish length(1969,142-3).Preliminary study of the comparative material confirmed that a strong relationship existed between otolith length and fish size and so detailed sampling was then pursued(Mellars 1978,382).

Before the analysis was started the technique for establishing the relationship had to be chosen. One consideration in this is the level of precision desired in the results. For some aspects of the study,particularly seasonality, small differences in size could be significant and so the most exact procedure seemed necessary. Such accuracy is also prompted by a further feature of the material;all the bones come from small fish and so only small absolute variations will exist, although in relative terms they will be significant. The sample of comparative material was chosen to match the size distribution of the archaeological samples as extrapolation beyond the range of values is not necessarily reliable. However,the modern material is deficient in two respects;firstly ,it was not possible to obtain fishes at the lower extreme of the size range as suitable gears were not available,and secondly the comparative assemblage is made up of a series of separate sub-samples collected at different times over several years and they do not provide an even distribution of data points.These sub-samples could be analysed separately or combined in various ways and it is necessary to consider which would be the most appropriate. There are two main alternative forms of grouping;a combination of all the material or a division into the two main size/age groups represented in the assemblage. An overall mean curve would be applicable to all material but may obscure differences that could exist in the relationships between the two age groups. Individual curves for the two groups would more exactly represent the relationship within each size range but there could be a difficulty in deciding which curve is more appropriate for size groups which include values in each size range. The individual sub-samples can be used to illustrate the relationship within a population at any time but as they make no allowance for variability within populations they should not be used for size reconstruction. The procedure decided upon in this case was to use the two size/age group curves for those archaeological distributions that were coincident with them and the overall mean curve in cases where the range overlapped the two individual ranges.

Regression analysis,by least squares,was used to calculate the relatioships(Casteel 1976,96) with the SPSS Mark 5 programme at the University of Sheffield Computing Centre. A total of 1032 cases(individual otoliths)were used,although not all of them could be used to calculate each relationship. The variables in the analysis were fish length,fish weight,and otolith length,and regression curves were drawn for normal and logarithmic relationships;seven sub-samples together with the three aggregated groups were processed. The statistics of the computations are given in Table 6 and the principal results of the analysis are:

Fish weight against fish length(FW:FL); this relationship is not used in reconstructing fish size but is included for two reasons. Firstly,to demonstrate the form of relationship between these two variables;the best fit varies between the subsamples but for all the aggregate curves it is a logarithmic relationship($W=aL^b$) and this shows how weight increases relative to length. The other purpose is to examine whether there are seasonal differences in the form of the relationship to study changes in 'condition'(K) as expressed by the exponent value(b);the results are not conclusive and so this remains an open question.(Table 6;Figure 12).

All fish $\log FW = -2.23083 + 3.18785 \log FL$
First year fish $\log FW = -2.57256 + 3.48660 \log FL$
Second year fish $\log FW = -1.90406 + 2.95821 \log FL$

Fish length against otolith length(FL:OL); again the best fit varies between sub-samples but in the majority of them and in two of the aggregates it is a normal linear relationship ($L=a+bOL$).The mean curve appears to be most appropriate for samples with ranges from 6mm to 10mm in otolith lengths as the difference between the two age/size curves is significant within this range,reaching c.20mm in estimated fish length for otoliths of 8mm.(Table 6).

All fish $FL = -7.58683 + 3.37816OL$
First year fish $FL = -0.24180 + 2.18588OL$
Second year fish $FL = -7.03110 + 3.32728OL$

Fish weight against otolith length(FW:OL); for most of the subsamples the best fit is the linear form but in all of the aggregates it is the log relationship. The pattern is similar to the previous relationship with a divergence of values from the two age/size curves between 6mm and 10mm otolith length. (Table 6;Figure 12).

All fish $\log FW = -2.16809 + 4.45722\log OL$
First year fish $\log FW = -1.12149 + 3.10610\log OL$
Second year fish $\log FW = -1.39439 + 3.69038\log OL$

Using these relationships ,with the most appropriate curve for the range of values in a sample,it is possible to accurately estimate the length and weight of a fish from the measure of otolith length. This can be done for each complete otolith but does not apply to any broken specimens as they almost invariably break longitudinally.In a proportion of cases the missing portion is only a small fragment and the length can be estimated reasonably accurately. For the remaining pieces an attempt could be made to calculate maximum length from a measurement of breadth as a relationship between the two variables has been demonstrated(Figure 10). However, the correlation is not particularly strong and so estimates would be less precise especially as breadth is less easy to measure than length. Instead all broken pieces were assigned to 1mm classes of estimated total length and the size of these otoliths is taken as the midpoint of each size class. The results of the calculations are not presented here as they really have no value in themselves;it is how they are used in comparisons and interpretation that is important and so the figures will be given as they are used in the analysis.

CHAPTER FOUR
CONSUMPTION

This chapter considers the ways in which fishes are utilised by man and the recognition of these practices in the archaeological record. The principal usage is as a source of human food and the discussion concentrates upon this aspect. It includes descriptions of the composition of the flesh and organs,the ways in which they are processed and cooked,and methods of preservation;the second stage examines how these can be identified from patterning among archaeological material and this involves discussion of discard and postdepositional processes as other agencies producing patterning. Fish have relatively little non-food value but it should not be ignored(Jochim 1976,105) as it is important in some situations and a wide range of products is involved(Norman & Greenwood 1963,346). These include shagreen and leather from the skin (Fenton 1976,80),bladders as window lights(Smith 1977,48)and for isinglass(Cutting 1955,140),glue(Smith 1977,72),liver oil for illumination and tanning(Cutting 1955,140),crab and fish bait(Jenkins 1974,16,282),animal food(Taksami 1975,224;Paine 1957,64;Fenton 1976,141) and fertilisers(Tesch 1977,150).Most of these can be complementary to the primary use as human food as they make use of the offal or surplus catch,and only occasionally do they provide the basis for a fishery;the modern 'industrial' fisheries are of course an exception but this account concentrates upon traditional fisheries.

Composition of fish

It is appropriate to include a brief description of the chemical composition of fish as it affects human nutrition. This section concentrates upon the flesh and the contents of the other parts of the body are dealt with later along with the effects of processing,cooking and preservation techniques; the figures given here refer to proportions in raw meat. More detailed accounts are available(Borgstrom 1961;Love 1957,1970; Murray & Burt 1969) along with tables of composition for many species of fish(McCance & Widdowson 1960;Watt & Merrill 1963). The principal components of fish flesh are:

<u>Water</u>: average values of 60-80% of the flesh(Norman & Greenwood 1963,334) mostly in the upper part of this range. The percent-

age of water is higher in 'non-fatty' fishes and values are inversely related to the proportion of protein and fat, in non-fatty and fatty fishes respectively (Murray & Burt 1969,12).

Protein: nutritionally fish protein is of good quality, with a balance of amino acids equivalent to other meats (Holt 1967,456) and sufficient lysine and methionine to complement cereals in a diet (Murray & Burt 1969,5). Average values are 15-20% but this is a slight exaggeration as the figures are derived from total nitrogen content which includes a small proportion in non-protein form; this is most significant for the selachians where it may account for up to 30% reducing true protein levels accordingly (Murray & Burt 1969,12).

Fat: or more accurately lipids, as it also includes oils, waxes and fatty acids. It is the most variable component, both within and between species. There is a general distinction between 'non-fatty' fishes like the cod which have a low level of fats in the flesh (1% or less) and the 'fatty' fishes such as the herring with values reaching over 20% (Burgess 1975,188).

Carbohydrates: a minor constituent, forming only 1-2% of tissues. Reserves are stored mostly in the liver and are rapidly depleted under stress conditions (Love 1970,250).

Minerals: the ash content of fish muscle is only 1-2%, with more in the skin and bone. There is no difference in the level between freshwater and marine species although the individual elements may vary. Fish is a balanced source of minerals in an accessible form (Hewes 1948,244), particularly iodine, and also phosphorus, potassium, iron and copper (Holt 1967,456).

Vitamins: the vitamin content is variable. It includes both water soluble and oil soluble ones; the former group are fairly evenly distributed but the latter are associated with the body fats and so levels are low in the muscle and high in the organs of non-fatty fishes. Fish can provide significant quantities of a number of vitamins (A, B group, D) to the diet (Burgess 1975, 188).

These average values obscure the variability that exists in the chemical composition of fish, both inter and intraspecific. The most obvious are the differences that occur between species and the scale of these is such that each species must be regarded separately (Love 1970,129); values for the main commercial species are widely available (McCance & Widdowson 1960; Murray & Burt 1969; Norman & Greenwood 1963,334). Fishes can be grouped together on the basis of their systematic position(Love 1970,135-43) or habitat(Love 1970,143-7) but the main distinction for the principal components is between the fatty and non-fatty species. The lipid content of the flesh is much higher among the former and contributes to the greater calorific value of such meat(Murray & Burt 1969,12);'fatty' fishes include the herring,mackerel,salmon and eel.

Variability in composition also exists between fish of the same species(Murray & Burt 1969,3),as a result of both internal physiological conditions and external environmental influences. The former include changes associated with age and sexual development,while temperature and competition for food are important factors in the differences between habitats and through the year. The fat content is particularly affected and so differences are most apparent among the fatty fish, with variations of up to 11% found in the fat content of herrings of the same age and sex in a catch(Love 1957,405);in the non-fatty fishes protein content is similarly affected. Reserves become depleted during times of stress,including spawning and migrations,and are built up before such events so there is a seasonal patterning in the condition of many fish. One further aspect of variation to consider is the difference that is found within the body of a single fish,not only between the muscle flesh and the organs,but also within the flesh (Rostlund 1952,5);the fat content within a herring fillet may vary from 14 up to 47% along the length and from skin towards the inner surface(Love 1970,37).

Parts of a fish

The first stage in considering how fish are processed is to understand their basic anatomical structure. The skeleton has already been described(Chapter 2) so this section concentrates on the 'fleshy' parts of the body:

The head: this makes up approximately 20% of the weight of most fishes(Cutting 1955,179) but does vary depending upon the species. Most of this consists of bone although there is a reasonable proportion of meat,and the brain and tongue are edible. Fish heads are a common food,often served in stews; occasionally they are regarded as a delicacy as in Iceland where dried cod's heads yielded some 67g of edible meat(Davidson 1979,395).

The viscera: these account for some 15% of the weight of a whole fish although the figure is highly variable(Coull 1972, 184) depending upon feeding conditions and the fullness of the stomach, the'condition'of the fish and body fat levels eg. the fat content of the liver of the cod accounts for 3.5% of the total weight of the fish in summer rising to 5.6% in the winter(Nikolsky 1963,297),and the stage of sexual development, with gonads forming up to 15% of the weight of a fish(Nikolsky 1963,209). Only the liver and the gonads are widely consumed; the former are a good source of fat and vitamins(Murray & Burt 1969,13) while the latter are marketed as caviare and roes and also are high in vitamins(Murray & Burt 1969,7).
The body: the main component of the 'body' region is the muscle along with smaller quantities of skin and bone. The chemical composition of the flesh has already been described but two points may be added. The body muscle is made up of a series of blocks separated by thin sheets of connective tissue and the small volume of the latter may account for fish being less tough than other meats(Murray & Burt 1969,4). Secondly,there are two types of muscle;the bulk of the flesh consists of light muscle but there are small bands of dark muscle below the lateral line and these are larger in the fatty fishes. There is more fat in the darker muscle but the differences between the two types are not fully understood. The bone structure of the body is basically similar in all bony fishes(Chapter 2) but there are variations in the size,number and arrangement of the bones which is important in determining the 'edibility' of particular fishes. In some species these bones can be eaten especially after cooking or preservation;one specialised example is the cartilagenous backbone of the sturgeon(Smith 1977,65). Usually some or all of the bone is removed;the most common procedure is filleting,and the waste from this may include some flesh so the total loss in the process can amount to 10% of the total weight of the fish. Thus the fillets of a fish such as the cod make up some 30-50% of the original weight of the fish(Coull 1972,184).

However,this figure should not be taken as representative of the edible proportion of a fish. This will depend upon what is considered edible and how the fish is prepared;there is flesh on the head and lost in the filleting in addition to the fillets themselves,and some of the body organs can be eaten;

> 'A fish was usually cooked whole in the ashes and most of its carcass was consumed with the exception of the skeleton(though bones were always sucked),scales,charred outer skin,gills and a small part of the guts.Flesh from the head,including the eyes and brains was relished' (Meehan 1977,499).

There are also considerable differences between species in the relative sizes of different anatomical parts. In the modern British diet for example the 'edible' proportion of a fish varies from 76%(sprat) down to 27%(skate),a difference of 50% (Barker 1968,121). Therefore any study of the food contribution of fish must take account of the species involved,the ways they are processed,and the parts of the body that are considered edible.

Processing and consumption

Little has been written on the butchery of fish and so patterns must be based on modern practices,in which appearance is an important factor,together with occasional references in historical and ethnographic accounts. Some fishes,especially if they are small or young,are eaten whole and few fish are large enough to require extensive butchery but most are subject to three processes:

Gutting: many species are eviscerated shortly after capture to prevent decay and tainting of the flesh,with the gills and body organs discarded. The most common method is by slitting the belly but they can be removed through the gills,as in the 'gipping' of herrings(Cutting 1955,62),or a cut across the throat. The head is often removed at the same time.

Beheading: generally severed behind the gill opening separating the cranium from the vertebral column although in some species the first few vertebrae are also included. The head may be butchered to remove the tongue and brain,or to extract the flesh on the head,but is more often discarded.

Dividing the body: this is dealt with in a number of ways. The scales or skin can be removed,along with the fins and tail as they have no value. The most common procedure is the removal of the flesh from the backbone in a series of fillets,two from roundfish and four from the flatfish;bones of the precaudal haemal region,such as ribs,may be included with the fillets and may have to be severed from the centra. The backbone,or part of it,can be completely removed but if left in place it helps to give some rigidity to the flesh. Alternatively,the body can be severed across the backbone into 'steaks';this is used mainly for round-sectioned portions as in the eels or tail section of other species.

Fish is eaten raw(Taksami 1975,224),as it is a relatively soft meat and can be enhanced by marinading,pulverisation or other softening procedures. Some preservation methods cook the flesh which is then ready for consumption,eg.hot-smoking. Any of the methods of cooking meat are appropriate for fish but there is little data on this subject. Gyllenskold produced times for cooking various sizes of different groups of fish (Davidson 1979,258) and there are a few other references,such as the hour taken to roast a split salmon(Granlund 1965,243).

Generally fish are a high quality and sought after food resource but there are considerable variations in the values attached to them. Such value systems are widespread-'noble'fish (Smith 1977,61),'rabble'fish(Day 1880-4,335)etc.-but the criteria on which they are based vary;for instance the value of a single species ranges from esteem through to unfit for human consumption as with the Lapps and the burbot(Ingold 1976,92). The value placed on a fish will depend upon such features as its age or size,the stage of the life cycle in which it was caught,its general condition, and how it has been handled and prepared. The condition of many fish alters markedly through the year,with a low point following spawning for many mature fishes;the salmon is a classic example,highly sought after on its migration upstream but shunned in its post-spawning stage (kelts). Most species are most highly valued in a fresh state but others are preferred when they have been preserved in various forms eg.the ling. The conclusions from this must be that it is not sound to transfer a value system to situations where the actual practices are unknown.

Preservation methods

Although most fish are more highly valued fresh(Cutting 1955,203) the bulk of catches are consumed in some preserved form. The main reasons for this are problems of availability, both of access to fishing grounds and changes in abundance through the year,and the rate at which fish spoils. This decay proceeds more rapidly than for many other food products(Schalk 1977,232)principally through bacterial action with changes in enzymes and oxidation of fats(Cutting 1955,1). The rate of deterioration depends upon conditions and the species involved;for example,mackerel flesh can become toxic within 24 hours whereas the characteristic flavour of the Dover sole takes two or three days to develop(Norman & Greenwood 1963,126).Alongside modern canning and freezing there are a number of 'traditional' methods of preservation(Cutting 1955;Rostlund 1952);they lead to little loss in the nutritional values of the catch and produce a wide range of products with varied storage lives (Hewes 1948,244;Reinman 1967,193). They all use quite simple technologies and are appropriate in varying conditions;both in environmental conditions and in the type of catch(species,sizes and numbers of fish)(Burgess 1975,194).

Live fish: if they are not injured in capture it is possible to keep both freshwater and marine fishes alive in tanks and ponds although their condition will suffer. Eels are particularly suited to this and can be kept alive for months(Bulmer 1976,181).

Freezing: in cold regions fish can be stored through the winter and this may coincide with the optimal availability of some anadromous species in such areas(Rostlund 1952,138). An extension of this is the use of fishing methods during this season which can be left unattended for lengths of time without the catch deteriorating(Ingold 1976,92).

Fermentation: the changes that accompany the death of a fish are not necessarily harmful and are sometimes sought after to impart additional flavour. The use of fermented fish is widespread(Rostlund 1952,199-200) and often goes with some other preservation technique like freezing(Maddox 1975,207),salting or air-drying(Davidson 1979,400).

Drying: this is most efficient either where conditions are hot enough to dry the fish before decay takes place or where it is cool enough to slow down the rate of spoilage(Paine 1957, 141). The best known example of the latter is the 'stockfish' produced in northern Europe;the fish are gutted,and sometimes beheaded,and then air-dried,and a range of species including several of the cod family are processed in large numbers.

Salting: pickling the fish in brine is a simple and rapid method of inhibiting decay and is often used as a first step in other processing techniques. It is also used by itself, particularly for the fatty fish,which cannot be dried because this does not prevent oxidation of the fats,to produce 'white

herring' etc(Cutting 1955,53).
Salting and drying: the two are often conbined as the salting helps to reduce the rate of decay although a lower humidity is required than for drying by itself(76% and preferably below 70%)(Cutting 1955,176).Salting and drying both lead to a loss in weight,mostly of water but some other values,particularly water soluble vitamins are also affected.Many of the codfishes are salted and dried and were collectively called 'ling' which is somewhat confusing as the ling is one of the main species dealt with in this manner;such fishes would have the viscera, head and backbone removed('split fish') before salting and then drying.
Smoking: this is basically artificial drying although the smoke imparts additional flavour and can therefore improve less valued fishes alongside prime species. Many fishes are briefly salted before smoking and a range of products are possible by varying the length and method of smoking. It is suitable for many species,of both fatty and non-fatty fish.

Archaeological approaches to the processing of fish

The identification of processing activities in the archaeological record can be based upon several lines of evidence, including artefactual remains,the condition of the bones,and the composition of the bone assemblage in terms of the species and parts of the skeleton represented.

Artefactual evidence: this can include both items such as cutting implements(Fitzhugh 1975,358) and storage containers (Coutts 1975a,277) and structural features like hearths or drying/smoking racks(Bulmer 1976,184). All of these are used in the processing,preservation and storage of fish but they are also employed for other purposes and it is very difficult to positively correlate their presence with fish processing as it has few diagnostic characteristics.

Condition of the remains: this should constitute the most direct form of evidence as it records the impact of various processes actually on the bones. Several forms of modification to the bone may be significant(Finlayson 1977,480-2):
i.cut-marks and butchered bones: because fish bones are relatively small and few elements occur within the fleshy parts of the body butchery marks are less frequent than on mammal bones.

The production of fillets and steaks will leave distinctive marks on the vertebrae,and these,together with other cuts, were recorded at Exeter(Wilkinson 1979,75-6).

ii.fragmentation of bone: may result from a number of processes but the deliberate crushing of fish,both of flesh and bone, is a well-documented practice(Casteel 1976,90-2;Goodlad 1971, 45).

iii.burnt bone: this could occur during cooking or some forms of preservation(Bulmer 1976,181) but may also depend on where the material is discarded(Cook & Heizer 1951,290-1).A further point to note is that burning can affect the structure and form of bones(Coy 1975,427;Lepiksaar 1978,244).

iv.distortion of bone: pathological conditions are common in fish(Ford 1937) and have been reported in archaeological specimens(Baker & Brothwell 1980,91;Wheeler 1977b408),but post-mortem alteration is also possible and could indicate how a fish was handled.

v.eroded bone: one of the agencies that would produce this effect is digestion,either in predatory species(Fitch 1967, 188) or by human consumption(Calder 1977).

Unfortunately,except for unambiguous butchery marks,all of these alterations could be produced in various ways and should only be attributed to processing activities where there is corroborative evidence or natural explanations can be ruled out(Terrell 1967,505). Another line of enquiry that might be worth investigating is to study whether methods of preserving or cooking fish bring about chemical or structural changes in the bone that are diagnostic.

Composition of the assemblage: the aim here is to establish and interpret patterns in assemblages,through the species, sizes of fish,frequencies of elements etc. in the samples.For instance the species list may contain some fishes that are not compatible with the rest of the assemblage in the season or location at which they would be caught and so may have been introduced in a preserved form(Coutts 1975a,276;Wheeler 1977b, 406). Another aspect of this subject is the interpretation of the relative frequencies of skeletal elements. It is exceptional for bones to appear in an assemblage(the observed frequency) in the same proportions as they occur in the body of the fish(expected frequency). Much of this variation is due to a combination of processes which are discussed below,but some results from the ways that fish are processed. The latter can be difficult to recognise or to separate from the other agencies,but may be indicated by a number of features.

If the composition of samples from within a site vary significantly then there is a greater likelihood that some of the patterning can be attributed to processing activity as a number of other sources of bias can be excluded. High frequencies of elements that would normally be underrepresented because of their small size or fragile form will suggest a more specific explanation than 'natural' agencies. Finally, explanations of assemblages in terms of processing should be related to actual patterns and parts of the body. The simplest example would be samples containing only a single element,such as scales(Cutting 1955,82;Hall 1976,23-4),but they are more likely to include various bones from particular parts of the body. The most commonly cited possibility is the separation of the head and body,as waste and meat respectively,although there are few actual examples and these are not very convincing (Coutts 1975a,277;Carver 1979,54;Shawcross 1967,114:1972,604). Further patterns could include gutting waste as represented by bones of the gills and throat(and stomach contents),and the production of'split fish'in which only the fins,pectoral girdle and tail vertebrae are left with the flesh. The latter was identified in the post-medieval material at Exeter and was supported by other lines of evidence;the pattern was not present in the sample of medieval cod bones,the butchery marks fitted with such processing,and there was historical evidence of the trade in dried split fish at this time(Wilkinson 1979, 75).

As mentioned earlier(Chapter 1) the relationship between archaeological assemblages and food consumption is not direct; there are a number of intervening stages and in particular the discard and burial of material and postdepositional processes(Yellen 1977,321-3). In addition there are several other potential sources of fish remains and while they will usually not be significant their existence must be acknowledged. Fish bone could be introduced by other agencies to the site,either in the stomachs of predatory species or left by other animals. The converse of this is that food refuse could also leave the site,through scavengers or by human agencies:carried away to remove its noxious smell(Grant 1979,287) or incorporated in excreta(Limp & Reidhead 1979,75). Secondly,there are fishes brought onto sites but not eaten,possibly because they are surplus to requirements,have spoilt,or which are considered inedible for some reason. As many fishing methods capture a range of fishes and communities have well-developed value systems,some wastage of this sort is not uncommon. Finally, there is fish acquired for purposes other than as human food. Some of these would produce specific patterns of discard but as most are complementary to using the flesh as food the main impact of these usages will be to obscure the patterns of normal discard;for example if the bones are fed to animals then they will either disappear completely or at least be seriously fragmented(Casteel 1971). These additional sources of fish remains may be identifiable from the species of fish involved,their sizes and numbers,the parts of the body,the state of the bone,and the context of the deposit(Fitch 1967; Jones 1978,27;Wheeler 1979,147).

Material from all these sources then becomes incorporated into the archaeological record through two sets of processes. Firstly,there is the manner in which it is discarded,and the study of groups of associated remains and of variations between contexts within a site could be used to identify stages in processing activities as has been achieved for other classes of remains. Once the material has been discarded then it is affected by various agencies including weathering,scavenging, transport and redeposition. The study of taphonomy is a difficult subject as there are many variables to consider and each context and assemblage is unique. However,the standard of preservation also depends upon intrinsic properties of the bone and some generalisations can be made on this aspect;the absolute level of preservation will depend upon the context but the relative frequencies of elements and groups of fish are more constant.

Although fish remains are less robust than mammalian bone they are preserved in most conditions where other bone survives and their absence is more often a reflection on recovery procedures(Chapter 1). The standard of preservation depends on the form and structure of the bone and on the degree of calcification of material. The position of the selachians is the clearest example of the latter,for their cartilagenous skeleton fails to survive and the only archaeological traces of such fishes are teeth,denticles and some vertebral centra(Wheeler 1978a,71). The same is true of bones of the head of the salmonids and some other fishes(Casteel 1976,88-92;Wheeler 1978a, 74) although alternative explanations have been given(Ekman 1973,59). At the other end of the range there are compact, dense elements that survive well;these include the tooth-bearing bones of many fishes,of both the jaws and pharyngeal plates.The pharyngeals of the wrasses illustrate this point by their appearance on many archaeological sites(Wheeler 1969, 371;Jones 1978,32;Leach & Anderson 1979a,5;Ledoux & Granier 1972,138). Much more work needs to be done on the frequencies of elements before a good understanding of the causes of the variability can be given;there are a number of influences, including recovery,identification and processing activity,to consider alongside preservation conditions.An idea of the expected frequencies of elements can be obtained from any of an increasing number of detailed reports(Ekman 1973,83:1974,228; Leach & Anderson 1979a,6;Lepiksaar 1974,153-6;Lepiksaar & Heinrich 1977;Shawcross 1967,113).

Archaeological assemblages are complex entities reflecting many influences and are thus difficult to interpret with confidence;more detailed studies of the impact of individual factors are clearly needed. It is important that attention is concentrated on this field, so that the effects of processing activities can be recognised. They are important not only in understanding the forms in which fish were eaten but because of the data they reveal on other important questions. For instance,the recognition that fish were being preserved has implications in the study of seasonality and resource scheduling (Coutts & Higham 1971;Schalk 1977). Another issue is the estimation of the meat yield of faunas;once the size of the animals has been established an estimate is necessary of the proportion of the carcass that was eaten. Figures used in faunal studies range from 80% of live weight(Cook & Treganza 1947, 138),through figures of 70%(Coutts 1975a,276) and 60%(Shawcross 1972,612) to 50% or less(White 1953,397). It should be possible to work out the parts of the body discarded by reconstructing the stages of processing and consumption from the composition of assemblages. There is a wealth of information contained in samples of bones but further studies are required to enable us to separate the various sources of patterning.

Consumption: Oronsay

The study of processing and consumption is a difficult subject as they are separated from the archaeological record by a series of processes,various lines of evidence have to be examined,and there are few patterns that can be attributed to a single cause. The aspects of the material studied here include the distribution of fish remains,the composition of assemblages,modification of the bone,artefactual and structural evidence,supported by comparisons with contemporary and historical practices. As all the remains come from shell midden deposits it is assumed that they represent the traces of human food activity and no evidence appeared to contradict this. The alkaline conditions within the midden deposits have resulted in a high standard of preservation of most of the material; the remains from Cnoc Sligeach are less well preserved than those from the other sites and bone recovered from deposits of sand within and below the middens is in a better state than that from shell matrix. Most of the discussion is based upon the saithe because of the dominance of this species and likewise much of the evidence comes from Cnoc Coig,the most extensively investigated of sites. The remaining species and sites are discussed after the evidence from these two sources.

Site structure

Shell middens are often complex heterogeneous structures made up of a series of layers or lenses(Coutts 1971,150;Noe-Nygaard 1967). Cnoc Coig is a well-structured site with clear spatial patterning in the distribution of features and types of deposit;there is abundant evidence for extensive human activity on the site in the numbers of artefacts,hearths and other features. The distribution of the fish remains provides a further example of the variability within the site. The quantity of fishbone in the fifty column samples varies enormously;for example,the number of vertebrae ranges from two up to over 2300,and otoliths from nil to 255(Table 7). There are no obvious groupings within this range apart from the five sub-samples that are much larger than the rest,each with over 1000 vertebrae,more than twice the number in any other sample. The significance of this variability is not apparent from the samples themselves and two factors must be considered. Many of the samples are very small and not reliable for comparisons, and there could be differences in preservation and recovery between samples. It is also possible that the variations in sample size bear no relationship to the ways fish were deposited;the sampling units are based upon midden volume and this is mainly a function of shell accumulation which is likely to be independent of the discard of other resources.

However,the apparent variability in the density of fish remains is supported by observations made during the excavations. Many concentrations of densely packed fishbone were noted,ranging from small units of a few cm^2 through to layers 30mm thick and extending over several square metres. They are interpreted as in situ discrete units of discard and show that the deposition of fish remains took place in a series of separate operations. The importance of these concentrations can be gauged from the figures for the column samples;if it is accepted that the five large sub-samples represent such concentrations then they make up only 5% of the volume of the site (5 of 97 sub-samples) but account for almost half of the fish eg,7448 of 16,480 vertebrae. The smaller concentrations must represent single units of discard but the larger 'layers' are more difficult to interpret;no stratigraphic divisions were visible within them but the quantity of material is very large. MNI counts of up to 71 individuals were obtained from $250mm^2$ samples of one layer that covered several square metres.These concentrations occur throughout the midden but are most clearly revealed in the sterile sand at the base of the midden deposits although they are contemporary with shell deposits in other parts of the site;two extensive layers were recorded in the south-east quadrant of the site.

The small numbers of fish bones in many of the samples could be explained in several ways. The preservation and recovery of elements is not complete(these samples are only based on the 2mm fraction) but this would affect mainly absolute numbers and not the frequency relative to other units. They could represent the occasional disposal of single or small groups of fish, or the result of postdepositional scattering of material from concentrations. Another alternative is also based on the idea that all or most of the fish was discarded in groups;the quantity of fishbone in a sample depends upon the proportion of the unit taken up by such concentrations with the small samples from the edges of concentrations. The solution may prove to be a combination of circumstances but it is clear that most of the fishbone in the site was dumped in concentrations that remain in situ and have not been affected by post-depositional dispersal and that conversely much of the site contains little or no fish remains.

Composition of assemblages

The main aspects examined here are the species and sizes of fish in samples,and the frequency of skeletal elements.The overall composition of the site is used as a norm for each variable and then the extent of variations from this in samples is considered.

Individual fish: the clearest way of demonstrating what happened to the fish from their arrival on the site through to the archaeological assemblage would be to identify the remains of individual fishes. This might be possible with some of the rarer species but not for the saithe except where groups of articulated elements were noted in situ. These were difficult to observe because of the loose matrix,small size of the fish, and the quantity of remains in the concentrations. However, sections of articulated vertebrae were noted in a number of places and the best example is shown in Figure 13;this reveals two features of interest as well as indicating that the deposit is undisturbed. The vertebral columns are aligned along similar axes showing how the fish were dumped,and the recognition of at least some otoliths in situ demonstrates that the head and body had not been separated in processing.

The range of fish: the presence of different species is considered later but the sizes of saithe are also of interest. The size distribution at Cnoc Coig is basically bimodal(Figure 24) with fish in the first and second year of life(Chapter 5).Most of the column samples contain values from both size modes although the ratio of the two varies;only 6 of the 28 samples with ten or more otoliths are essentially unimodal(Table 9). However,there is a different pattern among the concentrations of fishbone. In 31 samples from small concentrations 13 are exclusively unimodal and a further 6 contain only 1 or 2 different values(Table 9). Thus a large proportion of the fish remains in the site were dumped in single size groups;the bimodality of the column samples may demonstrate that some fishes were discarded in mixed groups but could also be attributed to their heterogeneous composition. The latter can be illustrated by reference to the large concentrations or layers of fishbone. Sampling these in adjacent 250mm^2 units has revealed clear spatial patterning within them(Figures 14 & 15);the changing frequencies of the two size classes could be explained by a series of adjoining or overlapping dumps of single size groups. This patterning also supports the view that these are in situ deposits and that they are composite entities made up of a series of smaller units of deposition.

The frequency of skeletal elements: when the numbers of each element identified in the samples are tabulated(Table 7) a number of points are apparent. Firstly,the bones are not present in the frequencies in which they occur in the skeleton and there are differences between the samples although the small size of many of them makes comparisons difficult. The interpretation of relative frequencies of elements is not a simple task as there are numerous potential influences. The advantages of combining the samples from the site(Table 8) are that this provides a large assemblage and these frequencies can then be used as a 'norm' for the site against which the variations in individual samples can be considered.

The main problem with this is that this combines all the sources of variability for the site and so makes it difficult to identify individual factors. However,a number of observations can be made from this summed list. There is no obvious pattern that could not be explained in terms of 'natural' causes and so consideration of processing activities must be left until other factors are ruled out. The overall frequencies of bones is not dissimilar to that recorded for other sites and species and so relative differences in preservation seem likely to account for much of the patterning:ranging from dense compact forms(otoliths,vertebrae,jaws) to thin plate-like bones(cleithrum,operculum etc). Size is also an obvious influence;most of the least frequent elements are small bones of the branchial region. The 2mm mesh used for these samples (as they are based only on the 2mm fraction) would only retrieve a variable proportion of each element.

The individual column samples are likely to share this drawback as many of them appear to be composite assemblages.

The fishbone concentrations seem to represent single discard units and therefore there is a greater likelihood of recognising single factors superimposed on those influences affecting all material. Two points should be mentioned;the concentrations are based upon the 1mm fraction and this may produce some differences from the column samples. Secondly,only a small number of concentrations have been fully analysed(12 of which 2 come from one fishbone layer) and so there is little data on which to base this study at present. The two samples referred to from the layer have been examined in separate 2 and 1mm fractions and show markedly different results for the proportions of each element in the two fractions;this is due to the different size range of fish in the samples(Table 7).

Overall,the frequencies of elements are similar to those recorded in the column samples but two somewhat different patterns can be observed. Firstly,there is a marked underrepresentation of elements,particularly from the branchiocranium, relative to otoliths;this is most apparent in L2 and 22,but is also visible to varying extents in some of the column samples eg.6C. The actual ratios of bones vary between samples but the basic pattern seems to consist of a high number of otoliths and very few branchiocranial elements with numbers of vertebrae and neurocranial bones variable. The other point that they share in common is that it appears to apply only to fish of the larger size grouping;as many of the samples include both size groups it is difficult to test this or to establish whether it applies to all larger fish but this is a possibility. The interpretation of the pattern is equally uncertain. It is possible to envisage a process that removes most of the branchiocranium leaving the articulated unit of neurocranium and backbone intact but preservation conditions seem a more likely explanation. The bones of the two size classes of fish do show differences in structure and standard of preservation which are biased against the larger fish;more work is necessary on this point before a definitive conclusion will be possible.

The second pattern is much clearer and easy to explain. In general the bones of the branchial region(Figure 6a) are poorly represented and this has been attributed to their small size and fragility. However,there are large numbers of such elements in a few samples;the clearest example is concentration 16 where there are the branchial bones of at least 46 individuals and only eight other identified bones. The argument against this being caused by natural agencies has already been given and there are strong reasons for identifying this as a result of processing activity. The bones all belong to the same part of the body and they could be separated from the rest of the body when the fish is gutted. The existence of this practice is thus established but its extent is unclear; only one concentration of gutting waste has been analysed and such bones occur in many of the other samples. However, their frequencies are variable and often low and this could be attributed to the existence of other concentrations;more concentrations will have to be analysed to resolve this.

Other sources of evidence

Additional information on the processing of saithe could be gained from comparisons with the other sites,the condition of the bone,and artefactual evidence.

Artefacts: no diagnostic tools or structures have been found at any of the sites. At Cnoc Coig numerous hearths,some surrounded by arrangements of post and stake holes,have been excavated and these could have served to cook or preserve the fish. Similarly,large numbers of fire-cracked pebbles were found and so fish could have been cooked in boiling water but there is no definite evidence of either practice.

Modification of the bone: no trace was observed of butchery on the bones but this is not altogether surprising given the small size of the fishes. A proportion of the pieces show signs of burning but as it seems to affect all parts of the skeleton this can be attributed to postdepositional proximity to the hearths. The final observation is more intriguing. A proportion of the vertebrae appear to show signs of distortion. This principally affects the caudal centra,which have been compressed along the anterior-posterior vertical axis,and the thoracic centra which show traces of distortion on the anterior face. The significance of this alteration is not known;deformation is fairly common in the vertebral column of fishes(Ford 1937) but such changes could also occur after death. There is thus the possibility that this is related to direct human activity but more work is necessary on the extent of these changes and potential causes.

The other sites: only column samples are available from the three sites(Cnoc Sligeach,CNG II ,Priory) and these raise the same problems of heterogeneity as at Cnoc Coig. However,it should be noted that concentrations of fishbone were not seen at these sites;this could reflect the more limited extent of excavations but the more equal spread of material through the samples suggests that this is the true picture. The small quantities of fishbone in some of the CNG II samples is due to their small overall size(Table 7) and the decreasing numbers of bones through the Priory deposits can be explained by a special factor,the season of occupation(Chapter 5). The overall frequecies of elements at these sites are similar to Cnoc Coig and the two special patterns are also visible. The under-representation of branchiocranial elements is clear in samples from the Priory(2 & 3) and this is interesting because the sizes of fish are intermediate between the two groups at Cnoc Coig. The second one,marked by concentrations of the branchial bones,is shown by CNG II sample R(Table 7). The recognition of the same patterns at all sites is interesting as it suggests that all the sites functioned in the same way but it does not directly advance the understanding of processing activities.

Interpretation

The archaeological data has provided some evidence of the ways that saithe were handled. The units of discard are taken to represent the groups in which fish were used. They range in size,although more concentrations must be analysed before this can be quantified,and at least some of them consist of a single size group of fish. This could be the result of selection in processing or reflect the groups in which they were captured(Chapter 6). The recognition of articulated vertebrae and associated otoliths shows that some skeletons were deposited intact and the identification of gutting waste is evidence of some processing of the body. The interpretation of the latter is limited however as it does not prove that the viscera were not used in some way and gutting is a step in most processing activities. The conclusion must be that our understanding of how the fish were utilised is fairly meagre and there is no data on such important issues as the proportion of a fish eaten or whether any fish were preserved.

The discussion of processing activity therefore can only conclude with an account of the potential forms of utilisation of this species. This is based principally upon historical sources as there were very important subsistence fisheries for young saithe until this century particularly in the north and west of Scotland;the fish was described as 'the treasure of the Orkneys'(Low 1813,193) and was exploited throughout the Scottish islands. The fish was taken mainly as food,for use in preserved and fresh forms,but also had some other applications. The chief of these was the oil obtained from the liver (train oil) which was used for illumination and in tanning (Cutting 1955,171;Loder 1935,186),while surplus catches were used as manure(Day 1880-4,296).

Opinions seemed to vary about the quality of the flesh, but this is also related to the size of fish and time of year when it was caught(Low 1813,193-4). Some of the inhabitants of Colonsay today fish for the species on a limited basis but the older residents can recall much more extensive reliance on the fish. The first year fish are ignored because of their size although there is no objection to eating them;the second year fish are caught in considerable numbers but most of these are stored in brine for creel bait. Some are gutted and beheaded,although the older fishermen were observed only gutting them,cooked in various ways and eaten fresh;they are a bony fish and must therefore be filleted or eaten with care. Occasional specimens that have been salted and dried can be seen but the practice used to be much more common;the fish would be gutted,sometimes beheaded,and then salted before drying in the open air.

Large quantities of the fish were eaten fresh,either fried, poached,grilled or baked(Davidson 1979,59). As the livers were highly regarded it was common for the fish to be roasted whole (mougeldings) on a gridiron(Firth 1974,102) or to be dighted through the gills and then stuffed with the liver(Davidson 1979, 59;Low 1813,194). Large numbers of the fish were also salted and dried:

> 'The piocach(seath or coalfish) hung up to dry,
> For winter store a good supply...'
> (Murray 1887,70).

The procedure followed in the Orkneys is well-documented(Firth 1974,101-2);the fish were dighted,soaked in brine overnight, then strung up on 'speets'(either pushed through the mouth or tied in pairs by the tail) for drying. Often they were hung over the fire suspended from the ceiling(Fenton 1976,175-6,197; Rendall 1974,91) but they could also be dried in the open air (Cutting 1955,170;Rendall 1974,91) or in kilns(Fenton 1976,197). The fish become hard and can be stored until needed when they would be soaked, skinned and boiled(Davidson 1979,59;Fenton 1976, 176). Young saithe were also caught in other areas, such as along the coast of Norway, and seem to have been treated in similar ways with both fresh and dried forms eaten(Smitt 1892-5,503;Paine 1957,143).

The references to the exploitation of the fish in Scotland are not always very clear and there are some ambiguities but three main patterns of activity have been recognised:

i.small first year fish eaten when fresh;often cooked whole.

ii.larger fish eaten fresh;gutted and sometimes beheaded and filleted.

iii.preserved fish;gutted and sometimes beheaded, then salted and dried;only the flesh eaten;assumed to be the larger fish.

This data can be used to estimate the proportion of the fish that could be considered edible. For the larger fish only the flesh of the fillets seems to have been eaten;there is little meat on the head and the body is particularly bony. The amount of flesh on a similar sized species(whiting) amounts to 47% of total weight(Barker 1968,121). This estimate has been checked by a study made on a sample of 21 saithe, belonging to the larger size class(Table 10);the average value for flesh from the body is 51% of the total weight. This should be regarded as the minimum percentage of edible meat, assuming that the fish were handled efficiently, as there is evidence that the liver was commonly eaten and that the smaller fish could be cooked whole. Therefore, figures of 50 and 60% provide the best estimates of the edible proportion of the fish;details of the chemical composition of the flesh are given in Table 11 and resemble those for other gadoid species(cod family).

Other species

The evidence for the other species of fish has nothing to add to the discussion of processing activities. They are present in such small numbers that it is not worth assessing their abundance or frequency of skeletal elements, and no traces of modification of the bones were noticed. There are no concentrations of these species(Table 5) and their scattered distributions,with only isolated bones in many samples,raises additional problems in explaining the discard pattern;some form of postdepositional movement seems logical although this might contradict the evidence for the saithe. Similarly,associated groups of bones from large fishes have been recovered from the trenches,including five consecutive ling vertebrae and cranial elements from a conger,but this only leads to speculation about the location of the rest of these fishes.

