The Fish Remains from Freswick Links, Caithness

One volume

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January, 1991

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ACKNOWLEDGEMENTS

This study would not have been possible without the co-operation and assistance of a large number of persons. I wish to record my gratitude to Professor Christopher Morris and Dr Colleen Batey, Department of Archaeology, University of Glasgow (formerly Durham), who directed the excavations and willingly provided maps of the site (figures 1-10), stratigraphic information and encouragement. Financial support for most of the excavation and post-excavation work was provided by the Scottish Development Department and this is gratefully acknowledged.

This work would not have been completed without the careful guidance and kindly encouragement of Alwyne Wheeler. Throughout the years I have studied fish remains he has been of inestimable help in a multitude of ways.

I wish to thank Dr Peter Hogarth who supervised the project throughout its long gestation. Laboratory facilities were made available at the Environmental Archaeology Unit, University of York, where I benefited from numerous discussions with my former colleagues Harry Kenward, Dr Allan Hall, Dr Terry O'Connor, Rebecca Nicholson and others. Assistance on a number of technical points was provided by members of Departments of Biology and Archaeology Department and the University of York Computer Service. In particular I wish to thank Peter Crosby for his careful photographic work, Mike Snelling and colleagues for access to rats and mice, John Byrne for patiently advising with statistical matters and Dr Rob Fletcher for assistance with computer graphics.

During the excavations many individuals helped with the work of processing of sediment samples and it is impossible to thank each by name. However, I am particularly grateful to Carol 'Caz' Garbut for her conscientious work in all three seasons of excavation, and to James Rackham who helped develop the sampling procedures, provided sieving equipment in 1980 and helped supervise sample processing.

Most of the sorting of processed dried sediment samples was ably and efficiently undertaken by Enid Allison, Steven Barnes, Jeff Maytom, Rebecca Nicholson and Sally Scott.

Peter Walker of the Fisheries Laboratory, Lowestoft, provided many of the modern fish specimens used to identify the archaeological material, while Bernard Bedford, formerly of the Fisheries Laboratory, Lowestoft, provided modern gadid otoliths, sectioned and examined some of the Freswick otoliths. The Trustees of the Natural History Museum, London, are thanked for access to collections of fish skeletons and otoliths.

Drs Peter Addyman and Dominic Tweddle encouraged the completion of this project by allowing access to the York Archaeological Trust's computing equipment. Charlotte Walton pasted up the final copies of the thesis and drew figure 80. Sandra Barton drew figures 11, 12 and 16-20 from my rough originals.

Finally, I wish to acknowledge assistance with proof-reading by my wife Julie. However, I am most indebted to her and my children William and Alice for their patience and forbearance during the long period of this project.

DECLARATION

Substantial sections of early drafts of chapters 1, 2, 3, and 4 were published in Wheeler and Jones (1989). Details of the fish trampling experiment have been submitted for publication with a forthcoming volume of the proceedings of the International Council of Achaeolozoologists Fish Remains Working Group. A summary of the results of experiments designed to assess how fish bones survive on human habitation sites has been submitted for publication in a forthcoming volume of papers presented to the Association for Environmental Archaeology.

ABSTRACT

Large assemblages of fish remains from Pictish and Norse deposits at Freswick Links, Caithness, were recovered by wet-sieving over 40 tonnes of archaeological deposit on 1 mm mesh. The recovered assemblages were dominated by the remains of large gadid fishes, principally cod, Gadus morhua, ling, Molva cf. molva, and saithe, Pollachius virens. In addition, 27 other species of marine fishes were identified including the first archaeological finds of the topknot, Zeugopterus punctatus.

Investigations of large numbers of modern specimens were carried out in order to refine identification and to investigate the relationship between fish total length and element size. Prediction intervals (95%) which take account the curvilinearity and heteroscedasticity of the relationship were calculated for the most common elements of the major gadid fishes found at the site.

In addition, feeding and other experiments were undertaken to assess how fish remains survive in archaeological deposits. These taphonomic studies made it possible to attribute some post-mortem damage to scavengers or other piscivores. Furthermore, experimental data and the numbers of elements surviving at Freswick confirm the view that most archaeological assemblages of fish remains are heavily biassed by decay processes. Although otoliths proved to be the most abundant identifiable cranial element in the assemblages, thin-sections showed diagenetic changes had largely obscured annual and other growth patterns.

Archaeological and documentary evidence from the area indicate that line fishing, mainly for large gadid fishes, was the dominant fishery operating at Freswick from the period of Pictish occupation until the site was abandoned.

LIST OF ABBREVIATIONS

BD = body depth
C. = Centigrade
C = cleithrum width
D1 = dentary depth at foramen
D2 = dentary depth at symphysis
g = gram
HL = head length
hr = hour
IR = index of robustness
kg = kilogram
L = left
log = logarithm
m = metre
M = measurement
Max = maximum
min = minute
Min = minimum
mm = millimetre
n = number of observations
OL = otolith length
OW = otolith width
p = page
P1 = premaxilla condyle width
P2 = premaxilla width at symphysis
pers. comm. = personal communication
PI = prediction intervals
R = right
T = total
S.D. = standard deviation
S.E.M. = standard error of the mean
s.g. = specific gravity
SL = standard length
TL = total length
µm = micron
? (in tables column headings) = unknown side

LIST OF FISH NAMES

This list is presented in alphabetical order of scientific names.

Taxon	Common name
Ammodytidae	Sand eel family
Anarhichas lupus L.	Catfish
Anguilla anguilla (L.)	Common eel
Belone belone (L.)	Garfish
Brosme brosme (Ascanius)	Torsk
Clupea harengus L.	Herring
Clupeidae	Herring family
Conger conger (L.)	Conger eel
Dicentrarchus labrax (L.)	Bass
Elasmobranchii	Cartilaginous fishes
Eutrigla gurnardus (L.)	Grey gurnard
Gadidae	Cod family
Gadus morhua L.	Cod
Gaidropsarus/Ciliata	Rocklings
Heterostomata	Flatfishes
Hippoglossus hippoglossus (L.)	Halibut
Hyperoplus lanceolatus (Le Sauvage)	Greater sand eel
Labridae	Wrasse family
Labrus bergylta Ascanius	Ballan wrasse
Labrus bimaculatus L.	Cuckoo wrasse
Lepidorhombus whiffiagonus (Walbaum)	Meagrim
Lophius piscatorius L.	Angler fish
Melanogrammus aeglefinus (L.)	Haddock
Merlangius merlangus (L.)	Whiting
Merluccius merluccius (L.)	Hake
Molva cf. molva (L.)	Ling
Myoxocephalus scorpius (L.)	Bull rout
Pholis gunnellus (L.)	Butterfish
Platichthys flesus (L.)	Flounder
Pleuronectes platessa L.	Plaice
Pleuronectidae	Plaice family
Pollachius pollachius (L.)	Pollack
Pollachius virens (L.)	Saithe
Raja clavata L.	Thornback ray
Raniceps raninus (L.)	Tadpole fish
Salmonidae	Salmon family
Scomber scombrus L.	Mackerel
Scyliorhinidae	Dogfishes
Spondyliosoma cantharus (L.)	Black sea bream
Taurulus bubalis (Euphrasen)	Sea scorpion
Trachurus trachurus (L.)	Horse mackerel
Triglidae	Gurnard family
Trisopterus luscus (L.)	Bib
Trisopterus minutus (L.)	Poor cod
Zeugopterus punctatus (Bloch)	Topknot

Fish nomenclature follows Wheeler (1969).

INTRODUCTION

Although accounts of fish remains recovered from archaeological deposits have been published since the middle of the 19th century (Clason, 1986), the potential of fish bones, scales and otoliths has been exploited infrequently by archaeologists. It is particularly surprising that fish bones have been so neglected given the amount of time and effort which has been dedicated to studying the remains of domestic mammals excavated from archaeological sites. For many years it has been accepted that mammal and bird bones (which are often referred to as 'animal bones') should be collected and reported, and in the last 20 years or so many archaeologists have realized that small mammal bones, plant remains, insect fragments and a host of other biological remains can also provide valuable information about life in the past. In order to recover these kinds of materials a number of sampling and sieving techniques have been developed. These have resulted in the recovery of a wide spectrum of fish remains, where once they were recovered rather sparsely. As a corollary modern recovery techniques have produced a much greater range of fish material which has increased the challenge of identification.

Furthermore, an increasingly large number of contemporary excavators share the view that because excavation is a destructive process there is a duty to record what is present, however small, if it provides information concerning the life of the site's inhabitants.

There are four main reasons for this scant treatment. First, there were, and still are, few individuals who can produce fish bone reports. The major difficulty for students, be they archaeologists or biologists, is access to adequate reference collections. Few institutions have skeleton collections which contain specimens of all the species likely to occur in archaeological deposits.

Second, there is a shortage of practical written accounts of how to carry out the work. Casteel's book, Fish Remains in Archaeology and Paleo-environmental studies (Casteel, 1976) gives copious examples of what might be achieved by studying fish remains from archaeological sites based on how fishery biologists analyse contemporary fish scales, otoliths and bones, but fails to give much practical advice for those finding fish bones for the first time. Not until very recently did Wheeler and Jones (1989) produced their Cambridge Manuals in Archaeology: Fishes which is an attempt to outline the methodology and to define the potential and limitations the study of fish remains from archaeological sites.

Third, fish remains are often neglected because they are relatively small and fragile. Many important food fish have small bones which are easily overlooked even if sediment samples are sieved using mesh with 1 cm aperture meshes. Because water provides more support to a fish than air does to a terrestrial vertebrate, fish bone is less dense and has different mechanical properties from other kinds of bone. Fish bone is more easily fragmented than mammal or bird bone.

Finally, widespread ignorance concerning the information that can be gleaned from fish remains has meant that archaeologists have not always insisted that their fish material was accurately identified. It is only in the last few decades that archaeologists have begun to appreciate how abundant and informative fish remains can be.

These are the prime factors which have caused fish remains to be neglected. Consequently it is hardly surprising to find that until the mid-1970s it was common to see archaeological reports referring to all fish remains simply as 'Fish' rather than identifying them to family or species (e.g. Harcourt, 1969); such incomplete identifications are still to be found in relatively recently published excavation reports (e.g. Cruse and Harrison, 1983).

It is not surprising that authors of archaeological text-books and general accounts of past cultures attempting to assess the importance of fishes and fishing were forced to make sweeping generalizations. For example 'Mesolithic inhabitants of northern Europe drew upon birds, fish, marine mammals, shell-fish and plants for sustenance, as well as land based mammals' (Clark, 1980, 49). In the light of recent exciting research, such bland statements are no longer acceptable, and it is hoped that the current work will help to illustrate how careful field and laboratory work can produce clear insights into several aspects of the exploitation of fishes in the past.

This study of a large assemblage of fish remains from eroding midden deposits at Freswick Links was undertaken in order to explore the potential of ancient fish bones and otoliths for providing evidence on human diet and fish exploitation. Important aspects of the work were investigations on the ability of modern fish bones and otoliths to survive mechanical and chemical attrition. Modern material also was studied to determine the relationship between fish total length and the size of cleithrum, dentary, otolith and premaxilla of five species of important gadid food fish. These investigations form the background to the analysis of fish remains recovered by sieving on 1 millimetre (mm) aperture mesh over 40 tonnes of midden deposits from excavations at Freswick Links, Caithness, (NGR ND 3765 6760) (Figure 1).

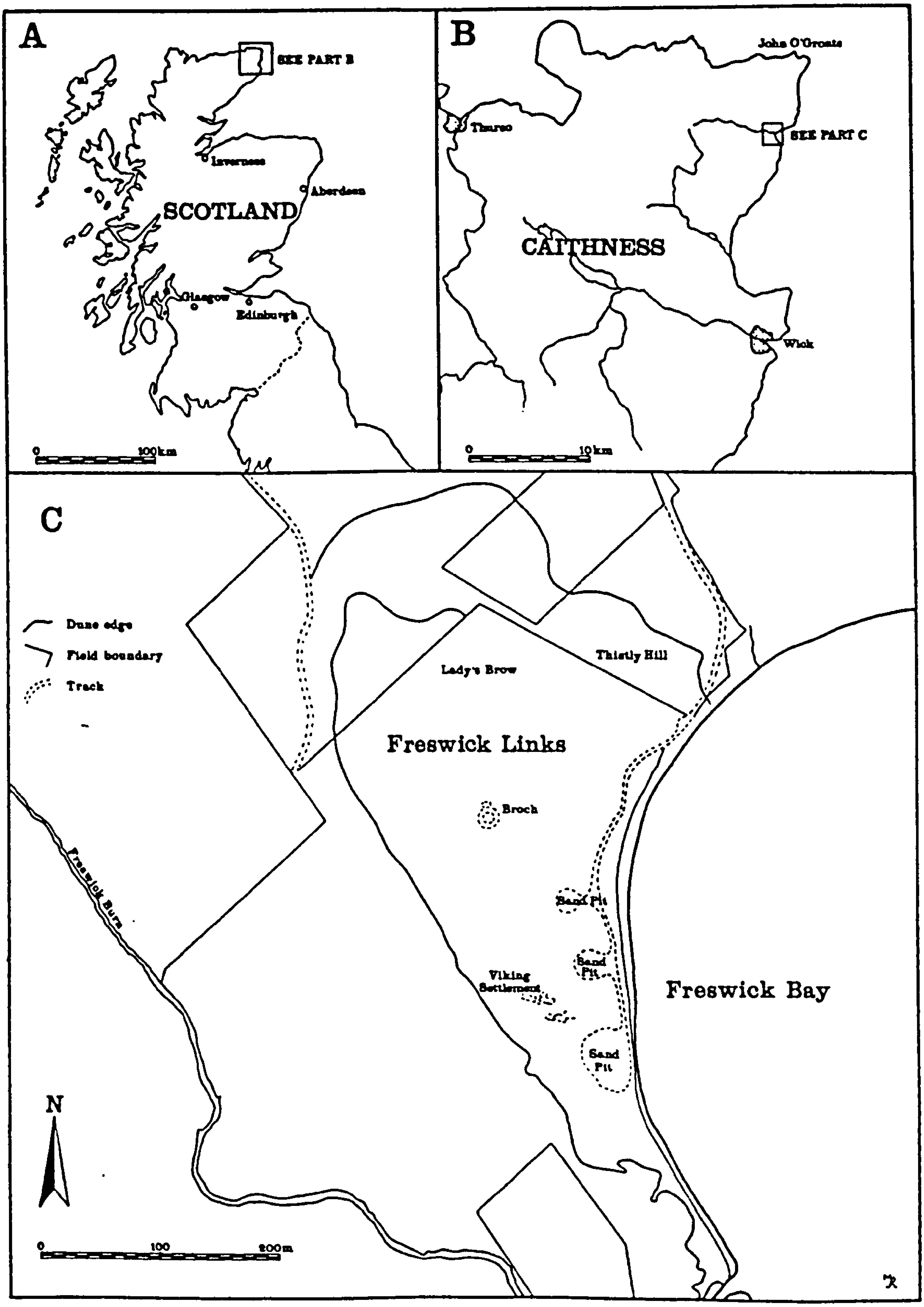
In addition to introducing the study of fish remains in archaeology, Chapter 1 places the site of Freswick Links in its geographical and cultural setting. Chapter 2 describes the development of the sampling strategy for the site and details of methods used to process the material.

Chapter 3 gives details of a series of experiments designed to investigate the taphonomy of fish hard tissues and demonstrates that fish bones are very vulnerable to decay into unidentifiable fragments on sites of human occupation. The fourth chapter investigates the relationship between fish total length and the size of selected bones and otoliths of cod, *Gadus morhua*, haddock, *Melanogrammus aeglefinus*, pollack, *Pollachius pollachius*, saithe, *P. virens*, and ling, *Molva molva* and provides confidence intervals for predicting the size of fish from their bones. Chapter 5 discusses the criteria used in identifying bones to species for the most abundant gadid fishes in the Freswick assemblage.

Chapter 6 describes the bones and otoliths recovered from Freswick Links considering the assemblage as a whole and by examining the remains recovered from different depositional environments (e.g. midden deposits and areas surrounding domestic buildings) and different phases of occupation.