There is indeed no evidence to demonstrate that these fishes were utilised but there seems no reason to doubt that they were eaten. Their contribution to the diet would have been minimal,except perhaps in terms of variety,although the larger fishes would represent a quantity of meat equal to several saithe. No data on size reconstruction is available for these species ,there is no evidence on the proportion of the fish eaten,and even quantifying the numbers of such fish is difficult(Chapter 3). Some figures on the average sizes of species, along with their composition,is given in Table 11. All the fishes are edible although some are generally ignored,either on the grounds of size(shanny,sea scorpion) or flavour(wrasse, monkfish,dogfish) and historical accounts demonstrate that they were eaten both in a fresh state and in various preserved forms.

CHAPTER FIVE
SEASONALITY

Food procurement strategies in temperate latitudes have to take account of the seasonal fluctuations in the availability of most resources. Economies have adapted to this situation in a number of ways. The minimal response is to limit the population to a level that can be supported during the period of least abundance. The alternative is to develop the economy by exploiting a larger territory,intensifying the use of particular resources,or broadening the subsistence to include additional foods. One further method of coping with varying availability of resources is the development of food storage techniques. The latter is much more widely used among food-producing groups although the problems of fluctuations in the food supply apply equally to food-collecting economies (hunting,gathering,fishing).The latter are consequently characterised by seasonal variations in their food supply, usually associated with a succession of occupation sites through the year. These features are widely used by prehistorians as the basis of a model for understanding such economic systems(Clarke 1976,469;Coutts & Higham 1971,266;Fitzhugh 1975,353,379).

Seasonality in the exploitation of resources and occupation of sites can be investigated in a number of ways(Rowland 1977). These can be grouped into two main approaches(Akazawa 1980,338;Coutts 1975b,244;Smith 1976,287-9). The first of these models the availability of resources from what is known about their behaviour patterns or on the basis of contemporary and historical exploitation systems;the results are therefore inferential although they can be used in predictive studies. The second approach is of more restricted application and is based upon direct archaeological evidence for the season of death of animals;the shedding of antlers and growth lines in mollusc shells are the best known examples(Coutts & Higham 1971, 226). This section considers how each of these can be applied to fishes and the ways that this has been handled in archaeological studies.

Modelling subsistence strategies

To establish the validity of using inferences from animal behaviour to predict exploitation strategies it is necessary to critically examine the principles of'resource use scheduling';this seeks to establish and explain the seasonal patterns of resource use and proportions in which different foods are utilised. For this,features of both individual resources and of the exploiting economy are considered(Mikkelsen 1978,89); most studies appear to agree on the criteria that are important in such choices:

i.Mikkelsen(1978,89) considered changes in animal densities, their behaviour patterns ,and their availability to human populations,

ii.Poiner(1976,188-9) in a comparative survey of coastal hunter-gatherers identified the range of resources available,their abundance and their predictability;accessibility was also a significant factor but this is dependent on the other variables and on the available technology,

iii.Bulmer(1976),in a study of the Kalam of New Guinea,found that the extent to which resources were used depended upon: their population density;the extent and proximity of their habitats to the homestead;the degree of domestication;the ease with which they could be caught;the skills,knowledge and technology of the group;the seasons in which they were hunted;and the relative economic and ritual values attached to resources,

iv.Jochim(1976) proposed two main goals in resource scheduling which could be calculated from various attributes of each resource:

$$\text{Reliability of resources} = \frac{\text{weight x non-food yield x density}}{\text{mobility}}$$

$$\text{Limiting of effort} = \frac{\text{weight x non-food yield x aggregation size}}{\text{mobility}}$$

The model would also have to take into account secondary goals, such as taste,variety and prestige,and technological factors including hunting gears and food storage systems.

Thus the extent to which a resource is exploited and the pattern of utilisation depends upon several factors and the abundance or density of the resource is only one of them:

> '..duration of availability,season of availability and congruency of fish with other resources would determine the degree to which anadromous fish would be exploited by humans,<u>regardless of abundance</u>'
> (Schalk 1977,242).

One point to emerge from this is that it may not be possible to predict the use pattern of single resources in isolation; the relationship with the available technology and with other resources must be considered. An example of where this would be important would be circumstances where two resources have coincident periods of optimal availability. A further problem which could undermine the validity of the technique, rests with the basic aims of the procurement strategy. Resource use scheduling is based on optimising solutions and this may not always be appropriate. For example, in 'high risk' environments stability and reliability may be more important goals than maximising yield; this would favour generalised strategies rather than more 'efficient' specialised ones (Schalk 1977,228). In any situation there will be a range of options and it cannot always be assumed that the apparently preferential choice will be followed.

Seasonal patterns of fish exploitation

This section considers those aspects of fish behaviour that are likely to influence the extent to which the resource is utilised. In most situations fishing is a 'hunting'-or a capturing (Hewes 1948,240) or food-getting (Ingold 1976,90)-activity in which control over the environment and the resource is limited (Andersen & Wadel 1972,153). Fishes are cold-blooded animals and so their body temperature and metabolism are closely related to the temperature of the surrounding water; the annual climatic cycle in temperate latitudes produces a marked seasonal patterning in the life of fishes in this zone. One more introductory point is that fishes differ greatly in their behaviour and so the tendency to lump them all together in one resource group may be misleading. From the studies mentioned above the most important factors governing the exploitation of a resource appear to be its abundance, predictability, accessibility and availability of other resources:

<u>Availability of other resources</u>: this emphasises that the exploitation of a resource cannot be considered in isolation. The main point to look for is when two or more resources coincide in the period of optimal availability; in such cases priority decisions are based upon a variety of criteria. A classic example of the tension in a dual economy is provided by the farmer-fisherman crofting system (Coull 1971). In Norway the two activities are easily combined because the peak of fishing falls in the winter when the demands of farming are low; but in Scotland the labour requirements of both are greatest during the

summer and the system is strained with much of the farmwork falling to the women(Grant 1961,262). It is interesting to note that in both areas this system seems to have developed through commercial pressures and not as a response to resource availability(Paine 1957,101).

Accessibility: the 'catchability'(Leach 1979,110)or vulnerability of the fish to the fisherman is important in determining the'effort'of fish capture. It depends upon:the behaviour of the fish,on whether it occurs in locations,such as shallows or close to the shore,which minimise effort and risk;the types of fishing gear etc. that are available;and on whether environmental conditions are favourable,with an obvious bias against the winter(Landberg 1975,159).

Predictability: The major components of this are the overall stability of the system and the regularity in the timing of events within the life cycle. Aquatic environments,and particularly the marine system,are fairly stable(Odum 1975,171);there are fluctuations in distribution and sizes of stocks but they are less than for many terrestial species. The marked regularity of the timing of events in the annual life of fishes has been stressed in many studies,in such things as date of spawning,migration runs etc.(Cushing 1969;Schalk 1977,220). Thus fish are a reliable resource,in the quantity and time of year they are available.

Abundance: this can take into account the sizes and condition of fish as well as their numbers. Many fish are mobile and the numbers of fish at any location will vary through the year. Densities are highest when the fish temporarily congregate on grounds for spawning,feeding or migration. The advantages of fisheries at such times are that mass capture gears are efficient in such situations and that the volume of water to be searched for a given quantity of fish is minimised.

Intensive exploitation of any species is likely to be concentrated on the times when various attributes of the resource,including abundance,accessibility and condition,are maximised. All of these vary markedly through the year but there are occasions when some or all of them are found together and these are obviously times for optimal fisheries. The circumstances will depend upon individual species and populations,but in general terms periods on the spawning and feeding grounds,and migrations to them,meet these criteria:

Spawning: as the time for spawning approaches fishes may comply with all the requirements for a fishery:

> 'Fishes are in best condition and provide most calories per pound just before spawning, and during that time they also become most readily available to the fisherman, for then many species approach shallow water or run up into small streams, while others ascend the rivers from the sea' (Rostlund 1952, ix).

Spawning is a predictable event in the life of fishes(Cushing 1969), both in the location and regular timing of the event (Cushing 1974, 400). Many species congregate at this time(Norman & Greenwood 1963, 215) and the grounds are often in shallow and protected waters(Norman & Greenwood 1963, 225). They have built up reserves of fat which become depleted through the season and the roes of many fishes are highly regarded(caviare etc.). The salmon is the ideal illustration of the case, except that they are one of the few fishes to spawn in the autumn; most species have their season in the spring or early summer.

Feeding: behaviour is more varied during the main summer feeding season but with the increasing quantities of available food aggregation on grounds or in open water is a favoured response. The fish increase in condition as the season progresses as a build up for the winter period.

There are other occasions when exploitation is favoured, eg. some species winter inshore, but they are more limited. Alongside the periods of maximum availability there are ones when the fish are least available, either because they move away or if they disperse and become inactive. For many species this coincides with the winter months when the lower temperatures limit the food supply and inhibit activity; some fishes respond to this by dispersal(O'Farrell 1971, 104) while others enter a state approaching hibernation(Nikolsky 1963, 258). As a final point it should be stressed that these are general observations and individual species, and even populations and age groups within them, will be characterised by different patterns of behaviour. Therefore discussions on a fish fauna should be based upon specific species and take account of the variability that will exist within the group of fishes.

Resource Scheduling and fish remains

It is very common in archaeological reports to make inferences about the seasons of occupation from the presence or absence of certain species(Munson et al 1971, 427). Because of their marked variations in abundance through the year fishes have formed one of the main sources for such interpretations. Examples in the literature are too familiar to require illustration but a number of points deserve mention. Presence of a species is a much stronger attribute than its absence;negative evidence can be accounted for by other factors,such as preservation conditions(Rowland 1977,142). Fish behaviour is very variable and so comparisons should be specific;based upon individual species,or even stages in the life cycle if appropriate,rather than on groups of fishes. In this context it is worth comparing Jochim's predictive model and the actual pattern of fish exploitation by the Round Lake Ojibwa(1976,43). There is a good general agreement with the period of maximum utilisation during the spring-summer spawning season but it failed to recognise a secondary peak in the autumn coinciding with the availability of the autumn-spawning whitefish. These fish should have been treated as a separate resource group because of their different pattern of behaviour.

One of the strengths of Jochim's system is that it does attempt to integrate resources within an economy. Other studies use various lines of evidence to support interpretations(Simonsen 1965,400-1) but this does not explain why particular resources are chosen,and in particular what happens when they are coincident in their occurrence(Wendorf & Schild 1976,286). A problem with all such modelling is that it is based upon optimising solutions stressing exploitation at times of maximum availability(Finlayson 1977,482-3). Yet there are other strategies and these receive scant attention(Kaelas 1976,134);besides ignoring fish because of competition from other activities (Rostlund 1952,147) they can be used to supplement the diet, provide variety,or as a back-up when the regular foods fail. The intensity of exploitation may provide an indication,as a concentration on a resource is most likely to coincide with its availability;this could be recognised by the size of the catch or the elaboration of the technology used to procure it. Most fishes,like other resources,are capable of being taken over a period of time(total availability) within which there are shorter episodes when they are most accessible or abundant(optimal availability). Thus interpretations based upon optimal availability are only statements of probability and an important development is the appearance of methods aimed at quantifying these probabilities. By calculating the proportion of the annual catch likely to be taken in each month,it is possible to assess the likelihood of capture at any particular time of the year. This is one of the results of the development of resource use scheduling(Jochim 1976) or the figures can be derived from fishery statistics(Leach 1979) as long as they are comparable with the archaeological situation(Butts 1980).

Age determination of fishes

The study of age and growth is an important branch of fisheries science;the behaviour and population structure of fish stocks are difficult to monitor and it has been necessary to develop techniques for evaluating them from small samples of fish. This is an enormous field with an extensive literature(de Bont 1967;Chugunova 1963;Graham 1929;Iles 1974;Tesch 1971;Weatherley & Rodgers 1978) and only the most important points can be covered here. Before the techniques used for age determination are described it is necessary to understand the nature of growth in fishes,as it differs in important respects from other vertebrates.

Growth in fishes: The pattern of growth must be analysed on two separate scales;growth through life and the rate of increase through the year. Most fishes,unlike other vertebrates, continue to grow through life even after reaching maturity (Iles 1974,334). The size of annual increments varies with age and the pattern of growth through life approximates to a sigmoid shaped curve. The amount of growth increases until maturity and then drops off toward senility,although in relative terms growth declines through life(Rounsfell & Everhart 1953, 311-4);for example,cod fry grow less during their first summer than in the second year,but this represents a 3-4 times increase in length as opposed to a doubling in size of the yearlings (Wollebaek 1900,104). It is possible to divide the life of fishes into a number of periods on the character of growth at each stage(Nikolsky 1963,201-2);the clearest division is into the period prior to maturity when there is rapid linear growth and that following it when effort is diverted into sexual development and size increments decrease.

Growth is a complex process,the result of internal physiological responses to a series of external influences which include the length of the photoperiod,pH and salinity values.

The most important of these are temperature and the available food supply(Fulton 1906,18;Weatherley & Rodgers 1978,67).One way in which fish respond to conditions is to vary their rate of growth. As they may continue to grow throughout their life at rates which depend upon individual circumstances,their growth can be classed as indeterminate(Weatherley & Rodgers 1978,64);there is not a definite final size for all fish within a species. Such variability in growth is particularly marked among freshwater fishes(Iles 1974,331) where populations from different water systems can exhibit quite distinct growth patterns;for instance stunting is common in overstocked waters. Size variations are apparent not only between populations but between individuals of the same species and age within them(Purdom 1974,348);these become particularly marked during times of stress(Nikolsky 1963,206).The distribution of values within such groups of fish will approximate to a Gaussian or normal distribution(Ricker 1979,692).

Growth does not take place at a constant rate through the year and shows a clear seasonal pattern(Nikolsky 1963,190). This resembles a sigmoid curve(Iles 1974,337;Ricker 1979,719) with growth increasing through the spring and summer and then falling off. Thus the year can be divided into two periods;the 'summer' when growth is rapid and the 'winter' when it is at a slower rate(Chapman 1978,7). For example,cyprinid fishes(of the carp family) in north-west Europe make most of their growth from June to September and almost none is recorded between November and March(Steinmetz 1974,148). The most observable point in the annual cycle is the resumption of growth in the spring following the winter slowdown or even cessation. If the annual pattern is superimposed upon the life cycle of growth then the latter is transformed into a series of waves of growth. These 'waves' are not necessarily identical in form through the life of the fish,particularly in the timing of stages during the year;for instance the period of body or somatic growth is often shorter for older,mature fish because much of the growth is channelled into sexual development.

Age determination: With the exception of fish reared in captivity or the occasional recovery of tagged individuals,ageing has to be based on intrinsic properties of the fish. Two techniques are widely used to age such fish,one employing size and the other growth marks on the bones. A large range of terms are used to describe the age of an individual and some explanation of the main ones is appropriate. All fish born in the same year can be assigned to a group;either referred to as the 'year class' or the 'age group'. The actual age may be specified according to various systems,either numerical or based on stages of life(larvae,fry,yearling etc);the most straightforward,and therefore preferable,is to call fish according to their age in years(first year,second etc) or by the fisheries system of O-group,I-group etc. The designation of fish to a particular age group/class and correct year is simplified by the restricted spawning season of most fishes; therefore individuals born in a year tend to form a clear group. If necessary,this can be further simplified by adopting an arbitrary birthday for all fish in a species;January 1 is often used and is reasonably close to the spawning season of many fishes(Chugunova 1963,5-8;Tesch 1971,106-7).

The simplest method of age determination is the Petersen length-frequency method(Chugunova 1963,110-112);the sizes of a group of fishes are plotted on a histogram and the modal values are taken to correspond with successive age groups.This employs the restricted spawning season of populations which ensures that individuals of the same age are of similar size. However,it is not always applicable as it depends upon a short spawning period,and relatively fast uniform growth within the population. Apart from species that do not meet these criteria other limitations exist such as when more than one population is represented or where older fish are present;the problems with the latter are the small numbers of fish of such ages and particularly the decreasing growth rate which results in increasing overlap of size ranges(Weatherley & Rodgers 1978,56). It is not an exact procedure but it is useful as a simple method of studying large samples rapidly.

The second method is more sophisticated and requires the collection of certain'bones'from the body of the fish;bone is a somewhat misleading term as much of this work is done on the scales and otoliths. The technique is to count the number of growth rings,or annuli,visible in these structures,each of which corresponds to a year of growth. On a very simplistic level this can be understood by referring to the patterns of fish growth. As the increase in bone size corresponds to the growth of the fish there will be a pattern of annual increments together with seasonal variations in the rate of increase (Nikolsky 1963,190). Thus the majority of growth is recorded during the spring and summer with much less over the winter months;Casselman observed that 80% of linear growth in the cleithrum of the pike occurred in only 22% of the year(1974, 13). These periods of faster and slower growth are reflected by differences in the structure of the bone deposited and in some elements,particularly the otolith,two clear zones are visible within each annual increment. However,the clearest division is at the end of a year's growth when rapid summer growth succeeds the winter ring;this is the annulus which is counted to estimate the age of the fish.

The extent to which annuli are visible varies according to the bone and between species. In general,the best structures are flat bones such as the operculum where growth is almost linear,and cylindrical forms,including vertebrae and fin spines, where concentric rings are laid down(Lagler et al 1962,174). The technique is very widely used in fisheries work and its validity has been firmly established against independent age assessments(Blacker 1974a,87-90). Inevitably ,there are problems with the procedure as growth is a complex and little understood subject(Casselman 1974,13;Nikolsky 1963,196).Because the causes of annulus formation are not fully understood it is necessary to establish the validity of the method for each body of material studied(Blacker 1974b,113). Besides the practical problems encountered in trying to read the rings,when they are obscured by subsequent growth,crowding etc(Blacker 1974b), difficulties arise when there are additional rings or alternatively some are absent. Supplementary or secondary rings are formed when the growth pattern of the fish is disturbed;these false 'winter' rings can be induced by the stress of spawning (de Bont 1967,71),or changes in diet for example. Less common are occasions when rings are missing which may occur when growth is so slow that changes are not recognisable.

These difficulties are not fundamental but illustrate the need for caution in applying the technique. One aspect of this is the choice of the most appropriate element for such studies. Annuli are not visible on all bones and some are less difficult to read than others. A range of bones have been studied(Nikolsky 1963,100-3) and it is clear that the best element varies according to species and families of fishes. Scales are used for the Salmonidae and Cyprinidae(Chugunova 1963,17-43),otoliths for the Gadidae and Pleuronectidae(Blacker 1974a;Williams & Bedford 1974),and a range of others in more limited circumstances(Casselman 1974;Frost & Kipling 1959). For more detailed information on age determination in fishes reference should be made to sources mentioned in the text and to papers in Bagenal(1974).

Archaeological applications of ageing

Both of the techniques of age determination can be used for archaeological fish remains although only a few of such studies have been made. Size reconstruction is quite simple (Chapter 3) but inferring age from fish size is less reliable because of the indeterminate nature of fish growth;except for the smallest stages a fish of a particular size could be various ages. However,the relative sizes of individuals within a sample can be used to reconstruct the age structure if clear modes exist in the range of length frequencies. The actual age of fishes can be established from the number of growth rings on their bones. Archaeological studies face the same limitations as in fisheries work(Wheeler 1978a,73) together with the handicap of the preservation and condition of archaeological specimens. The two elements most widely used in such work,otoliths and scales,are rarely found in archaeological deposits or are in a damaged state(Wheeler 1978a,71).

Besides their use to establish the age of fish the techniques might be used in other ways. For example,in the reconstruction of growth rates by back-calculation(Chapter 3),although the validity of this for archaeological material seems dubious. As patterns of growth differ between populations this can be reflected in the structure of growth rings,and this has been applied to fish stocks(Messiah 1972;Rauck 1974;Trout 1954, 89);it is possible that archaeological specimens could also reveal such detail. The age reconstruction of assemblages has two main applications;the age structure of the catch can be compared with that of a natural population to identify selectivity in the fishing method(Ekman 1973,58;Shawcross 1975,57-9); and to recognise age-dependent behaviour patterns for different age groups of a species(Akazawa 1980,336-7).

The most important application for age determination lies in extending the techniques to identify the time of year when a fish died. Fish size could be used although the variability in growth rates really restricts this to fish in their first year(Bowler et al 1970,53;Parmalee et al 1972,21-2). Growth rings are well suited to such an application,based upon the amount of growth recorded since the last annulus(Iles 1974, 336). If the time of annulus formation and the rate of bone deposition are known then it is possible to establish the time of death precisely. Further refinement is possible for elements which display two clear zones within the annual growth; the otolith is a good example of this. This has great potential but a thorough understanding of the principles of age determination is required;the problems can be demonstrated by one of the few archaeological studies published(Casteel 1972b,408-9). Casteel examined the growth rings on vertebral centra and by dividing the growth into three stages was able to recognise a clear seasonal pattern in his samples,but with a minor problem:

> 'a consistent value of from 12% to 14% of the readings which do not concur with the majority'(Casteel 1972b,409).

These he dismissed as the result of reader errors or the presence of extraneous material in the samples,but there are other explanations related to the manner of annulus formation. Different species,and even age groups within a species,can vary in the times of zone formation,and so the inclusion of a range of fish in a sample may recover this variability;this is why elements that can be identified to the species level are preferable for such studies. The other point to note is that growth is a complex process and annulus formation should not be regarded as a simultaneous event affecting all members of a population;it occurs at different times among individuals and so at any time there will be fishes at different stages of development and it is rare to find them all displaying the same condition(Gambell & Messtorff 1964,395;Trout 1954,100). This does not invalidate the procedure but should caution some care in its application.

Seasonality: Oronsay

The occupation of a series of sites in an annual cycle has been established as a characteristic of hunter-gatherer populations in temperate latitudes and is widely used as a framework for European mesolithic studies;several examples are given in the volume edited by Mellars(1978). The season of occupation is obviously a fundamental interest in the investigation of the Oronsay middens,especially with the existence of a number of similar sites on this small island;the exact chronological relationship between them is still not certain but they are contemporary in terms of radiocarbon years. One possibility,therefore,is that they functioned together as part or all of the annual cycle of a single group. Because of the importance of this question and the aptness of fish remains for such studies most attention has been concentrated on the subject;various methodologies have been tested including resource use scheduling,fish size analysis and the study of growth rings. Attention has been focussed on the saithe for a couple of reasons;because of its abundance in the fauna and also because it proved to be very suitable for such work.

Resource use scheduling

The aims in such studies should be to establish,firstly, the time during the year when a resource is available and from this the season when it is most likely to have been utilised. The evidence presented here is based upon what is known of the behaviour of the fish and on the evidence of historical and contemporary fishing practices:

Behaviour of the saithe: The life history of the species has been briefly described earlier(Chapter 2) and almost all the fish in the middens belong to the inshore or 'littoral' stage of its life(Bertelsen 1942,16). This lasts for some three years and during this time the fish remain fairly close to the shore and are static with little movement along the coast(Jacobsen pers.comm.). However,there is a series of 'migrations' away from the shore during the winter and back in the spring(Figure 16). The exact nature of these movements is not well documented but the fish probably move out only to shallow reefs;it is suggested that the distance involved may depend upon temperatures and local conditions(Kennedy 1969,318). The timing of these movements appears to vary according to location and the age of the fish. As with most other events in the life cycle there are differences between the northern part of the range and more southerly areas;in the Barents Sea the offshore move is completed by December(Baranenkova 1959,7) whereas in British waters they remain through the early part of winter(Kennedy 1969,318). In all regions there is a pattern with the older fish(second and third year) moving away before the younger ones;in the Barents Sea in September/October and December respectively,as compared with the end of the year and later in the winter on British coasts. The mechanism that triggers this movement is not known but in the Kattegat it was observed that the fish only disappeared when the temperature dropped below 0°C(Poulsen 1934,83).

After their first and second winters offshore the fish return to the coast in the spring;in British waters observations suggest that this is from the end of April onwards. For a while the littoral population is made up of fishes which are entering their second and third years but as summer progresses the older saithe range more widely in search of food;they reappear in numbers in the autumn before leaving the coast for the last time. Early summer also sees the arrival of the fry inshore in large numbers from May/June onwards(McIntosh & Masterman 1897,268-9).The first year fish stay very close to the shore in only a few metres of water while the second year saithe are found more widely in slightly greater depths. Thus the location, abundance and the ratio of the age groups varies greatly through the year(Figure 16) and this provides the opportunity for a number of different systems of exploitation.

Fisheries for young saithe: The inshore stage of the saithe are not seriously fished today but up to the early years of this century they formed the basis of very extensive fisheries. These were found throughout the range of the species,including Iceland(Saemundsson 1929,5),the Faroes and Norway(Meek 1916, 221),and off the north and west of Scotland. The latter area is very well-documented,from Shetland(Fenton 1976;Goodlad 1971), the Orkneys(Low 1813;Firth 1974;Rendall 1973) and the Hebrides (Mercer 1974). Details of the timing of the fishery and of the size/age of fish caught are not always clear from such accounts but two main fisheries seem to be represented.

In early summer(May onwards) the second and third year saithe would be sought from boats as they reappeared on the coasts(Davidson 1979,58);the references suggest that effort was concentrated on the larger fish(Darling 1947,173;Low 1813,194), which were in good condition for eating fresh from the sea (Day 1880-4,296). A more extensive fishery took place between late summer and winter using various gears(see Chapter 6) mainly from the shore;autumn or winter is given as the season for this activity when the fish were said to be very abundant. The fishery took first year fishes,which had reached a reasonable size by then,as well as older saithe;and they were taken as a source of oil,and even manure from surplus catches, in addition to being eaten fresh or preserved for winter use (Chapter 4)(Cutting 1955,171;Fenton 1973,77:1976,174;Goodlad 1971,71,119). Both fisheries were practised in the same areas and were not exclusive of each other(Low 1813,194;Day 1880-4, 296). Thus it seems that saithe were taken through much of the year apart from the late winter-spring quarter with an emphasis on the'autumn'fishery.

The scale of fishing by the residents of Colonsay is now much less than it was in the early part of the century. The first year fish,or 'cuddy',are not caught at all although they are visible in the harbour during the summer and autumn; the effort in capture is held to outweigh the catch. When saithe is wanted it can be obtained by a boat fishery for the older fish. This takes place in the summer and autumn months and they say that this coincides with the availability of the fish. However,other factors also seem to play a part;the fish caught in the summer are mainly eaten fresh,and they are taken with mackerel which seem to be more highly regarded,while many of the autumn fishes are stored in brine for use as creel bait over winter. Their reasons for not fishing at other times of the year seem to be based upon tradition,although weather conditions and the dispersal of the fish over winter will be mentioned if they are pressed. The older inhabitants can recall when saithe fishing was more important,and in particular for the cuddy in the autumn and winter,and older fishes for drying as winter food(Loder 1935,186;Murray 1887,170).

Young saithe are to be found in inshore waters throughout the first three years of their life but from what is known of their behaviour they can be regarded as relatively inaccessible during the 'winter' period of their offshore movement. Their total availability,therefore,spans the rest of the year. In Hebridean waters this will extend from late spring,when the second and third year fish return to the coast,through to the early winter,when the first year saithe move offshore(R Murray pers,comm.). This is supported by the timing of the samples taken off Colonsay and Oronsay for this study(Appendix 2):from the end of April through to mid-December for fish in their second year of life.

Within this period the location,abundance and ratios of the different age groups vary to a great extent;this can be illustrated by data for the Faroes(Figure 16) although the figures,particularly on timing and size,are not directly comparable with the populations in Hebridean waters. The definition of the season of optimal abundance therefore depends upon which aspect of the catch is being maximised. The largest numbers of fish will be available in the months immediately following the arrival of the fry inshore:May-June(Lie 1961,5), late July and early August(Bertelsen 1942,22) or September (Meek 1916,222). However,in early summer(Kennedy 1969,318) when the fry are most abundant the second and third year fish are more dispersed and they are found in greatest numbers close to the shore in the autumn(Low 1813,193). Maximum availability, in terms of numbers of fish,will depend upon the age groups being fished but another variable also deserves consideration. The fish are growing rapidly at this time,especially if it is looked at in terms of the rate of increase in relative size; for example they double in length,and increase more dramatically in weight,through the second growing season. Therefore, if total meat yield or the size and condition of individuals are the variables sought in the fishery the period of optimal availability is shifted to later in the year.

These differences appear to have been fully understood in the fisheries for young saithe. The main emphasis on the autumn months coincides with the presence of second and third year fish close inshore and the end of the growing season for them and the first year fishes;the size of individuals and numbers of fish made fishing viable,with both single and mass capture gears(Chapter 6). The quantity of fish yielded large amounts of liver oil,with surplus catches as manure,as well as human food. The early summer fishery on the other hand appears to have been more selective concentrating on fishes entering their third year;these were of good size,in reasonable condition,and available at this time before dispersing through the summer. However,exploitation depends not only on natural availability but is also influenced by the requirements of the wider economy and these must be considered before the pattern of a fishery is taken to mirror abundance of the species. The saithe fisheries were a crucial element in the survival of the poor in the Scottish islands in the last century. The economy was agricultural but there does not seem to have been competition between the activities for labour;indeed,the fishery could be carried on by the children and older inhabitants(Fenton 1973,Plate III). However,the fish were needed at times in the year when other foods were not available, especially in the summer before the harvest and to supplement the winter diet(Fenton 1976,175). This helps to explain the emphasis at two points in the year,early summer and autumn, although they do appear to coincide with periods of optimal availability. These seasons of activity should not be taken as reflecting the total availability of the fish;they are found close to the shore for some nine months of the year and the exact time of a fishery will depend upon the variables being sought in the catch and the needs of the overall economic system.

Fish size and seasonality:the background

To use fish size for age determination all individuals of the same age must be of similar size and quite distinct from those younger or older;these conditions are most likely to be met in species with restricted spawning seasons,fast relative growth and geographically separate populations. The saithe meets these conditions and length frequencies are widely used for ageing the young fish(Bertelsen 1942,24;Saemundsson 1929,7). The mode of the first year fish is always distinct (Kennedy 1969,322;Liao 1951,94) while there may be a small degree of overlap between the ranges of second and third year fish(Kennedy 1969,322;Saemundsson 1929,10). For older age groups the size ranges become increasingly mixed up and growth rings have to be used for ageing(Reinsch 1976,27-30). To use fish size to determine the time of year of death the criteria are even more exacting. A total separation of values between groups of fish caught over a few months is obviously not possible but even to identify the modal values there must be a tight distribution of values and fast growth. The potential for such studies on the saithe was demonstrated by Wollebaek in illustrating the rate of growth of first year fish(1900, Table 6).

The pattern of growth of the species is well-documented. Annual increments approximate to a sigmoid-shaped curve,with fairly rapid growth recorded for the first seven or eight years of life(Rojo Lucio 1967,9). The fish grow some 150mm in each of the first three years,100mm in the following three,and then increments decrease steadily thereafter(Smith & Hardy 1971,3). Differences in the rate and pattern of growth occur across its range,with populations to the south growing faster than those at the northern margin of its distribution(Reinsch 1976,30-53). There are a number of studies which provide detail on the rate and pattern of growth of saithe during their inshore phase(Appendix 3). None of them provides a comprehensive account of the subject but together there is sufficient data to reconstruct the overall pattern of growth,the range of variation within a population,and the variability through time and between populations.

Pattern of growth: Growth during the year conforms to the sigmoid curve(Figure 17),increasing through the spring and summer and then falling off towards winter;the growing season lasts from April through till December,with rapid growth recorded between May and November(Liao 1951,100;Mironova 1961, 449). The exact dates and length of the growing period may vary between localities but this is difficult to document because data on the end of the year and through the winter is poor in all cases. The same pattern is recorded in each of the three years,and presumably in later life,but the size of the increments differs.

The saithe fry leave their pelagic stage when they reach a length of 25-30mm and seek the shore. During the following month they double in size,with an increment of 30mm;all the figures presented here are taken from the Faroes and may differ somewhat in other locations(Figures16 & 17)(Bertelsen 1942). Monthly increases of 20mm are recorded through the rest of the growing season,when the fish will have reached an average length of 140mm. In a couple of studies a temporary reduction in the rate of increase was noted in the summer(Bertelsen 1942, 30;Damas 1909,195);if this is real then it is probably related in some way to feeding activity(Liao 1951,96;Lie 1961,11).In both instances growth recovered and continued as in the other studies through to the winter slowdown. Over the winter quarter the fish increase in size by less than the average monthly increment of the first and second growing seasons(20mm per month). The same pattern of growth characterises the second and third years,with the fish reaching lengths of 270mm and 400mm towards the end of the respective growing seasons. From this it is clear that saithe grow rapidly during the inshore stage,averaging over 10mm per month in the Faroes and even more in more southerly locations(15mm). Within the year growth is seasonal,with some six months of rapid increase and a virtual standstill for three months. The values presented here are average ones and are not matched by all individuals in a population.

Variation within populations: Only one study documents the range of values within a population in any detail(Bertelsen 1942) and the figures here are somewhat exaggerated as they also include results from various localities and years(Bertelsen 1942,36)(Figure 17). When these other sources of variability are removed(see below) the range of values is still significant although it appears to be less than for many other species(Sund 1938,36). Variations in size within a population are brought about by a combination of factors:

i.date of spawning: the spawning season of the saithe is relatively short when compared to other species(Dannevig 1933,356). It is spread over some four or five months(January-April) (Reinsch 1976,61) but is more restricted in any one area,being earlier in the southern part of the range and later further north;in the Faroes it lasts some two months(February to the beginning of May).There can,therefore be up to two months difference in the length of the growing season of individuals in a population.

ii.immigration into the littoral zone: the fish move inshore when they reach a certain size and so if growth is fairly constant during the pelagic stage then the size differences related to date of spawning will be maintained in the time of arrival at the coast. Other factors do influence the immigration,especially currents,and these have been used to explain the bi- and multi-modal size ranges sometimes found among the first year fish(Bertelsen 1942,21);this seems more likely than the alternative of a protracted and irregular spawning season(Kennedy 1969,318). In the Faroes the movement inshore covers some

one and a half months(end of May to mid-July).
iii.the rate of growth: differences in the length of the growing season cannot account for all the variability and the range clearly increases through the year(Figure 17) so there must be some differences in growth rates. Competition and the available food supply are likely to be important factors in explaining this situation.The earliest fish to hatch will have a size advantage and will also be the first to occupy new niches in the habitat,and so must benefit from such advantages;this is easily demonstrated from the amount of growth made by the fish during their first month inshore, with the first arrivals increasing in length by over 40mm while the last add only 20mm. This difference is maintained, and even increases through the growing season.
iv.winter conditions: no samples are available for the winter period but those from the end of the first year and start of the second growing season suggest that the amount of variability is reduced over these months. This was interpreted as the result of selective mortality of smaller individuals(Bertelsen 1942,36) but more work would be needed to confirm the significance of these results.

The range of sizes increases through the second year, but at a slower rate than in the first year,presumably as the result of differences in individual growth rates. No data is available for the third year but a similar pattern can be inferred. The total range of values is thus quite large,reaching 170mm and 210mm in the first and second years respectively; however,relative to the size of the fish,expressed by the range as a percentage of the mean,it becomes less important through the two years(from 211% in the first June to 77% in September of the second year)(Bertelsen 1942,35-6). It should also be remembered that all these values are likely to be inflated as variations between populations and through time are included. The total range is not the only feature of interest in considering variability within populations;the distribution of values is also important. The length frequencies of each of the age groups approximate to unimodal normal distributions, with the exception of those multimodal first year samples mentioned earlier(Wollebaek 1900,Table 7);this can also be expressed by the tight interquartile ranges,which cover 50% of values,which amount to less than 20% of the mean length in the second year.

Variability through time: No attempts have been made to systematically sample locations over a number of years and so the extent of annual differences in rates of growth is not fully known. The main points are clear though from a number of incomplete observations(Bertelsen 1942;Lie 1961). The causes of the differences have not been established but temperature and the food supply are likely to be important. Lie interpreted the faster growth among first year fish as the result of the more abundant food supply in that year(1961,7). Bertelsen was able to demonstrate that the amount of growth recorded in the second growing season did not depend upon the size reached in the first year and that the size of increment could be correlated with the temperatures during the intervening winter months(1942, 44);he was not able to recognise a link between size and temperature for the first year but more data would be needed to confirm this. The extent of annual variation recorded in the Faroes amounted to 35mm in the mean size of fish by the end of the second year and some 20mm in the first year;this is equivalent to one and a half or two months growth in the second year and one month in the first year,but these are the extremes and differences were much lower in most years(Bertelsen 1942,43).

Variability between populations: The saithe has a wide distribution(Figure 9b) and differences in the dates of spawning etc. have already been noted,and so variations in the rate of growth between populations are to be expected;differences in size have also been observed on a more local scale.

i.local variations: the mean size of samples of fish taken from the same body of water show significant variations which cannot be fully explained by inadequate sampling. The clearest examples come from a number of fjords where saithe in the inner part appear to grow more rapidly;differences of 26mm in the mean size of samples from the inner and outer areas are recorded by the end of the first year(Lie 1961,8-9). This is presumably a reflection of better conditions in terms of food,shelter etc. inside the fjords although there is also some evidence that the earliest fish to move inshore colonise such parts(Bertelsen 1942,38).

ii,latitudinal variation: differences between populations have been noted in many studies(Saemundsson 1929;Bertelsen 1942). The correlation with latitude is clear from observations along the coast of Norway(Damas 1909);for instance,the size of the second growth increment falls from 160mm in the Skaggerak to 80mm in the Lofoten Islands. Data from a number of studies have been collected together in Appendix 3 and the results are summarised in Figure 18. The individual growth curves are not all directly comparable,as sample sizes and the measure of fish length vary,but the general relationships are clear. The rate of growth falls as latitude increases,from the Irish Sea (53^{o}N) through to the Barents Sea(71^{o}N).

Many factors influence the rate of growth but the relationship with latitude demonstrates the importance of temperature;this helps to trigger the time of spawning and other events in the life cycle as well as influencing the food supply, rate of metabolism and digestion etc. Latitude and temperature are not directly related as currents and the distance from land affect the water temperature;therefore it is more useful to use the latter for this study especially when the relationship with mesolithic conditions is taken into account(see below). When the rate of growth is plotted against mean annual seawater temperature there is a broadly linear relationship. The locations for which samples of fish are available span a temperature range of some 7^{o}C and over this range there is an approximate 10mm increase in fish length for each 1^{o}C rise in temperature. For example,in the middle of August the mean sizes of the first and second year fish range from c.50mm to c.120mm and from c. 180mm to c.250mm respectively(Mellars & Wilkinson 1980,32-3). The samples cover most of the range of the species except for the southern limit(Figure 9b) but it cannot be assumed that the rate of increase is maintained up to the southern extreme. All species have an 'optimal zone' in which growth reaches its maximum(Weatherley & Rodgers 1978,67) and the position of this zone within the range of the fish will depend upon the evolutionary history of the species;the position of this zone for the saithe has not been established but could lie off the northern part of the British Isles or further south.

Fish size and seasonality:growth of saithe in Hebridean waters

The extent of variability in the rates of growth of different populations documented above shows that it is essential to find a modern population that is directly comparable with the archaeological population that is being studied. One gap in the range of studies in Appendix 3 are the seas off the north and west of Scotland. Therefore it seemed desirable to undertake a study of littoral stage saithe in these waters, and in particular of the population around Colonsay and Oronsay. The details of this work are given in Appendix 2 but a couple of points should be made here, It was not intended to undertake a comprehensive study of the species but rather to collect samples to augment data available from other sources. Following on from this there are a number of weaknesses in the results and these are discussed below. Two sets of data were collected;on the rate of increase in bone size and a more limited examination of fish growth.

Rate of growth of the fish: In seven sampling operations the lengths of all fish caught were recorded;except for the first occasion tail-fork length(FL) was the measurement used. This number of samples is not adequate to establish the pattern of growth for the fish but this was not an aim of the work. Most of the aspects of growth had been covered by other studies and these showed similar patterns but with different values for each population. The results from Colonsay-Oronsay were needed therefore simply for comparison with this published data. When they are plotted against all the other mean growth curves it is evident that growth in Hebridean waters is relatively fast and agrees most closely with values for the Irish Sea locations (Dublin Bay and the Isle of Man)(Figure 18).The latter are some distance south of Oronsay but an equivalence in the rates of growth is not surprising because mean annual seawater temperatures are similar(c.10.5°C).

Rate of increase in bone size: The archaeological data for this study is in the form of measures of bone size and so two approaches are possible. A close relationship has been established between the size of a fish and its bones(Chapter 3) and it would be possible to reconstruct the sizes of the archaeological specimens,but there is an alternative that avoids this extra work and loss of precision. The size of archaeological bones can be compared directly with a growth curve constructed from modern material in the same manner as for fish size. The measure chosen for this study was the maximum length of the sagittal otolith;the element was chosen because of its abundance in the archaeological samples,the ease of the measurement and the straightforward collection of the comparative material. There were no existing studies to provide a basis for comparison,as there were for fish size,and so it was necessary to undertake a more extensive collection of samples of fish,again around the shores of Colonsay and Oronsay(Appendix 2).

Between 1973 and 1978 fifteen samples of fish were collected,of which three are composite with groups of fish caught at separate locations on the same day or at the same location on successive days(Appendix 2). On a number of occasions more than one age group is represented but only once(April 1976) is there any difficulty in separating them. When the results are plotted,as in Figure 19,the weaknesses of the sampling are apparent in the absence of data from the winter months,when the fish retire to deeper water,and the poor coverage of the first and third years of life. The latter limitation is not as important as it might at first seem;the third year fish are very infrequent in the archaeological assemblages while the first year fish pose additional problems in interpretation. Apart from the difficulties associated with their small size, and hence biases in the modern catches and recovery of their bones,the biology of the first year fish is imperfectly understood;for instance,what causes the multimodal size range in some situations and what are the main influences on the rate of growth. A good series of samples have been obtained for the second year fish and these will form the basis of the analysis.