Chapter 7 is a discussion of the results in the light of evidence from other sites and local traditional fishing practices. The concluding chapter summarizes the findings from these investigations and suggests areas worthy of study in the future.

Figure 1. Location maps of Freswick Links



Chapter 1

BACKGROUND TO THE STUDY OF FISH REMAINS FROM FRESWICK LINKS

1.1 FISH REMAINS FROM ARCHAEOLOGICAL SITES

That small fish remains survive in a recognizable form in archaeological deposits for thousands of years will surprise few biologists; however, this fact does appear to have eluded many members of the archaeological community until recent years. Many archaeologists were unaware that fish remains are extremely common in archaeological deposits, and few archaeological site reports include adequate accounts of the recovered fish remains. That said, over the last few years careful studies of fish remains have been published. The following examples are presented in order to demonstrate the kinds of work currently being undertaken.

Fish remains may provide information on three main areas of interest to archaeologists: human diet; the economy of a settlement or culture; and the natural environment of a site. These areas of archaeological research have not always played the prominent role they now occupy in the subject. For many years archaeological research concentrated on the study of artefacts, be they buildings or brooches, as a key to past human culture. Since anthropological methods have been adopted by archaeologists over recent decades, studies of diet and food processing have become important aspects of research designs. This anthropologically inspired approach, while an advance, has sometimes exaggerated the role of human activity in the accumulation of ancient assemblages of fish remains and has not taken full account of the limitations of the material evidence.

1.1.1 Evidence of Human Diet

Fish remains are an excellent source of information on human diet. There can be little doubt that most of the fish bones recovered on archaeological sites were deposited either after the flesh had been consumed, or after the flesh had been processed for later consumption. Fish remains are often the waste from kitchens and tables and may also comprise food remains which passed through the gut of man and/or other animals which occupied the site.

An example of kitchen waste was provided at Barnard Castle, County Durham, (Donaldson, Jones and Rackham, 1980). A drain running from the kitchen to the curtain wall of the medieval castle was carefully sieved and a large range of fish, mammal, and bird remains recovered.

Material from pits, floors, yards, and other features within medieval tenements at Alms Lane, Norwich, (Jones and Scott, 1985) showed that a restricted range of fish was consumed by the urban population from the 12th to 18th centuries. There did not appear to be major differences between the fish assemblages from the various tenements, or from different feature types. The bones from this site can best be regarded as a component of domestic waste which was discarded in an indiscriminate manner.

Evidence that fish bones were swallowed and passed with faeces comes from several sites where multidisciplinary studies of animal and plant remains have been undertaken. They clearly demonstrate that human excrement can contain large numbers of fish bones. Follett (1967) examined desiccated human coprolites containing fish remains from cave deposits in Nevada, U.S.A. The 16-22 Coppergate site, at York, contained many latrine or cesspits which were recognized by the enormous numbers of eggs of two kinds of intestinal nematode worm parasites, whipworm, *Trichuris trichiura*, and the large roundworm or maw-worm, *Ascaris lumbricoides*. Plant remains from these same features were dominated by small fragments of the spermoderm (bran) of cereals (either wheat, *Triticum* spp., or rye, *Secale cereale*). In addition, seeds of fruits like raspberry, *Rubus idaeus*, blackberry, *R. fruiticosus*, apple, *Malus* sp., sloe, *Prunus spinosa*, and plum, *P. domestica*, testify that the deposits were faecal in origin. These layers also contained substantial numbers of fish bones, mainly vertebrae of eel, *Anguilla anguilla*, and herring, *Clupea harengus*. Many of the vertebrae bore signs of having been crushed during mastication (O'Connor, 1989; Wheeler and Jones, 1989).

Not only are fish bones found in unconsolidated layers rich in food debris and parasite ova; they are also occasionally found in 'faecal concretions' in waterlogged urban sites. Faecal concretions are a mixture of bran fragments, parasite ova and other faecal material bound by calcium phosphate into amorphous lumps. They are insoluble in water. Sometimes the lumps contain recognizable food remains e.g. sloe stones or fish vertebrae. Very rarely the vertebrae are crushed in a manner consistent with them having been chewed (Jones, 1984a; 1986a).

Coastal sites and those located on rivers occasionally yield such large concentrations of fish remains that they are interpreted as the remains of fish that have been processed for later consumption.

1.1.2. Evidence of Economy, Trade and Fishing Methods

Fish remains can yield a large amount of valuable and interesting information given careful and critical recording. The species represented may reflect the social status of the people inhabiting the site. Bones from 12th century levels in the Misericorde of Westminster Abbey, a wealthy monastery in London, clearly demonstrated that the monks enjoyed a varied diet including over 20 kinds of fish. Of particular interest were relatively large numbers of remains of sturgeon, Acipenser sturio, john dory, Zeus faber, and turbot, Psetta maxima species that are highly prized for their eating qualities. All are excellent food fish and today command the highest prices in fish markets (Jones, 1976).

Often the size and sometimes the age at death of the fish can be determined. Measurements on cod, Gadus morhua, jaw bones excavated at Great Yarmouth, Norfolk, were used to estimate the size of the fish present in medieval layers (Wheeler & Jones, 1976). Noe-Nygaard (1983) presented similar information for pike, Esox lucius, lower jaws (dentaries) and after careful scrutiny of incremental growth rings on vertebrae of 100 modern pike caught at known dates throughout the year, she has estimated the season of capture for Mesolithic pike from Praestelyngen, Denmark.

By considering the habits and ecology of the various species recovered, it is possible to reconstruct the sources likely to have been exploited by ancient fishermen and to learn something of the methods used to catch the different kinds of fish. Another approach to reconstructing fishing techniques is to compare the frequency of the different sizes of fish recovered from an archaeological assemblage with hypothetical selectivity curves for various kinds of fishing gear. Balme (1983) showed that three sites in the Darling Basin, New South Wales, Australia, gave fish length distributions of golden perch, Maquaria ambiqua, indicating that gill nets were used.

Fishing practices develop as a local response to the geography and distribution of fish. Line fishing for large cod was prosecuted by the Mesolithic community of Bua Västergård Goteborg, Sweden, (Wigforss, et al. 1983). Similar finds of large cod and ling, Molva molva, bones have been also reported from Mesolithic material at Morton, Fife (Coles, 1971). At Varanger Fjord in northern Norway a seasonally occupied Neolithic site yielded an assemblage of fish remains dominated by large cod (Olsen, 1967) indicating line fishing was carried out.

Spears were used by Mesolithic Danish lake fisherman for a pike with in situ spear tips has been excavated (Clark, 1948).

Wicker baskets and nets have also been found in Mesolithic deposits in Europe (Clark, 1980). All are essentially simple technologies using locally available renewable resources. It is therefore probable that traditional fishing methods have ancient roots in many places. This has been elegantly demonstrated by Enghoff (1983) for coastal fisheries in Denmark. Many small cod and whiting, Merlangius merlangus, bones were found in Mesolithic middens. The traditional fishing method in the area, still practised in this century, was setting wicker weirs at low tide and collecting trapped fish (mostly small cod and whiting) on subsequent low tides.

All these methods, harpooning, hook and line fishing, and building tidal traps are discussed for early fishing in Oceania (Reinman, 1967), and harpooning, line fishing, bow and arrow, and nets are used today by the aboriginal inhabitants of Amazonia (Smith, 1981) even though modern materials are now employed.

1.1.3 Evidence of Past Environmental Conditions and Fish Distribution

An assemblage of bones from a site is likely to reflect local contemporaneous ecological conditions in addition to providing economic information. For example, stickleback, Gasterosteus aculeatus, and small dace, Leuciscus leuciscus, bones which were recovered from Roman drainage ditches in Southwark, London, (Jones, 1978) provide evidence of the contemporaneous fish fauna. The distribution of stickleback remains at Bronze Age Fen-edge West Row, Mildenhall, Suffolk, indicated which areas of the site were flooded seasonally. The fish bone data provided complementary evidence to plant macrofossils data at West Row and helped to produce a convincing picture of past flooding (Murphy, 1983).

While almost all fish bones found on archaeological sites have been used by man and are the remains of food waste or food offerings, a small percentage may have been brought onto sites by agents other than man. For example, at coastal sites the wind can deposit bones washed up on the beach; likewise otters, sea birds or other scavengers can bring fish carcasses onto a site or they may pass faeces or pellets rich in fish remains. A good example of animal deposited fish remains recently came to light when bones from Orkney were studied (Colley, 1983a & b). A stone tomb floor at Isbister was found to be overlain by a concentration of small fish bones which at first sight resembled finely divided tobacco leaves. Closer examination showed that many of the fish were small species of shore fish which are unlikely ever to have been eaten by man. Otters, _Lutra lutra_, were suggested as the depositing agents. It was also thought that otters were responsible for some of the bones reported in the Quanterness tomb, Orkney, Scotland (Wheeler, 1979a). Similar finds of small mammal bones have been attributed to roosting owls (O'Connor, 1983). Low concentrations of fish bones in deposits at the Brough of Deerness, Orkney, were attributed to birds by Rackham (1986).

During the last few thousand years human activities have modified the environment dramatically. Drainage, urbanization and industrial pollution have had a major impact on freshwater biota. These changes have been particularly well documented for the river Thames, and its fish fauna (Wheeler, 1979b).

Fish remains provide clear evidence for the distribution of fish in the past. There are few other lines of investigation that are capable of providing information about the changing fish fauna of a region in the recent past. Some evidence is available from studies describing bones recovered from natural peat and other deposits laid down during the Pleistocene and Holocene (e.g. Stuart, 1982; Stinton, 1985).

Historical records, while they can be of immense value, only give occasional reference to fishes and it is not always possible to be certain that the name used by the writer refers to the same species today. Sometimes names in ancient documents defy translation. Occasionally, in medieval documents such as Kitchener's Rolls, lists of fish are itemized with their cost and amount purchased. Such records are obviously of considerable interest to historians and archaeologists.

The information gleaned from historical records and assemblages of ancient fish remains can be very helpful to present-day biologists managing fish stocks, whether marine or freshwater. Today most fish populations are subjected to heavy fishing pressures from commercial and sport fishermen. Evidence of the age and size structure of past fish populations can be inferred from archaeological material and the evidence considered during the development of a management strategy.

The study of fish remains can provide unequivocal evidence about the food and sometimes may give insights into the technology and trading methods of a past society. This information is primarily important to archaeologists. Fisheries biologists and ecologists are interested in archaeological fish remains as they provide evidence of the past distribution and abundance of species. Furthermore, it may be possible to deduce something about water quality or other environmental factors by considering analyses of fish remains.

1.2 GEOLOGY AND CLIMATE OF CAITHNESS

Caithness may best be regarded as a great plain more or less dissected by stream courses. Its characteristic rock-formation is the Middle or Orcadian Old Red Sandstone, a formation which is dominated by mudstones, sandstones and flags in the north and east of the county (Crampton and Carruthers, 1914). While not germané to the main body of this thesis, it is interesting to note that many eminent ichthyologists have been attracted to Caithness to study the fossil fishes preserved in the flagstones. In the 1890s Traquair announced that he was able to recognize three distinct faunas in the Caithness Old Red Sandstone, one characterizing the John o' Groats Beds, another the Achanarras quarry and a third in the rocks that formed the district between Halkirk and Thurso (Traquair, 1894). These fish faunas have been examined by many palaeontologists during the last century and an accessible summary account of their work was published by Saxon (1975).

However, the hard rock geology is only of marginal interest to the present study. The Quaternary deposits are more relevant.

Much of the county is overlain by Pleistocene drift deposits (Omand, 1973a). All but the southern and western parts of Caithness are covered by a shelly till upon which soils have developed. Glacial activity is largely responsible for the gently undulating landscape which is mostly below 100 m O.D. and is cut by deeply incising rivers and streams. The heart of Caithness is clothed by a deep bed of peat, up to 6 m deep in places, and peat is still the most common source of domestic fuel (Sharpe and Saxon, 1972; Omand, 1973b).

The spectacular coastline comprises high sandstone cliffs and rocky inlets with characteristic flagstone layering, and a few large sandy bays backed by extensive dunes, e.g. Sandside Bay, Sinclair's Bay and Freswick Bay.

During the Devensian (last glacial period), the ice invaded Caithness from two directions. The main body came from the North Sea and swept across the county into the Atlantic Ocean, bringing in a tenacious, shelly boulder clay, rich in lime, which filled hollows and swathed prominences. A lesser body of ice invaded from the interior of Sutherland leaving a sandy boulder clay which is less tenacious and nearly free of lime.

The eustatic uplift of mainland Scotland, forming raised beaches and a number of other features, as ice melted at the end of the last glaciation occurred several thousand years before Freswick Links was occupied by Pictish and Norse settlers. There is no evidence that the general topography of the region 2000 years ago was substantially different from that seen today.

The most important surface deposit in the Caithness is peat, which still covers more than two-thirds of the county and formerly clothed a greater area. This great accumulation of peat is caused by the post-glacial climate and geography. At present Caithness has less rain than more mountainous parts of Britain and the summer temperature is lower and humidity and range of temperature less. The wettest months are September and October, May being the driest. Annual rainfall is under 1016 mm on the high plateau and less than 762 mm on the Plain of Caithness. The annual range of temperature varies from 11 degrees Centigrade (C.) on the plateau to 8 degrees C. in the maritime regions. The relatively equable distribution of rainfall, and uniformly low temperature favour the growth of peat.

In a number of places where the basal peat can be observed resting on clay, the first growth appears to have consisted of dwarf willows, *Salix* spp., which are thought to have formed under subarctic conditions. This bed is generally followed in upward succession by remains of birch, *Betula* sp., and locally hazel, *Corylus avellana*. Nearer the surface, in several places, including near Freswick Bay, are buried pine, *Pinus sylvestris*, stumps which once formed a forest or series of forests.

1.2.1 Geology and Vegetational History of the Freswick Links Area

Freswick Bay is formed at the site of a fault. The rocks on the south of the bay are of two kinds: flags of the Noss Head type which overlie beds of Ackergill type sandstones. These vary greatly in colour from grey and brown to yellow and red. They often include fragments of fossil plants, and thin layers of fine grit may be present. They dip to the east at angles of 10 - 15 degrees, and form the reef beneath the cliff. They display two features, "nodule beds" and black bituminous shales, seen at Ackergill and Reiss. By contrast, on the north side of Freswick Bay the low cliffs are formed of friable yellow and red sandstones belonging to the John o' Groats Sandstones, the highest group in the Caithness Flagstone Series. These rocks dip to the west-north-west, precisely in an opposite direction to the dip of the southern Ackergill Beds.

The most recent deposits at the Freswick Bay are calcareous sands, composed of quartz and marine shell which have an formed extensive dune system.

It is also important to realize that Pleistocene drift deposits from the Black Hill, located to the north of the site, outcrop on the northern side of Freswick Bay. This till contains sands, clay and a variety of stones, including many rolled boulders. Thus Freswick Bay is provided with a number of exploitable sediments (peat, clay, sand and boulders) and rock types and it is likely that these geological factors greatly influenced the settlement Freswick Bay, while other bays (e.g. Sinclair's Bay) were rejected.

Like the bulk of the county, the area around Freswick is characterized by a lack of tree cover which appears to date back at least 8000 years (Peglar, 1979). Huntley (1985) carried out a series of pollen analyses on cores, one of which was 350 cm long, collected from the Hill of Harley (NGR ND 375 658) 1.5 km south of Freswick Links. She compared the pollen spectra with those obtained at Loch of Winless (NGR ND 294 546) (Peglar, 1979) which were also radiocarbon dated. Huntley concluded that pastoral farming appeared in the region at about 5000 radiocarbon years ago. Arable farming soon followed. The next 1000 years saw sporadic farming activity which may be associated with the Late Neolithic and early Bronze Age. During the period of Pictish settlement and into the Viking and Norse periods sporadic arable cultivation continued and Huntley concludes that cereals may have been imported during the late Norse occupation of the site. It must be noted, however, that such detailed interpretation based on a pollen sequence which has not been radiocarbon dated must be treated with caution.

Although rather bleak and windswept, the north-east corner of the country, particularly the parish of Canisbay, now includes rich farmland supporting cereals and beef cattle.

1.3 HUMAN SETTLEMENT IN CAITHNESS

Settlement, probably from prehistoric times, appears to have been concentrated along the coastal zone with some inland colonization around lochs and along rivers. However, it should be stressed that field work has been focussed along the coast and many traces of early occupation may lie undiscovered. Many place names in the county contain Old Norse elements (Omand, 1973b) and suggest considerable settlement in the Viking and Late Norse periods. Nicolaisen (1982) distinguished between the Norse names of the north and east of the county and the Gaelic names in the south and west. In the parish of Canisbay, all the surviving name elements, where not modern, are Norse or Norse-derived.

Archaeological evidence for Viking and Late Norse activity is relatively sparse. The site of Freswick, 5 km south of John o' Groats, has been known as a Late Norse occupation site from field walking and excavation since the early part of this century. Sites of similar period are well known on the islands of Orkney and Shetland (Wainwright, 1962; Small, 1968; Morris, 1989), but until recently Freswick was the only settlement site in Caithness producing Late Norse material. However, two sites on the north coast, Robertshaven (NGR ND 388 736) and Huna (NGR ND 399 735) have recently yielded pottery which is very similar to that found at Freswick (Batey, 1987, 31).

The precise dating of this Viking activity is uncertain. However, there does not appear to be any evidence for Viking activity in Caithness before the very late 9th or early 10th century, while Orkney was occupied much earlier (Batey, 1987). The current thinking is that the Orkneyinga Saga is likely to be accurate in stating that Caithness was settled by individuals from Orkney (Taylor, 1938).

A settlement frequently identified as Freswick is mentioned in both Njål's Saga and the Orkneyinga Saga and was the site home of 'a worthy man called Skeggi' (Batey, 1987, 21).

Broadly contemporaneous archaeological evidence in the county include pagan Viking graves at Westerseat and Castletown

(Anderson, 1874); Reay, Sandside Bay (Grieg, 1940); and a fine Runic cross-slab from Thurso. The towns of Thurso and Halkirk may have been settlements since the eleventh century; however, attestable evidence of this period is remarkably elusive.

The precise date of abandonment of settlement on Freswick Links is unclear but is thought to have been during the 13th or 14th centuries (Batey, 1987).

1.4 PREVIOUS WORK ON FISH REMAINS FROM FRESWICK LINKS

A number of excavations have been carried out at Freswick Links by Tress-Barry, Edwards, Curle and Childe (summarized by Batey, 1982). Edwards (1925; 1927), Curle (1939) and Childe (1943) all describe the occurrence of midden deposits during accounts of their excavations, sometimes noting deposits 'full of fish bones' or deposits of 'midden and fish bones' (Childe, 1943, 10). However the only analysis of bones from Freswick was a short report by Miss M. Platt (1939, 109) who examined bones excavated by Curle. The only fish species mentioned was cod, collected from Curle's excavations of Norse structures. She also noted the presence of remains of small mature ox, pony, red deer, grey seal, pig and gannet.

Between the 1940s and 1979 little systematic archaeological work was carried out at Freswick, or other sites in Caithness apart from the collection of casual finds and a little field walking. By contrast, excavations at a number of sites in Orkney have produced a plethora of fish bone reports including an account of the Pictish and Norse levels at Buckquoy, Bay of

Birsay (Wheeler 1977a), neolithic material from Quanterness (Wheeler, 1979a) and a number of sites investigated by Sarah Colley including Isbister chambered tomb, Saevar Howe (which also produced assemblages of fish bones of Pictish and Norse date) and other sites presented in her doctoral thesis (Colley, 1983b). These investigations have shown fish remains to be abundant in the region and have demonstrated that large and small gadid fishes have been exploited since the Neolithic period.

During 1979 a pilot study of the midden deposits at Freswick Links was undertaken (Rackham, Batey, Jones and Morris, 1984). Two small column samples were collected with the objective of assessing the range of animal and plant remains present in midden layers and to determine if excavation might be worthwhile. Column 1 produced bones of the following species (in rank order of number of identifiable remains) cod, Gadus morhua, ling, Molva cf. molva, haddock, Melanogrammus aeglefinus, and saithe, Pollachius virens. In addition flatfish and unidentified gadoid bones were also present (Rackham et al. 1984, 37).

Column 2 produced a higher diversity of species composed chiefly of those species found in Column 1, but including sprat, Sprattus sprattus, herring Clupea harengus, eel, Anguilla anguilla, lumpsucker, Cyclopterus lumpus and a gurnard, Triglidae (Rackham et al. 1984, 42-3). A wide variety of fish remains of the represented species were present including otoliths, scales and dermal structures, vertebrae, and other bones. The size of the fishes from the Column 2 samples was established by comparison with bones of the same species of known total length and the distribution of fishes in the layers examined. It appeared that large and medium sized cod were present throughout the column apart from the upper two samples and sample 8 which were formed of clean shell sand. Large saithe were only present in samples 2 and 4 from the top of the column but small and medium sized individuals were represented in almost all other samples. Ling bones, mainly from large individuals, were present in all samples but 2, 8, and 14 (Rackham et al. 1984, 46).

Further insights were gained into the fish remains present at Freswick by rescue excavations at Freswick Castle, located at the south of Freswick Bay undertaken in 1979 (Batey, Morris and Rackham, 1984). These excavations took place in cramped conditions and it was not possible to date the bone rich deposits closely. Nevertheless, bones of a small salmonid, cod, ling, saithe, gurnard and lumpsucker were found (Batey et al. 1984, 113).

Thus, at the start of the 1980 excavation there were very clear indications that large numbers of well preserved fish remains were present at Freswick Links.

Chapter 2

METHODS AND MATERIALS

2.1 THE DEVELOPMENT OF A SAMPLING STRATEGY

At the outset of the project it was apparent that it was neither practicable nor desirable to excavate the whole site. Constraints of time and money required that a sampling strategy be developed. To this end, the principal excavators (C. E. Batey, C. D. Morris and D. J. Rackham of the Department of Archaeology University of Durham) and the author met to formulate a cost-effective strategy to recover artefacts and biological remains while examining the nature of the deposits and structural remains.

Sampling strategies are designed to select a small, but representative, number of specimens from the target population. By examining characteristics of the sample it is possible to predict the nature of the target population. Approaches to sampling have been described and discussed by a large number of authors in many academic disciplines. Those directed towards environmental and biological investigations (e.g. Green, 1979; Gilbertson, Kent and Pyatt, 1985) proved to be less relevant to this project than those aimed specifically at archaeological work (Mueller, 1975; Cherry, Gamble and Shennan, 1978). These showed that a flexible approach was required to suit the varying nature of the deposits, and to answer specific research questions. Interim accounts of the excavations, including details of the development of the sampling procedure, were produced annually (Batey, Jones, Morris and Rackham, 1981; Batey, Morris and Jones, 1982 and Batey, Jones, Morris, Rackham and Rains, 1983).

2.1.1 Positioning of the Trenches

The prime reason for the excavations was to assess the nature of the deposits in the parts of the site which were threatened by and suffering from erosion. Thus, attention was concentrated on the cliff-edge, where sand extraction and storm damage were causing significant erosion, and on specific inland areas of deflation, caused primarily by over-grazing and burrowing by rabbits. The fourteen trenches (known as Areas 1-14) were located to avoid sand dune hills which had formed on top of archaeological layers. The excavators also wished to sample deposits associated with the remains of a broch, Viking buildings and cyst graves found on the Links. Figures 2-10 show the location of trenches, columns and the topography of the Links.

One small trench, known as Column 3, was deliberately sited in an part of the Links which had no signs of midden material or other archaeological features. This was excavated in order to investigate the kinds and concentrations of biological materials present in the accumulating sand deposits in a part of the site free of midden material and evidence of human occupation.

Random or regular interval siting of trenches was not possible. The excavators decided the position of each trench by referring to the eroding cliff-edge section or by considering the location of documented archaeological remains. This aspect of the sampling strategy is best described as 'judgment' or 'authoritative' sampling.

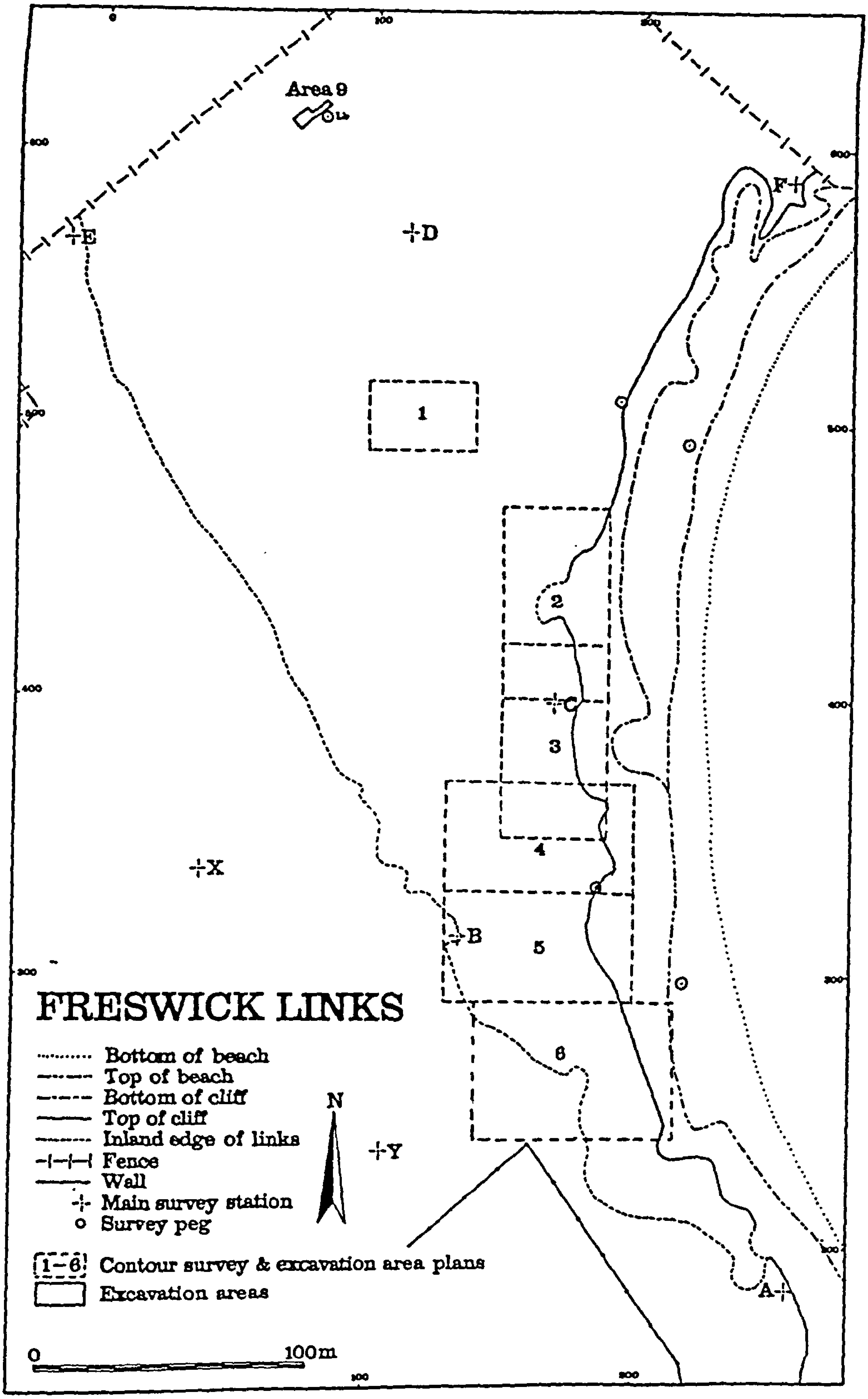


Figure 2. Map of Freswick Links showing location Contour Survey areas, Area 9 and Column 3.

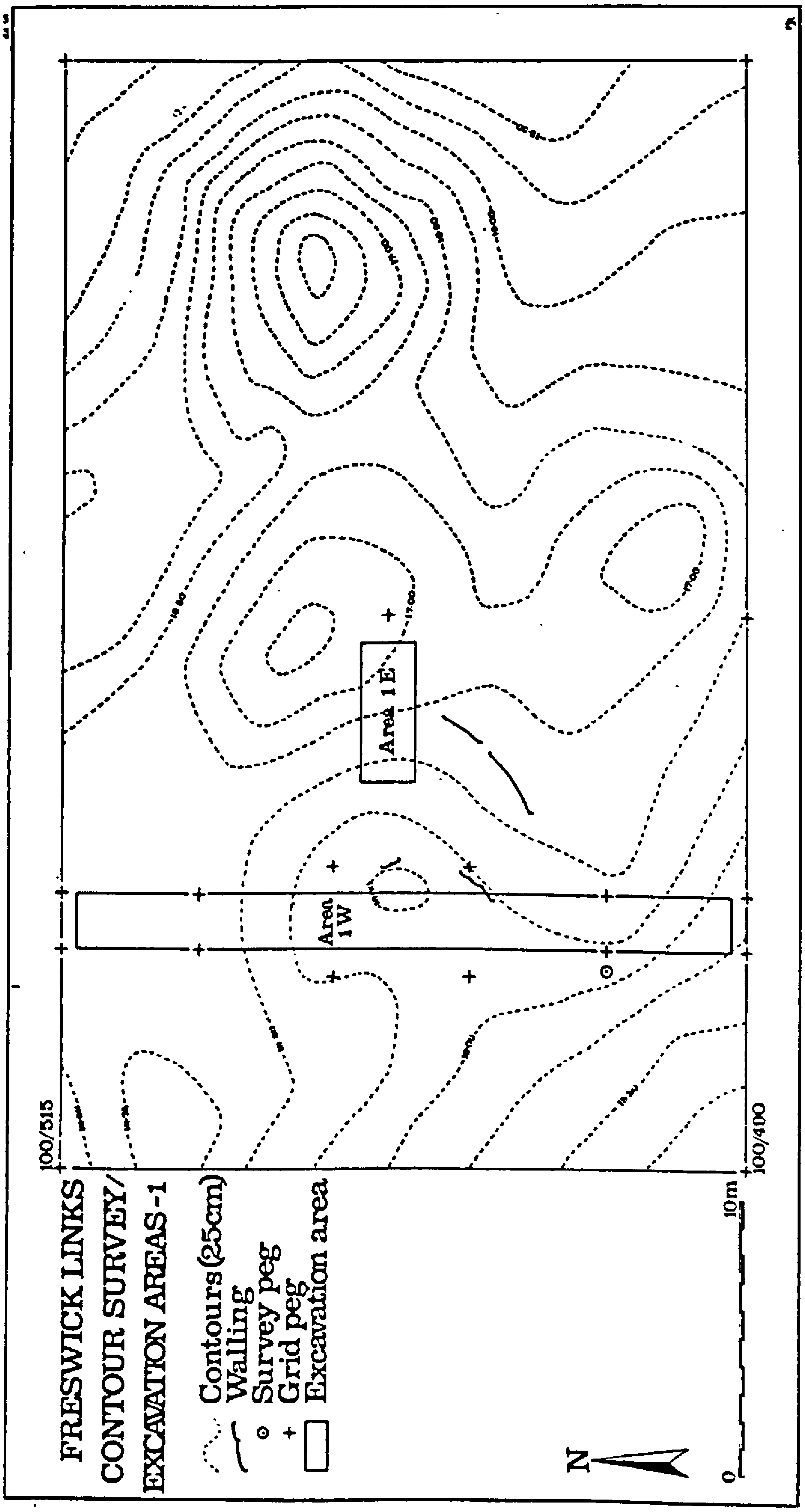


Figure 3. Contour Survey, Area 1 and surroundings.