The limitations of the data on the first and third years of life are obvious when attempts are made to fit growth curves to the material. The overall pattern appears to mirror the waves or seasonal sigmoid curves of fish growth(Figure 19) but in fitting a curve to the data there is scope for considerable variations outside of the second growing season. This is illustrated by the series of freehand and Gompetz curves(Ricker 1979, 719) fitted by Freeman and English(n.d.). At the same time it is encouraging to note the measure of agreement they obtained for the second year. The first one or possibly two(April,May) samples from the second year are small and may not be representative,but from mid-June through to mid-December there is a regular series of samples and the curves overlap for much of the period(Figure 20).

Taking the growth recorded in one year(1978) the mean length of otolith increased from 9.13mm to 11.07mm between

June 21 and December 14(Figure 21);this amounts to 2mm of growth over six months or an average of 0.33mm per month. There is a possibility that the rate of growth is not uniform but is faster during the first half of the growing season(June to September),although more samples are needed to confirm this. It would fit with a sigmoid growth curve and on the same grounds increments are likely to be lower in the months on either side of the sampling period. Unfortunately,the absence of samples from the winter months means that it is not possible to calculate the rate of growth in this season or to fix the exact limits of the growing season. While the data is therefore not ideal it is still possible to divide the year into a number of seasons on the basis of their rate of growth:

i.the first half of the growing season:rapid increase in the rate of growth,reaching 0.4mm a month. May? - end of August
ii.the second half of the growing season:growth decreasing with monthly increments below 0.3mm. September - December?
iii.the winter period:little growth. December? - April?

In addition to establishing the overall pattern of growth it was necessary to consider the sources of variability in the rate of increase and attempt to quantify their extent. The first of these is the variation found within a population. The spread and distribution of individual values is similar in most samples,with a range of 2-3mm in a normal distribution with a well-defined mode(Figure 21). This is also apparent from the low standard deviations of values;for the samples of second year fish they lie between 0.331 and 0.652. This pattern can be used as a model for catches made over a short fishing season but allowance would have to be made for the existence of local-scale variability. This was checked by the composite samples mentioned earlier;one of them consists of samples taken on successive days at the same location(July 1976) and the other two of catches off Colonsay and Oronsay at the same time (August 1976;July 1977)(Appendix 2). The differences in the mean values of these samples(0.039,0.141 and 0.146mm respectively)are small enough to show that significant differences in the rate of growth are not apparent at this scale.

The most important source of variation,given that fishing would have taken place over a number of years at the sites,are the annual differences in the rate of growth. Samples were taken over several years,in 1973 and 1975-8,specifically to quantify this range. The means of samples of second year fish are plotted in Figure 22 and this shows some variations between different years. Two years(1976,1978) show close agreement and appear to lie in the middle of the range while the rate of growth was clearly faster in 1977. At the one point when all the curves can be compared,at the end of August,the range is just under 0.6mm,or only 0.4mm if the small sample from 1973 is excluded;this is the equivalent of one month's growth(or 6 weeks) at this time of year. It is possible that the period of sampling does not encompass the whole range of year to year variability in growth rates,although the results are in agreement with the conclusions reached by Bertelsen(1942,43).Therefore it seems reasonable to adopt a value of one month as the normal range of variation and so the accuracy of interpretations will be to plus or minus two weeks.

The relevance of this data to the archaeological material: It has been demonstrated that the rate of growth of young saithe varies between populations living under different conditions and so it remains to be proven that the modern conditions in the waters around Colonsay and Oronsay are equivalent to those found at the time when the sites were occupied. It is not possible to compare many of the factors influencing growth,as there is no data on the location of the spawning grounds,direction and strength of water currents,the food supply etc. but something is known about temperatures and this is probably the most important single factor. Air temperatures at this time were some 2^{o}C warmer than the present day(Evans 1975,71;Lamb 1977, 290-3);seawater temperatures may not have risen to the same extent,as the oceans are less subject to fluctuations in their temperatures,but in shallow coastal waters an increase of up to this value is likely. As the fish maintain a similar temperature to their environment(Reinsch 1976,74) and can respond to very small gradients(Nikolsky 1963,20) an increase in temperature would have been noticed;its influence must therefore be assessed.

There is no data on the rate of growth of otoliths under different conditions and so it is necessary to refer back to the discussion on variability in fish size. Because an increase in temperature is being considered the comparison should be between the Colonsay-Oronsay population and one further south;only the Irish Sea samples are available and it has been shown that temperature conditions and the growth rate are similar between the two areas. Therefore,a comparison with a cooler more northerly location will have to suffice. The second year fish in the Faroes are some 20mm smaller than those of the Hebrides,or to put it another way they take a further month to reach a particular size(Figure 18);the mean annual seawater temperature is some 3^{o}C lower in the Faroes,which is greater than the maximum difference envisaged for mesolithic conditions. A similar result is obtained by using the average value from all the studies,of a 10mm decrease in length in response to a 1^{o}C drop in temperature.If this relationship can be extended to warmer conditions the increase in temperature would have lead to an increase in size of 20mm at most,with fishes reaching a particular length one month earlier. Many other factors may have influenced the exact form of the relationship but they are unlikely to have altered the position to any great extent. The conclusion from this is that the results of the modern study can be used for comparison with the archaeological material,with the proviso that growth may have been slightly faster then;in which case the fish would have reached the sizes recorded up to one month earlier in the year. This calibration will be included in all the estimates along with direct correlations because it is not certain that such changes are necessary.

Fish size and seasonality:the archaeological material

Length frequency data can be used to investigate two related aspects of the seasonality of fish capture. Firstly,the time of year at which the fish were caught;by comparing the positions of ranges and modes of samples a relative chronology is obtained and this can be converted into the actual months of the year by analogy with modern data. Each of the age groups should be considered separately in case they were caught at different times of the year. The second aspect is the actual length of the fishing season;the total range of values and the form of the distribution can be compared with the model for a short season derived from the modern data. Both of these aims should be reasonably straightforward in cases where the samples do come from single short periods of fishing. However,there are other possible options that would produce more complicated patterning:

i.a restricted fishing season repeated over a number of years: the annual differences in rates of growth would produce a slightly wider range of values.
ii.an extended period of fishing:would increase the range of each age group and possibly lead to overlap;the distribution of values would depend upon the rate of activity through the season.
iii.fishing during the whole year:a continuous range of values with modes reflecting peaks of activity.
iv.two or more periods of activity:will incorporate a series of separate distributions with overlapping ranges into one continuous range,with peaks determined by the intensity of activity in each period.

The interpretation of the archaeological samples may therefore be more complicated than a direct comparison with the modern results ; the form of the fishing will have to be decided before the timing is worked out. To avoid the danger of circular arguments from the data it is useful to assess independently the composition of the samples. The column samples come from a limited 'horizontal' area and so may not cover the complete spread of activity in a season but they have a relatively greater 'vertical' range that may well include material from more than one year;it seems likely that the majority of them will be composite samples. Samples taken specifically from concentrations of fishbone are more likely to represent single periods of fishing,or at least of discard, although across the large 'layers' some time interval is to be expected.

A total of 142 samples of otoliths have been measured (Appendix 1;Table 9) but a proportion of them are too small to be of value. There is no valid minimum sample size as they vary so much in the spread and distribution of values,but 20-30 measurements seem to be adequate for defining tight distributions. Because of the variation in sizes of samples and in the form of distributions no single statistic can describe the points of interest;a number of variables are used in the analysis including ranges,modes,means and standard deviations. The size interval chosen to record the measurements(0.5mm) was picked on several grounds;a smaller interval would require larger samples and could identify variations resulting only from annual fluctuations in growth(which amount to 0.3mm), whereas larger size classes could have obscured significant differences,bearing in mind the distance between the first and second year ranges is only 1.5mm at any time. The data and interpretations will be discussed for each site in turn as it was immediately apparent there were important differences between the sites(Figure 23) while the samples from within a site were broadly consistent(Figures 25-7).

CNOC COIG: The most informative site,as over one hundred samples have been analysed from both the sampling pits and concentrations of fishbone. The two types of sample show the same pattern,but the column samples are not included in the site totals(Figure 24),as they are based only on the 2mm fractions and this would bias the representation of the smaller fish(Figure 23). The overall composition of the site is strongly bimodal;the two ranges are normal distributions spanning 4-5mm with modes between 6-7mm and 10-11mm respectively. The distance between the modal values(4mm) is consistent with the two age groups having been caught at the same time,and the well-defined modes,narrow ranges of the distributions,and the clear antimode (8.0-8.45mm) all suggest a single short fishing season at the site.

When the samples are examined separately a slightly more complex situation emerges which can best be described by comparing the different types of sample:

i.Column samples: The 44 samples vary greatly in size and, unfortunately,there are few large groups and many that are too small(Table 9). Most of the samples contain values from both size groups but in varying proportions,with a clear gap in the distribution somewhere between 8.0mm and 9.45mm. However, a few have a continuous range of values but as they are all quite small it is difficult to recognise any patterning within them. The interpretation of the column samples,therefore,would be for a single short period of activity together with a few anomalous values with no obvious explanation. The date of the fishing season would have to be based on the larger size group (second year fish) as the recovery of the smaller range is biased by the 2mm mesh of the sieve.

ii.Fishbone concentrations: There are 38 samples from small concentrations(Table 9) although some are quite small. The distribution of values is similar to that observed in the column samples. However,the emphasis on a single size group is more marked here;only a few samples contain equal numbers of first and second year fish and almost half are unimodal. Unlike the column samples,where recovery of the first year fish was incomplete and the larger size group was poorly represented,it was appropriate to calculate the statistics for these distributions. This demonstrates the high measure of agreement,as almost all the means of both size groups lie within a range of only 1mm(6-7mm and 10-11mm);similarly the standard deviations of the larger size class mostly fall in the range of the modern material. The spread of the means would be consistent with a fishing season of only a couple of months,once allowance has been made for annual variations in growth;while the standard deviations are consistent with a single or short series of operations being represented in a concentration. Again there are a few values which fall within the antimode which are difficult to explain by one short period of fishing. But these can be related to three samples with means that lie well outside the ranges mentioned above,and which cannot be explained as the result of annual fluctuations in size;the obvious inference is that they belong to fish caught at different times of the year. There are two samples,one of first year and one of second year fish,where the means are 0.3-0.4mm below the main range of values and one with a single mode that lies between the two ranges. This may point to some fishing at two other times in the year but should not distract attention from the measure of agreement in all the other samples.

A series of adjacent 250x250mm samples have been analysed from two large concentrations or layers of fishbone(Appendix 1;Table 9). In one of them 24 units were examined,but the samples are all small and only the 2mm fractions were sorted(Figure 15);collectively they agree with the pattern for the site as a whole,bimodal with means around 6.5mm and 10.5mm. The other layer produced only six samples but they are all of reasonable size and show several interesting points(Figure 14). The distributions are again bimodal,but lie at the upper end of the range for the site;the means of the first year fish lie from 6.6-6.8mm and for the larger fish between 10.8-11,2mm. The spatial patterning in the distribution of the two size groups is obvious from these samples and the existence of an antimode between 8.5 and 9.5mm is clear in four of them with a solitary value in the fifth(L5). The sixth sample(L3) differs from the pattern and provides the clearest example of a second period of fishing at the site;the position of the large size range is the same as in the other samples but the distribution of the'first year' fish lies in the region of the antimode with a mean value of 8.14mm. It follows that these fish were caught at some time later in the year than all the others in this layer,and that the layer would have remained uncovered during the intervening time.

The analysis of Cnoc Coig has produced a number of important conclusions. Perhaps the most significant is the consistency of the results from such large-scale sampling. Almost all of the remains appear to originate from a single short fishing season,which by analogy with the modern data would have spanned some two months. This does necessarily mean that in any year there was two months activity but over the life of the site fishing was concentrated in those months;support for this view may be provided by a grouping of samples from 'within' and 'below' the midden(Mellars & Wilkinson 1980,23) as the modes in the latter are both somewhat larger,but further study of the stratigraphy of the site is needed to substantiate this. Comparison with the modern data indicates that the fishing season would have lasted from around September to December;if allowance is made for faster growth rates at this time the activity would fall at the end of summer and autumn.

There are a few samples and anomalous values which are best explained by a limited amount of activity at other times of the year.Two samples represent the capture of a single size group of fish whose length is intermediate between the two main size classes,and should indicate a point later in the year when the first year fish have grown further;the pattern is similar to that identified at the Priory midden(see below). Conversely,those samples and values which are smaller than the norm for the site can be explained by fishing slightly earlier in the year;the means of the two samples agree with those obtained for the site of Cnoc Sligeach.

CNOC SLIGEACH: The series of five samples from Cnoc Sligeach come from a single column of deposit;they are fairly small but show a clear and consistent pattern(Figure 25). The overall composition shares many of the features of Cnoc Coig;the distribution is strongly bimodal(with one much larger value),with two normal distributions and an antimode between 7mm and 8mm. The spread of the distributions,of 2-3.5mm,might be slightly misleading as the samples are small but they do suggest a short fishing season and the distance between the modes(4.5mm) is consistent with the two age groups having been taken at the same time. The mean values of the two size classes all lie within a 1mm range(5-6mm;9-10mm) and this confirms that fishing took place over a short period;the range for the second year fish of 0.47mm is equal to only just over a month's growth in midsummer.

The time period represented in the column samples is very short amounting to one or two months of the year,although there remains the possibility that other seasons are present in other parts of the site. Comparisons with the modern data indicate that the second year fish would have been taken at some time between June and August;taking into account the possible calibration this would place the fishing season in the early part of summer. The position of the first year modes and of the antimode support this;they are all approximately 1mm smaller than the values for Cnoc Coig,which is equivalent to 2-3months growth. A date in early summer could also be inferred from the very small size of some of the specimens(3mm) which must belong to fish caught soon after they arrive inshore from May onwards.

CAISTEAL NAN GILLEAN II : There are 14 samples from four columns,but in two of the trenches there is little material and only the 2mm fractions have been examined(ABCD,LMN) and the uppermost sample in the other two is also small(E,Q). It is unfortunate that there are so few large samples because the pattern at this site is complex. The overall composition of the site shows similarities with Cnoc Sligeach in the total range of values and in the position of a mode in the upper part of the size range(9-9.95mm)(Figure 23). This would suggest that the main fishing season at CNG II was also in the summer months. However,the distribution is not bimodal,with a break in the values reflecting the presence of two size groups caught over a short time period.

Two models can be proposed to account for this. Firstly, an extended fishing season,but this would have to be concentrated on the first year fish only because the second year range shows no such extension. The alternative is to suggest a second less important period of activity at a time when the fish were intermediate in size between the two main size groups; this has already been demonstrated at Cnoc Coig and the explanation for the presence of a single age group is given in the discussion on the Priory midden. Little can be added to this by examining the individual samples(Figure 26) although the emphasis on the second year fish is apparent in the three largest units.

CAISTEAL NAN GILLEAN I : The provenance of these samples, from the backfill of earlier excavations(Appendix 1), and their small size makes interpretation difficult. When they are grouped together a complex pattern emerges with a continuous range from 3mm to 11mm and a series of possible modes(Figure 23). The total range of values is similar to Cnoc Sligeach and CNG II and so a midsummer fishery may account for much of the material, with one or more subsiduary seasons to account for the complexity.

PRIORY: The uppermost three samples from a column of eleven units are large enough for study(Table 9). The same pattern is visible in each of them(Figure 27) and it differs markedly from that of the other sites. The Priory samples are essentially unimodal with 3mm ranges lying between 5.5mm and 9mm; there are a few larger values, some of which may belong to the related species of lythe(Chapter 2) or to another age group of fish. The main distributions are normal with clear modes of 7-7.95mm and mean values between 7.07mm and 7.65mm. There is a slight difference between the first and the following two samples which might be significant, as all the values in the former are one 0.5mm size class smaller; this is outside the range of annual variation but not sufficient to attract detailed comment.

The Priory samples lie in antimodes of the other sites and must represent fishing at a quite different time of year. This has to be placed at some point after the first year fish were caught at Cnoc Coig and before the fishery for second year fish at Cnoc Sligeach ie, between the autumn and early summer. The occupation of this site over the winter-spring months can be supported by other features of the samples; the small quantities of fish in most units can be explained by the scarcity of fish at this time of year and the presence of only one size group fits with the behaviour of the species.As winter approaches the fish begin to move away from the shore; the older fish leave earlier and so for a while only the first year fish remain,while in the spring these fish return(now entering their second year) a couple of months before the next year class of fry come inshore. So both in early winter and late in the spring one size group is likely to be caught;in the later part of the winter intensive fishing is unlikely as few saithe will be around.

This should not imply that the fishing season at the Priory spanned the whole winter but it is difficult to establish exactly when the activity took place. If midwinter is excluded by the absence of the fish this still leaves either the beginning or the end of the winter. Fish size is not precise enough to differentiate between these two options for two reasons. Growth is slowed down at this time of year and so a small increment in size will cover a larger span of time;it should be remembered that the annual variability in rates of growth(in fish length) is equal to the whole increase in size through this season. The second problem involves the subject of the calibration of growth to take account of a faster rate in mesolithic times;if this is necessary then it is most likely that the Priory samples belong at the beginning of winter but otherwise they could equally fit at the end of the season. Similarly, the length of the fishing season is difficult to establish;the tight distribution of values may reflect a short period of activity but a longer season might be masked by the slower rate of growth at this time of year.

The length frequency distributions of all the sites suggest that fishing took place predominantly in a short season and that it was based upon all the available age groups;only one at the Priory and two at the other sites. The ratios of the two age classes differ between the sites(Figure 28) and the consistency of this in the samples from each site suggest that it may be a real and significant pattern;the spatial segregation of the size groups at Cnoc Coig illustrates that the difference is important in discard behaviour but also cautions that the patterns found in part of the other sites may not be representative of the whole site. This is likewise a possibility in the season of activity at the site although the consistency of the samples from Cnoc Coig might be an argument against this.

The usefulness of the technique has been established,in identifying the measure of agreement of samples within sites and the differences between them,but there are certain limitations and difficulties. The interpretation of the actual time of year represented by a sample is complicated by the problem of ensuring comparability with the modern data;the evidence suggests,however,that this is not a major problem as the extent of the difference would only amount to one month. This is also the level of accuracy imposed by the degree of variation in annual growth rates. The winter months are a greater problem because the slower rate of growth requires greater resolution and this is not possible with the present data. The technique can be used to investigate both the time of year and the length of the fishing season but its usefulness is reduced as the degree of overlap of ranges increases;it is most effective where a single short fishing season is represented. Following on from this it is only applicable to large samples which display clear patterning and there are few occasions where a single specimen could be ascribed to a particular time of year. It was therefore necessary to consider other techniques for establishing seasonality where fish size proved inadequate;the reliance on size in the first instance is supported by its simplicity and ease,and by the results obtained from it.

Growth ring analysis

The potential for this technique is demonstrated by the use of the method in ageing studies of the species;while the younger fish can be segregated by size this is not applicable to older saithe and so annuli have long been used. In early studies scales were used as they were easy to collect and seemed quite reliable(Damas 1909,194). Growth commenced in April or May with rapid increase through the summer marked by wide sclerite rings and then slower growth over winter with narrow rings,with the annulus formed by the resumption of'summer' growth in the following spring. However,Saemundsson recorded a number of problems with the method(1929,7);these included the unsuitability of old fish(8-10+ years),the occurrence of false annuli,and the existence of dwarfed and blank scales which could not be read. The latter could account for half or more of the specimens from fishes in the first two years of life. Clear differences in the form and rate of growth of scales from different parts of the body have also been noted (Dannevig & Post 1931,73).

Growth marks have been observed on a number of other bones (Meek 1916,223) but as with the other gadoid fishes the otolith has become the standard element in ageing studies(Reinsch 1976, 27-30). The sagittal otolith of the saithe is similar in form to that of other gadoids(Figure 7a)(Schmidt 1968,14;Wysokinski 1970,185) and can be collected and studied in the same manner (Williams & Bedford 1974). The rings are sometimes visible through the whole otolith of young fish but in most cases it is necessary to obtain a cross-section of the structure. This is generally taken transversely across the interruption in the sulcus acusticus(Figure 7a) to ensure that the nucleus of the otolith is sectioned. There are various techniques for making the sections and enhancing the clarity of the growth rings,but the structure is fairly clear in saithe otoliths(Blacker 1974a). From a simple break the section can be viewed directly under low magnification using transmitted light.

Two rings are laid down in each year;a wide summer band that is opaque in transmitted light and a narrow hyaline winter ring(note that the appearance is reversed in reflected light)(Figure 7b). Age determination should then be straightforward based on a count of the number of annual growth rings but there are serious practical difficulties. There are occasional specimens that fail to grow normally,and either miss a number of rings(Reinsch 1968b-9)or possess a crystalline structure without rings(Reinsch 1976,36-7). More important are the errors in reading normal otoliths;the main problems encountered are the identification of secondary rings as true annuli,particularly of small hyaline zones within the summer rings,and conversely the difficulty of separating rings when growth is slowed down,especially as the fish get older. With experience and care such mistakes can be minimised but otolith reading should be regarded as an acquired skill

Such errors are less of a problem when the otoliths are being used to determine season of death because only the most recent annulus has to be correctly identified. However,this does require much more detailed information on the time of zone formation and rates of growth than is necessary for ageing.

Otoliths are potentially well-suited for seasonality studies because the two clear zones within each annual ring allow a greater degree of precision in the measurements. Little has been published on the rate of growth in saithe otoliths,but some inferences on the time of ring formation and variability between fish can be gained by analogy with other gadoid fishes.

All species show the same basic pattern of a wide opaque ring laid down generally over 4-5 months in the spring and summer,and a narrow hyaline zone formed over the winter(Blacker 1974a,80;Christensen 1964,74;Dannevig 1956,156;Mina 1968,96). The actual timing of zone formation shows considerable variation,particularly between species but also on other levels. It appears that at no time are all individuals in a species likely to be found at the same stage of development(Trout 1954,100), but this is compounding several sources of variability:

i.between individuals;the formation of growth rings is not a simultaneous event occurring in all fish at exactly the same time in response to a single stimulus,

ii,between age groups;rings tend to form earlier among younger fish;in North Sea cod the opaque zone starts in February in the youngest fish but may be up to four months later in older fish(Williams & Bedford 1974,119),

iii.between populations;differences of several months have been recorded across the range of a species and are generally later in the year in the northern part of the distribution(Gambell & Messtorff 1964,395;Williams & Bedford 1974,119),

iv.annual variation;differences in the timing of zone formation between years have been recorded eg. plus or minus one month from the average in North Sea whiting(Gambell & Messtorff 1964, 394).

This variability has to be acknowledged because it defines the level of precision that can be achieved with the technique. Annual variations cannot be avoided and so a range of one or two months must be allowed for estimates but the other sources can be minimised.

> 'A sample taken from fish of one age group all from the same area will usually show a clear seasonal pattern of zone development '(Williams & Bedford 1974,119).

The aim therefore must be to choose the most appropriate body of material for comparitive studies,with respect to the age and location of the population.

The comparative sample: The first stage in the study had to consist of the examination of modern otoliths from a population comparable to the archaeological fish. For this the samples of fish taken off Colonsay and Oronsay(Appendix 2) were used,as they seemed to be the closest available match. Such a study of fish of known age and date of capture would also provide a good opportunity to become familiar with the technique and the problems of reading the growth structures. So far only a minimum of material,from both modern and archaeological contexts,has been examined to test the validity of the approach and much more work will be needed before comprehensive results can be presented.

An identical procedure was adopted for both sets of material. The specimens were sectioned along a transverse axis through the interruption in the sulcus(Figure 7a). Initially, the pieces were mounted in transparent resin to make them easier to handle and then cut on a geological thin-section saw; this produced very clear and accurate sections but it was time consuming and made it difficult to examine the otoliths subsequently. Once the optimum section had been established and a number of accurate specimens prepared for detailed study, this technique was abandoned in favour of a simple pressure break along the same axis. This proved less accurate and the sections are not always flat but they are adequate for viewing the growth rings. No subsequent treatment of the surface was necessary although the resolution could be enhanced by brushing the surface with a clearing agent(cedar oil). The structure is visible by eye and the pattern was studied under low power magnification with transmitted light.

The modern material consists of some 60 otoliths taken from samples that cover the three age groups and the part of the year when fish were caught(April-December). All of them display the same basic pattern.The nucleus is a large opaque zone,with a complex structure and varying degrees of opacity, and often contains numbers of very narrow hyaline rings. This is followed by a clear hyaline zone, averaging one fifth of the radius of the nuclues,and then the second opaque ring which is about half the width of the nucleus;after this there are alternating narrow bands of hyaline and opaque material. Accurate measurement of the thickness of the rings is pointless as growth is eccentric and the width depends upon the axis chosen and the position of the section. The pattern is easier to read along some axes than others;the best radius appears to run from the nucleus to the dorsal margin on the internal side and this is noted in other studies(Gambell & Messtorff 1964, figure 4)(Figure 7b). It was also noted that the same stage of development had not been reached on all surfaces;rings are visible first on the dorsal margin,followed by the ventral surface,the external face and finally the internal face around the sulcus. Therefore a four stage recording system was evolved that did not rely on measurement;with partial(visible only on part of the surface),small,medium and large increments proportional to the final size of the zone.

The results of the analysis are given in Table 13. The coverage is somewhat limited and further specimens are needed to confirm the exact dates but the results are consistent and agree with the autumn to spring timescale for the hyaline zone (Reinsch 1976,27-30). The youngest fish sampled(4 months) at the end of July and beginning of August show traces of a hyaline ring around the nucleus and the pattern is the same a month later;by the end of September the hyaline zone is visible all around the otolith. It increases in size and is well developed by November;it must continue to form the outer margin until at least the following April when traces of an opaque ring are apparent. The new ring is still unsubstantial in the following month but then increases rapidly through July and August. The second hyaline zone is first recorded in August and is established by September. It develops through November and December and continues until the next opaque ring begins in May. This opaque ring is still growing in the August which is the last point sampled. To summarise,the opaque ring appears to form between April-May and August-September,with the hyaline zone forming the outer margin for the rest of the year. It was also clear that all otoliths do not reach the same stage of development at exactly the same time and there is some suggestion that the opaque ring may be laid down earlier in the first year fish.

The archaeological material: The choice of otoliths for this study was based on both the limitations of other elements and the advantages of this element. The only bones for which there have been studies to validate their use for age determination were scales and otoliths. The scales of the saithe are small and quite delicate(Reinsch 1976,33) especially for such young fish;preservation and recovery would present difficult problems. There would also be problems in interpretation particularly for the scales of first year fish which would show no annulus,and may even have only just begun to form in some cases (Saemundsson 1929,7);this would be compounded by the variations across the body in the time of formation(Dannevig & Post 1931, 73). A certain proportion of samples would also have to be discarded because they showed no clear structure.

The alternative element,otoliths,are well-preserved and easily recovered,and the principles and applications of the technique were well documented. A small proportion of the pieces show signs of weathering or burning but most of the material closely resembles the modern specimens except that the archaeological ones all display a dark opaque surface. This makes it impossible to detect the growth rings in the whole otolith and all pieces have to be sectioned. The actual ring structure is beautifully preserved and in some instances is clearer than in the modern specimens;this extends even to the fine structural components within the zones observed under high surface or S.E.M. magnification which are the same as in modern otoliths (Reinsch 1976,38). The one major difference therefore is this opaque surface,which is presumably the result of chemical weathering, as it is not an accretion;it penetrates into the otolith to some depth and thus gives all archaeological specimens an outer opaque ring. Sometimes this extends through the whole structure and makes it impossible to use the specimen for ageing(Wilkinson in press) but in other cases its depth is limited.

This could pose a fundamental problem in using otoliths for determining the season of death as it is exactly the part of the structure examined in such work,the most recent growth, that is always affected by this opaque layer. Obviously,where this weathering zone extends through the piece or to any depth it will be impossible to determine the time of year of death. However,if its thickness is less than the width of a growth ring it should be possible to extrapolate to the outer margin. The most difficult occasions will be where this indicates a fully formed ring as it is not possible to establish whether the next zone has started to appear. The width of the weathering zone does vary in the specimens from Oronsay but generally it is shallow and less than the thickness of one growth ring. The exception to this has been the one sample examined from Cnoc Sligeach(B28) in which the zone extended through the specimens examined and made it impossible to identify any of the structure;the preservation at this site is not as good as at the other sites. At the opposite extreme the zone at CNG I is very narrow;the other sites have a slightly thicker band but it does not prevent the reading of the ring pattern.

Only a few specimens have been examined from each site and so the results are not adequate for detailed consideration, but a consistent pattern is displayed within the sites:

CNOC COIG: A dozen otoliths from two units of one fishbone layer(L3,L5). Both the first and second year fish show a moderately developed hyaline zone at their margin(allowing for the weathering zone) which is consistent with a date in the later months of the year.

CNG II: Nine specimens of second year fish from three samples (F,G,J) reveal a small growth of the second opaque ring;this begins to form around May.

CNG I: All of the pieces in one small sample,including broken otoliths,were examined;the 35 sections revealed a number of different patterns. First year fish display an outer margin of the nucleus(early summer),the start of the hyaline zone (late summer) and a more developed hyaline ring(later part of year);the second year otoliths show the start of the second opaque ring(spring-early summer) and also of the hyaline zone (late summer). There would appear to be three periods of activity represented in this sample(Sample 5) but larger numbers of specimens are needed to confirm this.

PRIORY: The five otoliths,four from the main size class and one larger piece,all reveal a well-developed hyaline ring. This confirms that they were taken over the winter period,but it has not been possible to establish whether the hyaline zone had finished which would have placed the fishery at the end of the winter.

The consistency of the results,and the agreement with the seasons derived from fish size analysis,indicate the validity of the technique and it will obviously be most useful where large samples of complete otoliths are not available. Much more work needs to be undertaken so that more precise resolution is possible than the present broad seasons given above;larger samples of modern material have to be prepared and further thought given to the extent of variability and the comparability between the modern and archaeological data. Archaeologically,the main interest should lie in the composite samples,as at CNG I,and in resolution within the winter period. The weathering zone is clearly a major obstacle here but the recent interest in the structure and manner of otolith growth may provide an answer. One possibility may lie in the fine daily growth lines that make up the main growth rings(Pannella 1971:1974;Brothers et al 1976;Liew 1974;Struhsaker & Uchiyama 1976);these do appear to be preserved in the archaeological specimens but their usefulness will depend on whether they are obscured by the weathering zone. This is material for a detailed study in itself.

Conclusions

A very interesting pattern has emerged from the analysis of the fishing seasons of the Oronsay sites. The differences found between the sites(Figure 28) and the consistency of samples within each of them indicates a highly structured economic system. Each site was occupied regularly,through the period of its occupation,mainly or exclusively for one short season;where the length of this season can be established(Cnoc Coig,Cnoc Sligeach) it appears to span a couple of months but the occupation in any year may have been shorter than this. At three of the sites one or more subsidiary periods of activity have been recognised(Cnoc Coig,CNG I & II);these appear to coincide with the dominant season at another site but such precision is not certain until more sectioning is undertaken. Three of the sites are primarily summer activity sites(Cnoc Sligeach,CNG I & II) and the emphasis on this time of the year together with the differences between the middens in species and the ratio of age groups of saithe will have to be considered. With an autumn site(Cnoc Coig) and a winter occupation(Priory) much of the year is represented in the saithe fisheries.

It remains to be established that all other activities took place at a site at the same time and this should even include the capture of other species of fish;while it seems likely that some of the fishes came from the same fishery (Chapter 6) this does not apply to them all and independent evidence should be sought for each of them. The quantities of material and types of element recovered from these fishes are not adequate for detailed study;some scales of sea bream were looked at and showed that the fish were several years old but their condition was too poor for the margins to be examined. Therefore the only line of evidence is the behaviour pattern of the species and the limitations of this are already known;the aim will be to demonstrate when the fish were unlikely to be taken and the times when they were most available. The species found in all the sites are basically sedentary but may move away from the coast during the winter eg.shanny (Wheeler 1969,436) and ballan wrasse(Kennedy 1969,162). Those species that live further offshore are mostly found closest to the coast in the summer,including the dogfish(Wheeler 1969, 45) and monkfish(Kennedy 1969,447);in this category the red sea bream can be included(Smitt 1892-5,6) because it is only a summer visitor to these shores(Kennedy 1969,103). The sea bream is the only species that can be used as a seasonal indicator and so it fits with the other lines of evidence that it,along with the greatest number of species,occurs at the early summer site of Cnoc Sligeach. Beyond this,there is only the negative evidence that the species found at the other sites could all have been caught at the seasons when they are believed to have been occupied.

CHAPTER SIX
FISH CAPTURE

The structure of a fishery is a complex subject because it is the result of the interaction of various factors;these cover aspects of the physical environment,including the form of coastline,water depth and currents,type of seabed,weather conditions etc.,the fish fauna,and human influences,in the availability of labour,technology,markets etc.(Morgan 1956). Some of these help to determine,or are influenced by,the choice of fishing gear. Few species of fish have been 'domesticated' or reared in captivity until recently(Zeuner 1963,478-83) and so fishing can be regarded as essentially a hunting, or collecting,activity(Andersen & Wadel 1972,153). A range of fishing methods have been developed and most have appeared throughout the world. They also have a long history,with at least simple forms in use in Europe by mesolithic times(see below). The techniques are described and classified in many ways and there are many references on this subject for both modern(Sainsbury 1971) and traditional(Jenkins 1974;Oswalt 1976;Reinman 1967;Rostlund 1952) fishing methods. Rather than repeat all this,this section concentrates on a discussion of the factors that determine the choice of gear and then continues with an account of the ways that fishing methods can be recognised in the archaeological record.

Methods of fishing

There are three aspects of fishing methods to consider: the gear itself,how it is used,and the resultant catch. Gears vary in their complexity,and in the raw materials and labour in manufacture,and again in the amount of maintenance and frequency of repairs;as a simple example nets 'cost' more to produce and maintain than lines(Goodlad 1971,47). The costs of operation are also variable in the requirements for manpower and other facilities such as boats;some gears can be set up and then left unattended(passive fishery),such as traps and gill nets,whereas other fishing methods require active participation in the capture,including spearing and seine netting (Rostlund 1952,147). The number of people needed to set up or operate the gear range from the solitary individual to mass fish drives,while the age and particularly the sex structure of the fishers is also important. Fishing is an activity of both sexes(Murdock 1966,264) but there is a tendency for a division between high risk prestigious male activity and other forms which fall to the women(Andersen & Wadel 1972,141-2;Bowdler 1976,249-50;Paine 1957,62-3;Reinman 1967,181).

Part of this distinction may rest upon the location of the fishery;offshore activity faces greater risks to life and gear from weather and currents than inshore fishing. Gears are suited to operating in particular environments in response to a combination of factors. Depth of water is an important constraint;gears that rely on visibility or close control are restricted to near the surface and only traps and the hook and line(plus recent powered netting)can exploit the rest of the water column(Reinman 1967,104).Distance from the shore is another factor,because of water depth,strength of currents,use of boats etc.The type of bottom and vegetation cover affect gears that come into contact with them and fragile forms can also be damaged by strong currents and waves;shelter or strong anchorage can counter such destructive forces. Another way of classifying gears is according to their flexibility;some gears are fixed,like weirs,while others are mobile and can be moved in response to the location of the fish. Related to this is the specialisation of the gear;between those adapted to capture certain fishes most efficiently and others which can take a range of species and operate in a range of environments. One final point on the relationship between fishing gears and environmental zones is to remember the variations in the productivity of these zones(Paludan-Muller 1978) which controls the size and nature of the catch that is possible in different locations.

The main features of the catch are its size and its composition. Methods of fishing range from the long search for a single individual through to mass capture or 'harvesting';the size of individuals and the numbers of individuals must be considered in comparing such techniques. But the total size of catch,however it is calculated,needs to be related to other variables. The total catch per unit of time is important in periodic fisheries where the size of catch is limited by the ability to trap the fish as they pass through;examples of these include the runs of salmon and eels along rivers and the migrations of pelagic fishes like the herring and mackerel. The catch per man hour is a different value and reflects on the efficiency of the gear,as does the size of the catch over a year;the latter will depend upon the length of the fishing season for the species and the extent to which the gear is capable of being used in other ways. Fishing methods can differ in the reliability of the catch,with a choice between a smaller dependable catch and a larger more opportunistic policy.Whatever the size of the catch the effort will have been wasted unless it can be processed and consumed or preserved before it starts to decay.

The composition of the catch is obviously important and the list of variables includes the type of fish,the species of fish,the numbers of fish,the sizes of individuals,and their condition. This is important not only for 'secondary' goals such as taste,but determines the usefulness of the catch in the ways they can be processed and utilised. The choice between a specialised fishery to maximise one or more of these values and a more generalised strategy involves a consideration of various issues mentioned here. A completely unselective strategy is the exception because even if there is no conscious selection all fishing gears are biased to varying extents(see below);this is well understood and can be used to advantage to avoid parts of an undesirable catch,but equally few gears are so selective as to catch only the principal aim of the fishery.

The choice of a strategy and fishing method depends upon the balancing of all these factors. There may be situations where one or more of these must override the remaining values but otherwise the tendency will be towards the efficiency of the activity;the value of the catch set against the cost of the gear and the fishing operation. In such situations techniques of mass capture,like nets and traps,are likely to be most effective(Reinman 1967,117);the initial additional outlay on the equipment is repaid by an increase in the size of the catch with proportionally less input of effort. The complexity of this relationship is strikingly illustrated by the range of methods used to capture individual species,each of which is most appropriate in a particular set of circumstances;the best example is probably the salmon which is taken by most techniques(Granlund 1965;Jenkins 1974;Mills 1971,4-12;Thurow 1974). A simple classification of fishing gears,based on the form of the gear and how it is operated,is given in Table 14.

Archaeological evidence of fishing methods

Several lines of evidence can be used to reconstruct fishing methods and in particular traces of the gear and the form of the catch;other features such as the inferred location of activity,the available technology and manpower,etc. may provide a framework for interpretation but,as was inferred above, there is a range of options for exploiting most situations. Direct evidence of fishing methods must therefore be sought:

Fishing gears: As with other classes of artefactual evidence there are problems in the recovery and interpretation of remains. Organic materials are used in all fishing gears,with the possible exception of stone traps or weirs,and so under most preservation conditions all traces or parts of gears will have disappeared;many gears are made completely of organic components(basket traps,gorge and line,nets etc) and the composite form of almost all types makes interpretation very difficult from only the inorganic parts. In some locations preservation is more complete but then there is often the problem of associating the piece with a cultural context. Such conditions will include waterlogged deposits where the gears may in fact have been used but this introduces a further complication of where fishing implements are most likely to be discarded;in many situations they will be lost or thrown away at the site of use and not found in occupation sites,unless they were in the process of manufacture(Gould 1977,135;Iterson Scholten 1977,135).

The difficulties faced in the identification of fishing gear are on two levels. Firstly,the individual parts of composite gears have to be recognised(Bowdler 1976,250-1);for example,stones of particular form(grooved,bored,ovate etc) are described as net weights(Maury 1977) but they also function as weights on lines,looms etc(Goodlad 1971,58). When the basic form of the item is established the next step is to show that it was used in fishing;unfortunately,with the exception of the hook,few artefacts are diagnostic of fishing. Spears,nets,traps and even lines are used to capture a wide range of resources (Oswalt 1976) and some have other functions,in storage etc.It is therefore necessary to use supporting evidence to confirm the interpretation of artefacts as fishing gear,and to establish exactly how they operated;few fishing gears are specialised to the extent of only functioning in one manner for a particular fish. The most direct evidence can come from the detailed form of the gear;the size of mesh in nets and traps,of the point-leg in hooks,and the weight and shape of floats and sinkers can demonstrate specific adaptations by analogy with modern gears(Maury 1977,103-4) or experimental studies(Coutts 1975a). The location of items can be interpreted as showing how they were used(Wendt 1966,19) especially if the remains of fishes can be associated with them. Direct contact could be most convincing(Clark 1975,144) although fortuitous association is a possibility;however,a broader connection within a deposit(Jochim 1976,164) and even a general correlation between an artefact type and species(Clark 1948,58-9) have been cited as evidence of fishing techniques. The latter should be treated with caution unless accompanied by a more detailed analysis of the form of the catch to examine the suitability of the gear.

The catch: The composition of the catch can be used to deduce the method of capture from the knowledge of the ways that gears operate and how fish respond to them. All fishing gears are selective to varying extents,whether of species,size of fish,etc(Mills 1971,262;Pope 1966),firstly in terms of the habitats that they exploit and then selection within the environment. The first of these has already been discussed and the catch must consist primarily of fish that occupy the exploited zone. Within a zone the nature of the catch depends upon the composition and behaviour of the fauna. The ways that gears are operated,in terms of the bait used,speed of movement,visibility etc. will differentially affect parts of the fauna, and then there will be selection through properties of the gear,including its form,size and strength. The form of the gear restricts the types of fishes that it can capture;for example,soft-mouthed species like the herring are not successfully held by hooks while susceptibility to gill nets depends on the right configuration of head and gill opening. The size range of fish caught is closely related to the type of gear. The minimum size,apart from individuals accidentally caught up in it,depends upon the size of mesh,length of the hook point etc. while the upper limit is influenced both by this and the strength of the gear to hold trapped fish.

The selectivity of fishing gears can be used in two ways for archaeological material. The fauna of a site can be matched against the traces of gears to establish whether they are compatible(Coutts 1975a);changes in the fauna may be related to developments in fishing technology(Bowdler 1976,255;Payne 1975b,128;Poggenpoel nd.,5). Alternatively,the composition of the fauna can be examined for evidence of selection but this has to be based on comparisons with a theoretical natural population. This could be based upon comparable archaeological assemblages together with our understanding of the behaviour and structure of fish populations;in this it is essential to recognise the environmental zone being exploited,because of the differences in species and sizes of fish between them(Akazawa 1980,336-7;Cook & Heizer 1951,301). The size/age structure of the catch has been compared with general population structure (Ekman 1973,58) and with the composition of commercial catches (Shawcross 1975,56-9) in attempts to establish how and where they were caught. In other fields of economic and environmental reconstruction attention has been placed on the diversity of the fauna and this could also be attempted with the fish fauna because of the varying relative selectivity of fishing methods;the low level of selection in samples(Munson et al 1971,417;Parmalee et al 1972,23-4) has been used to indicate the adoption of mass-capture harvesting techniques(Limp & Reidhead 1979,72;Garson 1980,564). Of course,all such studies must first establish that the archaeological fauna is equivalent to the composition of the catch and that post-capture selection, and variations in preservation and recovery can be ruled out as biasing factors.

Oronsay: Fish Capture

The most direct form of evidence on fishing methods would be from the recovery of traces of the fishing gears;no such remains have been found in the Oronsay middens but this is not unexpected given the preservation conditions and the possibility of discard away from the sites. The approach adopted here, therefore,concentrates on the nature of the catch. The emphasis is placed on considering where and how the fishes could have been caught supplemented by inferences from the numbers and sizes of fish,comparison with the contemporary fauna,data on modern and historical fishing practices,and the known level of mesolithic technology.

The catch

As the main basis of this approach rests upon interpretations of the species represented in the middens the first point to establish is that the list is an accurate reflection of the fishing activity at the sites. There are a number of factors that could alter the relationship. It is possible that the species list is not complete as the sites have not been fully excavated and there is the problem of those species apparently found in the early work;however,if other fishes are present they are almost certainly only in small numbers and are unlikely to have much effect on the overall fauna.The alternative,that some fishes which were caught have been taken away from the sites,is not supported in any way by the evidence that exists of processing activities;fishes being caught and not brought to the sites is also unlikely given the range in the fauna. One other possibility is that some of the fish were introduced to the site by other than human agency;a number of predatory species,of mammal,bird and even fish,do occur in the fauna but it seems unlikely that they would carry fish actually onto the sites and there is no trace of gnawing or digestive action to hint that bones may have been introduced in the stomachs of predators. It thus seems reasonable to regard the species list as an accurate representation of the fishing activity by the inhabitants of Oronsay.

The next stage is to try to determine how and where the fish were caught from what is known of their behaviour. The difficulty here is that all the fishes can be found in more than one habitat and so there are no definite diagnostic features as a starting point for the study. Two different approaches can be used to reduce the range of possible options but each rests upon an assumption about the nature of the fishery. The first procedure is to take the most preferred habitat of individual species as the zone in which capture is likely to have occurred. This is certain to result in a list of several environments which may require a range of fishing techniques to exploit them. It is therefore most appropriate in situations where a series of fisheries for individual species is used as the model of the system. Although numbers are not an absolute criterion of specialisation the range of species(at least 16) and the small quantities of most of them suggests that they were not sought after separately. The numbers of saithe could indicate a special fishery for this species but this should first be checked against the relative abundance and availability of species in the natural fauna. The alternative is to establish features common to numbers of species and so minimise the number of fishing methods needed to account for the material. The real situation may be some form of compromise between them but the emphasis in this study is placed on the latter approach as the simplest solution to the problem and in the absence of any clear evidence of specialisation.

Summaries of the life history of the identified species were given earlier(Chapter 2) and will not be repeated at this stage. All of the fishes are marine or spend part of their life in the sea,but three of them do occur in freshwater.The salmonid bones provide the only clear indication that fish were taken in freshwater;although the salmon and some trout spend much of their life at sea the vertebrae come from small fish which must belong to the initial phase spent in rivers and streams following spawning. Assuming that the flatfish is the flounder they do enter estuaries and rivers although they are predominantly sea fish;the opposite is true for the eel because although it is best known as a freshwater fish many eels spend at least some time in the sea apart from the migrations to and from the spawning grounds. Leaving aside the salmonid fish the fishery could have been exclusively marine.

With the range of species present it is not surprising that there is no single zone in which they are all likely to occur and so it is necessary to attempt to divide them according to specific variables. The most obvious is the depth of water and distance from the shore. Here there is a measure of agreement,for with the exception of the hake and ling,they can all be regarded as fish of the inshore zone(Bagenal 1973; Cameron 1977). However it is necessary to make some distinctions within this zone although this is complicated by a gradation of changes,species found throughout the zone,and the position of some fishes where they occur in different depths on the basis of size. A somewhat arbitrary three part division can be proposed:

i.the intertidal and immediate sublittoral zone:shanny,eelpout, sea scorpion,first year saithe and lythe,eel,small conger, small wrasse and flounder(Bagenal 1973),

ii.sublittoral to depths of a few metres:second year saithe

and lythe, larger wrasse and most fish from the previous zone,
iii. inshore waters of 5-10m or greater depths: dogfish, monkfish, thornback ray and sea bream.
Ling and hake are found in greater depths, in water of 100m or more, although occasional specimens do stray inshore especially during the summer. Another variable that shows some patterning is the type of bottom over which the fish are found. The intertidal and sublittoral species are predominantly fishes of rocky weed-covered shores which supports the idea that they were taken in the same fisheries.

The second stage in the analysis of the catch is to consider whether there is evidence of selection from the populations of fish in the environments that were exploited. This raises two major difficulties; first, to show that the archaeological assemblage is the same as that caught, and then in reconstructing the natural population for comparison. The first of these, including post-capture selection, preservation and recovery, does not appear to be important for these assemblages (see Chapter 4). The second is more difficult because the contemporary fauna is not known; instead comparisons have to be made with the present and historical situations recorded for these waters. Three aspects of the catch can be considered:
i. the list of species: There is no detailed account of the fish fauna of these waters but comparisons can be made with a list by McNeil of species for which gaelic names were available (1910, 40-2), although the geographical range of this is not established, and general sources for Hebridean waters (Darling 1947, 161-2; Harvie-Brown & Buckley 1892, 219-34; Mercer 1974, 165-6); together with the species caught there today and in the past (Loder 1935). The seas are rich in fish and there are trout in the lochs on Colonsay and there were extensive fisheries for cod, ling, plaice, flounder and saithe although only saithe and mackerel are sought now. All of the species in the middens are recorded in the area but the archaeological fauna is not a full list of the actual fauna; McNeil's list includes some forty species. Some selection may exist, perhaps against fish of sandy shores (sand eels, grey mullet, gurnards) or offshore waters (cod, haddock, whiting), but negative evidence of this sort is not very reliable, especially if no allowance is made for their relative abundance.
ii. the frequencies of species: This is even more difficult to

study as there is no real data available. Personal observations confirmed the abundance of first and second year saithe; a few lythe, and mackerel for one or two months, make up the remainder of the catches from the island today. One shanny was taken with the first year saithe, and congers, eels and flounders are known to be local by residents; various small sharks and rays also turn up regularly in the trawling offshore for prawns. This list coincides very closely with the relative frequencies of species in the Oronsay fauna and shows no evidence of selection; this even extends to the predominance of young saithe and so while it is possible that this species was the main object of the fishery it does not necessarily imply that effort was concentrated on capturing this fish. The only exception to this is the mackerel and its absence could be the result of several factors; either the fishing technique, or as a seasonal migrant, the timing and pattern of its movements could be different so that it did not come close to the island or arrived at a time of year when there was no fishing. One more aspect of this could be the differences between sites in the list and relative abundance of species but seasonality may explain at least part of this; the occupation of Cnoc Sligeach coincided with the maximum diversity of the fauna in summer, although the contrast at CNG II which spans the same season remains to be explained (Tables 3 & 4).

iii. selection within species: Although detailed information on fish size is available for only one species and so this study is really confined to the saithe fishery, a couple of general observations can be made. The total size range of fish in the middens, from those of a few centimetres (first year saithe, shanny etc) up to species of over one metre (hake, ling), suggests that there was no conscious selection practised on size grounds; from this it also seems unlikely that all the fish were taken with the same fishing gear, so that at least different gears were in use in the various fishing zones.

Two features of the size distribution of the saithe remains can be examined: the ratio between the different age classes and selection within each size group. There appear to be differences between the sites in the frequency of first and second year fish which suggests that this might be significant and data is available on the ratio in one modern population (Bertelsen 1942) (Figure 16). The behaviour of the two age groups is not coincident and so attention can be concentrated on one or the other. However, there are other sources of variability to consider. The ratio changes through the year and so will depend on the season of activity while the archaeological evidence could be misleading given the findings at Cnoc Coig of the separation and spatial segregation of the two groups; simple inferences from the ratio should therefore be avoided. In samples where the size distribution of the two age groups can be studied, as at Cnoc Coig in the concentrations, it seems to match the normal distributions recorded in the modern samples; there thus appears to be no size selection in the fishing technique used. The most striking example of this comes from the very small individuals, of only a few centimetres in length, that occur in the summer fishing sites.

This attempt to identify selection within the catch has shown that it is a difficult area for interpretation. Several interesting points have emerged which may be relevant to the discussion but there is no definite example of bias that can be attributed to the method of fishing.

Interpretation of the fishery

The first stage is to establish the potential range of fishing methods for the environments being fished and the species caught within the framework of the known level of technology. There is a general gradient in the number of appropriate techniques from the shore out to the offshore waters. On the shore visibility and access are at a maximum and virtually all fishing gears can be used, from hand-capture and spearing, to traps, netting and angling. In the sublittoral zone most of the techniques are still possible but as the depth of water increases boats become essential and for species that live near the bottom only gears that can operate at depths are available. The two extremes are thus easily defined; the offshore zone could only be exploited from boats with baited hook and line while the shore fishes could be 'gathered' from rock pools at low tide but this leaves a range of options for catching the bulk of the fishes which come from the sublittoral-inshore zone.

When the emphasis is changed to consider individual species the predominance of the saithe must be acknowledged. The reliance on this fish in North and West Scotland lead to the development of techniques specifically for its exploitation. The most characteristic was the 'craig fishing'(Fenton 1973; Rendall 1973,87-92) with a rod and line from the shore. The rod or'wand' would be some 3.5 metres long with a fixed length of line of similar length;originally a single baited hook was used but this has been replaced by up to three hooks with feather lures. The most common bait was limpet and it was also spread as ground bait to attract the fish;they would either be boiled and chewed or were freshly mashed on the rocks from which the fishing was conducted. Although it was a method of individual capture it could be very productive;skilled anglers could man two rods and all members of the community could take part. The gear is very simple to make and operate and fish can be caught very rapidly once a shoal starts to feed. Rendall's account makes clear that attention could be focussed on the first year fish close to the shore or on the larger fish at greater depths;in his observations of the latter a wrasse also appears to have been caught(1973,90). The same procedure was used from boats,although the line could be used without a rod, presumably to take the larger saithe(Low 1813,194;Rendall 1973, 88). The shoaling behaviour of the fish also makes netting a very productive procedure;two forms are well-documented.Beach or shore seines,in which the catch is enclosed by a net carried around on a boat and then drawn up onto the shore(Fenton 1976, 174;Firth 1974,101;Paine 1957,143). Or by sack or scoop nets in which the catch is lifted out of the water(Smitt 1892-5, 503);scoop nets were developed as an extension of craig fishing with the net of up to 3 metres diameter joined by ropes to a strong pole(Cutting 1955,171;Fenton 1973,76-7).

A couple of points are worth making about the other fishes but they will not be discussed individually, because of the view that they were not sought separately. If modern forms of powered netting are excluded then most species are taken principally on hook and line;this includes hake and ling,dogfish, monkfish and thornback ray,large conger,sea bream and ballan wrasse. The second point is the ease with which the shore fish can be collected in rock pools or among the rocks,by hand or speared/gaffed;species in this category include the shanny,sea scorpion,flounder,eel,conger and wrasse. However,all of this latter group can be taken in various other ways including nets such as shore seines,and traps or on baited lines.

The final aspect is to consider which fishing techniques would have been feasible for the occupants of the middens.The main interest here lies in the level of technology although other factors such as the available manpower may also play a part. There is very little evidence for the technology of the 'Obanians' except for the high standard of craftsmanship in working bone and antler(Clark 1956) and skills in seamanship evidenced by the marine economy and island occupation. For an indication of the range of fishing gears in use at this time it is necessary to draw on sites from across North-west Europe because the evidence is not abundant;there is also a problem of the correct dating of isolated finds in waterlogged deposits and of the examples of rock art. But from these,together with the catches and artefacts from sites,it is possible to present an overview of mesolithic fishing methods(Clark 1948: 1975;Iterson Scholten 1977). It appears that all the main forms of fishing gear were in use by this period. This includes fish spears(Clark 1948,59),fish-hooks(Clark 1948,54;Indrelid 1978, 160),traps or weels(Iterson Scholten 1977,135),nets(Clark 1975, 224;Iterson Scholten 1977,135),and the use of the boat for fishing(Clark 1975,215). Other forms such as weirs and scoop nets can almost certainly be added to the list. Unfortunately,there are so few finds and little data from the ones that do exist to extend the description;the strength and size range of gears must await further discoveries. It is not clear how many of these techniques would have been known to the groups that lived on Oronsay but technology cannot be regarded as a constraint on interpretation.

There is no unequivocal evidence of any particular fishing technique in the Oronsay middens,either in the artefacts or in the form of the catch. The interpretation rests upon inferences from several lines of evidence and so it is important to show the basis and limitations of the conclusions reached. The first point is that none of the fishes were sought individually by specialised techniques. This would have required additional effort in the construction and operation of specific gears which is not justified by the low level of abundance of most fishes in the fauna of the sites;all of the species occur together in a small number of habitats which demonstrates how they could have been taken together. The one exception could be the saithe given its predominance in the assemblages. However,it is abundant in the natural fauna and other fishes of the same environments are present in the samples;the exploitation of the saithe may therefore have been the primary object in terms of fishing but it was not sought in isolation. As the fish are not all found in one single habitat it seems likely that several fisheries were practised;the considerable size range of the fish also suggests that a number of fishing gears were used to catch them. Three groups can be recognised in terms of the nearest proximity of the species to the shore but it should be remembered that most of them will also occur in zones further offshore:

i.'inshore' waters of 5-10m or greater depths: Exploitation of this zone requires a boat and as all the species live mainly near the bottom,some over rocky ground,only line fishing can really account for the catch. The fish are fairly large and so hook size is not a problem and they are all easy to take on baited lines. Included in this group are the large saithe and lythe,dogfish,monkfish and thornback ray,sea bream,large conger and possibly wrasse. The hake and ling could also be included;they are really fish of greater depths but occasional specimens do stray inshore. This fishery was on a very small-scale and it is even conceivable that it resulted from opportunistic catches while boats were at sea for other purposes; the potential existed for increased catches,and the large size of individuals should have been an attraction,but it is likely that the effort relative to the other fisheries did not justify more emphasis on this.

ii.intertidal zone: The widest possible range of techniques can be used to catch fish in this area but the simplest explanation is to envisage a range of simple opportunistic collecting procedures accompanying other activities on the shore;the fish could be caught by hand,speared etc. among the rocks,pools and shallows. Shanny,sea scorpion,conger,flounder and possibly eel could be taken in this way,and this could also account for the freshwater salmonid. If the flounder is excluded then all the fishes are ones of rocky shores which shows the parts of the coasts that were being exploited;this is also where the shellfish were collected. Occasional specimens of fish from deeper water might also be found in this way,as they were stranded by sea and weather conditions(Low 1813,210) or abandoned by predators;there is a good example of this from the Orkneys where the habits of the otter were exploited:

> 'where his haunts are known,the country people are very careful every morning to search for the remains of the night,and are seldom disappointed,but find cod,ling .. sometimes but especially congers '(Low 1813,186-7).

iii.sublittoral waters of a few metres: The fish of this zone are the most difficult to interpret as there are several potential methods of capture and no evidence to favour any one of them. This group includes the young saithe and lythe,wrasse, eelpout,and possibly the conger,eel and flounder. The abundance of saithe means that this zone dominates the archaeological fauna and most effort presumably went into the fishery. This must favour an 'efficient' method of capture. The second point to note is the size range of fishes caught and in particular the small size of some of the saithe;the size distributions of the saithe appear to show no signs of selection which with the large numbers of small fish suggests some form of unselective mass capture technique.

The main possibilities would be some form of net,either a scoop net or shore seine,or a tidal trap or weir(O'Farrell 1971,127),although the historical practice of craig fishing must be considered. The latter is feasible,with simple gorges on baited lines,but the fishing would have been a very time-consuming activity and the lack of selection among first year saithe is quite remarkable. At this stage it is worth considering whether the two age groups of the species could have been taken separately with different gears. The different ratios at the sites and more particularly the clear segregation at Cnoc Coig does not rule this out but equally is not proof of the practice. Their geographical ranges overlap but are not coincident,with the small ones close inshore,the older ones in deeper water and both taken between(as off harbour piers).

Very little is known about mesolithic net technology but it is difficult to envisage a large shore seine type of net that would be strong enough to hold the older fish and fine enough to take all saithe;the effort in manufacture and the difficulty of a rocky weed covered coast support this view.Of course separate nets could have been used for each age group and at least for the first year fish this is quite feasible; the older ones could then be taken on lines,either from the shore or as part of the inshore fishery.

The alternative is some form of tidal trap or weir. This would entail a fairly high initial labour input but would have a long life,constructed of rocks,wickerwork or netting and taking advantage of the form of the shore and the high tidal range of the island(Loder 1935,279). Large catches are possible with little effort and it would take a wide range of species. All of the intertidal and sublittoral fishes,and possibly some of the inshore species could be caught in such structures. If ground bait was used to attract the fish the yield would be even higher;limpets would be an obvious choice(Clarke D V 1976, 243-4;Fenton 1973,73-5;Goodlad 1971,138;Rendall 1974,90).

If one fishing technique is sought to account for the bulk of the fish fauna then a fish weir has to be the clear favourite both from the logistics of the gear and the nature of the catch. However,it is not easy to accept that it would take all the fishes,especially from the inshore zone. Therefore some line fishing from boats is likely and is not surprising for a marine oriented economy such as this. The other extreme from this minimal solution is to propose individual fisheries for each species. This has been ruled out but a range of fishing methods is quite possible where they are simple generalised techniques with straightforward gears and capable of taking a range of fishes eg.spears,scoop nets and small lines(Wheeler 1979,148). The large quantity of fish remains in the sites does tend to favour an explanation of a well-developed mass capture fishery and a tidal weir would fit this very well but a more individual opportunistic group of fishing methods could equally account for the remains. It may not be possible to resolve this problem,which highlights the difficulties of the subject,but perhaps a better understanding of the ways that other resources were managed will provide some indications.

CONCLUSION

The starting point of this study was the large assemblage of fish remains that were being recovered from the Oronsay shell middens. The existence of such a body of material provided the incentive to take the time to collect comparative material and investigate methodological problems, as well as providing adequate samples for analysis. The dominance of a single species in the fauna simplified the study as it was possible to concentrate upon this one fish and consider a whole range of questions, rather than a single aspect of many species. Finally, the work has been undertaken within the framework of a wider project. The study commenced while excavations were in progress and it was possible to develop and modify sampling and recovery procedures to produce the samples required for analysis. The project has also established a range of aims for the study(Mellars & Payne 1971) and the fish remains have demonstrated their appropriateness for investigating several of these issues.

The sampling and recovery procedures of the excavations were found to be appropriate for the fish remains, particularly in the use of fine-meshed wet-sieving. It has been possible to investigate much of the timespan of the sites through the column samples; the 2mm fractions are adequate to recover the species list and the 1mm fraction complete classes of material(the saithe otoliths etc). At Cnoc Coig the wider sampling and the area excavations gave a further check on the level of variability; trench recovery or one eighth inch sieving would have been an inefficient method of recovering all fish but gave an extra dimension for the less frequent classes of material. Also at Cnoc Coig it was possible to develop a sampling strategy for the concentrations and 'layers' of fishbone that were found; this flexibility, accompanying the standard procedures, has yielded important results and demonstrates the advantages of combining various strategies of sampling and recovery.

As the first stage of analysis the accuracy of identifications is important but there are problems and it is essential to record the criteria used in the work. In the first place, there are many gaps in the available reference collections, particularly among the selachians and smaller shore fishes; these form an important part of the fauna of the Oronsay sites.

Relatively few absolute diagnostic features have been recognised and there is potential for misidentification until many more comparative studies are available,detailing the extent of intraspecific variation and quantifiable characteristics. Even then the precision of identifications will depend upon the level of preservation,intrinsic properties of the element,and the taxonomic complexity of the group of fishes. All of this complicates attempts to quantify assemblages. The species list can be based on a single element for each species but other stages of analysis require further data. The most common procedures are the total number of identified pieces and the number of individual fish but both are faced with several problems. The ones that apply to fish more than other forms of vertebrate are the differences in the number of bones per animal and the level of taxonomic resolution that can be achieved for different bones. Any estimates must therefore take account of such difficulties and the aim must be to choose the simplest appropriate method of calculation. By comparison,the reconstruction of the size of individuals is straightforward;before bones are measured, however,a relationship has to be established with the size of the fish and the correct expression of its form decided. A simple regression analysis(least squares) is the best way to demonstrate this and encourages another good practice because it requires a reasonably large sample of observations. But it is not a goal in itself;the usefulness of size reconstruction rests in its application in questions about the meat yield, seasonality,method of capture,etc.

The calculation of meat weights should be based upon the actual size of individuals because of the indeterminacy of fish growth but the next stage of estimating the edible proportion of the fish is more difficult. Practices vary greatly and so a value of 50% for roundfish like the saithe is the minimum estimate,assuming only that the flesh on the body is eaten. Fish is a good nutritious food,particularly as a source of protein and some vitamins and minerals,but faces the drawback of a rapid rate of spoilage. Most of the catch is therefore preserved using a variety of techniques;all of the methods are relatively simple and likely to have been developed at an early stage(Campbell 1977,129). Various lines of evidence can be used to investigate the ways that fishes were utilised including artefactual remains,the patterns of deposition and the condition of the bones. However, few traits are diagnostic of single processes and the influence of discard patterns and taphonomy have to be included. It is not surprising therefore that it is difficult to positively identify specific practices in archaeological assemblages.

The presence of preserved fish could distort interpretations of the seasonality of sites and it should be emphasised that it is the season of capture that is being established. Fish have been used extensively in such studies because of their clear patterns of annual behaviour but few attempts have been made to distinguish between the total availability and optimal availability of fishes or to consider the probability of capture at any time of the year. Inferences from recent exploitation systems may not be appropriate as different criteria may be operating; for example, the emphasis on fisheries for young saithe in the autumn may reflect their size and abundance at this season but also the need for dried fish over the winter months, and the fish is otherwise available for most of the year. It is therefore necessary to develop independent measures of seasonality. Fish size is one technique, but it is only appropriate in very specific circumstances. Growth rings have a much wider usefulness despite the practical problems in correctly reading the patterning and the archaeological difficulties posed by preservation conditions.

Interpretations of the methods of fishing are as difficult as the recognition of processing activities because they rest upon the same types of evidence and many of the results can be explained in a number of ways. Inferences from remains of fishing gear are complicated by the patterns of discard and preservation, as most gears are made of organic materials and are composite. Patterning among the fauna, in the species or sizes of fishes represented, may reflect where and how they were caught but also consumption and discard behaviour, preservation or recovery conditions. Broader indications of the nature of the fishery may be provided by the scope of the fauna; the quantity and diversity of the catch can be used to infer the type of gear, given the selectivity of most fishing methods, and possibly the nature of the activity in terms of the degree of specialisation or efficiency of the practice. This last point should remind us that the capture and utilisation of fish is not an isolated activity but is part of wider economic systems and the study of the relationship between them may throw more light on the pattern of exploitation of the fish,

The fish fauna of the Oronsay middens is quite diverse, with at least 16 species and possibly over 20 if all the early identifications were correct. Most are represented by small numbers of bones and there are no concentrations of non-saithe material which suggests that they were not caught in a series of separate specialised fisheries. They are all marine,with one exception,and are common in the inshore waters around the island today. However they occur in a variety of habitats and it is unlikely that they could be caught in the same fishery. Those species that live away from the shore were presumably taken on baited lines from boats;the individuals are all quite large and the species represented are all easy to hook. The fishes of the intertidal and sublittoral zone are more difficult to interpret because a range of fishing methods are suitable. The lack of selectivity in the catch,both in species and sizes,and the large numbers of fish indicates an efficient fishery probably with a combination of techniques:including collecting activity along the shore and some form of mass capture such as a tidal fish weir.

The absolute dominance of a single species could be taken to indicate a specialised fishery but it does seem to agree with the availability of the fish paralleled in the historical exploitation of the seas. The evidence from these and from the behaviour of the fish indicate that it can be caught over most of the year with no particular season of optimal availability. Therefore it has been necessary to develop alternative methods of assessing seasonality from the size of the fish and growth rings on the otoliths. Both of these have worked fairly well and show consistent results. Consistency is the most striking aspect of the results,in the measure of agreement between samples from within a site and the differences between the sites. At each site there is a single short season of activity,possibly spread over a couple of months,or less in any year,with one or more subsiduary periods at different times of the year at some of the sites. Three of them appear to be 'summer' sites(Cnoc Sligeach,CNG I & II),one in the autumn,and one at some period over the winter(Cnoc Coig and the Priory respectively). The reason for the predominance of summer is unclear and may not be dependent on the availability of the fish. The differences between the sites in the species lists can also be partly explained by the season of saithe fishing as rather more fishes are available during the summer;the differences between the summer sites themselves are more complex and will need further consideration.

The historical references demonstrate that the young saithe can form a very useful resource:easy to catch in large quantities,reasonable taste with the liver oil as a second product,and suitable for use fresh and for drying. There is little evidence of how the archaeological fish were treated. At Cnoc Coig concentrations of up to several dozen fish of one size group were noted but these represent units of discard and it is not certain that these equal groups of caught fish. Also noted were concentrations of bones from the branchial region and groups of articulated bones with the cranium and vertebral column intact;however,it is not known how widespread these practices were and they do not provide much insight into processing activities because gutting and leaving the head and body intact can accompany various forms of use. Similar patterns seem to exist at the other sites,especially in the relative frequencies of elements,which might indicate that the same practices were used at all the sites with the implication that there were no seasonal differences in the ways the fish were handled. Unfortunately there is no evidence as to whether the fish were preserved or not,as this could influence the overall interpretation of these middens.

Fish clearly formed an important part of the diet. Calculations of the meat yields of other resources are not yet available but on rather crude estimates fish exceeded shellfish in a few samples and contributed roughly half as much meat overall(Mellars 1978,378-9). The sites are broadly contemporary and could have been occupied at the same time;the evidence of fishing activity suggests that they could have functioned in turn as part of an annual settlement system. This provokes a series of further questions as to whether all activity on a site occurred at the same season,why the sites are located where they are,and whether there are other sites on Oronsay or elsewhere that functioned as part of the same system but these must wait until data is available on other aspects of the Oronsay material;the exploitation of the fish was only one part of an economic system and it cannot be understood in isolation.

In some senses this study should be termed an introductory account. For the Oronsay material the analysis of the fish remains is not yet completed, especially on the seasonality, the contents of the fishbone concentrations at Cnoc Coig, and column samples from CNG I; and other aspects of the sites are currently under investigation. While in terms of the wider interest of the thesis, the methodology of the analysis of fish remains, there is much scope for development. When this study was begun there was no published framework for such work but a number of important contributions have since appeared; these include Casteel(1976), Wheeler(1977c; 1978a) and papers by Leach. The subject is now clearly beyond the 'descriptive-inferential' stage and into an 'analytical' framework; the potential exists for fish remains to make important contributions to studies of economic systems, in such fields as seasonality, the development of exploitation technology, trade etc. but this will depend upon gaining a better understanding of our material and its limitations. At the same time it is interesting to note the parallel development of interest in understanding the wider question of how the exploitation of fish fits within the whole 'economy'(Allen 1979; Andersen 1974; Jones 1978; Schalk 1977); by attempting to model patterns of exploitation we move closer to understanding the factors underlying the system.

Appendix 1

Analysis of samples of archaeological fish remains

Procudure

Sieving: all of the samples were carefully wet-sieved through meshes of 2mm and 1mm(the material retained by the sieves is referred to as the 2mm and 1mm fractions),dried and then gently resieved before sorting.

Sorting: all fragments identified as belonging to species other than the saithe were removed and recorded. The intention was to recognise as many elements as possible from the different parts of the body of the saithe;the list of those counted is given in Table 8. The remaining elements were present,including scales,but were too fragmented to count accurately. All items were counted by a specific feature of the bone,divided into left or right etc.,as appropriate together with the number of other fragmentary pieces. The numbers of complete otoliths and parts of broken specimens was recorded with counts of the numbers of whole bones based on various parts of the bone; the anterior,posterior and central points with the latter recognised as the interruption in the sulcus acusticus(Figure 7a). Counts of the numbers of whole elements in samples are given in Table 7.

Measurement: taken on the otolith,premaxilla and dentary. The maximum length of all complete otoliths;estimated lengths of almost complete specimens and broken ones that could be pieced together;and fragments were assigned to millimetre length classes;the maximum breadth was taken at 90° to the axis of greatest length. On the jaw bones,the depth of the dentary at the symphysis and the width of the base of the ascending and articular processes of the premaxillla(Wheeler & Jones 1976, 240-1) were measured. All taken using dial calipers to an accuracy of 0.05mm. The otolith length measurements are given in Table 9,grouped in 0.5mm classes.

Full details of all the identified and measured material will be included in the site archive.

The Samples

CNOC COIG

50 column samples from 13 test pits(Peacock 1978),with 1-8 vertical units in each pit. 2mm fractions completely sorted

and analysed, except for the last 9 which are only partly analysed; no 1mm fractions have been analysed. Samples 1a - 14d

38 small concentrations from across the whole site. 2mm and 1mm fractions sorted, completely in 10 samples and for otoliths only in the remainder. Samples 1 - 38

30 units from two large concentrations or layers (adjacent 250x250mm squares) in the south east quadrant of the site.

Lower level: 6 units, 2mm and 1mm fractions sorted for otoliths, and all bones in two of them. Samples L1 - L6

Upper level: 24 units, only the 2mm fraction sorted for otoliths and the 1mm fraction in one sample. Samples L7 - L30

PRIORY

One trench excavated with a single column of 11 samples. 2mm fractions completely sorted and analysed; 1mm fraction of the 3 uppermost units sorted for otoliths. Samples 1 - 11

CNOC SLIGEACH

A single trench with a column of 5 samples. 2mm fractions completely sorted and analysed and 1mm fractions for otoliths.

Samples 28 - 32

CAISTEAL NAN GILLEAN II

Four trenches excavated, each with a column of 2-5 samples. 2mm fractions completely sorted and analysed and 1mm fractions for the richest deposits (EFGHJ, QR) sorted for otoliths.

Samples A - R

CAISTEAL NAN GILLEAN I

Two test pits excavated in the backfill of the earlier excavations and five samples taken. 2mm and 1mm fractions sorted for otoliths in 4 samples and for all bones in two of these (4,5). Samples 2 - 5

Appendix 2
Samples of saithe caught in the waters off Colonsay & Oronsay

Capture

Samples of the fish were obtained at different times of the year(from April to December;a trip in February 1976 caught no fish) over a number of years(1973,1975-8) and with different gears at several locations along the east coast of the islands. Most of the first year fish were obtained in Colonsay harbour (Figure 1) on a simple handline or rod and fixed line with a small hook baited with periwinkle;the remaining individuals and some second year fish were caught by angling from the harbour pier. The majority of second year fish were taken on a multiple hook handline with feather lures('darrow') either a little way south of the harbour or off the east coast of Oronsay.

Processing

The principal aim in all samples was the collection of the sagittal otoliths. Several dissection techniques were tried but the most appropriate was found to be a single transverse cut across the head down to the level of the otoliths(Williams & Bedford 1974,115);some were broken particularly in the early samples,which accounts for the lack of pairing in the material. The maximum length of all specimens has been measured together with the breadth of some samples;all the material has been retained. In one sample,April 1976,the premaxillae and dentaries were also kept and a number of whole skeletons from various samples are available. Observations on fish size were made in a number of samples. Fish length was recorded as total length or as tail fork length(Figure 8);measured to an accuracy of 50mm or 10mm in later samples. Fish weight was recorded as total weight throughout,although some other details on the weights of dismembered parts of the body were taken on some fish(Table 10);except for the 1973 sample when ounces had to be converted to grams measurements were recorded to 0.5g.

The Samples

<u>Key</u>: Location of fishing-Colonsay harbour(CH),east coast of Colonsay(C),east coast of Oronsay(O). Age of fish-first year(1), second year(2),older fish(2+). Measurements-total length(TL),

fork length(FL),weight whole(FW),weight dressed(DW),weight boned(BW),meat weight(MW),otolith length(OL),otolith breadth (OB),premaxilla(P),dentary(D).

Date	S	Location	No. fish	Age	Measurements(no. of pieces)
26.08.73	1	O	24	2	FW(24),OL(31),OB(44)
?.08.75		O	2	1/2	FW(1),OL(3)
25.08.75	2	O	38	2	TL(78),FW(78),OL(104),OB(124)
04.09.75	3	O	40	2	
21.11.75	4	O	51	2	TL(10),FL(104),FW(104),DW(23), OL(182),OB(102)
22.11.75		CH	53	1	
30.04.76	5	C	7	2/	TL(22),FL(22),FW(22),DW(20),BW (20),MW(20),OL(43),P(44),D(40)
		O	15	2+	
19.06.76	6	O	-	2/2+	OL(119)
06.07.76	7	C	27	2	TL(27),FL(78),FW(78),OL(166), OB(62)
07.07.76		C	51	2/2+	
		C	-	2/2+	
27.08.76	8	O	53	2	FL(94),FW(94),DW(33),OL(175)
		C	41	2	
30.07.77	9	O	30	2	FL(86),FW(85),OL(151),OB(169)
		CH	22	1/2	
02.08.77		CH	22	1/2	
03.08.77		CH	12	1/2	
21.08.77		O	3	2+	OL(6),OB(6)
06.09.77	10	CH	7	1	FL(30),FW(30),OL(59),OB(60)
07.09.77		O	23	2	
21.06.78	11	C	-	2	OL(74)
02.08.78	12	O	-	2	OL(157)
20.09.78	13	O	-	2	OL(109)
02.11.78	14	C	-	2	OL(147)
14.12.78	15	O	-	2	OL(75)

S -sample numbers used in Table 12:otolith length frequencies

Appendix 3
Studies of the rate of growth of young saithe

The growth of the older fish is well-documented(Reinsch 1976) but less work has been done on the younger age groups. Almost twenty references have been traced which contain some data on the size of individuals at specific locations and times of the year. None of them provides a comprehensive account, although Bertelsen(1942) is a detailed study, and some only contain one or two observations(McIntosh & Masterman 1897) or repeat the figures from other studies(Meek 1916). It is very difficult to make detailed comparisons of the sets of results because of the limited information accompanying most of the data, differences in sample sizes and forms of presentation, and the various measures of fish size that have been used(Lie 1961, 7). Nevertheless, many features can be studied from individual accounts and there is sufficient material to make some general comparisons worthwhile, particularly of the differences in the mean rate of growth of populations between areas(Figure 18). There is reasonable coverage throughout most of the range of the species(Figure 9b), with the exception of the southern limit, and the studies can be listed on the basis of their geographical range:

1.Murman coast(68 - 70°N). Mean growth curves 1a, 1b(Fig 18)
Baranenkova(1959): includes 3 sets of data: a large sample of fish up to 3 years collected through the year over several years; one of first year fish also over several years; and a single population of first year fish over the summer months.(1a)
Mironova(1961): single set of data, with a very large sample of fish up to 3 years taken over 5 years. (1b)

2.North Norway(67 - 70°N).
Damas(1909), Lie(1961) and Nordgaard(1901): a few isolated samples taken at particular times of the year, mostly for comparison with results from further south.

3.Iceland(64 - 66°N).
Saemundsson(1929): fairly extensive sampling of populations from fjords on different coasts over a number of years; all ages of fish included.
Schmidt(1909): two samples of first year fish after their movement inshore.

4.The Faroes(62^{O}N).   Mean growth curve 4

Bertelsen(1942): the most comprehensive survey covering the range of growth within populations,between them and through time;but samples only collected over the summer. (4)

Schmidt(1909): two samples of first year fish.

5.West Norway(60 - 63^{O}N).   Mean growth curves 5a,5b

Damas(1909): series of samples at a number of locations, including a sequence at Romsdal.

Nordgaard(1901): collection of samples from different times of the year and locations. (5a)

Lie(1961): series of samples of first year fish from a small area over two separate years. (5b)

6.South Norway(57 - 59^{O}N).

Wollebaek(1900): three groups of first year fish over one summer.

Dannevig(1933): nine separate groups of fish from along the Skaggerak during one year.

Poulsen(1934,1937): series of samples of an isolated influx of saithe fry into the Kattegat.

7.Hebrides(56^{O}N).   Mean growth curve 7

Personal observation of the populations around Colonsay-Oronsay(Appendix 2). (7)

Schmidt(1909): single observation of fry in early summer at Stornoway.

8.Irish Sea(53 -54^{O}N).   Mean growth curve 8

Liao(1951): monthly catch data over three years from the Isle of Man.

Nagabhushanam(1959): quarterly catch data from the Isle of Man.

Kennedy(1969): samples from Dublin Bay of fish of first 3 years caught over a period of 5 years;only ranges are given and so it is not possible to calculate mean values. (8)

Schmidt(1909): two samples of fish in the first summer from Valentia Harbour,S,W.Ireland.