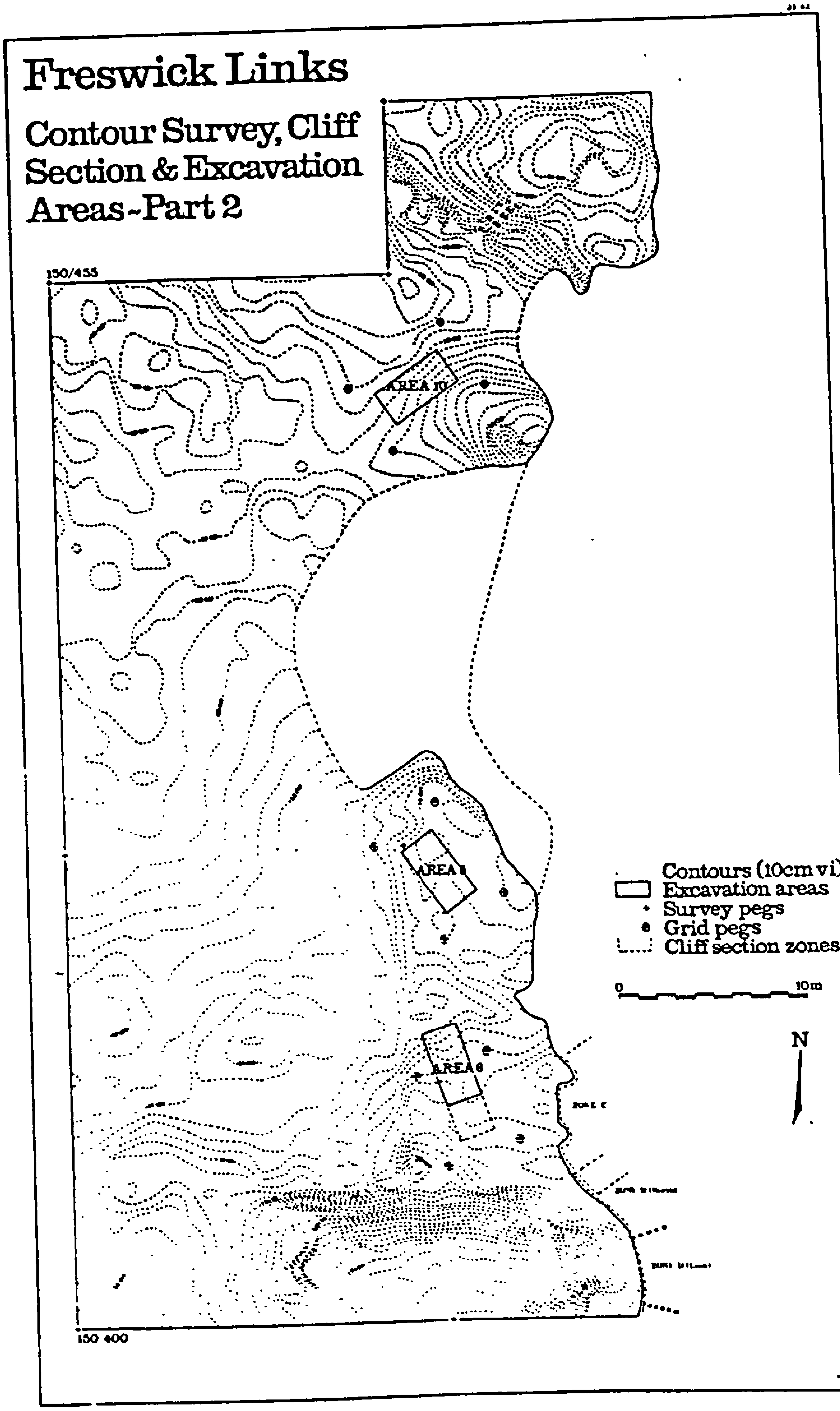


Figure 4. Contour Survey, Areas 5, 6 and 10 and surroundings.

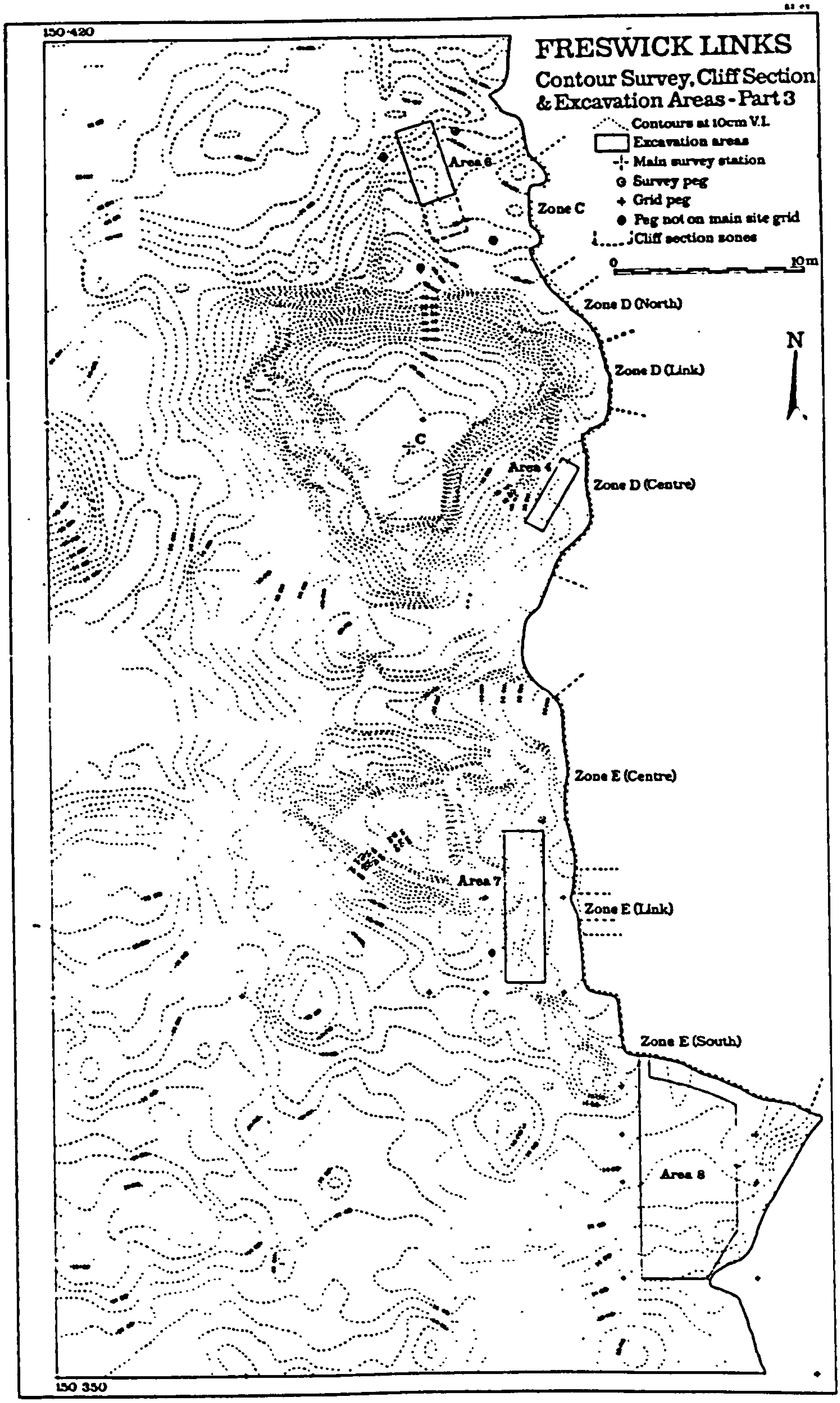


Figure 5. Contour Survey, Areas 4, 6, 7 & 8 and surroundings.

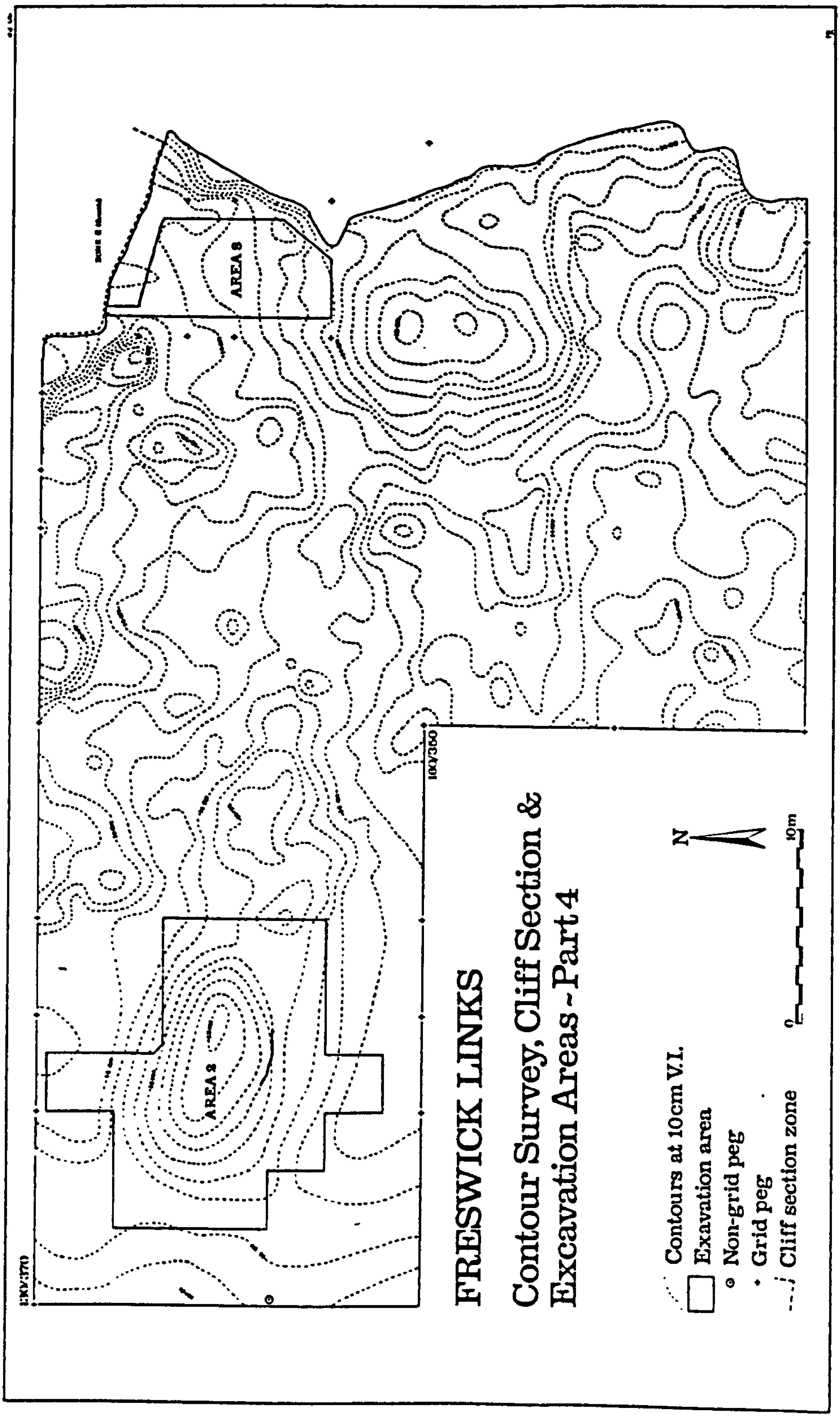


Figure 6. Contour Survey Areas 2 and 8 and surroundings.

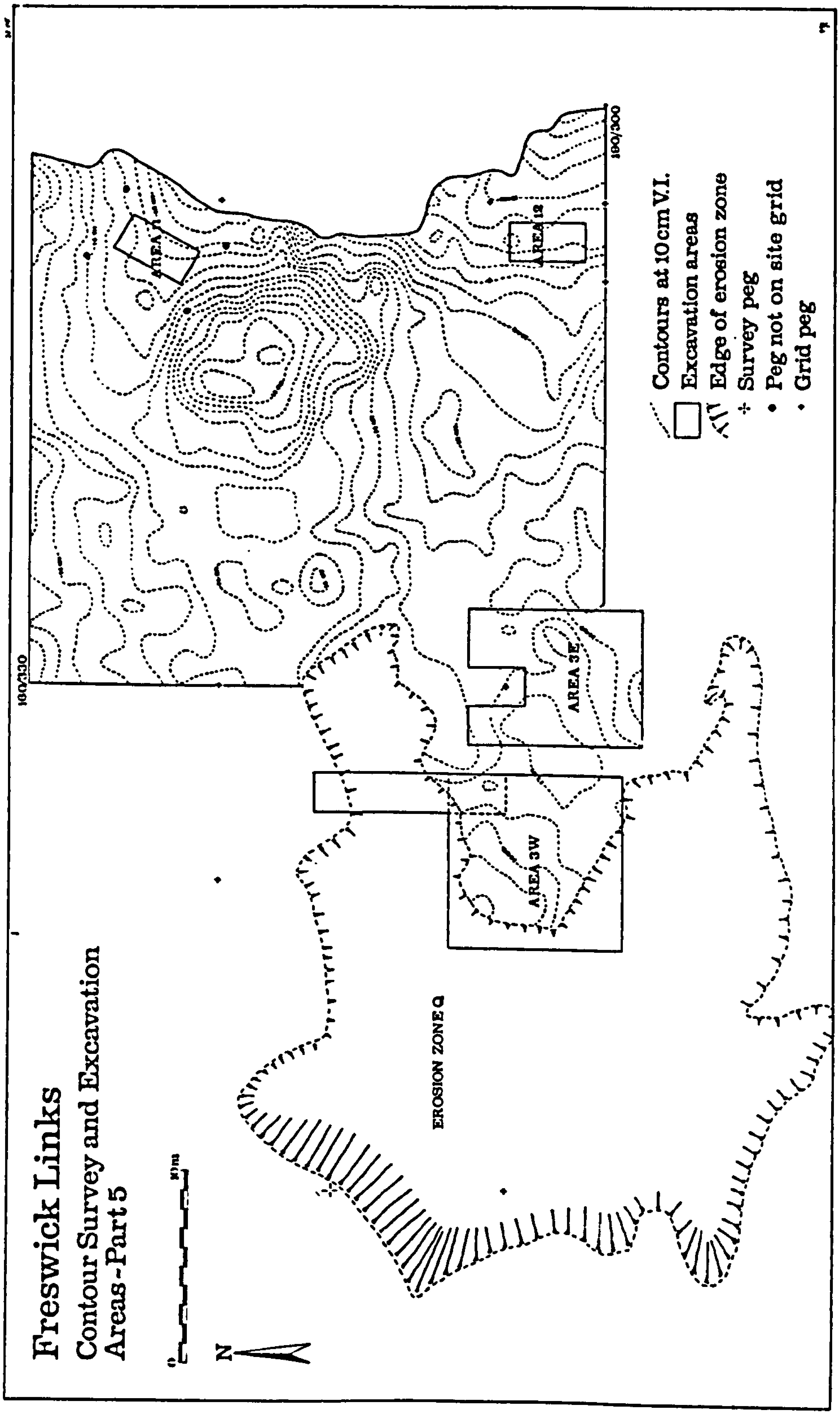


Figure 7. Contour Survey, Areas 3, 3E, 11 and 12 and surroundings.