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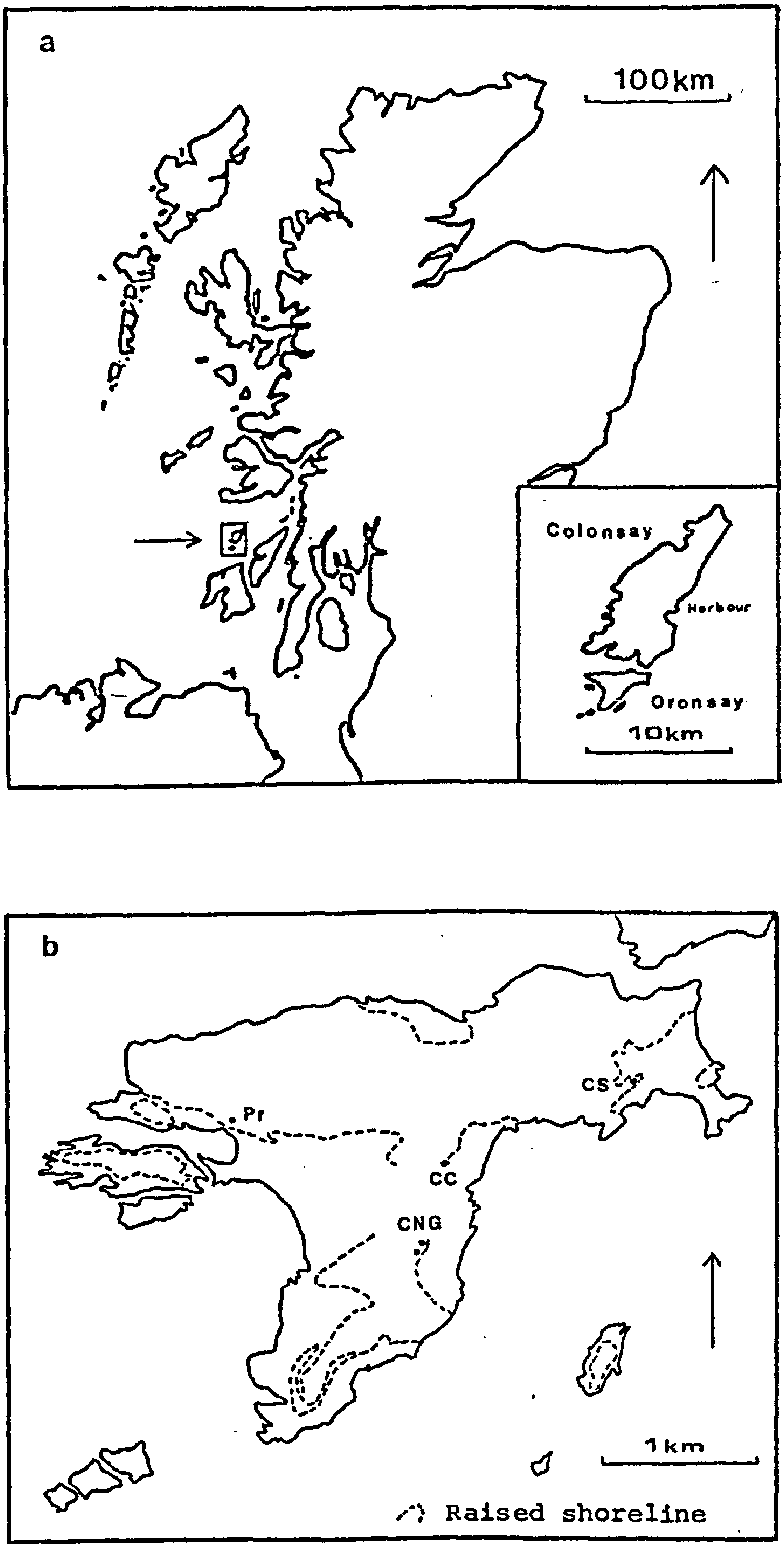

CNG Caisteal nan Gillean CC Cnoc Coig
CS Cnoc Sligeach Pr Priory

Figure 1 Location of (a) Colonsay-Oronsay and (b) the sites

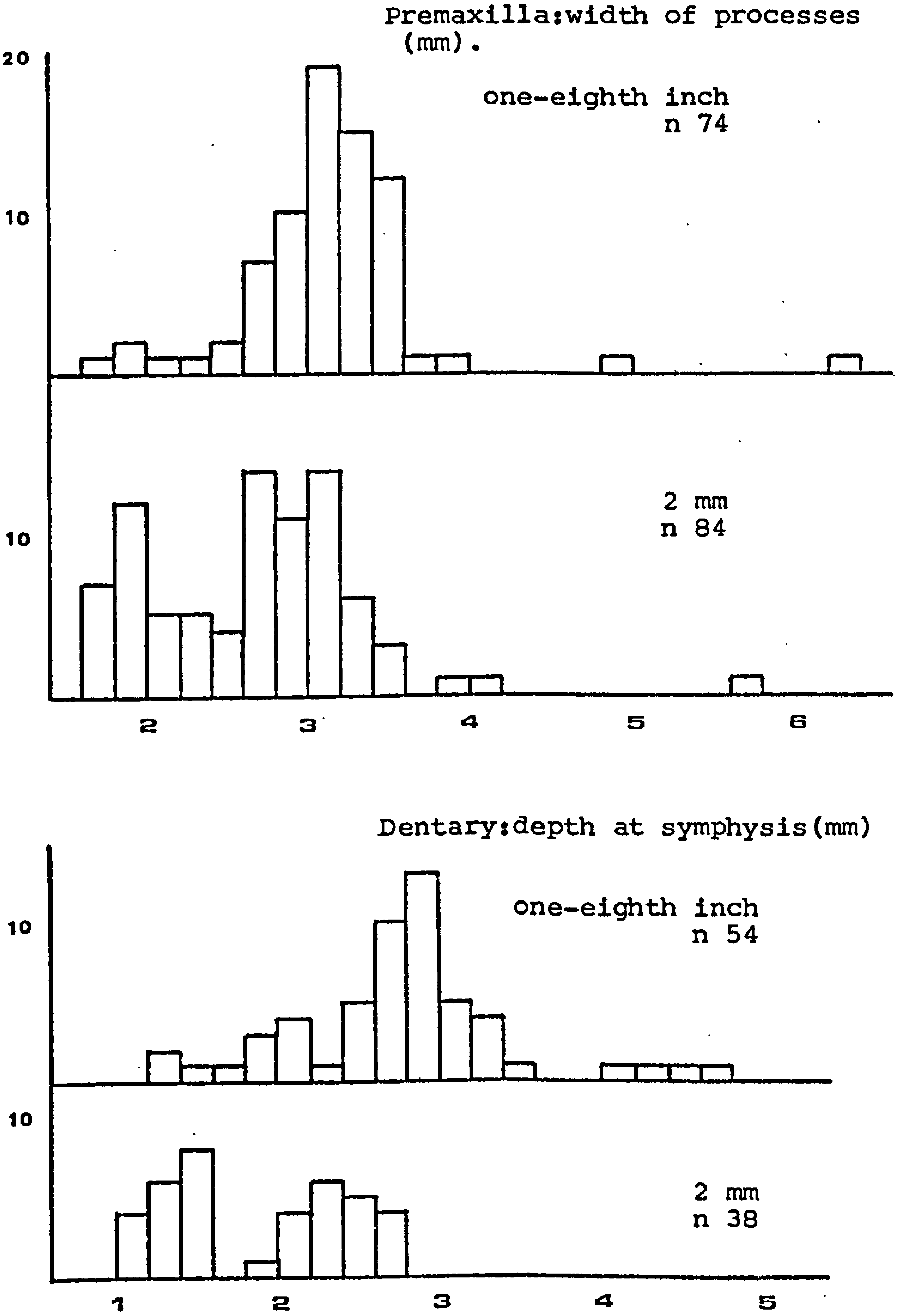

Figure 2 Comparison of recovery procedures:the sizes of jaw bones from CNG II

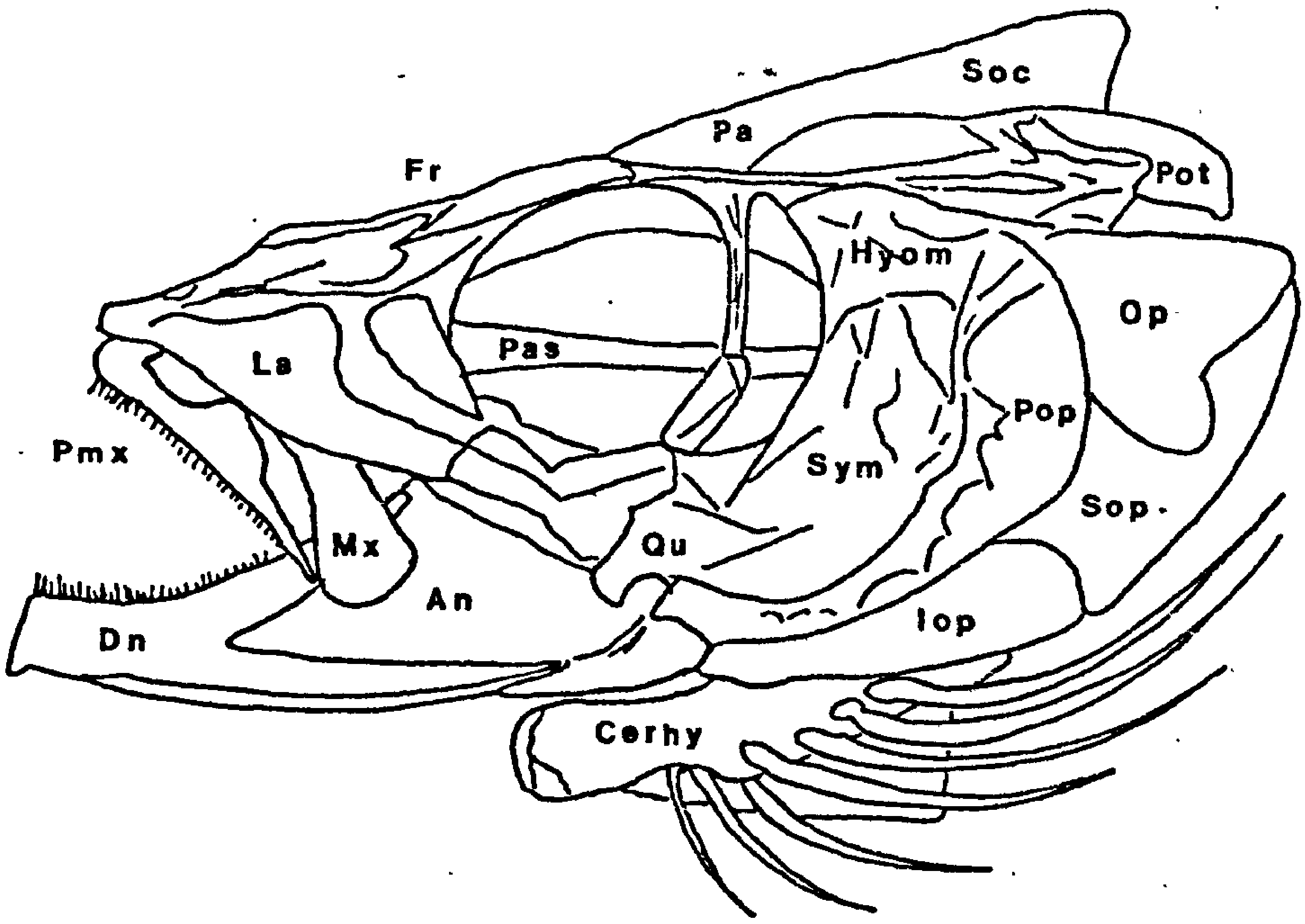

Figure 3 Skeleton of a gadoid fish:the head

For key see the list of abbreviations(page 7)

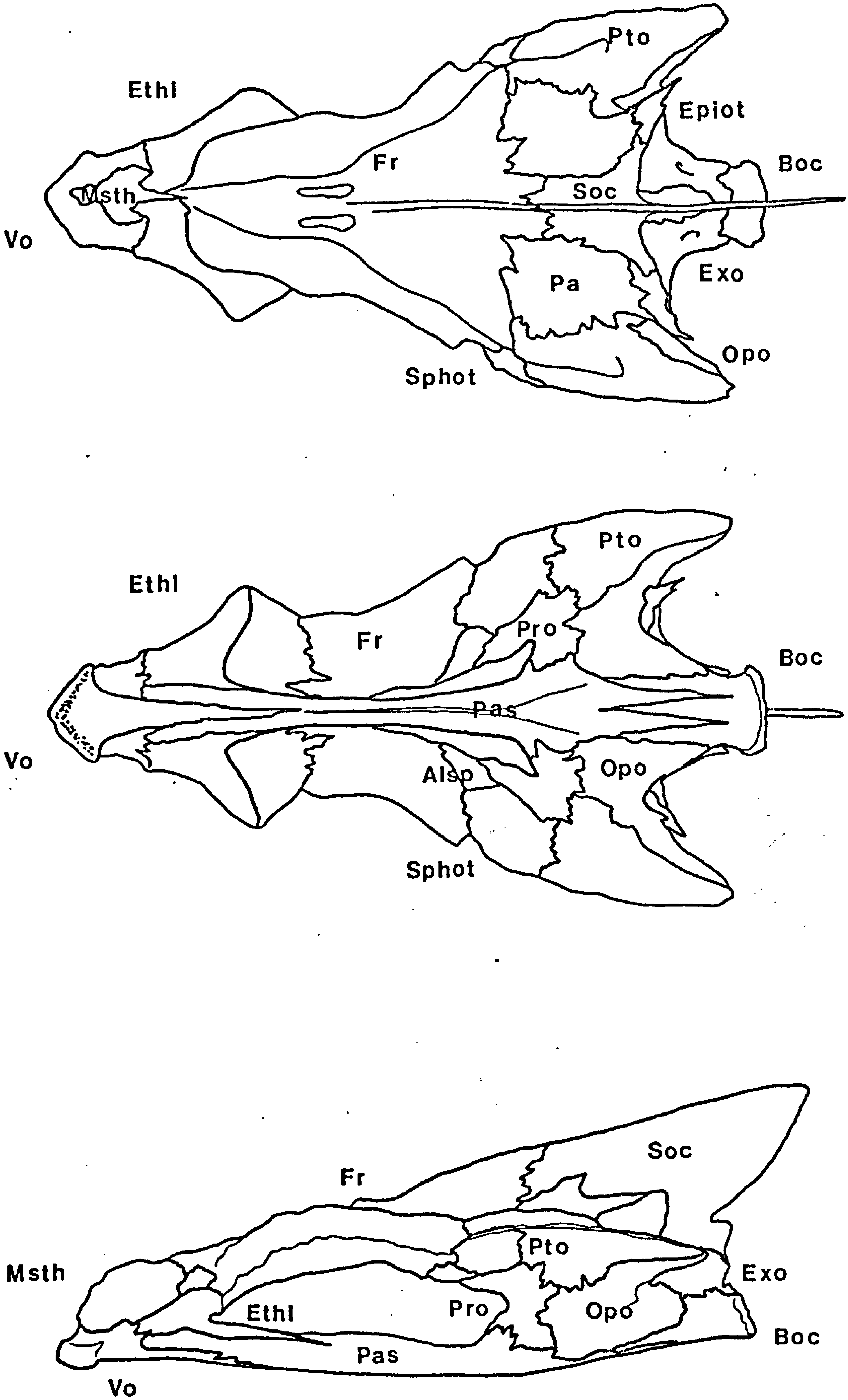

Figure 4 Skeleton of a gadoid fish:the neurocranium

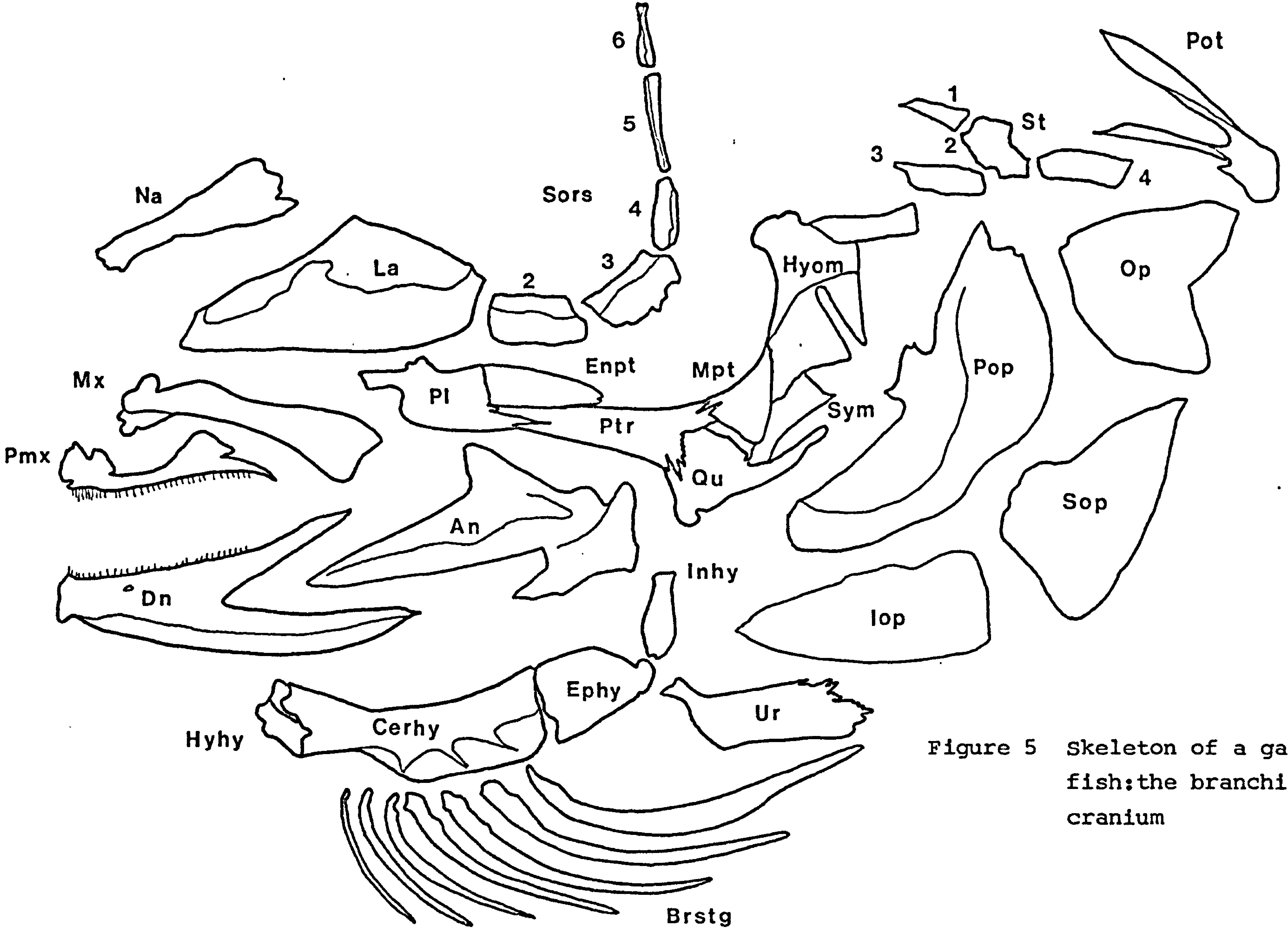

Figure 5 Skeleton of a gadoid fish:the branchio-cranium

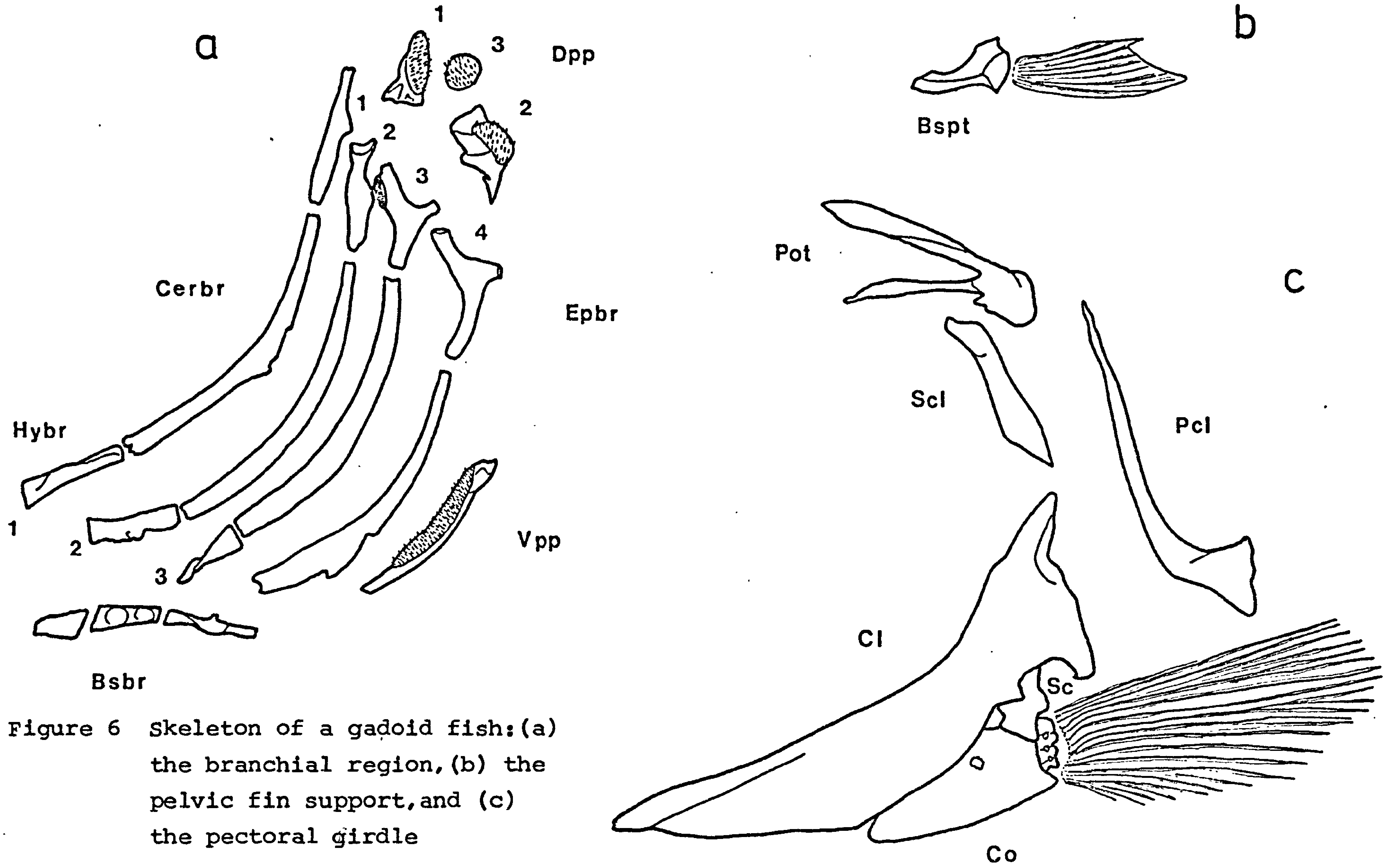

Figure 6 Skeleton of a gadoid fish:(a) the branchial region,(b) the pelvic fin support,and (c) the pectoral girdle

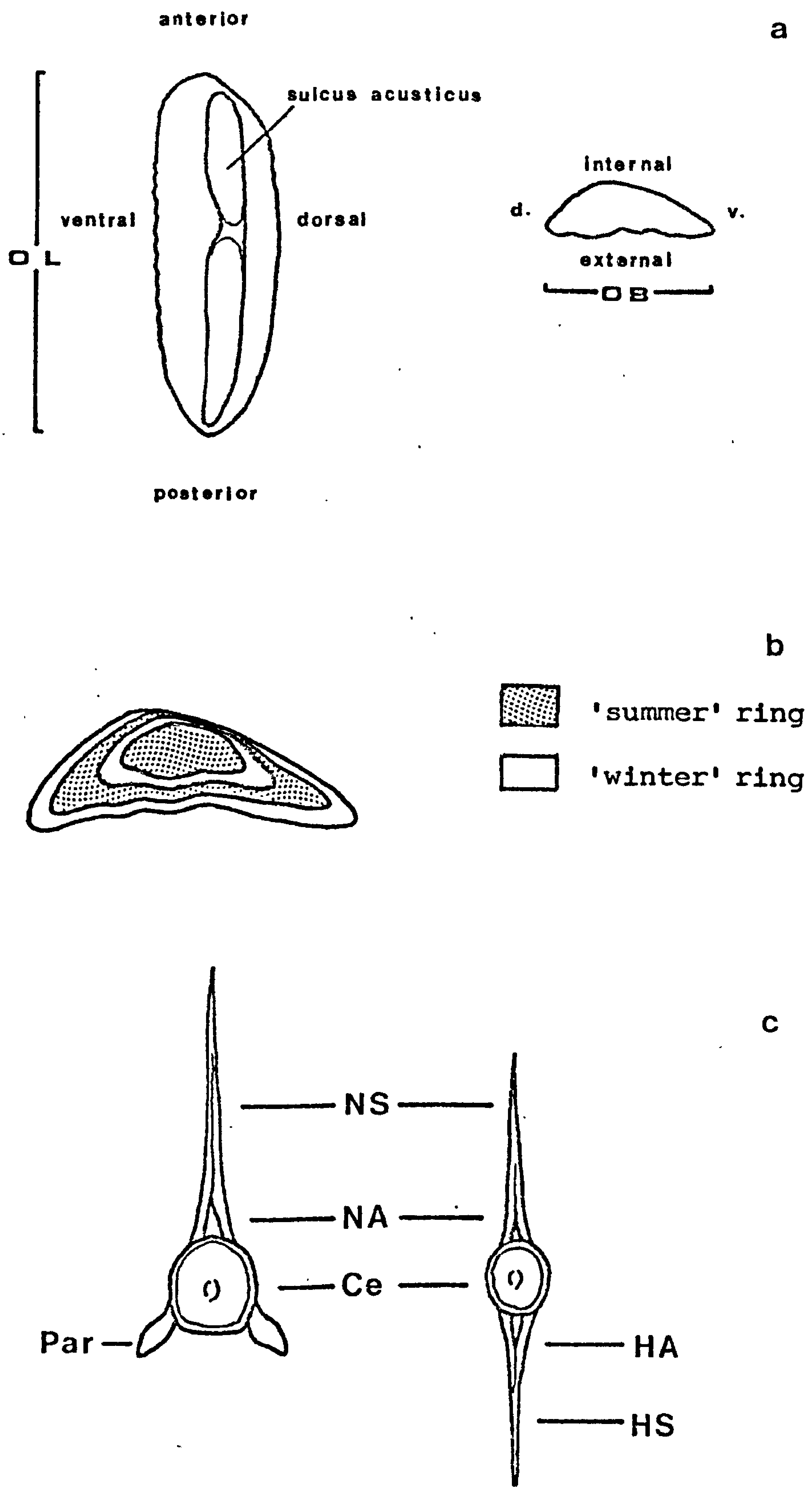

Figure 7 Skeleton of a gadoid fish:(a) sagittal otolith,(b) otolith in section,and (c) abdominal and caudal vertebrae

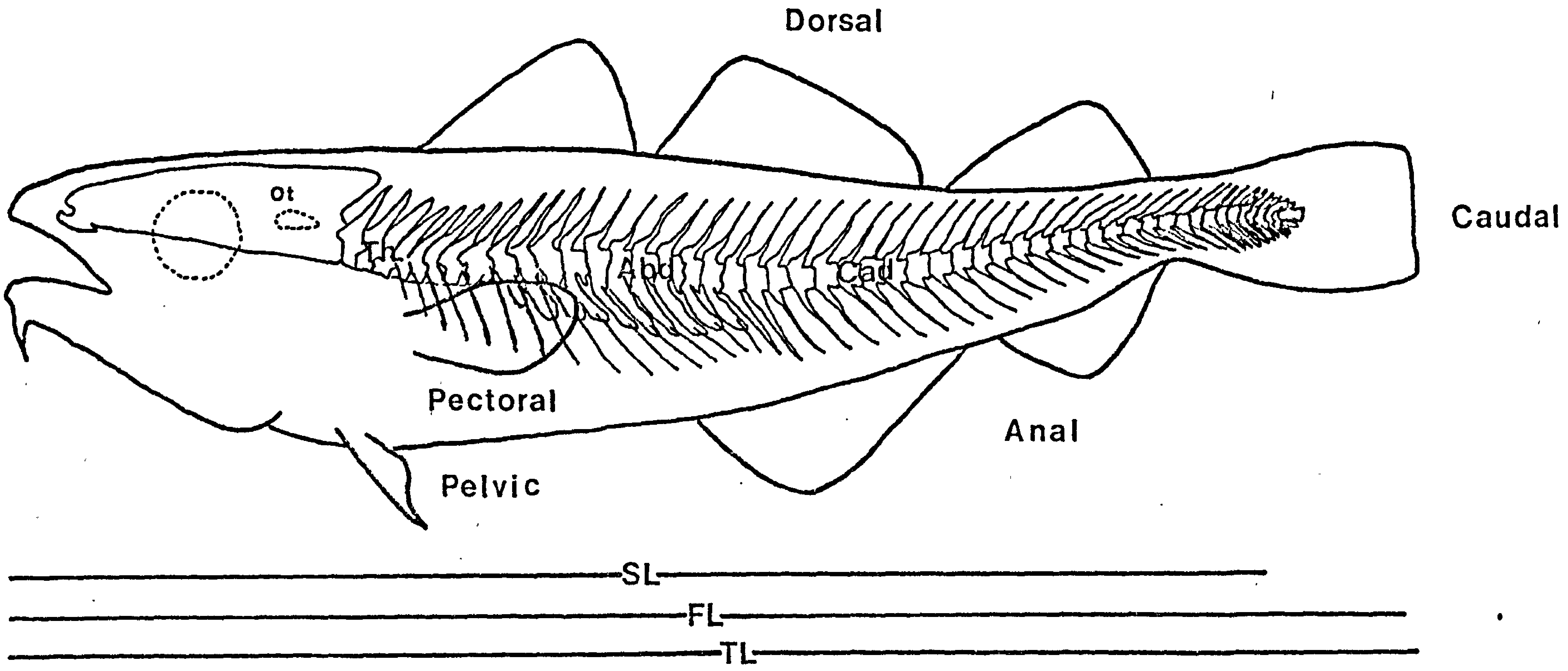

Figure 8 · Skeleton of a gadoid fish: the arrangement of fins and the vertebral column

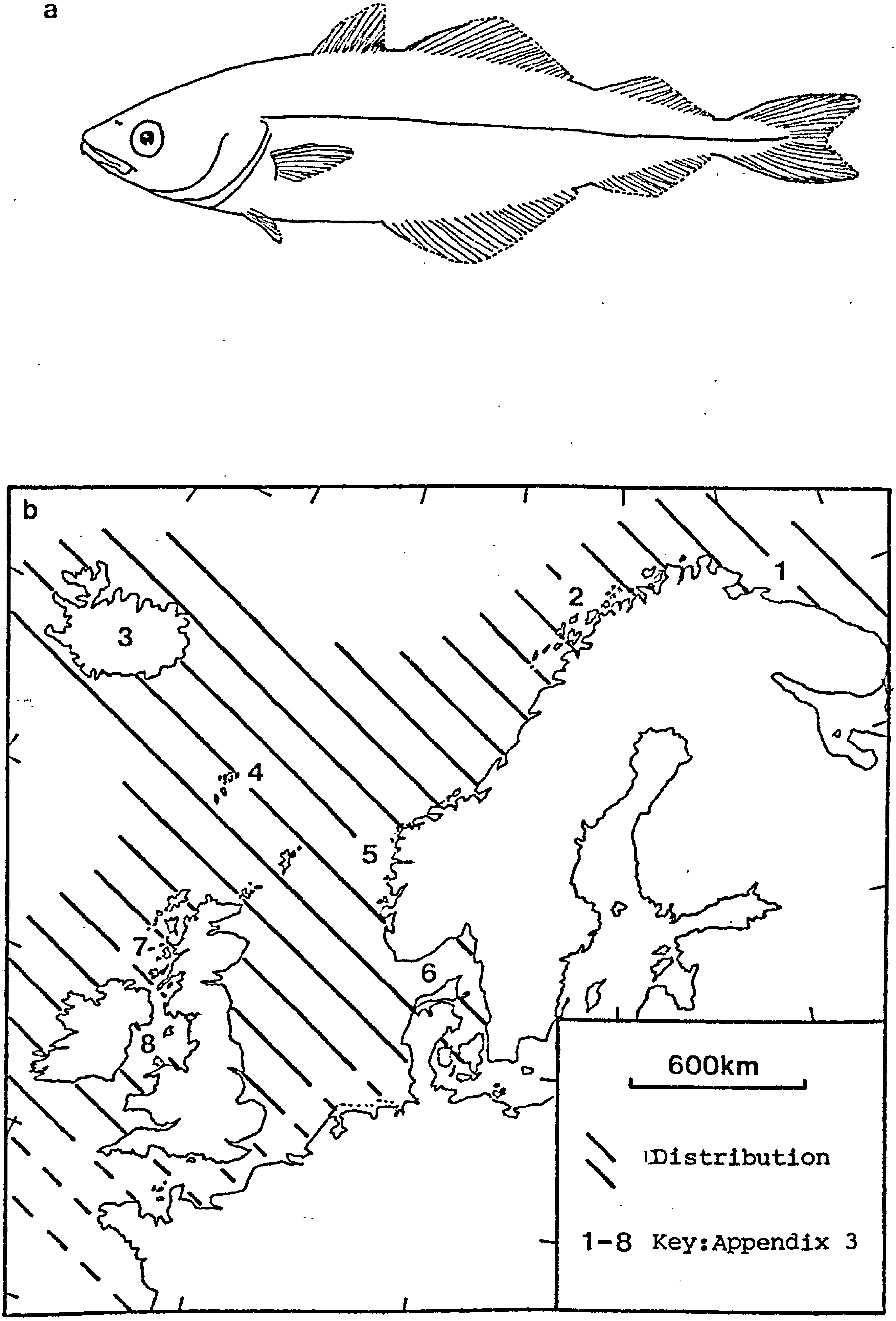

Figure 9 The saithe(a) and its distribution(b)

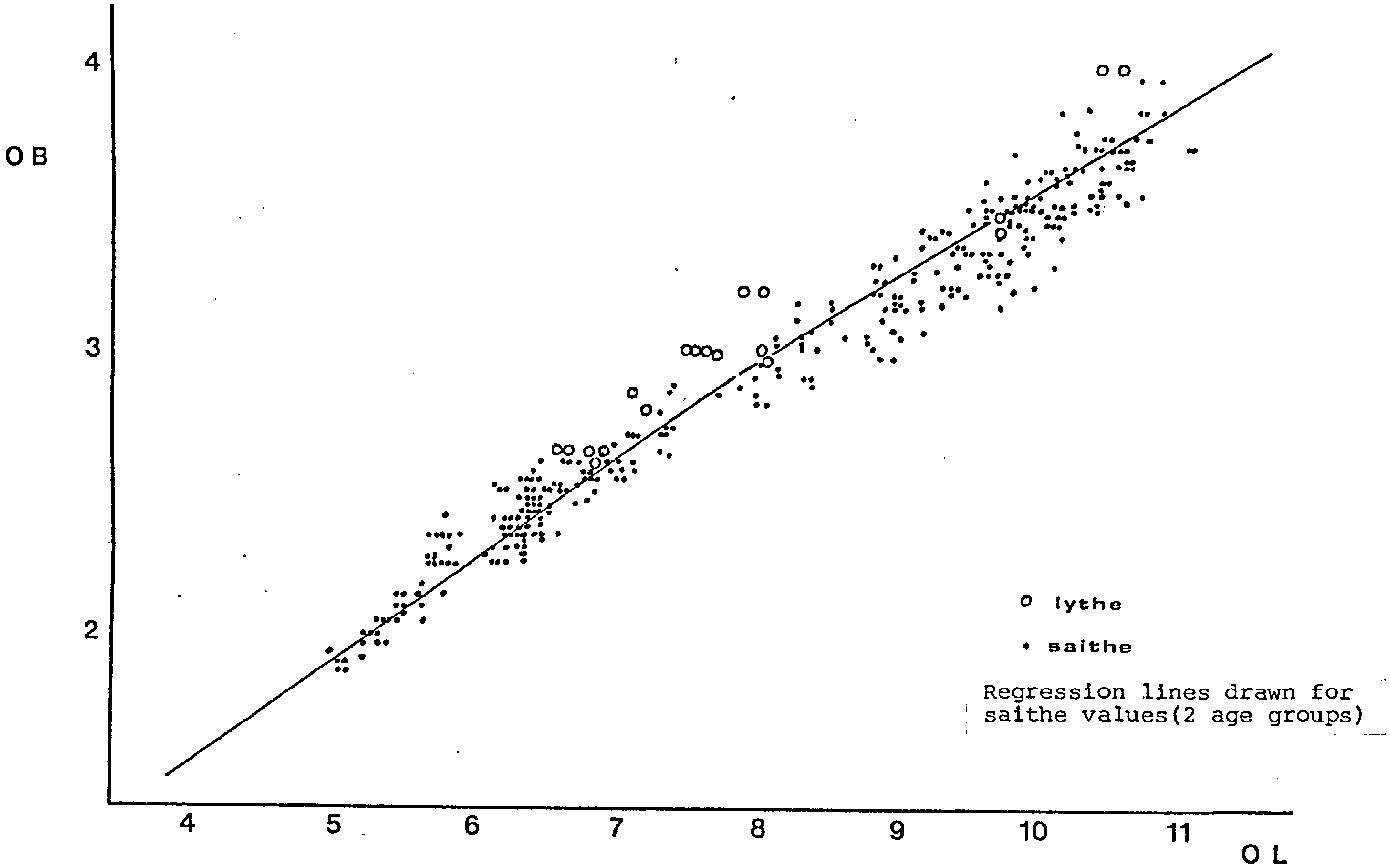

Figure 10 Length:breadth ratio(OL:OB) of saithe otoliths

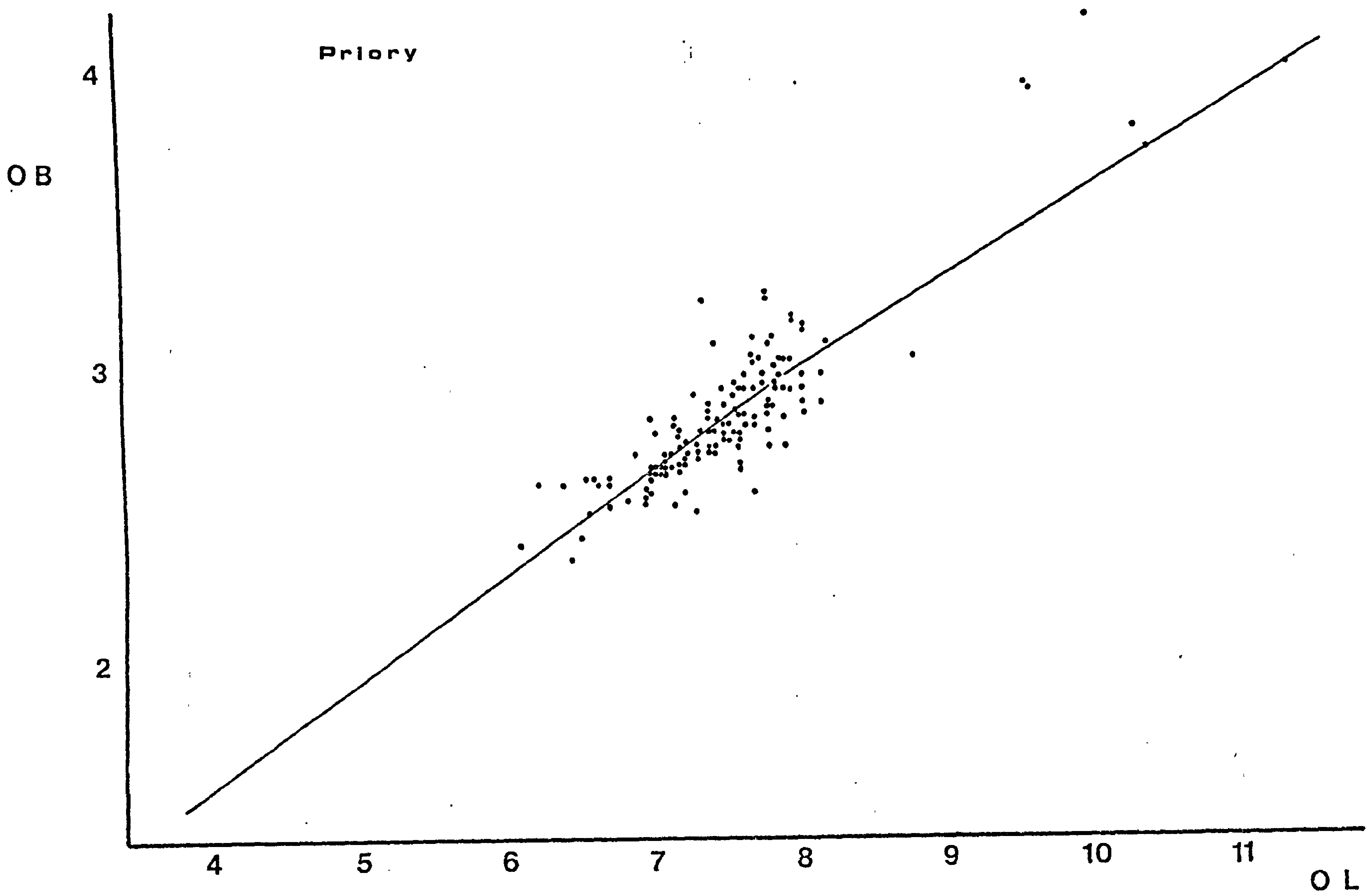

Figure 11 Length:breadth(OL:OB) ratio of archaeological otoliths:the Priory

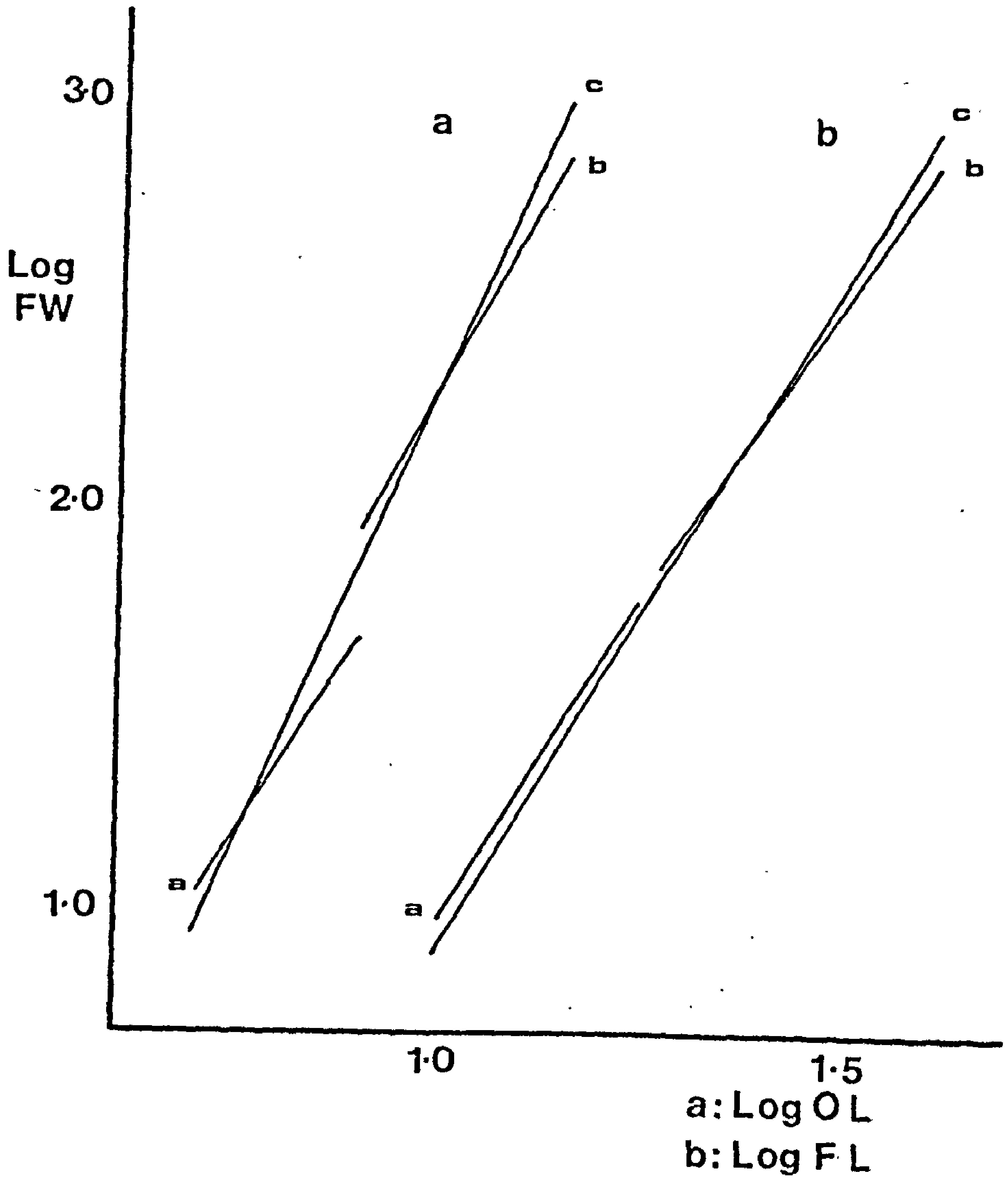

Figure 12 Relationships between fish weight(FW), fish length(FL) and otolith length(OL) of saithe

a First year fish
b Second year fish
c All fish

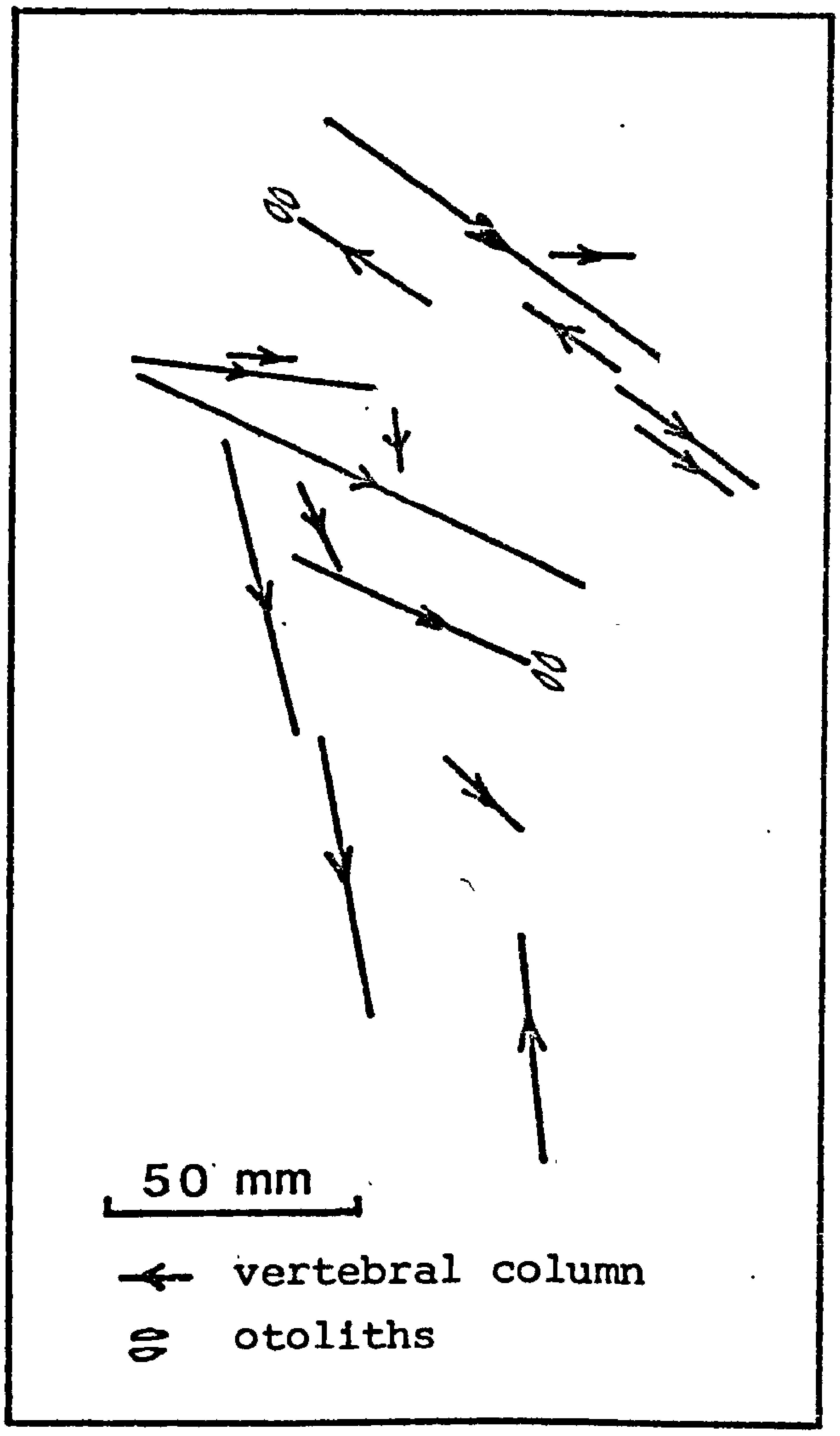

Figure 13 Concentration of articulated fish remains(Cnoc Coig)