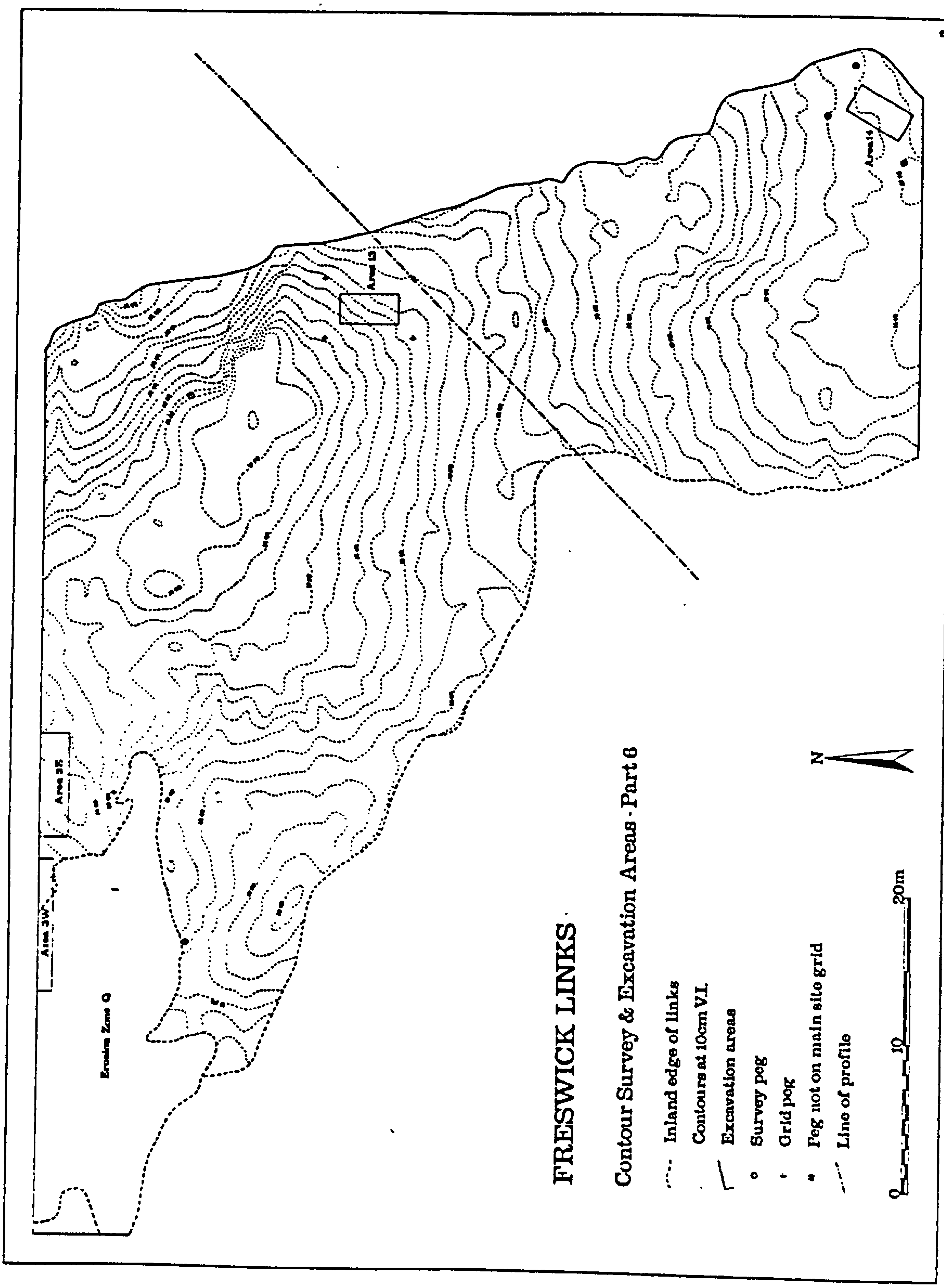


Figure 8. Contour Survey Areas 13 and 14 and surroundings. The line of the profile (Figure 9) is also indicated.

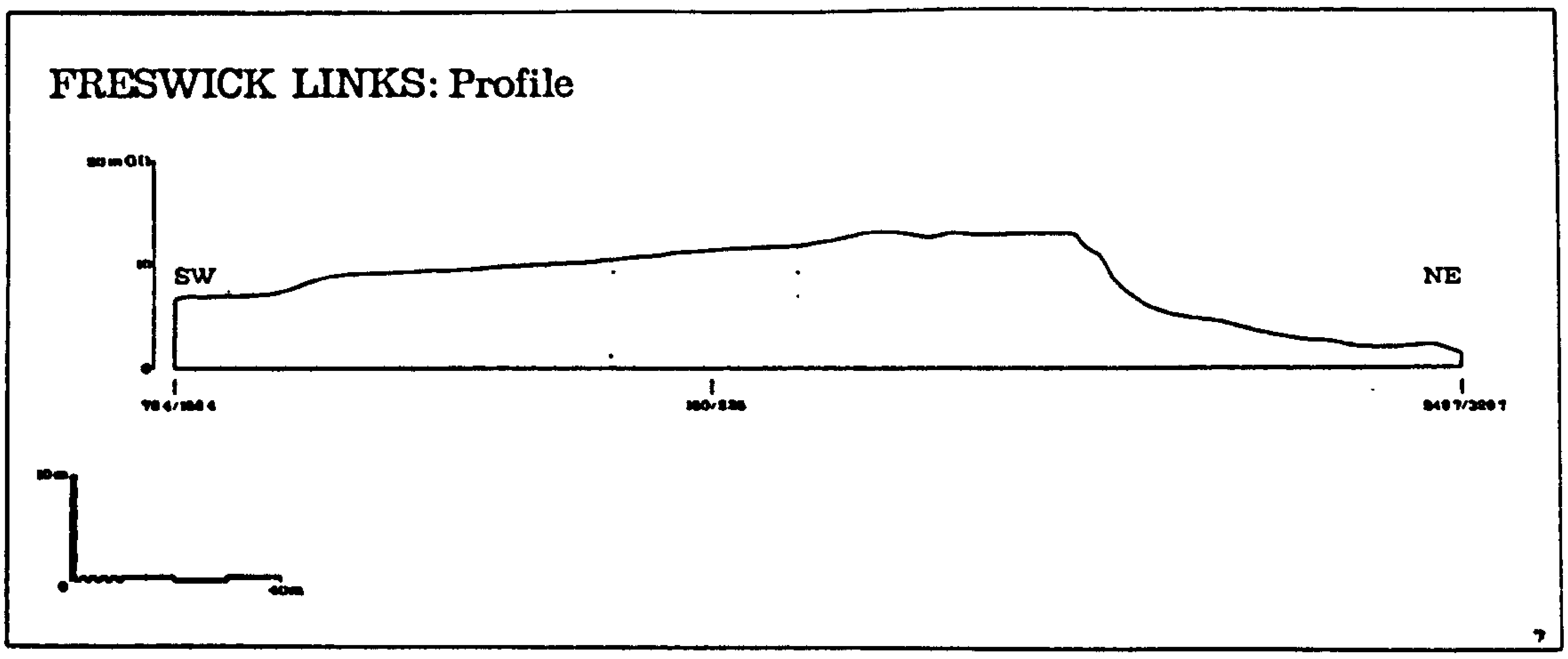


Figure 9a. Profile of Freswick Links.

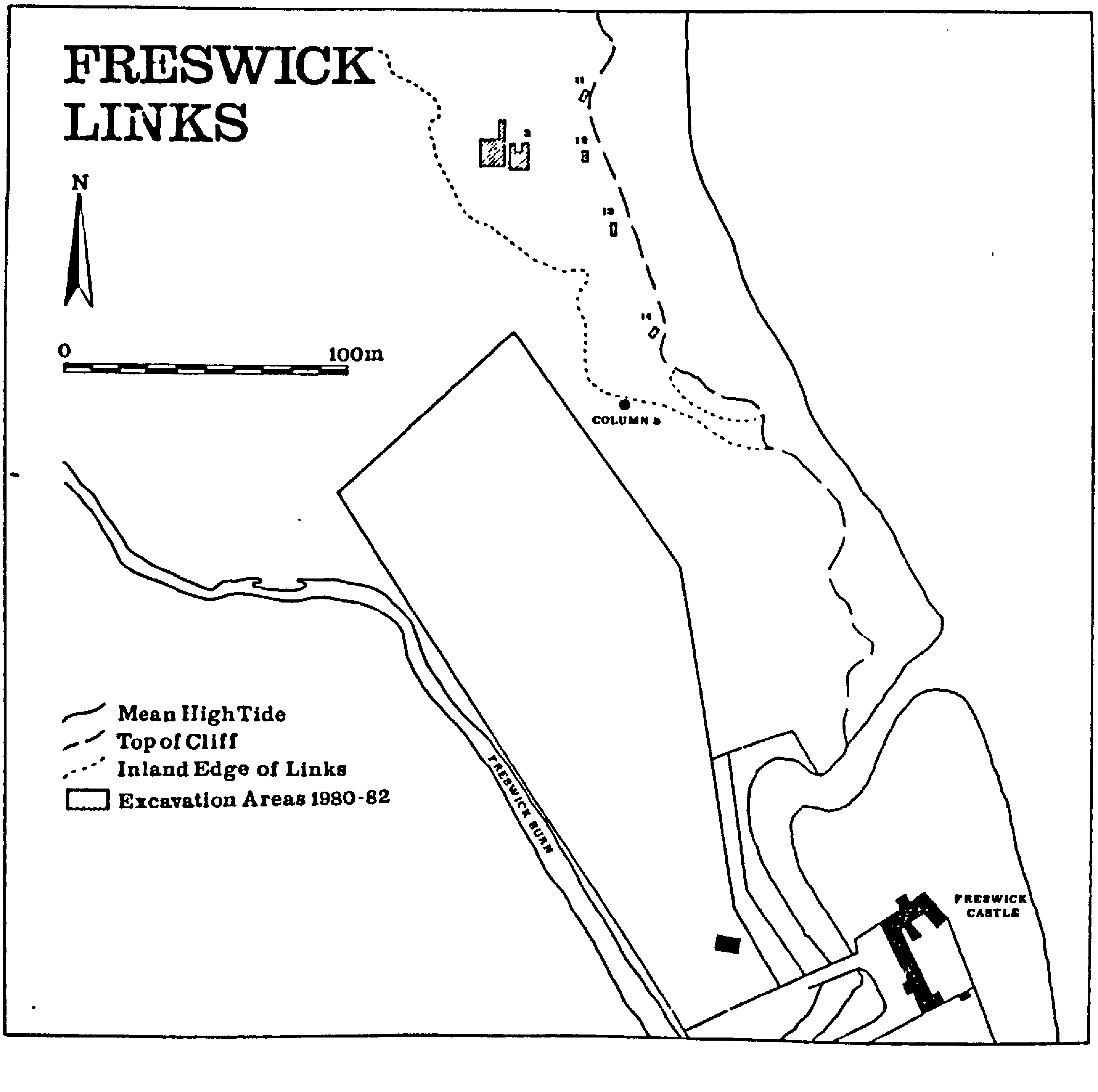


Figure 9b. Location map showing position of Column 3.

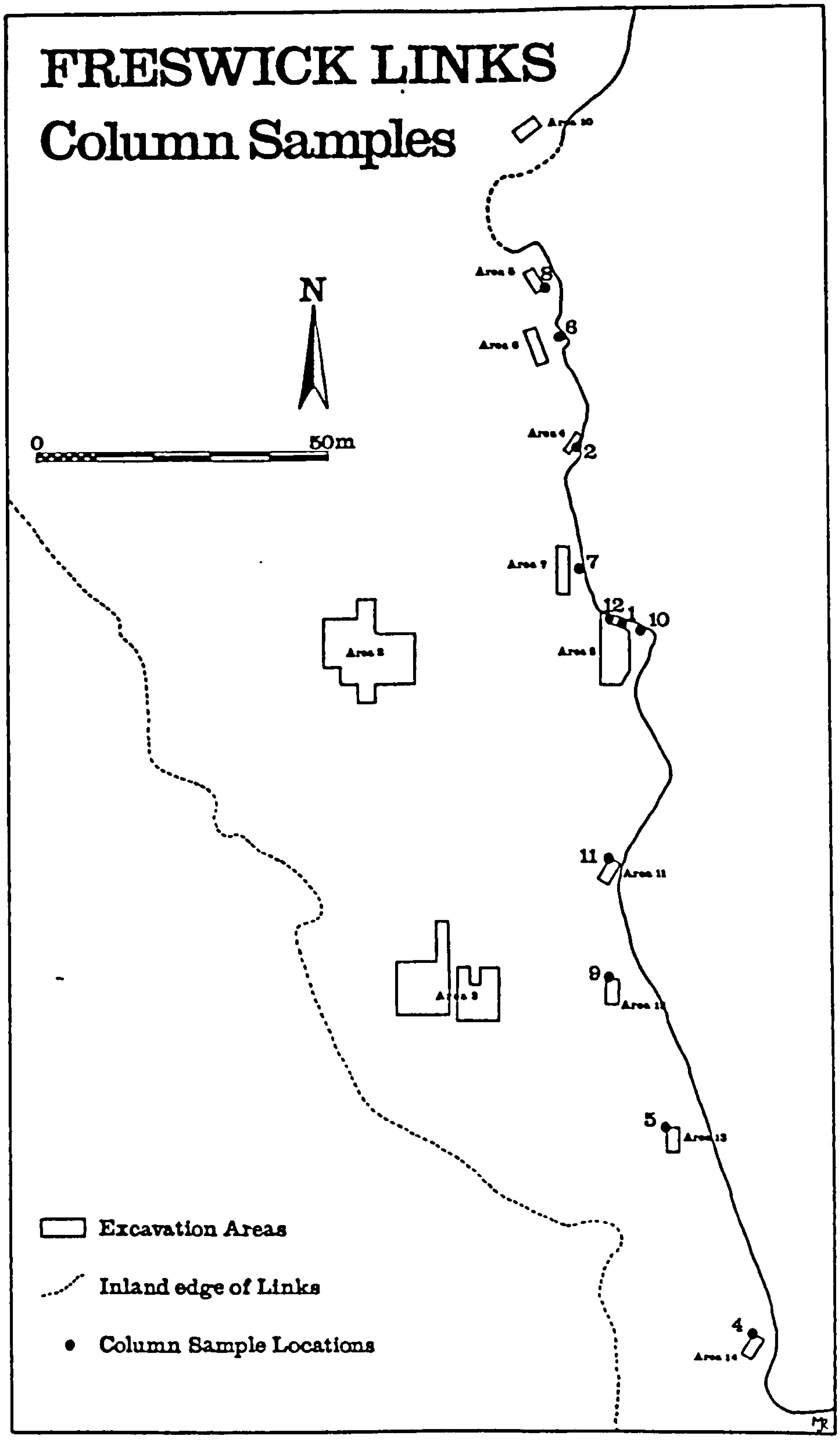


Figure 10. The location of column samples.

Three sampling methods, designed both to assess variation across the site and within the deposits, were employed for the recovery of artefacts and biological remains. First, a series of small columns, similar in size to those described by Rackham et al, (1984), was collected for detailed laboratory analysis by sieving the sediment samples on 500 μm aperture meshed sieves. Second, large amounts of midden deposits from standard sized trenches and large quantities of other deposits from layers associated with walls and other structural features were sieved on 1 mm square aperture mesh. Third, all unsieved excavated deposits were removed by excavators carefully trowelling deposits and picking out finds by hand. This three-pronged approach allowed the excavation of trenches large enough to record the direction and construction details of walls and other features while systematically recovering large samples of artefacts and biological remains.

2.1.2 Sampling the Deposits for Fish Remains

It was decided that the sampling strategy should be designed to elucidate the following questions:

1. What species of fishes were present?

2. What was the relative abundance of each species?

3. What was the size of the fishes?

4. Were different kinds of fishes (species and size classes of each species) distributed evenly across the site?

5. What did the nature of the assemblages and the condition of the remains indicate of their taphonomic history?

From the information collected to answer the above, the following questions could be addressed:

6. What could be learnt about fishing methods, locations and season of capture?

7. Was there any evidence for fish processing on the site, and if so was the material consistent with a local subsistence economy or were there indications of bulk fish processing as part of a market economy?

From the outset it was decided that, in order to collect material to answer these research objectives it was necessary to examine fish remains from a large number of weighed (in kg) sediment samples from a variety of locations on the site. Furthermore, it was agreed that fish remains would be collected by sieving sediment samples on fine meshed sieves rather than solely relying on excavators to collect bones by picking out those they saw during excavation. Hand collection produces samples biased towards those fishes which produce large robust bones (Payne, 1972; Levitan, 1982). It was agreed that 1 mm aperture meshed sieves would be used as the coarsest mesh for the bulk of the sediment sieved on site and that a series of small column samples would be processed using 500 μm square aperture sieves to check whether identifiable remains were being lost.

The following practices and principles were adopted in collecting sediment samples from the whole site. Layers (contexts) were identified by considering the colour, texture and composition of the sediment in the field and assigned unique codes. As far as was practicable material from different contexts was sampled separately. The location of each sediment sample was carefully recorded.

Where the deposit extended over a large area within a trench, samples of sediment were collected from predetermined square or rectangular sample areas. Where a deposit did not extend over the entire sample area, its extent was planned and the material within the sample area collected. Thus, it was impossible to ensure that sediment samples were of constant weight or volume.

Deposits excavated outside of specific sample areas were removed carefully trowelling. Bones and other finds were being collected following standard archaeological procedures.

2.2 SITE PROCESSING METHODS

2.2.1 Collection of Samples

A brief description of the excavations illustrates the application of the practices and principles guiding the sampling strategy and demonstrates why sample areas were not kept of constant size. In 1980 an attempt was made to sieve, using 1 mm aperture mesh, the entire fills of a trench 4 m long, 1 m wide and 1.25 m deep (Area 4). The trench was divided into four metre square sample areas in order that spatial variation in the density and kinds of find might be observed. Generally each midden deposit (assigned a unique context code) extended across the entire length of the trench and was excavated in shallow spits. Thus the intention was to excavate the trench as four separate 1 m square blocks or columns. Each block formed of a series of sediment samples uniquely identified by a context code and sample number.

Severe practical problems were encountered because of the instability of the sand and the absence of adequate shoring equipment. For safety reasons it became necessary to batter the sides of the trench and the trench widened to the northwest. Despite this widening the sample area of this trench decreased with depth. Thus, at its deepest the trench decreased in area to measure 3.4 x 0.75 m. Consequently the southwest and northeast sample area reduced from 1 m square to 0.7 x 0.75 m while the two central sample areas gradually altered from 1 m squares to 1.0 X 0.75 m in area. (Every effort was made to keep the boundaries between sample areas constant.) Despite the reduction is size of the sample area, each block was formed of a series of overlying sediment samples uniquely identified by a context code and sample number. As the layers varied in thickness from block to block, the number of samples (and volume of sediment collected) of each context was not uniform.

In the light of this experience, trenches measuring 4 x 2 m were excavated in later seasons and the sample area limited to a central strip 0.5 m wide divided into 1 m rectangular sample areas.

In Area 2, which included the remains of a building previously excavated by Curle, and *in situ* dark midden layers surrounding the structure, a fairly large area was excavated around the buildings. Sediment samples from four 1 m square sample areas were selected for sieving. *In situ* deposits within the structure were not investigated.

Sampling many of the midden deposits at Freswick was relatively simple using the block sample procedure when the layers were thick and extensive. At parts of the site where remains of domestic buildings and other structures were revealed (Areas 7 and 8) the procedures were modified because the highly complex and variable stratigraphy meant excavation using the block sample method would have indiscriminately cut across walls and other features, mixing material from two or more deposits. Consequently, layers were selected for sampling. These can best be described as 'judgment' samples. That is, the excavators and environmental archaeologists jointly agreed that some layers were more likely to produce valuable evidence than others. For example, the ashes from around hearths were carefully collected as they were likely to contain charred grain and food remains. By contrast, after trial investigations showed little to be present, the clay bases of hearths were not extensively sampled on the grounds that they contained few informative remains. This approach was based on experience and common sense. That said, most contexts from these Areas 7 and 8 were sieved. During the excavation of several trenches, once the conspicuous midden layers had been removed, the position or area of the sample area in a trench was usually reduced as the concentrations of shell and other materials indicated the presence of few finds.

During the course of the excavations a standard procedure was adopted with the aim of keeping the recovery of fish and other remains as simple as possible as many of the excavators were first or second year undergraduate students with little excavation experience. Each trench was supervised by an experienced excavator who was responsible for allocating context codes, sample numbers, recording levels (Ordnance Datum), planning, photography and ensuring that labels were correct.

For Areas 5, 6, and 10-14 inclusive, the two outer 0.75 m wide strips of each trench were excavated by hand to a depth of 20-30 mm, the excavators collecting bones and other finds while also examining the stratigraphy. The excavators then began to remove the central strip of the trench to be sieved, within 1 m long sections, by trowelling through the material to loosen it and shovel it, in roughly 20 kg aliquots, into clean 500 gauge polyethylene sacks. This procedure made it impossible to keep to a standard sample weight as individual excavators varied in how much they filled the sacks and how deeply they excavated. Sample size also varied because for some parts of the site (notably Areas 3) samples were gathered from sample areas much larger that 0.5 X 1 m. By contrast, in Areas 1 and 9 sample size was often smaller because the contexts were of a small volume.

The sacks of trowelled deposit were labelled, tied securely with twine, lifted from the trench and placed in a dumper truck and driven across the links to the sieving equipment.

2.2.2 Recovery of Fish Remains from Samples

Having decided to reject hand collection as the sole means of recovering fish remains, it was necessary to decide which sieving technique should be used. Two kinds of sieving method were used to obtain fish remains from samples of archaeological deposit: dry sieving and wet-sieving. Dry sieving was carried out by placing the excavated sample on a sheet of 1mm square aperture bolting mesh and agitating the sample until no more particles would pass through the mesh. This was found to be the most effective method for a small number of dry free-flowing sand dune deposits from the upper layers in Area 10 on a few uncharacteristically fine days. The vast majority of samples were damp on excavation and would not pass through a 1 mm aperture mesh unless wet-sieved.

A number of wet-sieving techniques have been developed for processing archaeological deposits. Most use water to wash the fine sample particles through meshes. Several techniques shower water onto a mesh or tower of sieves gradually disaggregating the lumps of soil and separating the soil components into similarly-sized fractions. Descriptions of this kind of sieving have been published by Payne (1972), Guerreschi (1973), Jones, A. (1983) and Mantle et al. (1984). A useful review of techniques used for separating isolated teeth and bones of small vertebrates has been given by Ward (1984).

The simplest kind of wet-sieving procedure involves clipping 1 mm mesh to a garden sieve. The soil sample is placed on the mesh and water played onto it until all the fine soil particles have washed away. Alternatively, a basket constructed from weld mesh can be lined with 1 mm aperture nylon mesh and soil washed by shaking the basket in the running water of a stream.

The second kind of sieving equipment used in archaeological fieldwork uses flotation to remove particles with a specific gravity (s.g.) less than that of water. Such devices were primarily designed to extract floating materials (charred plant remains and small gastropod mollusc shells) and a well known example is the 'Cambridge froth flotation tank' (Jarman et al. 1972). This device consists of a tank of water into which air is pumped to create a column of air bubbles. Various additives can be mixed with the water to aid particles floating to the surface where they are collected in a sieve. This device may be used to collect fish bones and other dense materials which do not float if the sample residues from the bottom of the tank are washed onto screens as a second stage in the operation. The author's experiences of this device on excavations on North Uist in 1971 were sufficient to reject this apparatus for Freswick Links because of the time required to process the sediment samples in the flotation chamber and sieve the dense fraction.

The second technique which also uses flotation is known as 'the modified Sīrāf tank' (after the name of a site in Syria). The modified Sīrāf tank has been developed from the David Williams's design (Williams, 1973) and has been described by Kenward et al. (1980). Several years' experience have shown that the original design can be improved by fitting a 100 mm diameter drain plug to facilitate emptying. In addition, flot (the component of a sample that floats) collection is most efficient if the inlet pipe is positioned beneath the weir rather than opposite it.

The modified Sīrāf tank works by suspending the sediment on 1 mm mesh within the tank of water. Water is pumped through the tank and flows over a weir carrying floating particles into a sieve. Washed sample residues are collected on the 1 mm mesh clipped within the tank.

Over the last few years the modified Sīrāf tank has emerged as probably the most suitable, and certainly the most commonly used, device for collecting a range of materials, such as small bones, artefacts, and other remains (including charred seeds) from archaeological deposits. Sīrāf tanks have been used on a large number of urban and rural excavations in Europe and western Asia to process many tonnes of soil, varying from wind-blown sand to boulder-clay and waterlogged organic deposits. Moreover, they are portable, and easy to construct and repair. For these reasons details of construction and operation are given below.

Two techniques were tested at Freswick Links during the 1980 season to establish which technique was the most cost-effective. The first, (known colloquially as 'The Thunderbird') employed the showering principle; it consisted of an 40 gallon oildrum with several holes punched into the base mounted on a scaffold platform above a series of mesh screens. Water was pumped into the oildrum, whence it fell by gravity onto the mesh screens gradually washing the samples (see Jones, A. 1983, Figure 1).

The second apparatus tested was the Sīrāf tank. Details of this work were published (Jones, A. 1983) and a copy of this paper is bound into the thesis. The trials showed that 15 kg wind blown sand from Freswick Links could be processed in 5 minutes while a similar weight of clay-rich deposit took 12 minutes to process. By contrast, the showering method was much slower, taking 20 and 30 minutes respectively. Furthermore, the shower system was more difficult to use, made the operators very wet and failed to work in strong winds. Consequently it was abandoned in favour of the Sīrāf tank.

The sieving area was divided into a number of separate, clearly marked zones in order that the samples could be processed methodically. The samples were dumped in a 'General Storage Zone'. Here the bags were sorted into samples. When all the bags for a sample were assembled the entire sample was transferred into the 'Weighing Zone'. Here the bags were opened, labels checked and the deposit emptied into standard-sized 15 litre capacity plastic buckets. Each bucket was weighed using a spring balance reading in 0.5 kg units to a maximum of 25 kg. (Buckets of deposit weighed up to 20 kg, usually 12-15 kg). The weight of each sample was recorded in a note book.

Once weighed, the sample (now occupying a number of buckets) was transferred to the 'Holding Zone' close to the sieving equipment.

Only when a sieving tank was completely clear of material from the previous sample was the entire sample moved to the tank, where it was processed in aliquots of bucketful or less.

The empty tank was relatively light (approximately 20 kg) and fairly portable, and was set up on level ground adjacent to Freswick Burn. Duck-boarding was used to prevent the area surrounding the tank becoming waterlogged.

Water was pumped from Freswick Burn using 2 inch (51 mm) diameter piped diesel pumps. The weir of the tank was positioned so that effluent water ran into Freswick Burn. Sand and other fine soil particles and dirty water were also channelled into Freswick Burn when the tank was emptied. The flow of water was regulated by means of a gate valve on the inlet pipe. The intake hose was fitted with 300 µm aperture mesh to prevent contaminant seeds and other particles larger than 1 mm entering the tank with the water.

The tank, mesh and flot sieve were checked to ensure that they were thoroughly clean before each sample was processed. While the tank was filling with water, the weld- mesh support for the nylon mesh was positioned. Two of the hooks of this support were positioned on the rim at either side of the weir, and the basket pushed into the body of the tank. The mesh (normally 1 mm aperture) was secured upon the weir using the V-shaped rod, and fold-back clips were used to anchor the mesh to the rim of the tank. It was necessary to pleat the mesh at the rim in order to allow the support mesh to take the weight of the sample. Two spring clips were bolted onto the weir using brass screws and wing nuts to hold the flot sieve.

For all but one sample (346) 1 mm aperture mesh was used in the tank. (Sample 346 was found to contain a relatively large amount of charred grain and 300 µm aperture mesh was employed.) Generally the flot sieve was also of 1 mm square aperture mesh. However, some samples were judged to warrant using 500 µm aperture mesh (full details of these samples are in the site archive housed at the Department of Archaeology, University of Durham).

A record sheet was completed and four waterproof labels marked (using a black spirit-based waterproof felt-tip pen - see Jones, Jones and Spriggs, 1986) with the site code, context number and sample number. A separate code was used to distinguish the residue and flot (R and F respectively). Particular attention was paid to recording accurately the volume and weight of soil processed, the size of the aperture of the mesh and flot sieve, the nature of the sediment and evidence of modern contamination (for example, living insects and airborne seeds etc.).

As water was freely available it was possible to maintain a constant flow of water over the weir during washing. When water was flowing steadily through the sieve, a bucket of deposit was introduced onto the nylon mesh, care being taken to avoid losses by splashing. The lumps of earth were gently disaggregated by hand, so as to minimize mechanical damage to fragile remains. Large stones (roughly > 50 mm) were cleaned and set aside in a bucket, weighed and discarded. Floating debris was encouraged into the flot sieve by manually generating small waves at the water surface. During washing, notes were made of the nature of the sample, including the size and types of stone; particular attention was paid to any possible modern contaminants, for example, airborne seeds or live insects. The process continued until all the sand, silt and clay was washed through the nylon mesh leaving only clean soil residues.

The flot sieve was emptied when about one third of the mesh was covered with flot (usually root fragments) to avoid blockage and subsequent spillage. If the sieve needed emptying before the whole sample had been washed, the V- shaped rod which clipped the mesh to the weir was removed and lodged so that the portion of mesh lying on the weir was raised above of the water, thereby preventing further flow of flot. The flot sieve was removed, briefly drained, and emptied onto a labelled tray by inverting the sieve and giving it a sharp tap onto kitchen foil. Often a small amount of flot adhered to the sides of the mesh. This was rinsed to one side of the sieve and emptied as outlined above, this process was repeated until all the flot was removed. As drying facilities were not immediately available, the flot was labelled and temporarily wrapped in kitchen foil which was punctured with pin pricks to allow water to evaporate. Two labels were placed with each packet of flot. The sieve was then replaced into the stream of water, the V-shaped clip replaced and washing continued. The flot sieve was thoroughly cleaned after each sample had been washed to avoid contamination.

Paper towel was used to package flot in 1980, but was abandoned in later seasons as small pieces of paper often adhered to the dried flot particles. Furthermore, packets of flot wrapped in kitchen towel began to sprout moulds and produce unpleasant odours when left in a confined place for more than a few weeks. Few flot samples were air dried during the excavation. The majority were gently warmed (20 degrees C.) in an oven at the University of York.

When the sample had completely disaggregated and its constituents appeared spotlessly clean, the residue was removed. This was usually done while the flot sieve was in position beneath the weir. The spring fold-back clips were removed from the rim of the tank, and the mesh gently agitated to free any material rim of the tank, and the mesh gently agitated to free any material trapped by surface tension. Particles of charcoal, charred grain etc. adhering to the mesh were removed by dabbing the mesh on the surface of the water. Floating particles were then carried over the weir and into the sieve with the continuing flow of water. When most of the flot was cleaned from the mesh, the V-shaped clip was removed and the four corners of the mesh gathered together. The mesh was lifted from the tank, allowing free water to drain into the tank. The gathered mesh was then dunked 2 or 3 times into Freswick Burn to give the sample residues one final rinse.

The sample residues were then tipped onto a drying tray, 2 labels placed with it, and set to air dry. Once dry the residues were placed in polyethylene bags prior to sorting. Towards the end of each season it was necessary to package some of the residues in polyethylene bags and transport them wet to York. These samples were placed on trays in an oven set at 20 degrees C. until dry.

The tank was emptied when the level of sand reached the level of the support mesh by removing the drain plug. At first a cylindrical plug of sediment gradually emerged from the plug-hole to be followed by a sudden rush of sand and water. After all free water had drained from the tank the remainder of the sediment was pushed through the plug-hole using a spade and by regulating the water flow into the tank with the drain plug removed. When all the sediment had been flushed out, the drain plug was fitted and the tank refilled with water. The nylon mesh required only a vigorous shake to free it from any small particles of residue.

2.3 PROCESSING THE WASHED SAMPLE RESIDUES

The sample residues consisted of two parts: a small package of flot and a bag residue comprising a mixture of different kinds of animal, vegetable, and inorganic substances occurring in a wide range of size and density. Although the simple way to collect materials is to pick out materials by hand using forceps, this work is time-consuming and tedious. A number of investigators have developed alternative techniques to sort such residues. Ward (1984) reviewed the techniques used by palaeontologists to collect small remains of vertebrates. These include a number of acids used to dissolve selectively unwanted components of the residues; heavy liquids such as bromoform or tetrabromoethane used to float quartz (s.g. 2.6) from bone (s.g. 2.7-3.0); and employing di-iodomethane and tetrachloromethane to float less dense materials. Within the archaeological community Struever (1968) described a process where bone and plant remains were separated from the 'light fraction' (presumably equivalent to the flot) by using a solution of zinc chloride (s.g. 1.62). More recently, Bodner and Rowlett (1980) determined the density of materials in washed soil residues and by using a solution of ferric sulphate (s.g. 1.6 - 2.1) separated bone fragments from gravels.