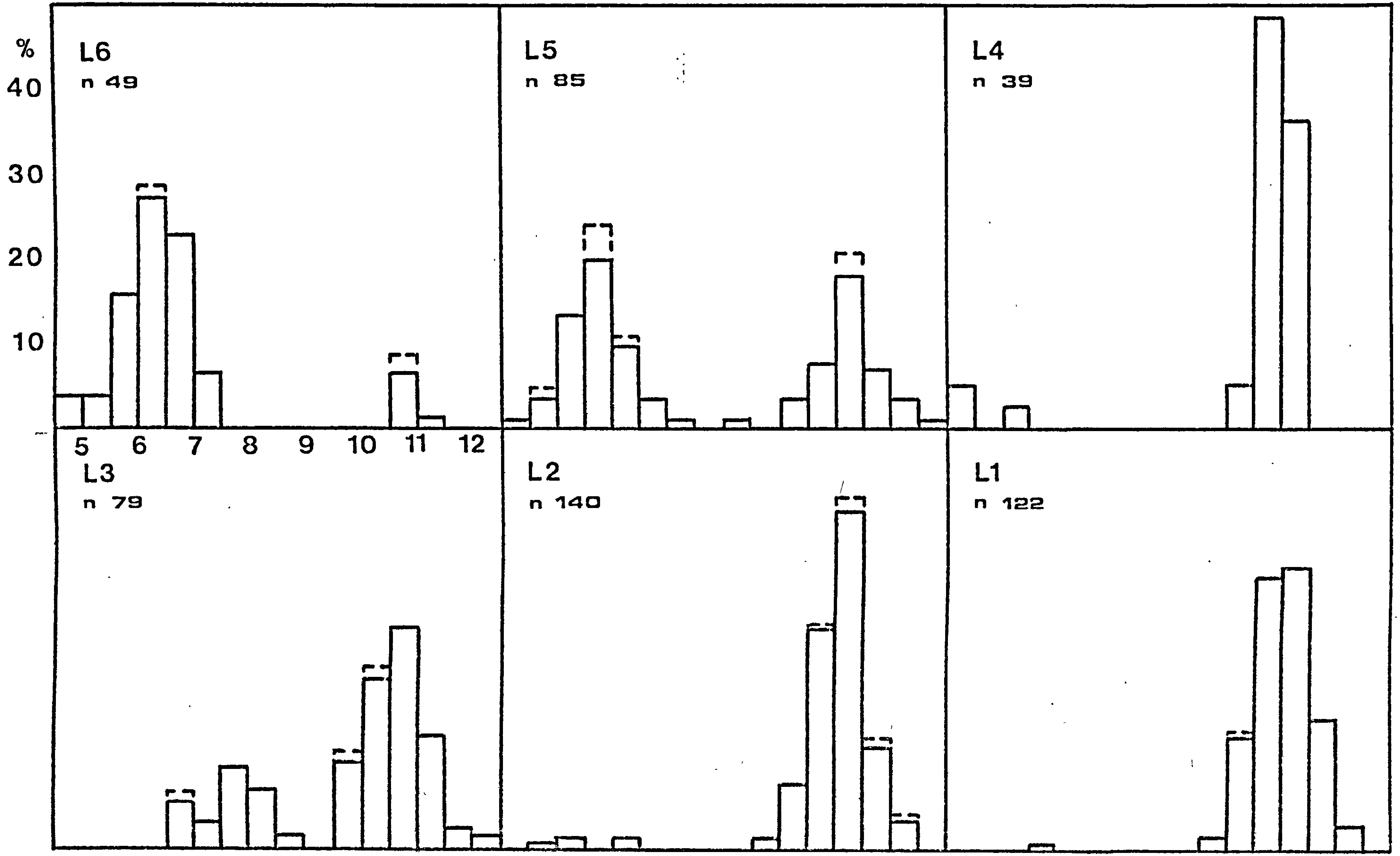

Figure 14 Distribution of fish within a fishbone 'layer'(L1-L6)

Figure 15 Distribution of fish within a fishbone 'layer'(L7-L30)

Conger(C) Wrasse(W) Shanny(S) Ray(R) Eel(E) — Complete --- Estimate

▭ 2mm fraction ▨ 1mm fraction

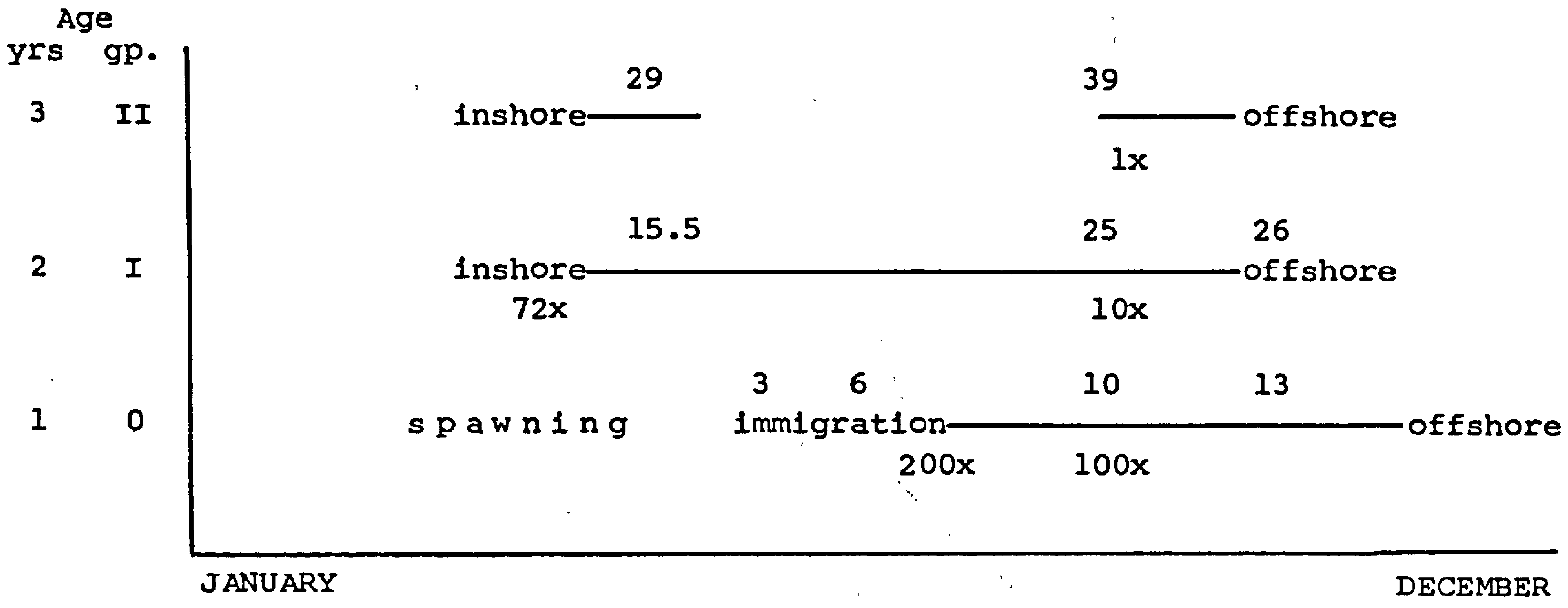

Figure 16 The movements, numbers and sizes of saithe in the littoral zone, based on the Faroes (after Bertelsen 1942)

29 average length of individuals (cms)
72x average number of individuals per haul

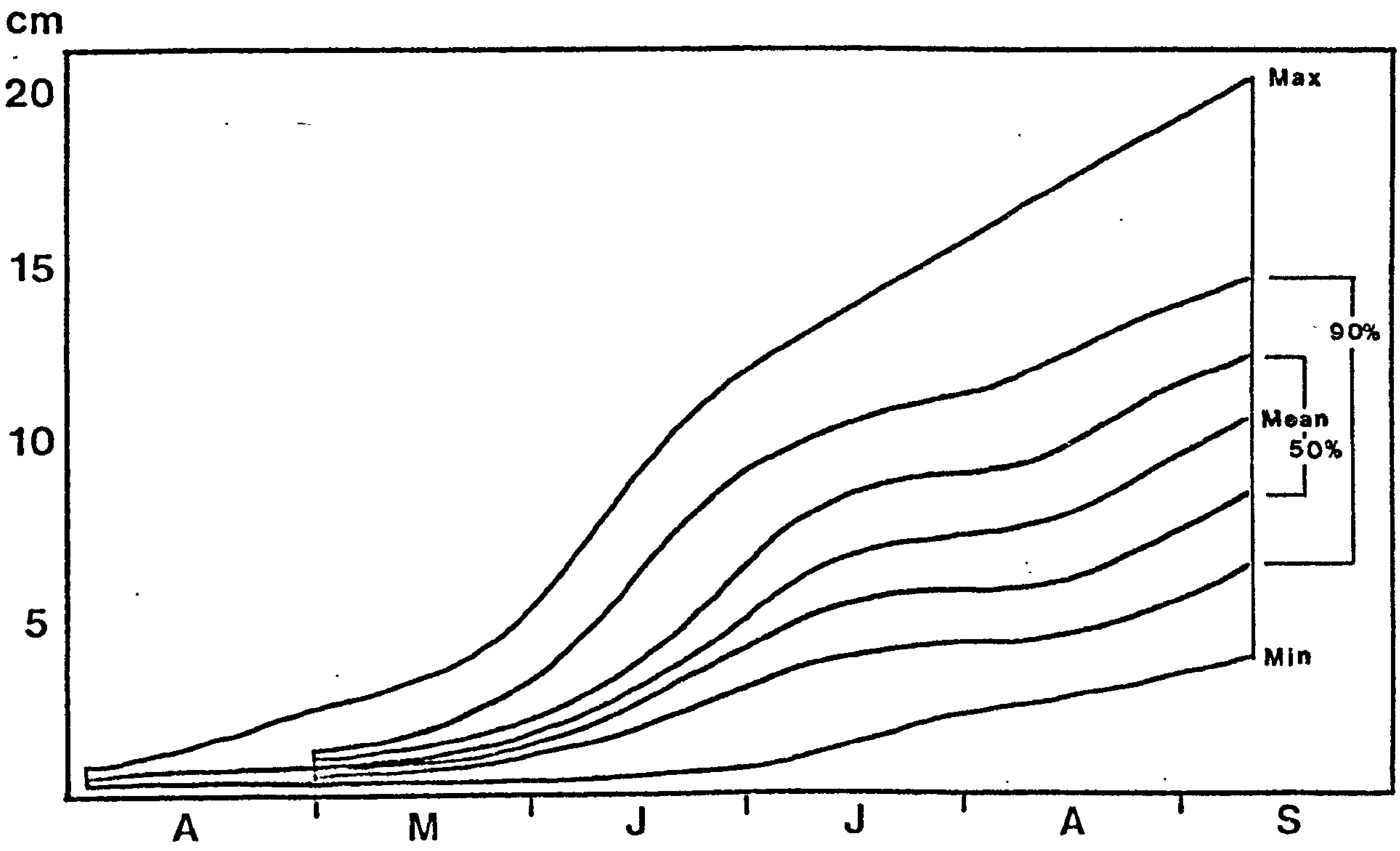

Figure 17 Variability in the rate of growth of first year saithe in the Faroes (after Bertelsen 1942)

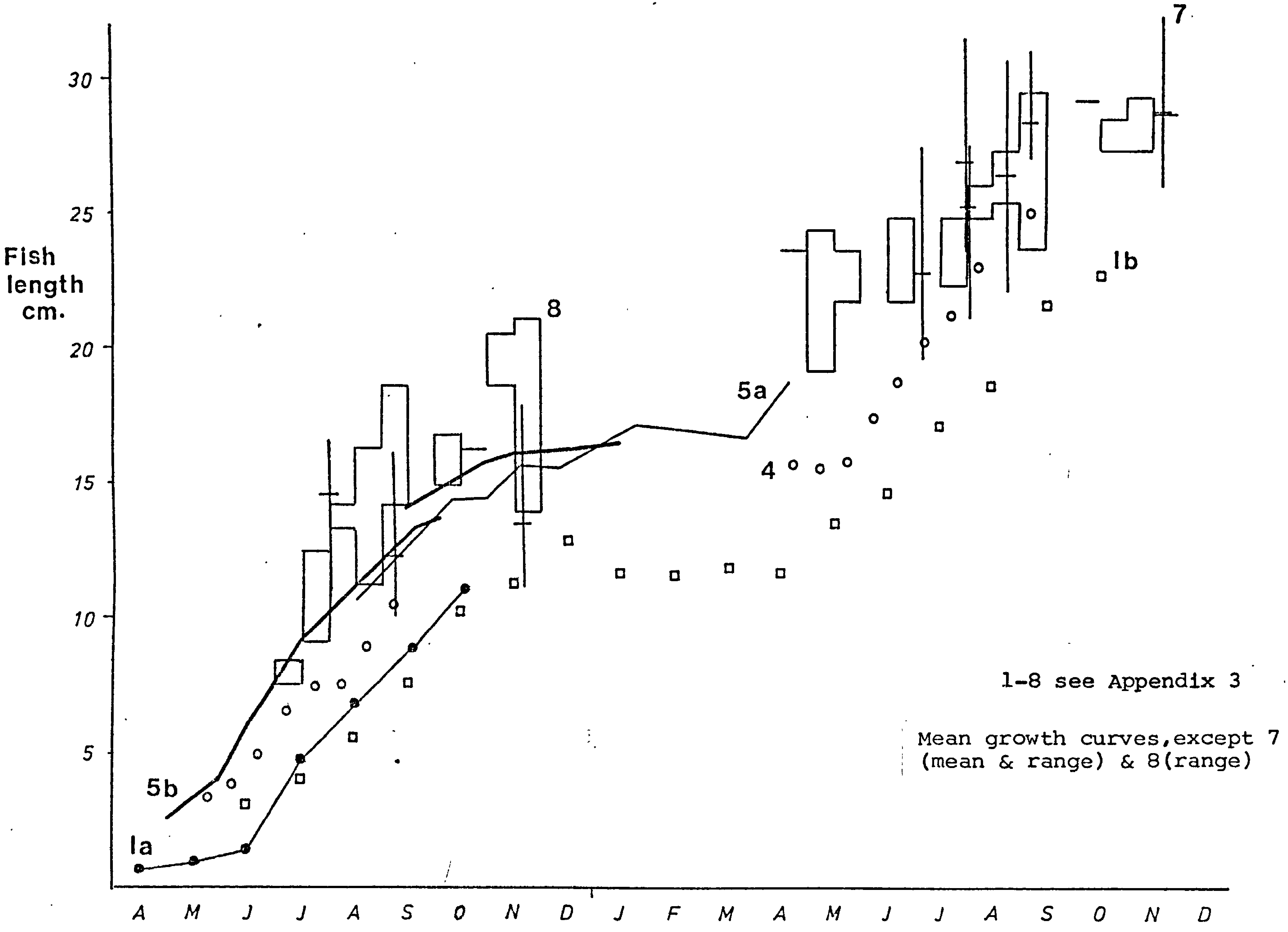

Figure 18 Comparison of rate of growth of saithe populations in different areas

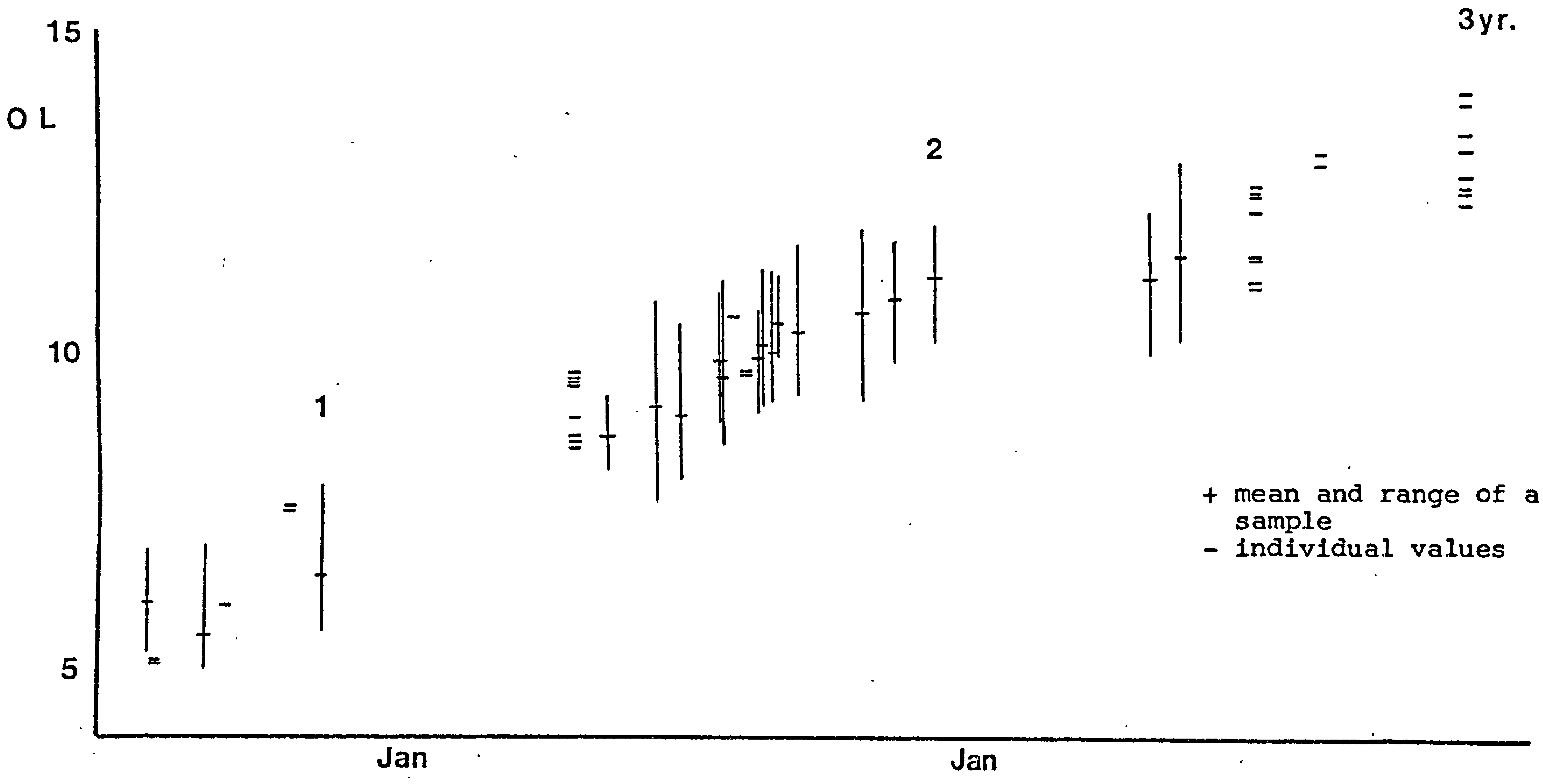

Figure 19 Rate of growth in otolith length(mm) in saithe from Colonsay-Oronsay

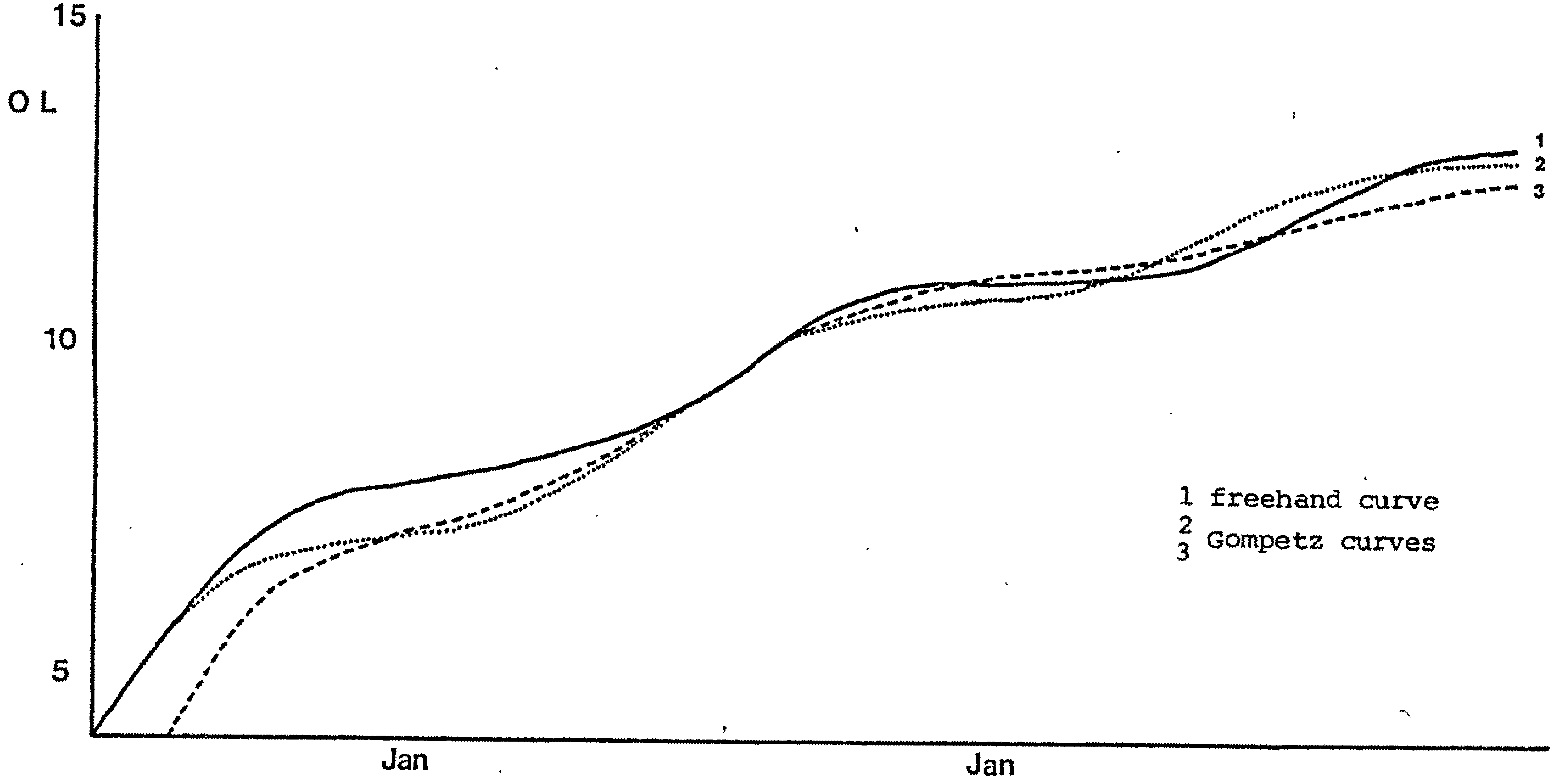

Figure 20 Growth curves fitted to the data on otolith length

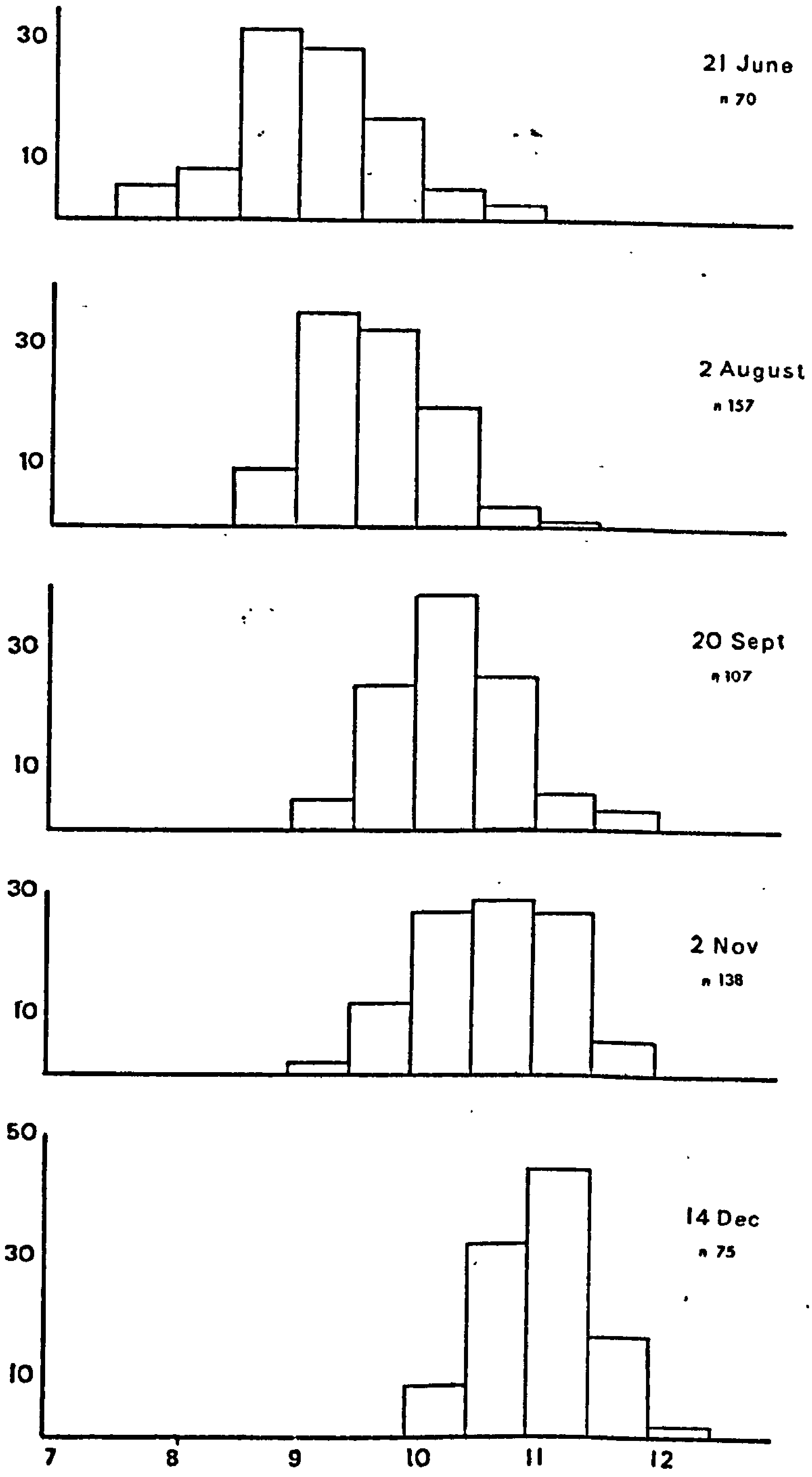

Figure 21 Sizes of otoliths in a single year(1978) (mm)

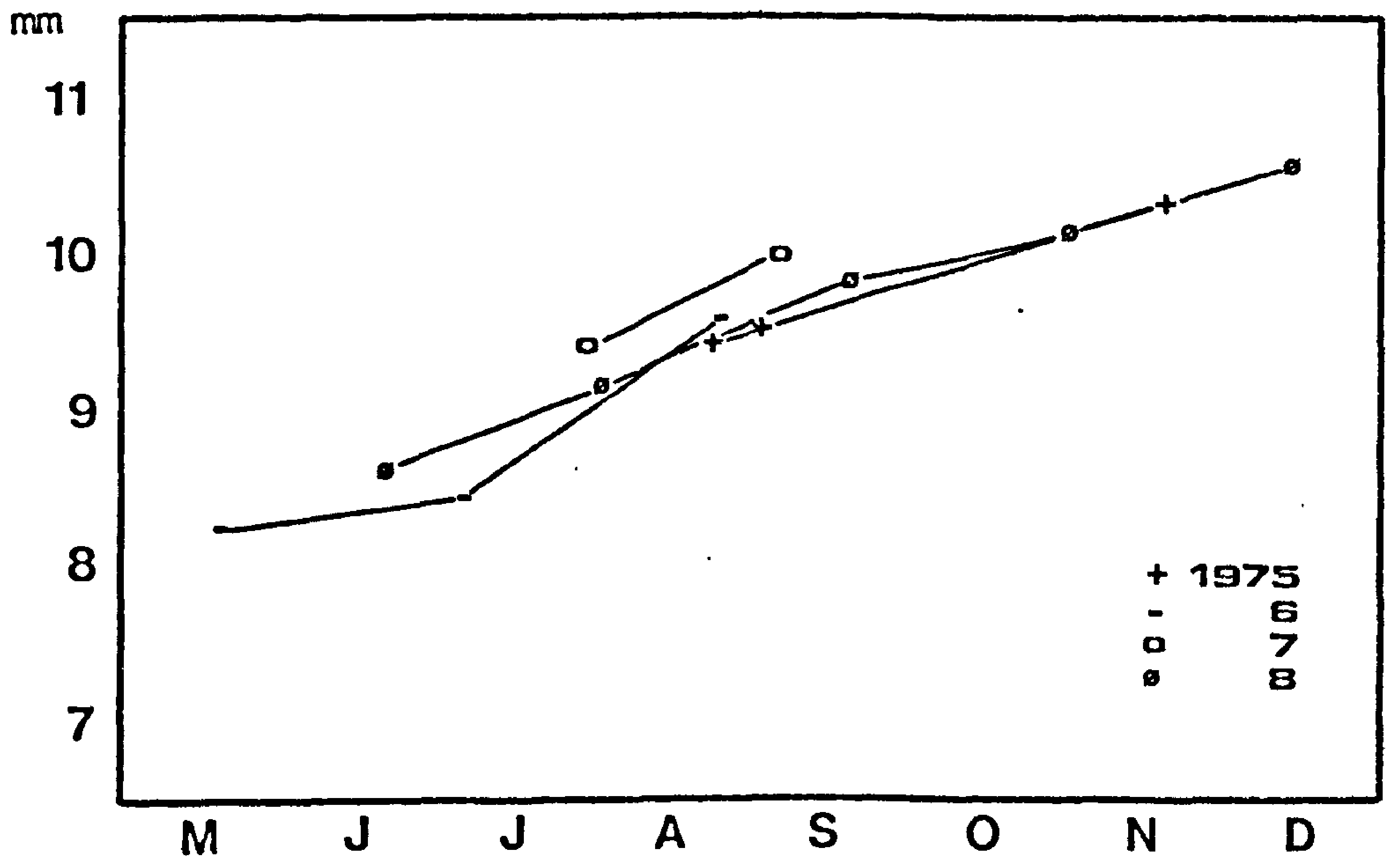

Figure 22 Annual variations in rate of otolith growth

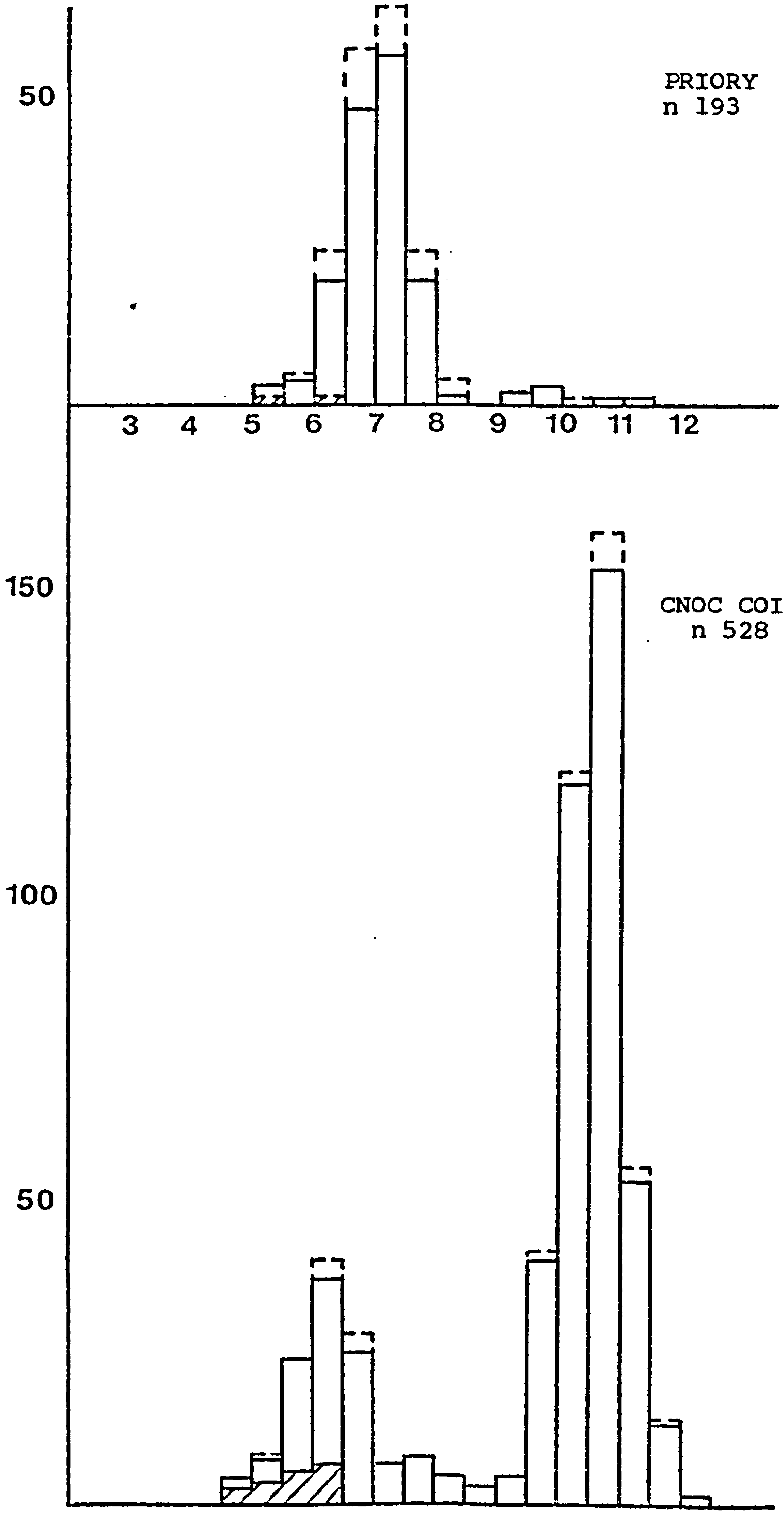

Figure 23 Otolith length frequencies:2mm & 1mm fractions (mm)
For key see Figure 15(p.190)

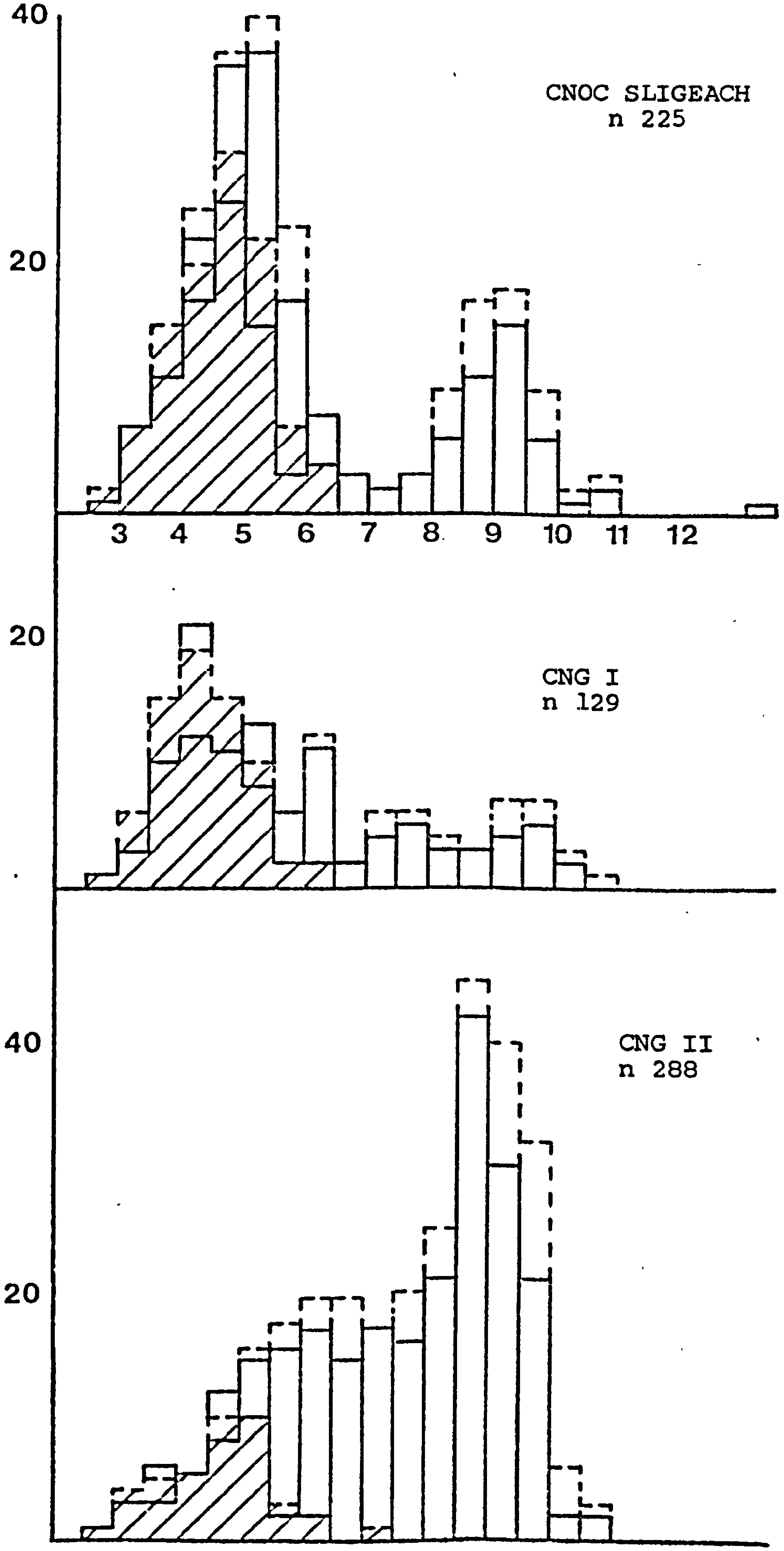

Figure 23 Otolith length frequencies: 2mm & 1mm fractions (continued)

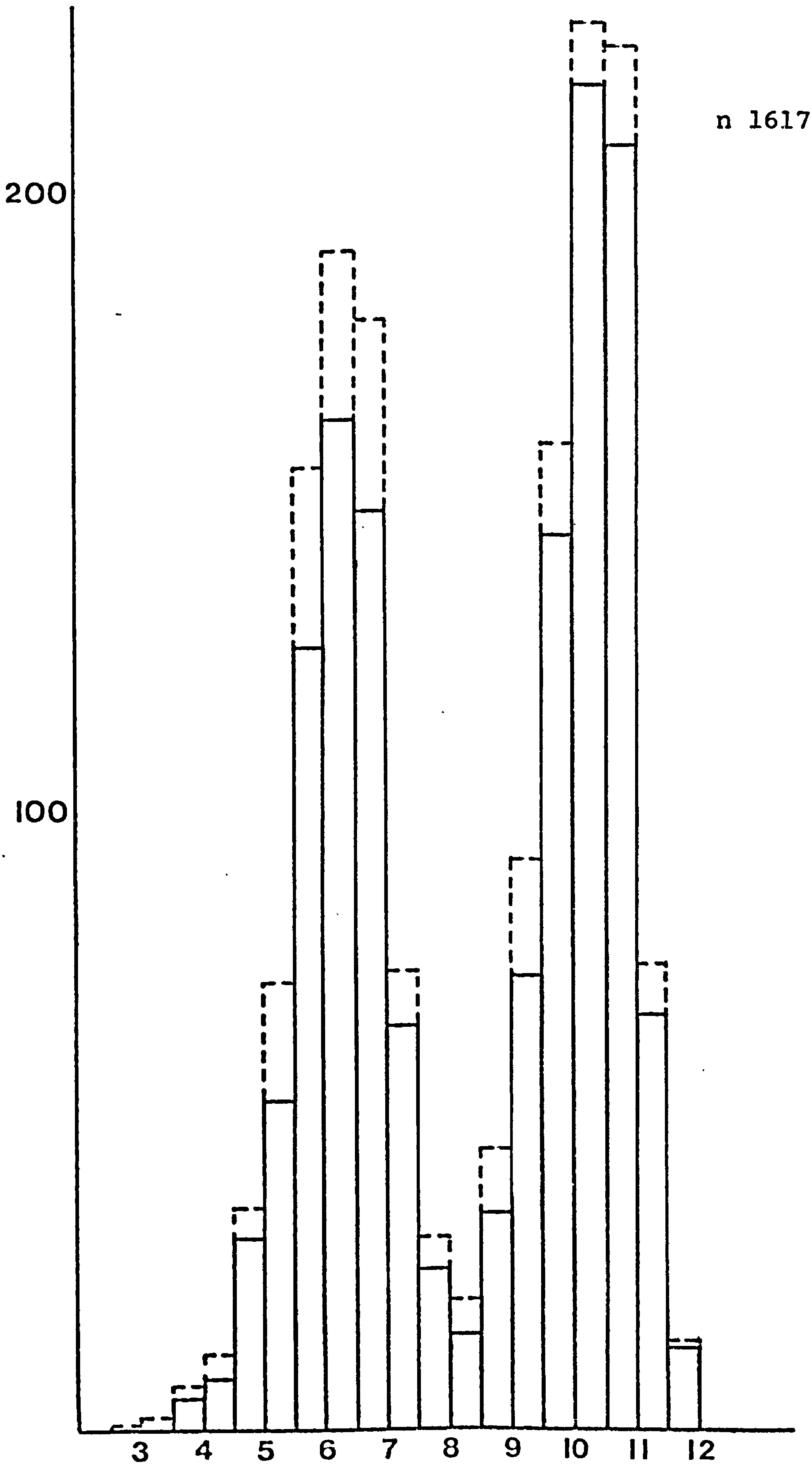

Figure 24 Otolith lengths(mm):Cnoc Coig 1mm fraction total

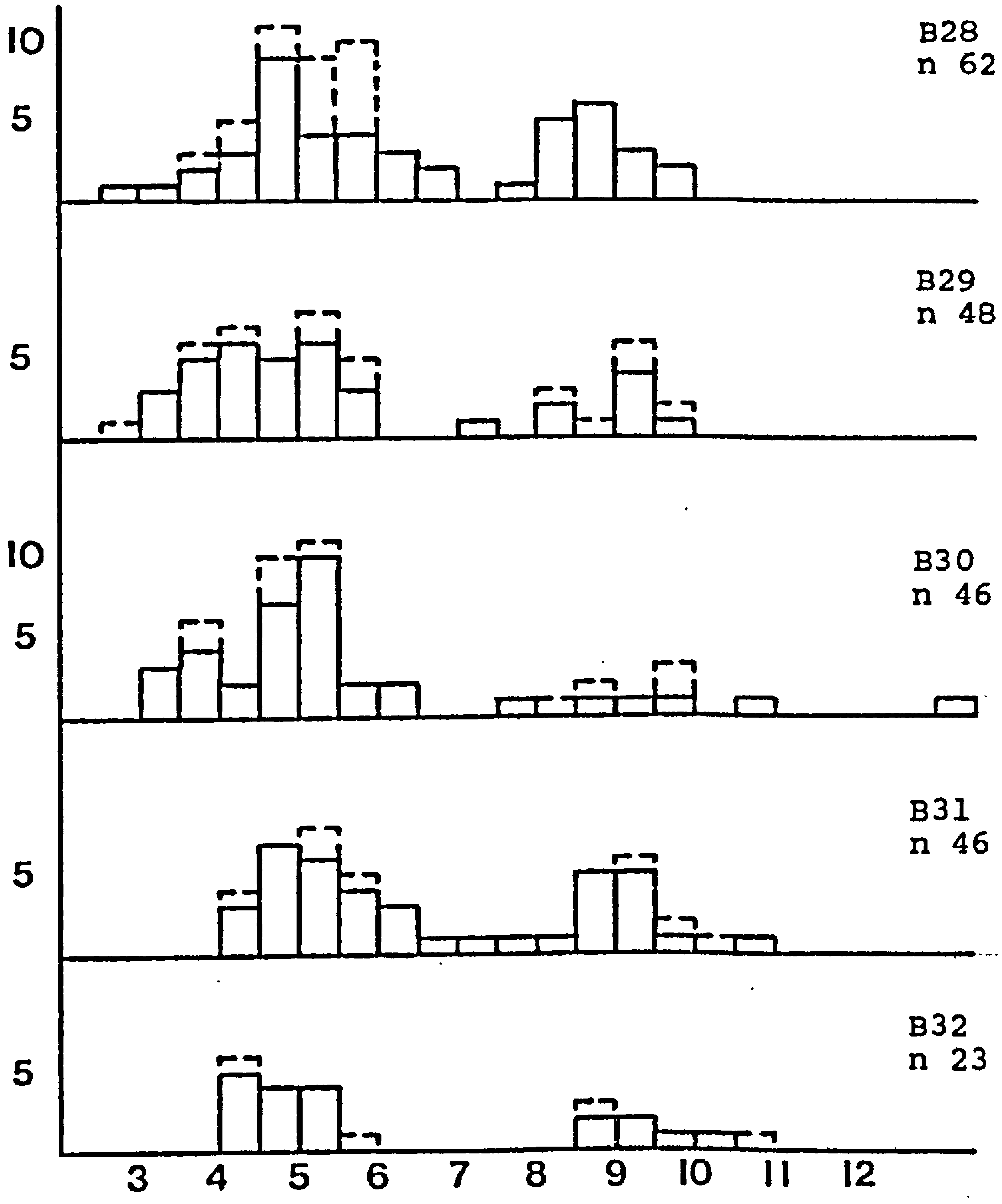

Figure 25 Otolith lengths(mm):Cnoc Sligeach samples(1mm)

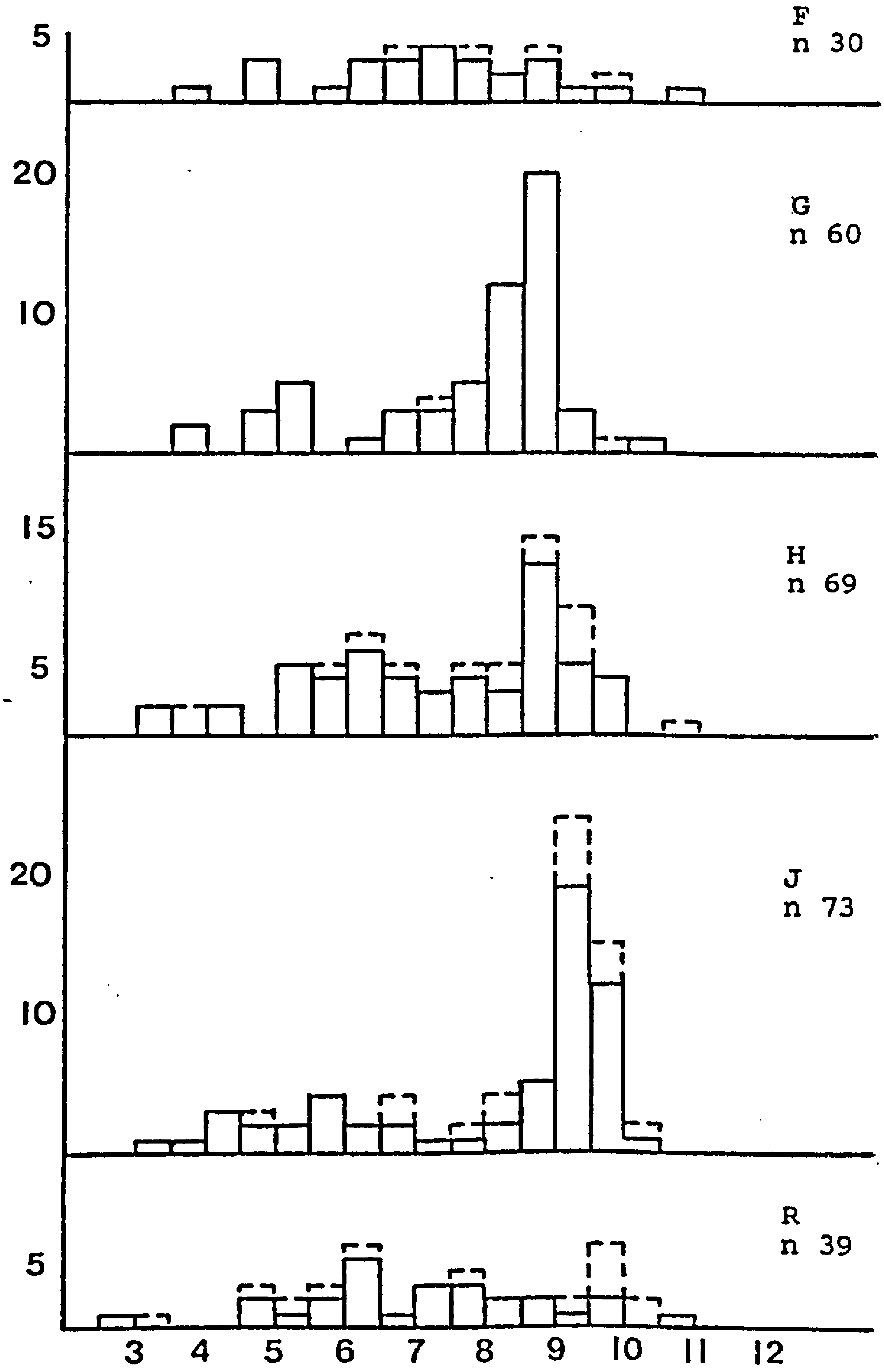

Figure 26 Otolith lengths(mm):CNG II samples(1mm)

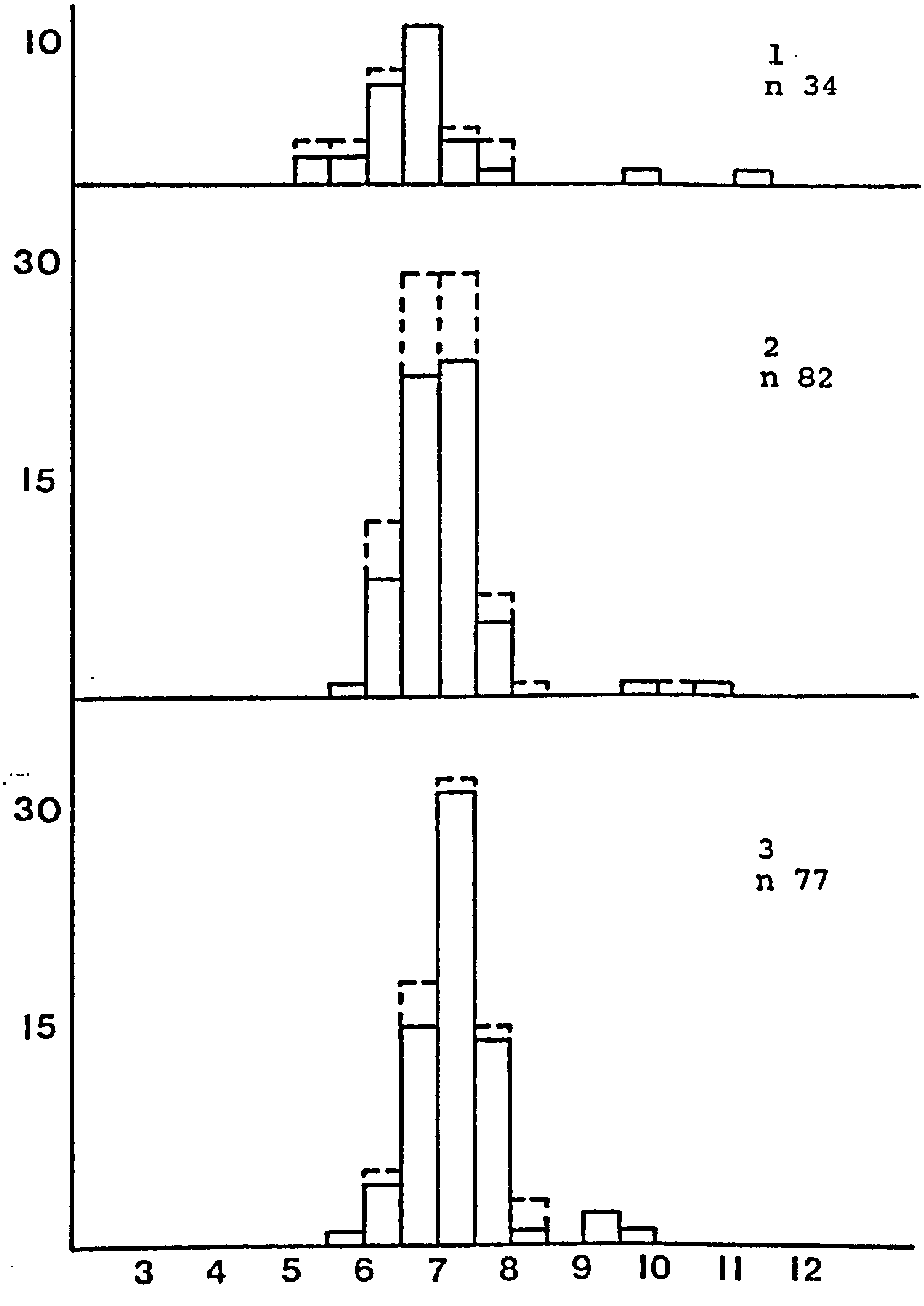

Figure 27 Otolith lengths(mm): Priory samples(1mm)

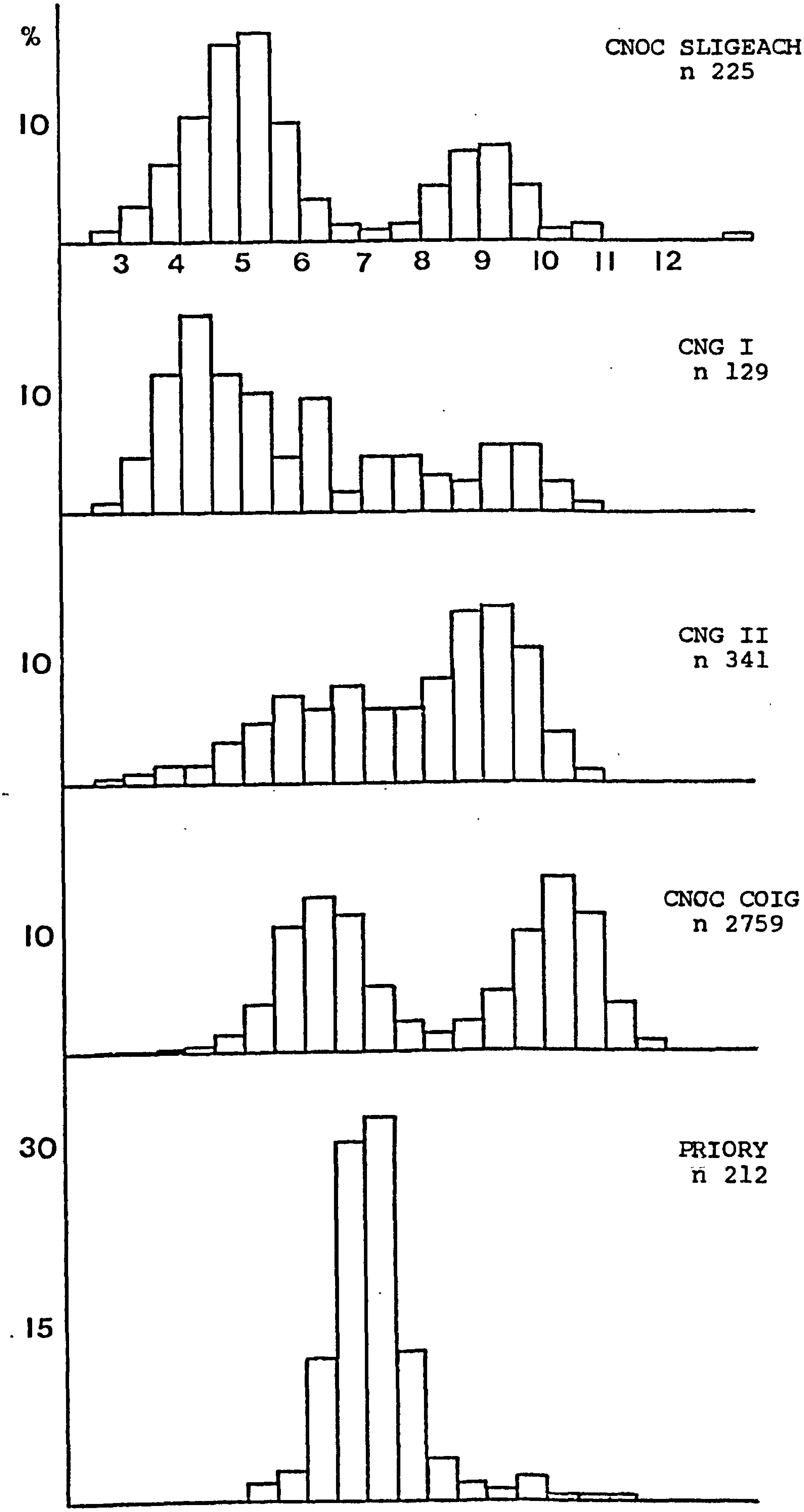

Figure 28 Comparison of otolith length frequencies(mm) of Cnoc Sligeach,CNG I,CNG II,Cnoc Coig and the Priory:combined samples

CNOC COIG

Trench excavation of c.125 square metres of site including 21 test pits (one metre square).
One-eighth inch sieving of all excavated material.
Column samples from 13 of the test pits:2mm fraction.
Samples from fishbone concentrations:2 & 1mm sieves.

CAISTEAL NAN GILLEAN I (CNG I)

Nineteenth century excavations.
Excavation of two one metre square test pits.
Small samples from the pits:4,2 & 1mm sieves.

CAISTEAL NAN GILLEAN II (CNG II)

One-eighth inch sieving of material from four trenches.
Column samples:2mm fraction.

CNOC SLIGEACH

Nineteenth century excavations.
Column samples from a single trench:2mm fraction.

PRIORY MIDDEN

One eighth inch sieving of material from one trench.
Column samples:2mm fraction.

Table 1 Sampling and recovery procedures that have produced fish remains from the Oronsay sites

	Cnoc Coig			CNG I			CNG II	
	1	2	3	1	3	4	2	3
Ling	+	-	-	-	-	-	-	-
Hake	+	-	-	-	-	-	-	-
Conger	+	+	+	+	-	-	+	+
Wrasse	+	+	+	+	+	+	+	+
Sea bream	-	-	-	+	+	+	-	-
Saithe	+	+	+	+	+	+	+	+
Shanny	-	+	+	-	+	+	+	+
Eel	-	-	+	-	+	+	+	+
Eelpout	-	-	+	-	+	+	-	-
Sea scorpion	-	+	+	-	-	-	-	-
Shark/ray	+	+	+	-	+	+	+	+

Table 2 Recovery of selected species by various recovery procedures.

Species are ranked according to size of their largest bones (large to small)

1 Trench recovery
2 One-eighth inch sieve
3 2mm sieve
4 1mm sieve

\+ presence
\- absence

	Early				Current				
	Oban	Risga	CNG(I)	CS	CS	CNG I	CNG II	CC	PR
DOGFISH Scyliorhinus caniculus(L)					+				
TOPE Galeorhinus galeus(L)		+		+					
SPURDOG Squalus acanthias(L)		+	+	+					
MONKFISH Squatina squatina(L)		+		+	+	+			
SHARK-RAY SP.					+	+	+	+	+
SKATE Raja batis L		+	+						
THORNBACK RAY Raja clavata L				+			+	+	
RAY SP.					+	+	+	+	
SALMONID Salmo sp.					+			+	
EEL Anguilla anguillà(L)					+	+	+	+	+
CONGER Conger conger(L)		+		+	+	+	+	+	
LYTHE Pollachius pollachius(L)					+			+	+
SAITHE Pollachius virens(L)	?			+	+	+	+	+	+
HADDOCK Melanogrammus aeglefinus(L)		+							
HAKE Merluccius merluccius(L)								+	
LING Molva sp.					?			+	
RED SEA BREAM Pagellus bogaraveo(Brünnich)				+	+	+			
BLACK SEA BREAM Spondyliosoma cantharus(L)		+		+					
BALLAN WRASSE Labrus bergylta Ascanias	?		+	+	+	+	+	+	+
SHANNY Lipophrys pholis(L)					+	+	+	+	+
EELPOUT Zoarces viviparus(L)					+	+		+	+
THIN-LIPPED GREY MULLET Liza ramada(Risso)		+	+						
SEA SCORPION Taurulus bubalis(Euphrasen)								+	+
FLATFISH cf.FLOUNDER Platichthys flesus(L)					+	+			

Table 3 List of species found in the earlier and current work on the Oronsay sites

Source for earlier excavations:Lacaille(1954)

	C.S.	Priory	CNG II	C.C.
Saithe	100%	100%	100%	100%
Shanny	40	100	21.4	48
Eel	100	51.5	14.3	18
Eelpout	80	36.4	-	6
Shark-ray	100	9.1	14.3	4
Wrasse	60	27.3	14.3	-
Sea scorpion	-	18.2	-	6
Sea bream	100	-	-	-
Monkfish	80	-	-	-
Ray	40	-	-	-
Conger	20	-	7.1	-
Flatfish	20	-	-	-
No. of samples:	5	11	14	50

Table 4 Relative abundance of species of fish in samples from Cnoc Sligeach, Priory, CNG II and Cnoc Coig

Sample	Saithe 2mm	Saithe 1mm	Sea bream	Eel	Shark-ray	Eelpout	Monkfish	Wrasse	Shanny	Ray	Conger	Flatfish
B 28	22.5	24	(+)	+	+	+	+	(0.5)	-	-	+	-
	(47)											
B 29	13.5	24.5	0.5	+	+	-	+	0.5	-	(+)	-	-
			(1.5)									
B 30	16.5	18.5	0.5	+	+	+	(+)	-	(+)	-	-	-
B 31	19	12	0.5	+	+	+	-	0.5	(0.5)	+	-	+
B 32	7.5	8	(+)	+	+	+	+	-	-	-	-	-

Table 5 Numbers of fish per species in samples: Cnoc Sligeach

0.5	Total based on most abundant element overall
(0.5)	Total based on most abundant element in the sample
+	Species present
-	Species absent

Sample	Saithe 2mm	Saithe 1mm	Shanny	Wrasse	Eel	Shark-ray	Conger
A	5.5		(+)	-	-	-	-
B	12.5		(+)	-	-	-	-
C	6		-	-	-	-	-
D	4.5		-	-	-	-	-
E	3	3.5	(+)	-	-	-	-
F	12	1.5	(0.5)	-	-	-	-
G	30.5 (36.5)	4	-	-	-	-	-
H	33 (34.5)	8.5	-	(+)	+	+	-
J	38 (41.5)	6	-	(0.5)	+	+	+
L	8		-	-	-	-	-
M	15		-	-	-	-	-
N	7.5		-	-	-	-	-
Q	12.5	1	-	-	-	-	-
R	21 (52.5)	5	(0.5)	-	-	-	-

Table 5 Numbers of fish per species (continued): Caisteal nan Gillean II

Sample	Saithe 2mm	Saithe 1mm	Shanny	Eel	Eelpout	Wrasse	Sea scorpion	Shark-ray
1	12	0.5	0.5	+	+	(+)	-	-
2	46.5	0	(0.5)	-	-	-	-	-
3	40.5	0.5	(+)	-	-	-	-	-
4	3		(+)	+	+	-	-	-
5	0.5	0 (2)	(1)	-	-	-	-	-
6	4.5 (5)		(0.5)	+	-	-	0.5	+
7	1.5 (3)		(0.5)	-	-	(+)	-	-
8	0.5 (1)		(0.5)	+	-	(0.5)	-	-
9	0.5		(+)	-	-	-	-	-
10	0 (1)		(0.5)	+	+	-	-	-
11	0 (1.5)		(1)	+	+	-	(+)	-

Table 5 Numbers of fish per species (continued): Priory

Sample	Saithe 2mm	Shanny	Eel	Sea scorpion	Eelpout	Shark-ray
1 a	25	0.5 (1)	+	-	-	-
1 b	24.5	0.5	+	-	-	-
1 c	5	-	-	-	-	-
1 d	(3.5)	-	-	-	-	-
1 e	(0.5)	(+)	-	-	-	-
2 a	18.5	0.5	-	-	-	-
2 b	46	6.5	+	-	-	-
2 c	127.5 (141)	4 (4.5)	-	-	-	-
2 d	14.5 (15)	(+)	-	-	-	-
2 e	23	(+)	+	-	-	-
2 f	5 (7)	-	+	-	-	-
2 g	3 (4)	-	-	-	-	-
3 a	6	(+)	-	-	-	-
3 b	(0.5)	-	-	-	-	-
4 a	(0.5)	-	-	-	-	-
4 e	1	-	-	-	-	-
4 f	15.5	(0.5)	-	(+)	-	-
5 a	2	(+)	-	-	-	-
5 b	0.5	-	-	-	-	-
6 a	11.5	(+)	+	-	-	+
6 b	41.5	-	-	-	-	-
6 c	90	-	-	-	+	-
6 d	18	-	-	-	-	-
6 e	8	-	-	-	-	-
7 a	17	(+)	-	-	-	-
7 b	5.5	(+)	-	-	-	-
7 c	7	-	-	-	-	-
7 d	13	-	-	-	-	-
7 e	0.5 (1.5)	-	-	-	-	-
7 f	7	-	-	-	-	-
8 a	11.5	-	-	-	-	-
9 a	4.5	-	-	-	-	-
9 b	7 (7.5)	-	-	-	-	-
10 a	20.5	(1)	-	-	-	-
10 b	7.5	-	-	-	-	-
10 c	4.5	-	-	-	-	-
10 d	7	-	-	-	-	-
11 a	5	(+)	-	-	-	-
11 b	26	(+)	-	-	-	-
11 c	8.5	1	+	(+)	-	+
11 d	7	0.5 (1)	+	-	-	-
11 e	11.5	(+)	-	-	-	-
11 f	11.5	(1)	+	-	-	-
11 g	4.5	-	-	-	+	-
11 h	36.5	(0.5)	-	-	-	-
13 a	9	-	-	-	-	-
14 a	12.5	(+)	-	0.5	-	-
14 b	9	-	-	-	+	-
14 c	3 (4)	-	-	-	-	-
14 d	3.5	-	-	-	-	-

Table 5
Numbers of fish per species (continued): Cnoc Coig

	a	b	r	$n_{(i)}$	a	b	r	n	a	b	r	n
	FW : FL				FL : OL				FW : OL			
1	-212.93885	16.22215	95	826	-7.58683	3.37816	98	733	-321.97992	53.24306	92	866
2	-58.79061	6.22135	95	196	-0.24180	2.18588	73	182	-48.33799	11.64771	62	182
3	-412.12034	23.56850	96	630	-7.03110	3.32728	93	551	-555.70655	76.25632	87	684
	FW : logFL				FL : logOL				FW : logOL			
1	-799.02556	714.85835	90	826	-37.18604	63.57716	97	733	-765.47662	977.43161	89	866
2	-189.07698	190.18781	94	196	-11.69484	31.62692	73	182	-109.03272	168.10802	61	182
3	-1794.98486	1413.82945	94	630	-50.76850	77.14501	93	551	-1540.01429	1749.49490	86	684
	logFW : FL				logFL : OL				logFW : OL			
1	0.49139	0.06768	98	826	0.67991	0.07311	97	733	-0.05826	0.23332	96	866
2	-0.16285	0.11249	97	196	0.68324	0.07055	72	182	0.00781	0.21396	62	182
3	1.03190	0.04770	96	630	0.87286	0.05429	93	551	0.71881	0.15717	88	684
	logFW : logFL				logFL : logOL				logFW : logOL			
1	-2.23083	3.18785	99	826	0.02250	1.39365	98	733	-2.16809	4.45722	97	866
2	-2.57256	3.48660	97	196	0.31094	1.02414	73	182	-1.12149	3.10610	62	182
3	-1.90406	2.95821	97	630	0.14979	1.26818	93	551	-1.39439	3.69038	89	684

Table 6 Statistics of the relationships between fish size and otolith size

1 All fish

2 First year fish

3 Second year fish

(i) these values are exaggerated as each fish is recorded twice (the two otoliths were entered separately in the programme)

	PRIORY												CNOC SLIGEACH				
Sample	1	2	3	4	5		6	7	8	9	10	11	28	29	30	31	32
mm	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2
Ot	24	93	81	6	1	--	9	3	1	1	-	-	45	27	33	38	15
Pmx	13	2	---	2	--	--	3	--	-	-	-	1	20	9	9	6	---
Mx	6	3	---	--	--	--	4	1	-	-	-	-	12	3	10	10	3
Dn	3	1	---	--	--	2	3	1	-	-	-	-	4	5	4	8	5
Vpp	15	11	1	1	1	1	--	2	-	-	-	-	6	---	---	3	---
Dpp1	7	---	---	--	1	--	--	--	-	-	-	-	2	---	---	---	---
Dpp2	7	6	1	2	3	1	--	6	-	-	-	1	6	---	2	1	---
Dpp3	--	---	---	--	--	--	--	--	-	-	-	-	1	---	---	---	---
Vo	4	1	---	1	--	--	2	1	-	-	-	-	5	1	6	6	1
Pas	3	10	14	2	--	--	--	--	-	-	-	-	12	2	9	4	5
Pl	5	---	---	--	--	--	2	--	-	-	-	1	3	---	2	4	---
An	12	8	2	2	1	--	2	1	-	-	-	-	23	9	14	19	7
Qu	10	---	---	3	--	--	1	--	-	-	-	2	7	6	6	2	---
Sym	5	1	---	--	1	--	--	--	-	-	-	1	1	1	---	---	2
Ptr	5	1	3	--	--	--	5	--	-	-	-	-	1	---	---	---	1
Hyom	14	6	1	--	1	--	3	--	-	-	-	2	16	3	1	5	7
Pop	11	2	---	2	--	--	1	--	-	-	-	1	8	1	6	8	2
Op	4	1	---	1	--	--	2	--	-	-	-	-	---	---	1	2	---
Pot	13	4	3	--	--	3	5	--	-	-	-	-	22	4	5	6	2
Scl	6	---	---	--	--	--	1	--	-	-	-	2	11	3	---	5	2
Cl	4	4	---	--	--	--	2	--	-	-	-	-	3	---	---	4	2
Ephy	3	---	---	--	2	--	2	--	-	-	-	3	4	---	---	1	---
Cerhy	7	1	---	--	--	--	1	--	-	-	-	-	12	---	3	4	5
Hyhy	4	---	---	--	--	--	1	2	-	-	-	-	---	---	---	2	2
Ur	1	2	---	--	--	--	--	--	-	-	-	1	---	---	---	---	---
Epbr1	1	---	---	--	--	--	--	--	-	-	-	-	---	---	---	---	---
Epbr2	--	---	---	--	1	--	--	--	-	-	-	-	---	---	---	---	---
Epbr3	--	---	---	--	1	1	--	--	-	-	-	-	---	---	---	---	---
Epbr4	4	2	---	--	--	1	--	--	-	-	-	-	4	---	---	3	---
Hybr1	--	---	---	1	3	--	--	1	-	-	-	-	---	---	1	---	1
Hybr2	--	---	---	--	--	1	--	--	-	-	-	-	---	---	---	---	---
Hybr3	--	---	---	--	--	--	--	1	-	-	-	-	---	---	---	---	---
Bsbr	--	1	---	--	--	1	--	--	-	-	-	-	---	---	---	---	---
Opo																	
Exo																	
Boc	9	25	27	1	--	--	3	2	-	-	1	1	10	5	10	16	8
Th	42	118	110	6	1	--	7	7	-	1	-	-	77	46	49	53	32
Abd	92	460	360	46	12	1	22	34	-	1	1	-	250	101	241	270	131
Cad	140	436	417	49	9	10	44	60	2	4	-	3	322	138	239	357	137

Table 7 Frequencies of skeletal elements in samples from the Priory, Cnoc Sligeach, CNG II, CNG I and Cnoc Coig : saithe

	CAISTEAL NAN GILLEAN II														CNG I			
Sample	A	B	C	D	E	F	G	H	J	L	M	N	Q	R	4		5	
mm	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	1
Ot	11	25	12	9	6	24	61	66	76	16	30	15	25	42	20	16	15	18
Pmx	--	2	--	1	-	6	10	25	48	1	--	1	6	4	13	14	6	4
Mx	--	--	--	--	1	5	7	29	29	--	--	--	2	9	9	3	2	2
Dn	--	--	--	--	-	7	7	12	35	--	--	--	4	3	12	6	4	3
Vpp	--	1	--	--	-	---	1	---	3	--	--	--	2	105	11	4	2	1
Dpp1	--	--	--	--	-	---	---	1	---	--	--	--	1	34	3	--	--	1
Dpp2	--	--	--	--	-	1	---	---	1	--	--	--	---	55	5	1	5	3
Dpp3	--	--	--	--	-	---	---	---	---	--	--	--	1	---	--	--	4	---
Vo	--	--	--	--	-	3	---	7	13	--	--	--	---	4	1	--	1	---
Pas	--	2	--	--	-	1	23	26	28	--	--	--	3	7	6	1	2	---
Pl	--	--	--	--	-	2	1	11	6	--	--	--	---	2	3	1	1	---
An	--	--	--	--	-	6	10	27	17	--	--	--	2	13	10	2	4	2
Qu	--	--	--	--	-	7	4	20	28	--	--	--	2	10	5	5	2	1
Sym	--	--	--	--	-	---	---	4	4	--	--	--	1	3	2	--	--	---
Ptr	--	--	--	--	-	---	---	2	---	--	--	--	---	---	--	3	1	---
Hyom	--	--	--	--	-	1	6	10	3	--	--	--	2	4	5	1	2	---
Pop	--	--	--	--	-	1	5	8	7	--	--	--	2	2	6	--	1	1
Op	--	--	--	--	-	1	1	4	2	--	--	--	---	---	--	1	--	---
Pot	--	--	--	--	1	6	10	9	12	--	--	--	8	8	3	1	9	2
Scl	--	--	--	--	-	2	6	6	13	--	--	--	4	5	5	2	3	---
Cl	--	--	--	--	-	---	1	5	---	--	--	--	---	---	2	--	3	---
Ephy	--	--	--	--	-	4	---	3	1	--	--	--	2	---	--	--	--	---
Cerhy	--	--	--	--	-	2	5	14	5	--	--	--	3	5	6	4	3	---
Hyhy	--	--	--	--	-	---	2	---	3	--	--	--	---	3	--	2	--	---
Ur	--	--	--	--	-	---	---	2	---	--	--	--	---	---	--	--	--	---
Epbr1															--	--	--	---
Epbr2															--	--	1	---
Epbr3															1	--	2	---
Epbr4	--	--	--	--	-	---	---	---	1	--	--	--	---	47	7	4	7	1
Hybr1															5	--	3	---
Hybr2															4	--	3	---
Hybr3															1	--	--	---
Bsbr															--	--	1	---
Opo															5	--	1	---
Exo															--	--	--	1
Boc	--	--	--	1	-	8	34	24	16	2	1	1	4	13	5	5	1	4
Th	2	8	--	5	8	34	145	138	167	5	10	4	27	80	18	16	20	12
Abd	1	8	4	10	8	172	584	663	667	8	6	4	109	269	83	62	56	49
Cad	--	7	--	9	8	191	620	703	752	3	3	--	114	242	77	94	90	148

Table 7 Frequencies of skeletal elements(continued)

CNOC COIG

	Pit 1					Pit 2							3
Sample	a	b	c	d	e	a	b	c	d	e	f	g	a
mm	2	2	2	2	2	2	2	2	2	2	2	2	2
Ot	50	49	10	--	-	37	92	255	29	46	10	6	12
Pmx	10	5	--	1	-	5	82	207	3	13	9	--	3
Mx	6	6	--	1	1	5	71	146	1	9	6	--	2
Dn	4	1	1	1	-	4	46	50	4	13	2	1	2
Vpp	---	---	--	7	-	6	5	18	---	1	5	--	--
Dpp1	---	---	--	--	-	--	1	3	---	---	1	--	--
Dpp2	2	---	--	--	-	3	6	32	1	---	5	--	--
Dpp3	---	---	--	--	-	1	---	----	---	---	---	--	--
Vo	3	2	--	--	-	2	32	59	2	6	---	--	--
Pas	6	2	--	--	-	2	15	89	10	12	3	2	--
Pl	---	---	--	--	-	1	10	19	1	3	---	--	--
An	10	4	1	1	1	11	70	275	4	27	4	5	4
Qu	6	2	--	2	-	3	51	135	2	10	4	2	2
Sym	---	---	--	--	-	--	3	6	---	---	---	--	--
Ptr	3	---	--	1	-	--	20	55	---	11	1	--	--
Hyom	3	---	1	2	-	5	56	241	3	17	4	8	1
Pop	3	1	--	--	-	3	33	139	---	12	2	1	--
Op	2	1	--	1	-	1	15	32	1	4	2	3	--
Pot	4	---	--	1	-	9	43	128	4	8	9	2	--
Scl	3	---	--	--	-	2	18	25	2	2	4	--	1
Cl	---	---	--	3	-	5	6	50	---	12	1	--	1
Ephy	---	---	--	--	-	--	5	15	---	2	1	1	--
Cerhy	3	---	--	1	-	--	49	220	3	12	5	3	--
Hyhy	---	1	--	--	-	--	2	7	---	---	1	--	--
Ur	---	---	--	--	-	--	---	12	---	---	2	--	--
Epbr1	---	---	--	--	-	--	---	----	---	---	---	--	--
Epbr2	---	---	--	--	1	1	1	----	---	---	1	--	--
Epbr3	---	---	--	--	-	1	1	----	---	1	2	--	--
Epbr4	---	---	--	--	-	1	---	2	---	---	3	--	--
Hybr1	---	---	--	--	-	2	1	----	---	1	2	--	--
Hybr2	---	---	--	--	-	--	1	1	---	1	3	--	--
Hybr3	---	---	--	--	-	--	---	----	---	---	---	--	--
Bsbr	---	---	--	--	-	2	---	----	---	---	1	--	--
Opo	7	---	--	--	-	2	15	47	7	17	3	3	1
Exo	1	---	--	--	-	--	17	30	2	13	---	4	--
Boc	6	8	--	--	-	2	38	141	15	17	17	1	5
Th	43	26	3	2	-	14	118	307	51	91	26	4	18
Abd	147	59	5	16	3	73	608	457	241	466	114	12	70
Cad	136	100	13	17	2	72	544	1604	266	363	88	17	65

Table 7 Frequencies of skeletal elements(continued)

CNOC COIG(cont.)

Sample		Pit 4			5		Pit 6					Pit 7		
	b	a	e	f	a	b	a	b	c	d	e	a	b	c
mm	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Ot	-	-	2	31	4	1	23	83	180	36	16	34	11	14
Pmx	-	-	2	1	1	-	4	14	9	25	2	4	5	2
Mx	1	-	-	2	2	-	6	9	8	13	5	8	8	--
Dn	-	-	-	2	-	-	1	25	5	11	6	2	2	1
Vpp	-	-	-	---	-	-	2	9	85	2	--	1	1	--
Dpp1	-	-	-	---	-	-	2	4	12	---	--	1	--	--
Dpp2	-	-	-	---	-	-	--	5	93	1	--	1	2	--
Dpp3	-	-	-	1	-	-	--	2	----	---	--	--	--	--
Vo	-	-	-	2	-	-	2	4	10	5	3	--	--	2
Pas	-	-	-	3	-	-	1	7	40	13	--	--	3	--
Pl	-	-	-	---	-	-	--	---	1	2	--	1	--	--
An	-	-	-	2	-	-	9	6	14	9	4	4	4	5
Qu	-	1	-	2	-	-	7	6	5	6	1	4	2	--
Sym	-	-	-	---	-	-	1	---	----	1	--	--	--	--
Ptr	-	-	-	---	-	-	--	1	2	2	--	--	--	1
Hyom	-	-	-	---	-	-	--	3	5	9	2	--	1	--
Pop	-	-	-	---	-	-	2	3	3	2	--	--	3	1
Op	-	-	-	---	-	-	--	---	1	2	--	--	--	--
Pot	-	-	-	---	1	-	--	6	5	7	1	--	3	1
Scl	-	-	-	---	-	-	--	1	2	1	--	--	2	--
Cl	-	-	-	---	-	-	--	---	----	---	1	1	--	1
Ephy	-	-	-	---	-	-	1	---	----	2	1	--	--	--
Cerhy	-	-	-	---	-	-	--	6	6	2	--	--	--	--
Hyhy	-	-	-	---	-	-	1	---	----	---	--	--	--	--
Ur	-	-	-	---	-	-	--	---	----	---	--	--	--	--
Epbr1	-	-	-	---	-	-	--	1	16	---	--	--	--	--
Epbr2	-	-	-	---	-	-	--	2	9	---	--	--	--	--
Epbr3	-	-	-	---	-	-	--	---	9	---	--	--	1	--
Epbr4	-	-	-	---	-	-	1	5	25	---	--	--	2	2
Hybr1	-	-	-	---	-	-	1	4	28	---	--	--	--	--
Hybr2	-	-	-	---	-	-	2	3	36	---	--	2	--	--
Hybr3	-	-	-	---	-	-	--	---	5	---	--	--	--	--
Bsbr	-	-	-	---	-	-	--	---	10	---	--	2	--	--
Opo	-	-	1	3	1	-	--	---	----	---	--	--	4	1
Exo	-	-	-	---	-	-	--	---	----	---	--	--	--	--
Boc	-	-	-	---	-	-	4	3	33	7	3	4	3	--
Th	1	2	-	19	-	1	36	76	238	34	7	48	14	13
Abd	3	-	8	42	-	3	91	354	762	154	33	92	38	26
Cad	7	-	5	100	7	-	91	229	1116	177	79	77	68	39

Table 7 Frequencies of skeletal elements(continued)

CNOC COIG(cont.)