A further technique used successfully by palaeontologists to separate small fossils from sieved residues is termed magnetohydrostatic separation (Stone and Saunders, 1987). This is a density separation in which the heavy liquid is replaced by paramagnetic solution (e.g. manganous chloride solution) placed in an inhomogeneous magnetic field.

Although these methods of sorting were considered, they were rejected because none was capable of separating the complete range of finds from stone, unidentifiable shell and root fragments. Other reasons for rejecting these separation methods were the high cost of materials and safety considerations. Rather, it was decided to sieve the flot and residue of each sample into fractions of similar sized particles and to collect shells, bones and other remains manually. All residues were sieved on 2 mm aperture mesh sieves and sorted for fish remains.

The exact details of this procedure varied from sample to sample and between operator. Large residues were generally sieved in a tower of 200 mm diameter brass laboratory sieves provided with 4 mm, 2 mm and 1 mm mesh. This allowed the largest finds to be collected from the 4 mm sieve. Smaller remains were then collected from fraction retained by the 2 mm aperture sieve, leaving the finest material on the 1 mm sieve. The fraction retained by the 1 mm sieve rarely contained more than a few identifiable few fish remains. Nevertheless at least one quarter of this fraction was also sorted. Residues larger than 2 mm of all samples from Areas 2, 4, 5, 6, 7, 8 and 11-14 inclusive were sorted a second time to check that identifiable remains had not been missed.

No attempt was made to sort the dry residues during the seasons of excavation. All sorting was carried out under laboratory conditions at the University of York under the author's supervision. Experiences gained sorting the samples from the columns in 1979 when all recognizable fragments of bone, shell etc were carefully sorted from the sand particles showed that a more rapid form of sorting was necessary if the residues were to be sorted within a reasonable time, and the staff doing this work were to be kept sane.

A timed trial was carried out to compare the time and effort needed to sort a sample completely (i.e. pick out all fragments of bone, shell etc) and carry out a selective sort in which the following remains were collected: all artefacts, all shell apices, all mammal and bird bones, charred plant remains, fish otoliths, and a selection of fish bones including vertebrae and toothed bones.

Sample 129 (Context DH Area 2b) was divided into two subsamples. Ideally this should have been done using a sample riffler capable of dividing all particles equally. However, the only riffler available was able to accept particles 4mm and smaller. The following procedure was adopted. First the entire sample was sieved on a sieve with 4 mm square apertures. The fraction which passed through the 4 mm sieve was divided into equal portions using a sample riffler. The fraction retained by the 4 mm sieve was spread out evenly on a tray and divided into two by eye. Each fraction was weighed and adjusted to the nearest gram. The riffler was 99.8% accurate and eye 97% accurate.

Each fine fraction was mixed with one of the coarse fractions to produce two subsamples 'A' and 'B'. Each subsample was sieved on 2 mm and 1 mm mesh and sorted. Sample A was sorted selecting those fish remains itemized above, sample B sorted to remove all fish bone fragments. Accurate records of time taken to process the material were kept. As it took over three hours to collect all the bone fragments from the fraction > 2mm it was decided to subsample the fraction >2 <1 mm. This fraction was divided into four using the sample riffler and then sorted.

Table 1. Time taken to sort 2 subsamples of sample 129

Sample		Sorting time	
A		50 min	
B	>2 mm fraction	3 hr 25 min	
	<2 >1 mm fraction	8 hr 40 min	(4 X 2 hr 10 min)
	Total	12 hr 5 min	

Thus it took 14.5 times longer to sort the samples and collect all fish bone fragments than to collect a selection of bones. Despite adopting this relatively speedy procedure, sorting the samples was a slow process employing 2 laboratory technicians for 4 man years.

2.3.1 Bone Selection

An important aspect of the present study was deciding which bones should be collected for detailed analysis. Unlike mammals and birds, fishes have a very large number of skeletal elements which survive in archaeological deposits. However, many fish bones cannot be readily identified to species, particularly when the material is fragmentary. Many elements can generally only be identified to genus, family or higher taxon. Thus to attempt to identify all fish bones results in the compilation of a vast mass of redundant information. This problem has been faced by a number of other workers.

For example, Olsen (1967) when faced with the formidable task of reporting on several thousand hand collected bones from Varranger-Funnene, northern Norway, decided to examine 20 selected bones from members of the cod family. He chose the dentary, articular, premaxilla, maxilla, palatine, ectopterygoid, quadrate, hyomandibular, prevomer, parasphenoid, opercular, preopercular, suboperculum, interoperculum, ceratohyal, epihyal, post temporal, supracleithrum, cleithrum and the postcleithrum. He ignored other elements and judged that 'It would be quite impossible, within a reasonable amount of time, to identify all the osteological material'.

Wheeler (1977b), working on material from King's Lynn, concentrated on bones associated with the cranium (prevomer, parasphenoid, basioccipital) and jaws (maxillary bones - especially the tooth-bearing bones, the dentary, and premaxilla). In addition any other identifiable or characteristic bones were collected. The same author reaffirmed this selection of bones in a later publication (Wheeler 1978) and added the following elements: articular, quadrate, preopercular, opercular and cleithrum.

Leach (1986) maintained, after 16 years of work on archaeological fish bones from the Pacific region, that five parts of the cranial anatomy are the most useful for identification. These bones were: the dentary, articular, quadrate, premaxilla and maxilla. In addition, certain other 'special bones' have been found to be characteristic of particular species, genera or families. Typical examples of these bones and some of the fish taxa represented are as follows (scombrid nomenclature updated following Collette and Nauen (1983)).

Table 2. Elements selected by Leach (1986) for various fish taxa.

Specialized spines	- Elasmobranchs, Balistidae, Aluteridae, etc.
Sternum	- Balistidae
Scutes	- Carangidae
Pharyngeal clusters	- Coridae, Labridae, Scaridae
Bucklers	- Acanthuridae
Teeth	- Nemipteridae, Elasmobranchs, Balistidae
Vertebrae	- Elasmobranchs, Istiophoridae, Xiphiidae, Scombridae
Caudal peduncle	- Istiophoridae, Xiphiidae, Scombridae

Colley (1984) urged that a wide variety of elements should be analysed. She stated: 'that very detailed analysis of a wide range of skeletal elements may be necessary to answer some of the fundamental questions about differential preservation, inter-context variability and fish processing and butchery' (Colley, 1984, 128).

She lists 48 kinds of bone. Many of her skeletal elements are well recognized bones; however, she also uses several terms including 'cranial' bone, 'facial' bone, unspecified 'opercular' bone which do not unambiguously identify specific elements.

Other workers collect and identify most bones in a fishes skeleton (e.g. Lepiksaar and Heinrich, 1977; Enghoff, 1983). While studying material from at Eketorp, Sweden, Hallström (1979) identified almost all the bones of herring including the 5 infraorbitals (1, 2, 3, 4 & 5), the lateral radials (I, II & III) and hypurals (1, 2, 3, 4, & 5).

Kenchinton, Carter and Rice (forthcoming), while investigating the remains of a mid-eighteenth century vessel in Terence Bay, near Halifax, Nova Scotia, examined a large collection of fish bones recovered from an area at the forward end of the vessel's hold and extending into the forecastle. These workers were able to identify fin rays from the caudal, pectoral and pelvic fins as well as a range of other bones.

Such detailed work is desirable under particular circumstances, for example when the bones are recovered from a wreck, pot or from deposits of very great antiquity. To apply such detailed analysis to all deposits produces enormous amounts of data of limited interpretive value. It is doubtful if the extra knowledge warrants the effort involved.

As the contexts excavated at Freswick were a mixture of middens (rubbish dumps) and occupation detritus clearly dominated by the bones of large gadid fishes, a highly selective approach was adopted.

Although a wide range of bones was collected from the washed and dried sample residues by the team of sorters, the following bones were selected for detailed recording: otoliths, premaxillae, dentaries, cleithra for cod, ling, saithe, pollack and haddock.

All bones of other species (with the exception of small (<300 mm total length) gadid vertebrae) were collected and identified.

That said, for some parts of the site all identifiable bones were recorded. All bones and otoliths recovered from the column samples (including Column 3) and Areas 1, 3 and 9 were identified.

2.3.2 Selection of Other Finds

All mammal and bird bones, shell apices, charred plant remains and artefacts were collected. The weights (in grams) of fish bone, mammal and bird bone combined, and shell, were recorded. As limpet shells were particularly abundant in the samples, the numbers falling into the following categories were recorded: complete shells, apices with part of the margin, and apices without margin.

2.4 METHODS OF RECORDING FISH REMAINS

Early in the project it became apparent that a number of aspects of recording had to be established. Measurements had to be taken systematically, the data recorded consistently and bone nomenclature used consistently. It was decided to store and analyse the data describing the identified remains using a computer database management or similar system.

2.4.1 Bone and Otolith Measurements

Many suggested fish bone measurements presented by Morales and Rosenlund (1979) assume that complete bones are to be measured. Rarely is this the case. The measurements taken in the present study deliberately take into account the fragmentary nature of archaeological fish remains and concentrate on the most robust parts of the bones. All sufficiently complete identified bones and otoliths were measured using sliding vernier 'Kanon' callipers reading to the nearest 0.1 mm. Measurements are illustrated in Figures 11 and 12.

One measurement was taken on cleithra: the maximum median width of the cleithrum - coded as 'C'.

Two measurements were taken on dentaries. The first, known as dentary depth at the foramen (Wheeler and Jones 1976) and given the code 'D1', the second termed anterior height (Morales and Rosenlund, 1979, 22) or depth at the symphysis - code 'D2'.

Otolith maximum length and width, coded as 'OL' and 'OW' respectively, were recorded.

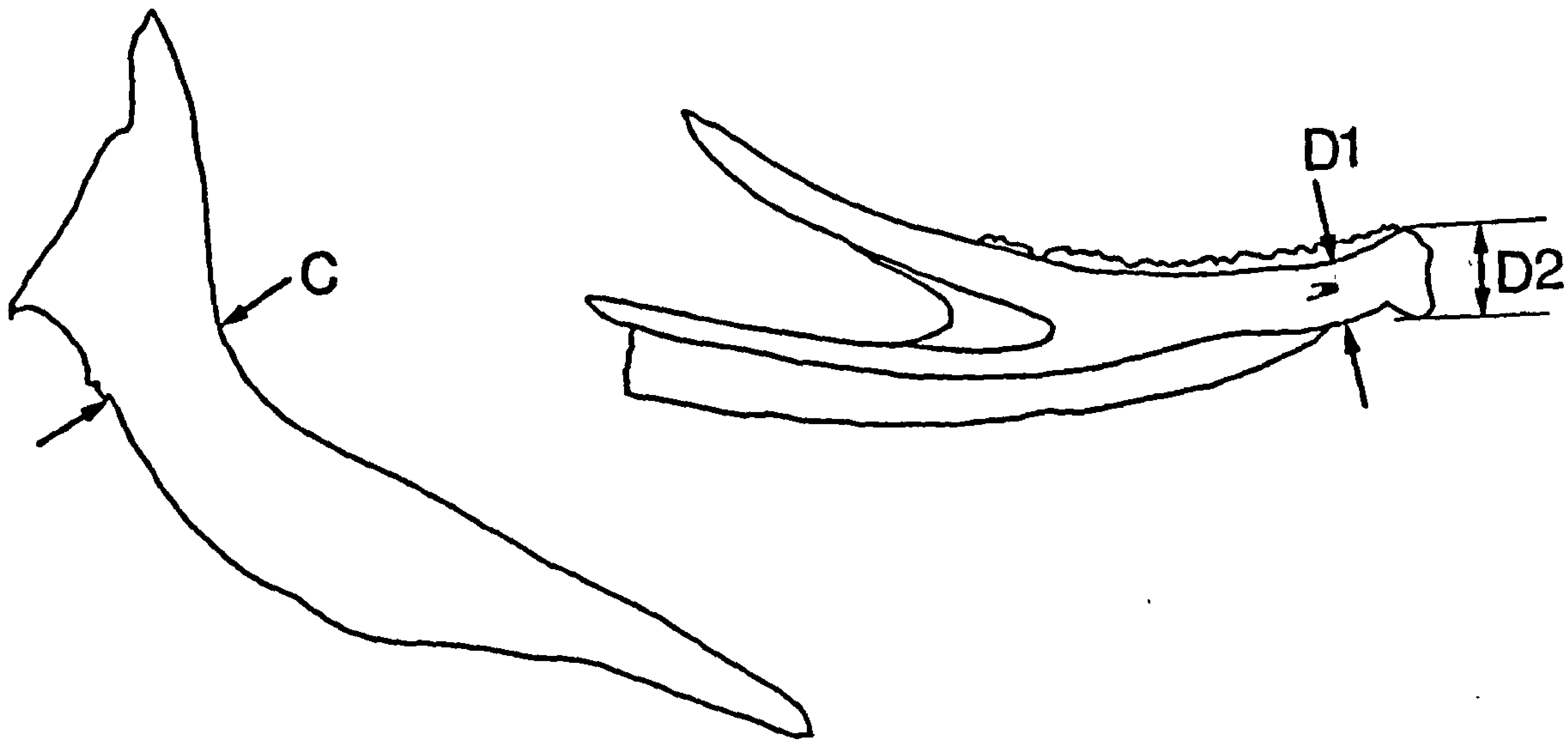


Figure 11. Measurements taken on cleithra and dentaries.

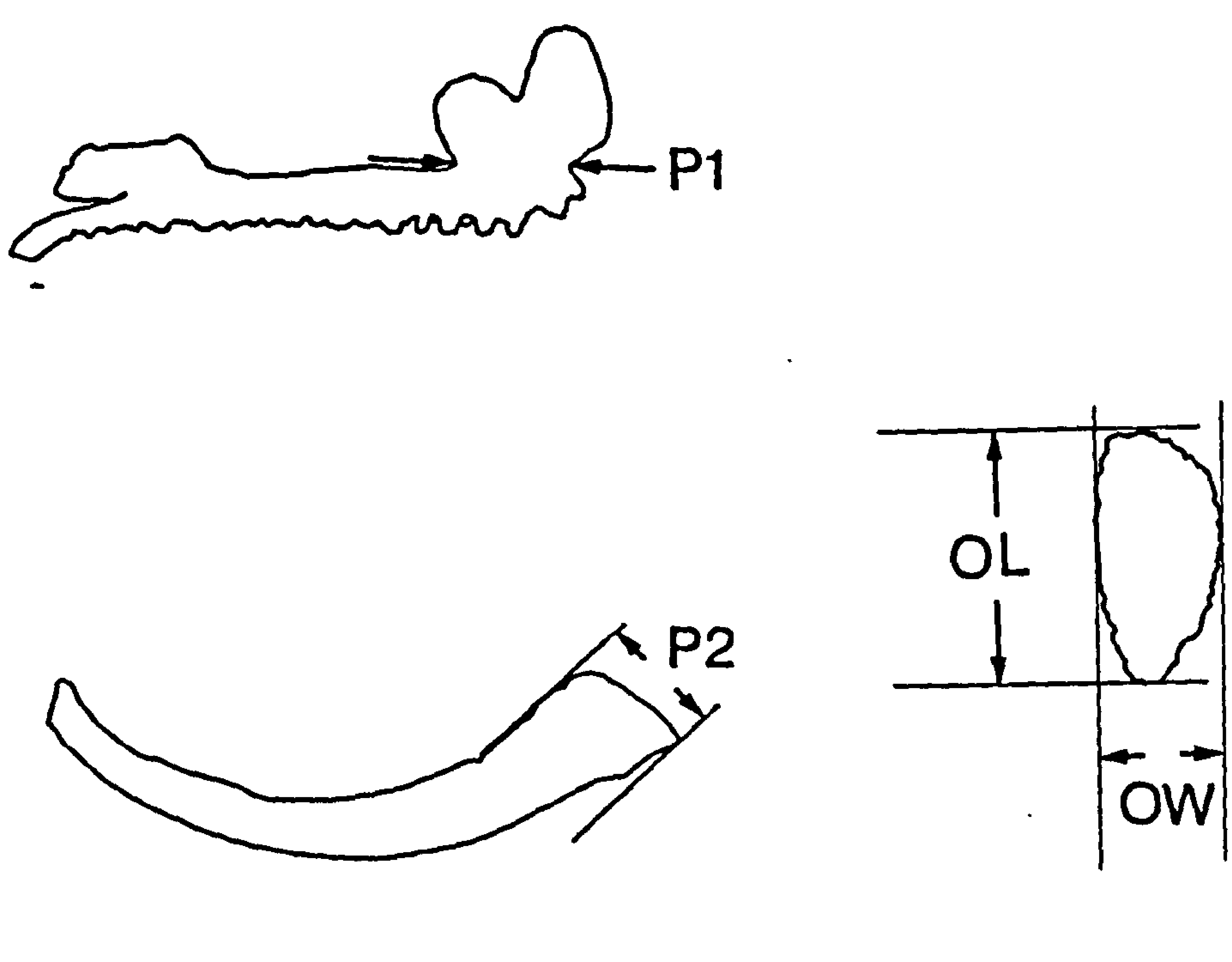


Figure 12. Measurements taken on premaxillae and otoliths.