				8	9		Pit 10				Pit 11			
Sample	d	e	f	a	a	b	a	b	c	d	a	b	c	d
mm	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Ot	26	1	14	23	9	14	41	14	9	14	10	52	17	14
Pmx	5	1	1	3	1	2	11	14	4	5	2	11	15	---
Mx	2	--	1	1	--	--	5	8	3	4	2	8	7	1
Dn	1	--	6	--	--	1	14	9	2	4	--	3	7	---
Vpp	1	--	1	--	1	--	--	--	--	--	--	2	1	---
Dpp1	---	--	--	--	--	--	--	--	--	--	--	---	--	---
Dpp2	---	--	1	--	--	--	--	--	--	--	--	1	--	---
Dpp3	---	--	--	--	--	--	--	--	--	--	--	1	--	---
Vo	1	--	1	--	--	1	--	1	--	2	--	3	1	---
Pas	4	--	2	--	--	1	6	4	1	3	--	---	2	2
Pl	1	--	1	--	--	--	--	1	--	--	--	---	--	---
An	5	2	2	--	--	1	2	2	5	6	2	7	9	4
Qu	2	1	4	--	1	1	3	4	1	2	1	2	2	2
Sym	---	--	1	--	--	--	--	1	--	--	--	---	--	---
Ptr	1	--	2	--	--	--	2	1	--	--	--	1	--	---
Hyom	7	3	1	--	--	--	--	6	--	2	--	1	4	1
Pop	2	--	1	--	--	--	1	1	1	1	1	3	1	---
Op	---	--	1	--	--	--	1	--	--	--	--	1	3	---
Pot	2	3	4	--	1	--	--	3	--	1	3	3	4	1
Scl	1	2	3	--	--	--	1	2	--	--	--	1	1	---
Cl	1	1	1	--	--	--	--	--	--	1	--	---	--	---
Ephy	1	—	1	--	--	--	--	1	--	--	--	2	--	1
Cerhy	1	1	2	--	--	--	--	--	--	--	1	4	1	1
Hyhy	---	--	--	--	--	--	--	1	--	--	--	---	--	---
Ur	---	--	--	--	--	--	--	--	--	--	--	---	--	---
Epbr1	---	--	--	--	--	--	--	--	--	--	--	---	--	---
Epbr2	---	--	--	--	--	--	--	--	--	--	--	---	--	---
Epbr3	1	--	--	--	--	--	--	--	--	--	--	---	--	---
Epbr4	---	--	3	--	--	--	--	--	--	--	--	---	--	---
Hybr1	1	--	2	--	--	--	--	--	--	--	--	---	--	---
Hybr2	---	--	--	--	--	--	--	--	--	--	--	---	1	---
Hybr3	---	1	--	--	--	--	--	--	--	--	--	1	--	---
Bsbr	---	--	--	--	--	1	--	--	--	--	--	---	--	---
Opo	6	1	5	1	--	1	3	2	1	4	1	5	1	---
Exo	---	--	1	--	--	--	--	2	--	3	--	2	--	---
Boc	4	1	3	--	1	--	2	5	--	6	2	7	6	3
Th	26	4	4	8	6	1	26	19	11	15	15	75	26	|
Abd	107	19	40	9	21	6	59	94	26	48	37	235	71	300
Cad	134	28	67	3	21	25	96	98	55	54	41	233	95	|

Table 7 Frequencies of skeletal elements(continued)

CNOC COIG(cont.)

Sample	L2		L6		16	18	20	21	22	23	24	29	30	31
mm	2	1	2	1	1	1	1	1	1	1	1	1	1	1
Ot	142	--	55	13	2	58	70	1	64	60	5	31	19	22
Pmx	3	1	19	31	--	13	26	2	2	42	10	17	13	14
Mx	5	1	27	19	--	6	41	---	2	54	11	17	18	10
Dn	4	--	18	35	--	13	21	2	---	54	11	17	5	16
Vpp	2	1	26	36	92	32	10	1	75	29	4	4	6	5
Dpp1	---	1	---	34	66	26	4	1	67	15	10	---	5	1
Dpp2	1	2	17	21	99	31	9	2	81	24	8	1	6	4
Dpp3	---	---	1	17	30	---	8	---	15	---	6	2	---	---
Vo	3	1	19	16	--	6	12	1	1	28	9	6	4	6
Pas	40	--	15	9	--	5	13	---	6	16	3	7	7	2
Pl	2	3	15	32	--	6	20	---	1	28	9	8	6	5
An	6	1	49	12	1	15	24	1	---	54	7	11	8	9
Qu	5	--	37	12	1	14	35	---	---	59	8	11	12	13
Sym	1	1	13	33	--	15	6	---	---	23	8	3	3	5
Ptr	6	--	33	15	--	5	17	---	2	26	14	1	2	2
Hyom	2	--	57	---	--	15	15	---	---	40	19	2	5	2
Pop	4	--	56	3	--	8	21	---	---	26	9	1	---	4
Op	3	--	28	4	--	9	6	---	---	29	8	2	2	6
Pot	8	1	29	40	--	19	13	2	1	68	20	9	14	13
Scl	2	3	8	33	--	22	7	1	1	46	8	4	4	10
Cl	---	--	43	---	--	4	4	---	1	1	---	1	2	---
Ephy	2	--	32	13	--	12	16	1	---	30	11	---	3	5
Cerhy	5	--	---	8	--	3	25	---	---	36	10	5	---	7
Hyhy	---	2	3	46	--	10	13	1	1	31	8	5	2	4
Ur	---	--	16	4	--	1	3	---	---	11	3	---	---	---
Epbr1	---	--	---	+	28	---	---	---	3	4	2	---	---	---
Epbr2	---	--	2	+	36	---	1	---	21	11	4	---	---	---
Epbr3	---	--	2	+	60	---	1	---	56	8	8	---	---	---
Epbr4	---	1	5	35	88	30	7	1	51	14	11	1	4	1
Hybr1	---	2	1	+	64	3	5	---	52	14	9	---	1	---
Hybr2	---	2	2	+	63	---	3	1	49	20	9	---	---	---
Hybr3	---	1	1	+	38	---	---	---	17	---	3	---	---	---
Bsbr	---	--	1	+	27	---	---	---	12	---	4	---	---	---
Opo	78	1	32	3	--	---	18	2	7	23	5	---	---	---
Exo					--	---	4	---	2	16	6	---	---	---
Boc	39	--	16	4	--	5	15	1	10	13	4	4	10	5
Th	│	│	│	│	--	9	60	7	80	37	5	58	26	10
Abd	2502	87	596	390	3	32	101	49	205	100	6	255	26	39
Cad	│	│	│	│	1	151	250	107	344	617	123	409	101	124

+ total 170

Table 7 Frequencies of skeletal elements(continued)

	1	2	3
Ot	2	1298	100
Th	4	1454	56.09
Boc	1	346	53.31
An	2	521	40.14
Abd	19	4621	37.47
Pmx	2	473	36.44
Pas	1	233	35.90
Cad	32	6232	30.01
Hyom	2	386	29.74
Mx	2	375	28.89
Cerhy	2	321	24.73
Vo	1	144	22.19
Qu	2	279	21.49
Pot	2	256	19.72
Dn	2	231	17.80
Pop	2	218	16.79
Dpp2	2	154	11.86
Vpp	2	148	11.40
Opo	2	146	11.25
Ptr	2	104	8.01
Cl	2	85	6.55
Exo	2	75	5.78
Scl	2	74	5.70
Op	2	71	5.47
Hybr2	2	50	3.85
Epbr4	2	44	3.39
Hybr1	2	42	3.24
Pl	2	41	3.16
Ephy	2	34	2.62
Ur	1	14	2.16
Dpp1	2	24	1.85
Epbr1	2	17	1.31
Epbr2	2	16	1.23
Hybr3	2	16	1.23
Bsbr	2	16	1.23
Hyhy	2	13	1.00
Sym	2	13	1.00
Hybr3	2	7	0.54
Dpp3	2	5	0.39

Table 8 Frequencies of skeletal elements in the column samples(2mm fraction) from Cnoc Coig:combined totals :saithe

1 Frequency of element in the body

2 Number of identified specimens

3 Index of under-representation;the observed frequency as a percentage of the expected frequency based on the the element giving the highest MNI count(otolith)

CAISTEAL NAN GILLEAN II

	A		B		C		D		E			F			G				H				J				L		M		N	
	2		2		2		2		1	2		1	2		1		2		1		2		1		2		2		2		2	
	c	e	c	e	c	e	c	e	c	c	e	c	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	e
3.00- 3.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.50- 3.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	1	-	-	-	-	-	-	-	-	-
4.00- 4.45	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	2	-	-	1	-	-	-	-	-	-	-	-	-
4.50- 4.95	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	-	-	-	3	-	-	-	-	-	-	-	-	-
5.00- 5.45	-	-	-	-	-	-	-	-	-	-	-	3	-	-	2	-	1	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-
5.50- 5.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	3	-	4	-	1	-	2	-	-	-	-	-	2	-	-	-
6.00- 6.45	-	-	1	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	2	-	2	1	-	-	4	-	-	2	1	1	-	1
6.50- 6.95	-	1	-	-	1	-	-	-	-	-	-	-	3	-	-	-	1	-	1	-	5	1	-	-	2	-	-	-	-	-	-	-
7.00- 7.45	-	-	4	-	-	-	-	-	-	-	1	-	3	1	-	-	3	-	-	-	4	1	-	-	2	2	1	1	1	-	-	1
7.50- 7.95	1	-	-	1	1	-	-	1	-	-	-	-	4	-	-	1	3	-	-	-	3	-	-	-	1	-	-	-	-	-	-	-
8.00- 8.45	-	-	-	-	-	-	-	-	-	-	-	-	3	1	-	-	5	-	-	-	4	1	-	-	1	1	-	-	1	-	-	-
8.50- 8.95	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	12	-	-	-	3	2	-	-	2	2	-	1	1	-	1	1
9.00- 9.45	-	1	-	-	-	-	1	1	-	-	-	-	3	1	-	-	20	-	-	-	12	2	-	-	5	-	-	-	-	-	-	-
9.50- 9.95	-	-	1	1	2	1	2	-	-	-	-	-	1	-	-	-	3	-	-	-	5	4	-	-	19	5	-	1	-	1	-	-
10.00-10.45	-	1	1	-	-	-	-	-	-	-	-	-	1	1	-	-	-	1	-	-	4	-	-	-	12	3	-	1	-	1	1	-
10.50-10.95	-	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	1	-	1	-	-	3	1
11.00-11.45	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-
Totals	1	3	9	2	5	1	3	2	1	1	1	3	23	4	6	1	52	1	11	2	43	13	8	1	50	14	1	7	7	3	5	4

Table 9 Length frequencies of otoliths in samples

c complete lengths 1 1mm fraction
e estimated lengths 2 2mm fraction

	CNG II(cont)							CNOC SLIGEACH																			
	Q			R				28				29				30				31				32			
	1	2		1		2		1		2		1		2		1		2		1		2		1		2	
	c	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	e
3.00- 3.45	-	-	-	1	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.50- 3.95	-	-	-	-	1	-	-	1	-	-	-	3	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-
4.00- 4.45	-	-	-	-	-	-	-	2	1	-	-	5	1	-	-	4	2	-	-	-	-	-	-	-	-	-	-
4.50- 4.95	-	-	-	-	-	-	-	2	2	1	-	6	-	-	1	2	-	-	-	2	-	1	1	5	1	-	-
5.00- 5.45	-	-	-	2	1	-	-	6	2	3	-	5	-	-	-	4	2	3	1	6	-	1	-	4	-	-	-
5.50- 5.95	1	-	-	1	-	-	1	3	3	1	2	4	2	2	-	4	-	6	1	2	2	4	-	2	-	2	-
6.00- 6.45	-	3	1	-	1	2	-	1	3	3	3	-	1	3	1	-	-	2	-	2	-	2	1	-	-	-	1
6.50- 6.95	-	-	-	1	-	4	1	2	-	1	-	-	-	-	-	-	-	2	-	2	-	1	-	-	-	-	-
7.00- 7.45	-	1	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
7.50- 7.95	-	2	-	-	-	3	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-
8.00- 8.45	-	-	-	-	-	3	1	-	-	-	1	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-
8.50- 8.95	-	-	-	-	-	2	-	-	-	3	2	-	-	2	1	-	-	-	1	-	-	1	-	-	-	-	-
9.00- 9.45	-	-	-	-	-	2	-	-	-	3	3	-	-	-	1	-	-	1	1	-	-	5	-	-	-	2	1
9.50- 9.95	-	1	-	-	-	1	1	-	-	3	-	-	-	4	2	-	-	1	-	-	-	5	1	-	-	2	-
10.00-10.45	-	2	2	-	-	2	4	-	-	2	-	-	-	1	1	-	-	1	2	-	-	1	1	-	-	1	-
10.50-10.95	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-
11.00-11.45	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	1
13.50-13.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Totals	1	9	4	5	3	21	10	18	11	22	11	23	5	13	7	17	4	19	6	14	2	25	5	11	1	8	3

Table 9 Length frequencies of otoliths(continued)

	CAISTEAL NAN GILLEAN I															
	2				3				4				5			
	1		2		1		2		1		2		1		2	
	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	e
3.00- 3.45	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.50- 3.95	-	-	-	-	-	2	-	-	2	-	-	-	1	1	-	-
4.00- 4.45	1	1	-	-	4	4	-	-	4	-	-	-	1	-	-	-
4.50- 4.95	1	1	-	-	8	5	2	-	2	1	-	-	1	-	-	-
5.00- 5.45	-	-	-	-	3	1	-	-	4	1	-	-	4	2	-	-
5.50- 5.95	2	-	1	-	4	1	2	-	-	-	-	-	2	1	-	-
6.00- 6.45	-	-	-	-	-	-	4	-	2	-	-	-	-	-	-	-
6.50- 6.95	-	-	2	-	1	-	7	-	-	-	-	-	1	-	-	1
7.00- 7.45	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-
7.50- 7.95	-	-	1	-	-	-	2	-	-	-	1	2	-	-	-	-
8.00- 8.45	-	-	2	-	-	-	-	-	-	-	1	1	-	-	2	-
8.50- 8.95	-	-	-	1	-	-	-	-	-	-	-	-	-	-	3	-
9.00- 9.45	-	-	1	-	-	-	1	-	-	-	-	-	-	-	1	-
9.50- 9.95	-	-	1	2	-	-	-	-	-	-	1	-	-	-	2	1
10.00-10.45	-	-	2	-	-	-	-	-	-	-	2	2	-	-	-	1
10.50-10.95	-	-	-	1	-	-	1	-	-	-	1	-	-	-	-	-
11.00-11.45	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
11.50-11.95	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Totals	5	2	10	4	20	13	19	1	14	2	7	6	10	4	9	3

	PRIORY												
	1			2		3			4	6		7	8
	1	2		2		1	2		2	2		2	2
	e	c	e	c	e	e	c	e	c	c	e	c	e
3.00- 3.45	-	-	-	-	-	-	-	-	-	-	-	-	-
3.50- 3.95	-	-	-	-	-	-	-	-	-	-	-	-	-
4.00- 4.45	-	-	-	-	-	-	-	-	-	-	-	-	-
4.50- 4.95	-	-	-	-	-	-	-	-	-	-	-	-	-
5.00- 5.45	-	-	-	-	-	-	-	-	-	-	-	-	-
5.50- 5.95	1	2	-	-	-	-	-	-	-	-	-	-	-
6.00- 6.45	-	2	1	1	-	-	1	-	-	-	-	-	-
6.50- 6.95	-	7	1	8	4	1	4	-	-	-	-	-	-
7.00- 7.45	-	11	-	22	7	-	15	3	2	3	-	-	1
7.50- 7.95	-	3	1	23	6	-	31	1	2	1	-	-	-
8.00- 8.45	-	1	2	5	2	-	14	1	1	1	-	-	-
8.50- 8.95	-	-	-	-	1	-	1	2	-	1	-	3	-
9.00- 9.45	-	-	-	-	-	-	-	-	1	1	1	-	-
9.50- 9.95	-	-	-	-	-	-	2	-	-	-	-	-	-
10.00-10.45	-	1	-	1	-	-	1	-	-	1	-	-	-
10.50-10.95	-	-	-	-	1	-	-	-	-	-	-	-	-
11.00-11.45	-	-	-	1	-	-	-	-	-	-	-	-	-
11.50-11.95	-	1	-	-	-	-	-	-	-	-	-	-	-
Totals	1	28	5	61	21	1	69	7	6	8	1	3	1

Table 9 Length frequencies of otoliths(continued)

CNOC COIG

	Pit 1						Pit 2													3		4		5	Pit 6										7	
	a		b		c		a		b		c		d		e		f		g	a		f		a	a		b		c		d		e		a	
	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	c	e	c	e	e	c	e	c	e	c	e	c	e	c	e	c	e
5.00- 5.45	-	-	-	-	-	-	-	1	1	-	--	--	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	-	-	-	-	-	-	-
5.50- 5.95	1	2	-	-	-	-	-	-	3	3	4	2	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	1	1	-	-	-	-	-	-	-
6.00- 6.45	1	3	3	-	2	-	6	-	7	4	6	9	-	-	3	3	-	-	1	1	-	2	-	-	-	1	2	-	2	-	3	2	-	-	2	-
6.50- 6.95	3	2	3	2	2	1	1	1	5	6	10	18	2	-	1	1	1	-	1	2	1	-	1	-	1	-	1	1	6	1	2	1	5	1	3	-
7.00- 7.45	4	2	4	2	1	-	3	3	1	6	4	10	1	-	5	-	1	-	1	1	1	-	1	2	1	1	1	1	12	-	4	1	1	1	1	-
7.50- 7.95	4	1	1	-	-	-	1	-	1	1	1	7	7	-	7	-	-	-	-	2	-	1	-	-	-	-	2	-	1	1	3	2	-	-	-	-
8.00- 8.45	-	-	-	-	-	-	-	-	1	-	--	--	3	-	4	1	1	-	-	-	-	-	-	-	-	-	2	1	--	-	-	-	-	-	-	-
8.50- 8.95	-	-	-	-	-	-	-	-	-	-	--	--	2	2	3	-	-	-	1	-	-	-	-	-	-	-	2	-	--	-	-	-	-	-	-	-
9.00- 9.45	-	-	-	1	-	-	-	-	-	-	--	--	4	-	2	-	-	-	-	-	-	-	-	-	-	-	3	-	--	-	1	-	-	-	-	1
9.50- 9.95	-	-	-	1	-	-	2	1	-	-	--	--	1	1	1	-	-	-	-	-	-	-	-	-	-	-	1	1	4	1	-	1	-	-	1	2
10.00-10.45	3	-	-	-	-	-	-	4	-	-	--	--	-	1	-	1	-	1	-	-	-	1	-	-	1	-	5	1	19	1	1	-	2	-	-	-
10.50-10.95	2	2	1	-	-	-	2	-	-	-	--	1	-	-	2	1	1	2	-	-	-	2	2	-	-	-	3	2	31	3	3	-	-	-	3	-
11.00-11.45	-	1	-	-	-	-	-	-	-	-	--	--	1	-	1	1	-	-	-	-	-	-	-	1	-	-	2	3	26	5	-	-	-	-	1	-
11.50-11.95	-	-	-	-	-	-	-	-	-	-	--	--	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	23	2	-	-	-	-	-	1
12.00-12.45	-	-	-	-	-	-	-	-	-	-	--	--	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	1	-	-	-	-	-	-
12.50-12.95	-	-	-	-	-	-	-	-	-	-	--	--	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-
Totals	18	13	12	6	5	1	15	10	19	20	25	47	21	4	30	8	4	3	5	6	2	6	4	3	4	2	25	11	138	15	17	7	8	2	11	4

Table 9 Length frequencies of otoliths(continued)

CNOC COIG(cont.)

	Pit 7(cont)									8		9			Pit 10								Pit 11														
	b		c		d		e	f		a		a	b		a		b		c		d		a		b		c		d		e	f		g		h	
	c	e	c	e	c	e	c	c	e	c	e	c	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	c	e	c	e	c	e
5.00- 5.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	-	-	-	-	-	-	-	-	-	-	--	-
5.50- 5.95	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	--	-	-	-	-	-	-	2	-	1	-	--	-
6.00- 6.45	-	1	-	-	1	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	3	-	1	-	-	-	2	3	-	2	-	--	1
6.50- 6.95	-	-	-	1	-	-	1	-	1	1	-	-	1	1	2	4	3	1	-	-	3	1	-	-	1	-	1	1	-	-	6	5	1	-	-	--	-
7.00- 7.45	2	-	1	-	-	-	-	3	2	3	1	-	-	-	8	1	2	-	1	-	-	-	-	-	12	1	2	-	-	-	4	1	-	1	-	3	-
7.50- 7.95	-	-	-	-	1	-	-	-	-	1	1	-	1	-	3	1	1	-	-	-	-	-	1	-	8	1	-	-	-	-	1	1	-	2	-	1	-
8.00- 8.45	2	-	-	1	2	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	1	-	-	1	2	-	-	2	-	-	2	1	-	-	-	1	-
8.50- 8.95	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	--	-	1	-	-	-	-	-	-	-	-	--	-
9.00- 9.45	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	1	1	-	-	--	-	-	-	1	-	-	-	-	-	-	--	-
9.50- 9.95	-	1	1	-	3	-	-	1	-	-	1	-	-	1	-	-	-	-	-	-	2	1	-	-	--	-	-	-	2	-	-	-	-	-	-	3	-
10.00-10.45	-	-	1	1	2	4	-	2	1	1	-	-	1	-	-	-	-	2	2	-	-	-	-	-	1	-	1	-	4	1	-	-	-	-	-	14	1
10.50-10.95	-	-	1	-	3	1	-	-	-	-	1	2	2	1	4	1	1	-	1	1	-	-	-	-	1	-	1	1	1	1	-	-	-	-	-	27	6
11.00-11.45	-	-	1	-	2	2	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	2	-	-	1	10	2
11.50-11.95	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	-	-	-	-	-	-	-	-	-	-	2	-
12.00-12.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	--	-	-	-	-	-	-	-	-	-	-	--	-
12.50-12.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	-	-	-	-	-	-	-	-	-	-	--	-
Totals	4	2	5	3	16	8	1	7	4	9	5	3	5	4	19	7	8	3	4	1	7	4	3	1	30	2	7	4	8	2	15	15	1	6	1	61	10

Table 9 Length frequencies of otoliths(continued)

CNOC COIG(cont.)

	13		Pit 14								Concentrations(L7 - L30) 7		8		9	10	11		12	13		14	15			16		17	18		19		20	
	a		a		b		c		d		2		2		2	2	2		2	2		2	1	2		2		2	2		2		2	
	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	c	c	e	c	c	e	c	c	c	e	c	e	c	c	e	c	e	c	e
4.50- 4.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
5.00- 5.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
5.50- 5.95	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	2	-	-	-	-	2	-	-	-	2	1
6.00- 6.45	-	-	2	-	-	-	1	-	-	-	-	1	2	-	1	-	2	-	4	1	-	2	2	-	-	3	1	-	2	-	-	-	10	1
6.50- 6.95	3	1	2	-	1	1	2	-	-	-	2	-	3	1	-	-	1	-	1	1	-	3	2	4	-	2	-	-	1	-	1	-	5	3
7.00- 7.45	-	-	2	-	-	1	-	-	1	1	1	-	-	-	-	1	1	-	1	1	-	1	-	-	1	-	-	-	2	-	-	-	3	1
7.50- 7.95	-	-	-	-	1	1	-	-	-	-	-	-	1	1	-	1	-	-	-	1	-	-	-	-	-	1	-	-	1	1	-	-	2	-
8.00- 8.45	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	2	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-
8.50- 8.95	-	-	-	1	3	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
9.00- 9.45	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	2	-
9.50- 9.95	1	-	-	-	1	-	-	-	-	1	1	-	1	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-
10.00-10.45	3	-	1	-	2	1	-	2	-	-	3	-	1	-	-	4	2	-	-	2	1	3	-	-	-	-	-	-	1	-	2	-	-	-
10.50-10.95	1	1	1	1	1	-	-	-	-	-	4	-	1	-	3	7	2	-	3	1	1	4	-	1	-	-	-	1	2	-	5	1	-	-
11.00-11.45	-	-	-	1	1	-	-	-	-	-	1	-	-	1	-	1	-	1	1	-	1	4	-	-	-	-	1	-	3	-	1	-	-	-
11.50-11.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12.00-12.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Totals	8	2	9	3	12	5	3	2	1	2	13	1	12	3	4	16	8	1	12	10	3	20	4	9	1	6	2	1	14	1	10	1	27	6

Table 9 Length frequencies of otoliths(continued)

CNOC COIG(cont.)

Concs.(L7-L30)(cont)

	21		22	23		24		25	26		27		28		29	30
	2		2	2		2		2	2		2		2		2	2
	c	e	c	c	e	c	e	c	c	e	c	e	c	e	c	c
5.00- 5.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.50- 5.95	-	-	1	-	-	2	1	-	-	-	-	-	1	-	-	-
6.00- 6.45	-	-	2	-	-	7	4	-	-	1	-	-	5	-	-	1
6.50- 6.95	2	-	-	-	1	8	2	-	-	-	-	1	1	1	1	1
7.00- 7.45	-	-	-	-	-	1	-	-	-	-	-	-	1	1	-	-
7.50- 7.95	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
8.00- 8.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8.50- 8.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.00- 9.45	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
9.50- 9.95	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2
10.00-10.45	-	1	2	2	-	-	-	1	3	-	-	-	2	-	3	-
10.50-10.95	1	-	2	1	-	4	-	4	2	-	-	-	-	-	2	3
11.00-11.45	-	-	-	1	1	-	-	-	1	-	1	-	-	-	2	2
11.50-11.95	-	-	1	-	-	1	-	-	-	-	-	-	1	-	-	-
12.00-12.45	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
12.50-12.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Totals	4	1	9	5	2	23	7	5	7	1	2	1	12	2	8	9

Concentrations(L1 - L6)

	1		2		3		4			5			6		
	2		2		2		1	2		1	2		1	2	
	c	e	c	e	c	e	c	c	e	c	c	e	c	c	e
5.00- 5.45	--	-	--	-	--	-	2	--	-	1	--	-	-	2	-
5.50- 5.95	--	-	1	-	--	-	-	--	-	2	1	1	2	--	-
6.00- 6.45	--	-	2	-	--	-	-	1	-	3	8	-	1	7	-
6.50- 6.95	1	-	--	-	--	-	-	--	-	2	15	3	3	10	1
7.00- 7.45	--	-	2	-	4	1	-	--	-	-	8	1	-	11	-
7.50- 7.95	--	-	--	-	2	-	-	--	-	-	2	-	-	3	-
8.00- 8.45	--	-	--	-	7	-	-	--	-	-	1	-	-	--	-
8.50- 8.95	--	-	--	-	5	-	-	--	-	-	--	-	-	--	-
9.00- 9.45	--	-	--	-	1	-	-	--	-	-	1	-	-	--	-
9.50- 9.95	2	-	2	-	--	-	-	--	-	-	--	-	-	--	-
10.00-10.45	16	1	11	-	8	1	-	2	-	-	3	-	-	--	-
10.50-10.95	39	-	37	1	16	1	-	19	-	-	6	-	-	--	-
11.00-11.45	41	-	57	2	20	-	-	14	-	-	15	2	-	6	2
11.50-11.95	19	-	17	2	10	-	-	--	1	-	6	-	-	1	-
12.00-12.45	3	-	5	1	2	-	-	--	-	-	3	-	-	--	-
12.50-12.95	--	-	--	-	1	-	-	--	-	-	1	-	-	--	-
Totals	121	1	134	6	76	3	2	36	1	8	70	7	6	40	3

Table 9 Length frequencies of otoliths(continued)

CNOC COIG(cont.)

Concentrations(1 - 38)

	1		2		3		4		5		6		7		8	9		10		11		12		13		14		15		16	17		18		19		20	
	1		1		1		1		1		1		1		1	1		1		1		1		1		1		1		1	1		1		1		1	
	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	c	e	c	e	c	e	c	e	c	e	c	e	c	e	c	c	e	c	e	c	e	c	e
3.50- 3.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.00- 4.45	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.50- 4.95	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	2	-	-	-	-	-	-	-
5.00- 5.45	1	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	2	-	-	-	1	-	1	-	3	-	-	-	-	2	-	2	-	-	-	-	-
5.50- 5.95	2	-	-	-	1	-	-	-	-	-	1	1	-	-	-	1	-	-	-	-	-	2	1	4	1	6	-	1	-	-	2	-	5	-	-	-	3	-
6.00- 6.45	2	-	-	-	4	-	-	-	1	-	1	1	4	-	1	1	1	1	-	4	1	1	2	10	3	8	1	-	-	-	1	-	12	2	1	-	8	-
6.50- 6.95	-	-	1	-	5	1	1	-	-	-	4	-	5	1	2	4	-	3	1	6	2	3	-	7	4	1	3	1	-	-	4	-	9	1	3	-	20	1
7.00- 7.45	1	-	-	-	5	1	1	-	-	-	3	-	9	2	1	11	-	8	2	5	2	4	2	5	6	1	2	1	-	-	2	1	12	2	3	1	7	-
7.50- 7.95	-	-	1	-	1	-	-	-	-	-	-	-	4	-	-	7	-	3	-	3	3	4	-	-	2	-	1	1	-	-	-	-	1	-	2	1	1	-
8.00- 8.45	-	-	-	-	4	-	4	-	-	-	-	-	1	-	-	-	-	-	-	4	1	-	-	2	3	-	-	-	-	-	-	-	-	-	1	1	-	-
8.50- 8.95	1	1	-	1	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.00- 9.45	8	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
9.50- 9.95	19	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	2	-	-	-	-	-	3	-	3	1
10.00-10.45	27	5	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	9	2	-	6	-	-	-	2	-	7	1
10.50-10.95	17	1	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5	-	11	-	-	-	2	1	8	-
11.00-11.45	4	2	-	-	-	-	1	-	2	1	-	-	-	-	-	-	-	3	-	-	1	-	-	-	-	-	-	2	3	-	12	-	-	-	1	1	3	-
11.50-11.95	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2	-	-	-	-	-	-
Totals	83	15	2	1	20	2	18	1	4	1	18	2	23	3	4	24	1	22	3	23	10	15	5	30	19	19	7	28	12	1	42	3	41	5	18	5	60	3

Table 9 Length frequencies of otoliths(continued)

CNOC COIG(cont.)

Concentrations(1 - 38)(cont)

	21	22		23		24		25		26		27	28		29	30		31		32	33		34		35		36		37		38
	1	1		1		1		1		1		1	1		1	1		1		1	1		1		1		1		1		1
	c	c	e	c	e	c	e	c	e	c	e	c	c	e	c	c	e	c	e	c	c	e	c	e	c	e	c	e	c	e	c
3.00- 3.45	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.50- 3.95	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.00- 4.45	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.50- 4.95	-	-	-	1	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.00- 5.45	-	-	-	1	-	-	-	1	-	1	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	4	5	1
5.50- 5.95	-	-	-	3	1	-	-	3	-	1	-	-	1	-	-	-	-	1	-	-	2	-	1	-	-	-	-	1	5	13	-
6.00- 6.45	-	-	-	6	6	1	-	5	-	3	-	1	5	3	5	2	1	-	-	-	2	-	-	-	-	-	1	2	11	6	-
6.50- 6.95	-	1	-	1	-	-	-	1	-	10	1	-	4	1	3	3	3	1	-	1	5	-	-	-	1	-	7	1	9	3	-
7.00- 7.45	-	-	-	1	1	1	1	1	-	14	1	1	-	1	-	1	1	4	1	2	7	1	-	-	1	-	9	-	2	-	-
7.50- 7.95	-	-	-	-	-	1	-	-	-	10	-	1	-	-	1	1	-	6	-	2	6	2	-	-	-	-	1	-	1	-	-
8.00- 8.45	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8.50- 8.95	-	-	-	-	-	-	-	1	-	-	-	-	5	4	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
9.00- 9.45	-	-	-	-	-	-	-	-	-	-	-	-	21	10	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
9.50- 9.95	-	3	-	-	-	-	-	1	-	-	-	-	28	11	2	1	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-
10.00-10.45	-	23	-	-	-	-	-	3	-	-	-	-	13	4	-	-	-	2	-	-	-	-	1	-	6	1	-	-	-	-	-
10.50-10.95	1	26	-	-	-	-	-	4	-	-	-	-	-	-	4	-	-	1	-	-	-	-	8	-	8	-	-	1	-	-	-
11.00-11.45	-	7	1	-	-	-	-	1	1	-	-	-	-	-	9	-	-	1	-	-	-	-	-	-	2	-	4	-	-	-	2
11.50-11.95	-	-	-	-	-	-	-	2	-	-	-	-	1	-	5	1	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-
Totals	1	60	1	14	17	3	1	23	1	39	2	3	82	34	29	9	5	16	1	5	23	3	10	1	20	1	25	5	32	27	3

Table 9 Length frequencies of otoliths(continued)

Based on a sample of 20 fish caught in April 1976 (Appendix 2);the fish were just entering their second or third year of life,with a size range of 230-321mm(TF) and 125.5-330.5g (FW). Figures are expressed as a percentage of the whole weight.

	Mean	Range		
Whole weight(FW)	100%			
Dressed weight(DW)	66.9	(64-72)	Head & viscera	33.1
Boned weight(BW)	58.6	(54-64)	Backbone & fins	8.3
Meat weight(MW)	51.7	(46-67)	Skin & bone on fillets	6.9
			Body flesh	51.7

Table 10 Estimation of the edible proportion of young saithe

	water	fat	protein	Cal/lb.	S	% edible	1	2	3	4
Dogfish							s-m	<0.5m cl-2kg	low	dried
Monkfish							s-m	?	low	
Thornback	77-82	0.1-1.6	18.2-24.2	400-450	i	27	s-l	0.5m	good	salted;dried
Salmonid	80.5	0.7	18	365	ii	53	s	c100mm	good	
Eel	71.2	7.9	17.6	660	ii	67	s	c200mm	varied	smoked
Conger	80	0.2-11.9	19.1	360	i		s-m	0.5-1m	varied	dried
Lythe	79	0.6-0.8	16.4-20.3	320-400	i	49		(see text)		
Saithe	81	0.3-0.6	16.4-20.3	320-400	i	49		(see text)		
Hake	80	0.4-1.0	17.8-18.6	320-380	i		l	0.75m 2kg	good	salted-dried
Ling	78	0.1-0.4	19.5-22.2	370-430	i		l	0.75m	good	salted-dried
Sea bream	79	1.5	17.6	390	i		m-l	c200mm 1kg	low	
Wrasse							s-l	c300mm	low	dried
Shanny							s-l	c120mm	too small	
Eelpout							m	c150mm	varied	
Sea scorpion							m	c120mm	too small	
Flounder	81	0.3	16.8	330	i	41	s-m	c150mm	good	

Table 11 The composition, sizes and edibility of species in the Oronsay sites

Composition: Sources(S)-i Murray & Burt(1969), ii Varley(1967); %edible-Barker(1968), McCance & Widdowson(1960).

1-size range of archaeological specimens 2-rough estimates of reconstructed fish size
3-general value of the species 4-main methods of preservation.

	1	2	3	4	5	6	7			8		9					10	11		12	13	14		15
	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	e	c	c	c	e	c
4.50- 4.95	--	--	--	--	--	--	--	--	--	--	--	--	--	-	-	--	--	--	-	--	--	--	-	--
5.00- 5.45	--	--	--	--	--	--	--	--	--	--	--	--	2	2	-	--	10	--	-	--	--	--	-	--
5.50- 5.95	--	--	--	15	--	--	--	--	--	--	--	4	16	3	4	--	--	--	-	--	--	--	-	--
6.00- 6.45	--	--	--	47	--	--	--	--	--	--	--	2	7	6	5	--	2	--	-	--	2	--	-	--
6.50- 6.95	--	--	--	18	--	--	--	--	--	--	--	2	2	3	7	--	2	--	-	--	--	--	-	--
7.00- 7.45	--	--	--	18	--	--	--	--	--	--	--	--	--	-	-	--	--	--	-	--	--	--	-	--
7.50- 7.95	--	--	--	4	--	--	--	--	--	--	--	--	--	-	-	--	--	4	-	--	--	2	-	--
8.00- 8.45	--	--	--	--	--	7	12	12	2	--	--	--	--	-	-	--	--	6	-	--	--	--	-	--
8.50- 8.95	--	--	--	--	3	1	11	33	4	--	--	--	--	3	-	--	--	22	2	14	--	--	-	--
9.00- 9.45	7	6	9	--	1	7	12	23	17	11	2	2	--	3	-	12	--	20	2	55	5	2	-	--
9.50- 9.95	13	28	12	1	6	--	6	9	7	36	22	--	--	9	4	17	5	12	-	51	25	16	1	--
10.00-10.45	9	24	13	15	4	2	2	1	6	32	39	2	--	6	3	17	14	4	-	31	41	37	-	8
10.50-10.95	2	3	6	28	8	4	--	--	--	18	10	--	--	-	-	8	22	2	-	5	27	39	3	21
11.00-11.45	--	--	3	26	14	52	--	1	2	--	5	--	--	-	-	--	2	--	-	1	6	37	3	33
11.50-11.95	--	--	--	2	5	32	--	1	--	--	--	--	--	-	-	--	--	--	-	--	3	7	-	12
12.00-12.45	--	--	--	1	2	12	--	2	--	--	--	--	--	-	-	--	--	--	-	--	--	--	-	1
12.50-12.95	--	--	--	3	--	2	--	2	--	--	--	--	--	-	-	--	--	--	-	--	--	--	-	--
13.00-13.45	--	--	--	2	--	--	--	--	--	--	--	--	--	-	-	--	--	--	-	--	--	--	-	--
13.50-13.95	--	--	--	1	--	--	--	--	--	--	--	--	--	-	-	--	--	--	-	--	--	--	-	--
14.00-14.45	--	--	--	1	--	--	--	--	--	--	--	--	--	-	-	--	--	--	-	--	--	--	-	--
Totals	31	61	43	182	43	119	43	84	38	97	78	12	27	35	23	54	57	70	4	157	109	140	7	75

Table 12 Length frequencies of otoliths in samples of saithe from Colonsay-Oronsay

Further details and sample numbers are given in Appendix 2

30.04.76		OH(l) OHO(p)	OHOH(l) OHOH(l)
19.05.76		OHO(p) OHO(p)	OHOHO(p) OHOHO(p) OHOHO(p)
21.06.78		OHO(s) OHO(s) OHO(s)	
6-7.07.76		OHO(s) OHO(s)	OHOHO(s)
15.07.78		OHO(l)	
30.07- 3.08.77	O OH(p) OH(p) OH(p) OH(p)	OHO(l) OHO(l) OHO(l) OHO(l) OHOH(p)	
2.08.78		OHO(s) OHO(s) OHO(l)	
21.08.77			OHOHO(m)
6-7.09.77	OH(p) OH(p) OH(p) OH(s)	OHOH(s) OHOH(s) OHOH(s)	
20.09.78	OH(m)	OHOH(s) OHOH(s) OHOH(s)	
2.11.78	OH(m)	OHOH(s) OHOH(s) OHOH(m) OHOH(m)	
21-2.11.75	OH(m) OH(l)	OHOH(s) OHOH(m) OHOH(l)	
14.12.78		OHOH(s) OHOH(s) OHOH(m)	

Table 13 Results of the analysis of growth rings in otoliths from saithe caught off Colonsay-Oronsay

Further details of the samples are given in Appendix 2.

Outer ring:stages of visibility- partial(p), small(s),medium(m) and large(l).

Man-power Engines/Impaling Gears.

Spears,gaffs & harpoons;nooses;rakes.

Small-scale simple active gears;highly mobile and adaptable;mostly low level of catches.

Fixed Engines/Mazes & Baricases.

Pots & baskets;fyke & stake nets;stream & tidal weirs.

Efficient,mass-capture techniques which can operate unattended;relatively unselective in their catch;mostly fixed in location.

Line Fishing.

Gorges or hooks,with bait or lure;range from simple single one-piece hooks on a short line (angling) through to multiple hooks on 'long-lines'.

Mobile with reasonable catch rates;mostly active fisheries;highly selective gears.

Net Fishing.

Scoop(dip,poke,push);encircling(beach/shore seine, purse seine);entangling(drift,gill,trammel);towed (trawl,Dutch seine).

Mobile mass-capture gears mostly operating near the surface;mainly active fishing.

Miscellaneous.

Capture by hand('tickling' trout),collecting fish stranded by natural conditions or predators,use of poison etc.

Table 14 Simple classification of fishing gears