Two measurements were taken on premaxillae. The first, was the width of the condyle, termed premaxilla width (Wheeler and Jones 1976) and coded here as 'P1', and the second the anterior width of the tooth row at the symphysis - coded as 'P2'.

While every attempt was made to hold the fish remains and callipers in the same way when taking measurements, it was clear that some measurements could be taken more consistently than others. Consistency also varied with the size of the bones. Large bones could more easily be measured than small ones.

To investigate this further a series of bones was subjected to repeated measurement to assess the inherent variation. The percent error was calculated as the range (maximum minus minimum) expressed as the percentage of the mean. Table 3 gives the results of this investigation.

Two important conclusions can been drawn from this investigation. First, measurement error varied considerably but never exceeded 10% and was generally below 5%. Second, measurement error on otoliths was smaller (range 0.00 - 2.54%) than on bones (range 2.22 - 8.35%). These observations must be borne in mind when considering the sizes of the fishes calculated from bone and otolith measurements.

Table 3. Statistics of repeated measurements (in mm) of selected archaeological bones to assess measurement consistency.

Bone and measurement	Mean	Min	Max	S. D.	S.E.M.	n	%error
Saithe dentary D1	4.79	4.6	4.9	0.078	0.014	30	6.26
Cod dentary D1	8.66	8.5	8.8	0.081	0.015	30	3.46
Pollack dentary D1	10.95	10.7	11.4	0.157	0.029	29	6.39
Ling dentary D1	12.08	11.9	12.3	0.109	0.020	30	3.31
Saithe dentary D2	4.79	4.6	5.0	0.096	0.018	30	8.35
Cod dentary D2	9.00	8.9	9.1	0.046	0.008	30	2.22
Pollack dentary D2	11.56	11.2	11.8	0.130	0.024	29	5.19
Ling dentary D2	11.89	11.3	12.2	0.236	0.043	30	7.56
Saithe premaxilla P1	6.80	6.6	7.0	0.096	0.017	30	5.88
Ling premaxilla P1	13.81	13.3	14.2	0.273	0.050	30	6.51
Cod premaxilla P1	16.29	16.1	16.6	0.166	0.030	30	3.06
Saithe premaxilla P2	3.63	3.5	3.7	0.071	0.013	30	5.50
Ling premaxilla P2	10.98	10.8	11.1	0.113	0.021	30	2.73
Cod premaxilla P2	13.96	13.6	14.2	0.165	0.030	30	4.29
Saithe otolith OL	6.88	6.8	6.9	0.038	0.007	29	1.45
Cod otolith OL	18.47	18.3	18.6	0.088	0.016	30	1.62
Saithe otolith OW	2.50	2.5	2.5	0.000	0.000	29	0.00
Haddock otolith OW	7.85	7.7	7.9	0.057	0.010	30	2.54
Cod otolith OW	11.02	11.0	11.1	0.045	0.008	30	0.90
Haddock cleithrum C	13.49	13.2	13.5	0.125	0.023	30	2.22

2.4.2 Recording Bones and Otoliths

Coding archaeological data to ensure that attributes of archaeological assemblages are consistently and rapidly recorded has been given thorough consideration by Richards & Ryan (1985, 120-133). Following this advice and after frustrating experiences using hand written cards and a purpose built interactive computer program, it was decided to use a computer-based system incorporating a series of mnemonic abbreviated codes for various bone attributes to store bone identifications.

In order to manage the large number of fish bone records anticipated from the excavations at Freswick Links a computer database was devised. This consisted of a series of data files which were interrogated using the powerful and versatile data-query language DATATRIEVE (Digital Equipment Corporation, 1984) using the University of York VAX cluster computer. The fish bone recording system was designed to record a large number of details about the bones as simply and economically as possible.

In the recording system, several kinds of information were collected for each bone or group of bones and using a standardized record structure. Each record was divided into 12 data fields or attributes.

The first three attributes of each record related to the archaeological provenance of the bone(s); the majority of attributes, however, were characteristics (e.g. name of bone and measurements) of the bone(s). For each record all 12 attributes were filled in. Once a single record was completed in full, duplicated attributes (e.g. site name, context and sample number) could be rapidly inserted by instructing the computer to make use of the details contained in the first record.

In the EAU system the first three attributes of each fish bone record are the site code, context code and sample number; these comprise the main data concerning the provenance of the bones. The site code was designated as a text field because FL80 was the code for material from the 1980 excavations at Freswick Links, Caithness.

The next attribute recorded was the kind of element present. This was coded as a maximum of three alphabetical characters, for example PX = premaxilla, D = dentary, PAR = parasphenoid.

The next field was the number (an integer) of bones comprising the record. This number was usually 1, but groups of remains of the same kind from a single taxon could be recorded as a single record. For example, a group of three otolith fragments which could only be assigned to family were recorded as one record.

The side from which the bone is derived was next recorded as follows: R = right, L = left, - = midline, ? = unknown.

A field known as 'Group' was the next field and was used only for vertebrae. This was used to distinguish between the different kinds of vertebrae present in a vertebral column of a species. Each species or family had its groups defined independently. As an example, the divisions of a gadid vertebrae are explained. Group 1 vertebrae were defined as the first vertebra and those following three or four anterior abdominal vertebrae which lack transverse processes. Group 2 vertebrae were defined as the small number of abdominal vertebrae with transverse processes which lie roughly at right-angles to the dorso-ventral axis of the bone. Group 3 were the remaining abdominal vertebrae. Group 4 vertebrae comprised the bulk of the caudal vertebrae. Group 5 were defined as the last ten or so vertebrae, which support the caudal fin.

The condition of the element is assessed in the next field. Condition 1 = complete; 2 = 75-99%; 3 = 50-75%; 4 = 25-50%; 5 = less than 25% complete; P = proximal; M = median; D = distal; A = anterior; C = caudal (5D signified that less than 25% of the distal portion of the element was present).

The size of the bone(s) was recorded in the next two fields.

For some bones, two different measurements were taken, for other elements only one measurement was recorded. Because bones were often fragmentary it was not always possible to fill these fields with measurements so numeric codes were assigned to represent an estimated size of the individual fish with such a bone. For example -2 = small sized individual; -3 = medium sized individual; -4 = large individual; -5 unmeasured). The values -2 to -4 were defined for each species and are presented in Table 4.

Table 4. Size codes allocated to bones that could not be measured.

The numbers show the approximate range of total length in millimetres, estimated by comparing the bone to specimens of known length.

Species	Small -2	Medium -3	Large -4
Cod	0-350	350-750	>750
Haddock	0-350	350-600	>600
Saithe	0-200	200-600	>600
Pollack	0-200	200-600	>600
Ling	0-500	500-1000	>1000

Identification was the next field. It was coded as a text field of maximum length 5 characters. Most identifications were based on a contraction of the scientific name, for example PO-PO = *Pollachius pollachius* L. and GAD = Gadidae. In addition, 'quick' codes were assigned for some species and other taxa which occur commonly, for example C = cod (*Gadus morhua* (L.)), HD = haddock, *Melanogrammus aeglefinus* (L.).

The final field in each record was a comment, usually coded, where additional information, for example, evidence of butchery or burning was recorded.

One of the main facilities of a DATATRIEVE data-query system is its ability to link different data files together via a common attribute. Thus it has proved possible to build a file of coded fish bone data which can be linked to a 'translation file' which will enable full scientific names (or English names) to be output instead of the coded identifications. Another translation file contains the codes for the elements and their full names. Because these two files are independent of one another and each links to the main data file via different fields it is possible to use the same abbreviation to mean different things. Thus in the field 'kind of element' the abbreviation 'C' is used for 'caudal vertebral centrum' while in the field identification the same abbreviation is the code for 'cod'.

Rather than attempt to record directly onto a micro- or mainframe computer, 80 column FORTRAN coding sheets were found to be an efficient means of recording fish identifications. These sheets were filled out at the time of identification and form the primary record for the site. The coded information is typed onto a computer (in the past, punched onto cards) by skilled VDU operators. The resulting data files were systematically checked against the hand written coding forms for errors and ambiguities.

Selected data were subjected to statistical analysis using the statistical package MINITAB (Minitab, Inc., 3081 Enterprise Drive, State College, PA 16801, USA, 1985) and graphics packages UNIRAS (Uniras A/S, Gladsaxevej 376, DK 2860 Søborg, Denmark, 1988).

2.4.3 Preparation of Reference Collections

Access to an adequate collection of modern reference material is essential for accurate identification of archaeological fish remains. The skeleton collection of the British Museum (Natural History), the Faunal Remains Project, University of Southampton, the Environmental Archaeology Unit, University of York and Alison Locker's private collection were consulted during this study.

The following paragraphs describe the methods used to prepare fish skeletons in the EAU's collection. Each specimen was first identified by a competent ichthyologist (usually a professional fisheries biologist) and assigned a skeleton number. Labels of spun-bonded polyethylene marked with black spirit-based felt-tipped marker as used during processing sediment samples proved to be durable and legible throughout the preparation.

The following measurements were taken of the fish: total length, standard length, body depth and head length (see Figure 13). The total and gutted weights of the fish were also recorded.

Scale samples were taken from different parts of the body and placed in glass vials. Scales were eventually mounted between two microscope slides.

Two methods of skeleton preparation were used. The first, a careful dissection method based on notes privately circulated by Johannes Lepiksaar (1981) was employed for a small number of specimens. These fishes were prepared by boiling for 5-10 minutes (depending on the size of the specimen) to loosen the musculature from the bone and placing it on a dissection board to cool.

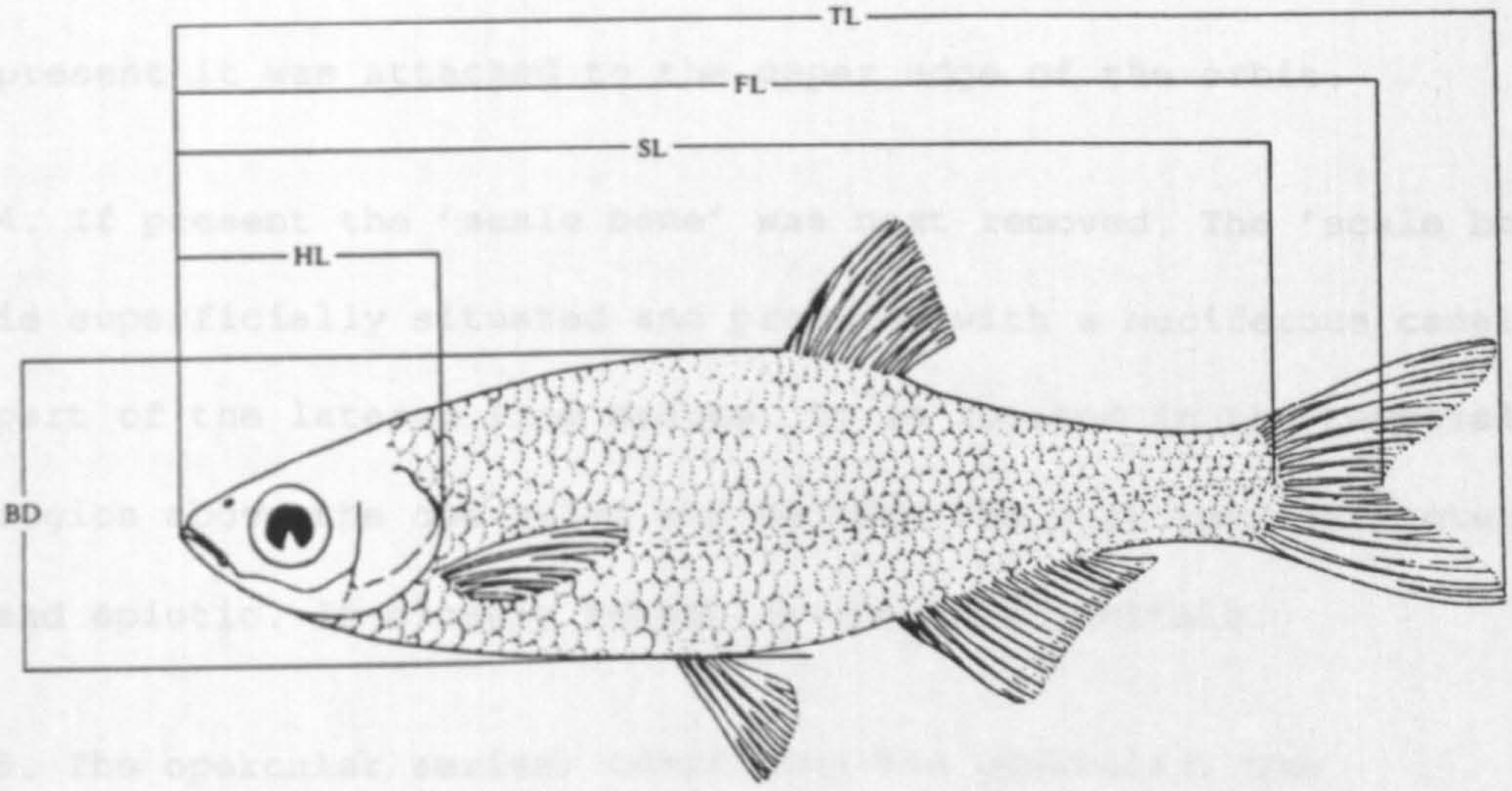


Figure 13. Measurements taken on whole fish. (After Wheeler, 1969.)

As far as was practical bones were removed in the following order:

1. The nasal was removed from the region of the external nostrils.

2. The eye-ball was next removed in order to gain access to the circumorbitals. These thin scale-like bones are provided with muciferous canals and surround the orbit superficially.

In most fishes the lens of the eye-ball contains ossifications which are resistant and occasionally persist in archaeological deposits; these were cleaned and preserved.

3. Once the circumorbital were removed, the infraorbitals were located. There are usually 5 or 6 infraorbitals which form the infraorbital arch. The arch was lifted, separated anteriorly from the ectethmoid and posteriorly from the sphenotic. Sometimes these bones were picked out individually. When a supraorbital was present it was attached to the upper edge of the orbit.

4. If present the 'scale bone' was next removed. The 'scale bone' is superficially situated and provided with a muciferous canal - part of the lateral line system. It is located in the temporal region above the opercular and between the post-temporal, pterotic and epiotic. It closely resembles the infraorbitals.

5. The opercular series, comprising the opercular, the preopercular, the interopercular and the subopercular bones were next removed. At its anterior part, the preopercular is attached to the hyomandibular by a ligament. Its inferior part is attached to the hind-part of the quadrate. This connection was broken by gently bending the preopercular forwards and the preopercular and interopercular removed.

The opercular is articulated to a knob-like formation on the dorsal hind-part of the hyomandibular. It was easily detached and the opercular and subopercular removed.

6. Bones of the secondary upper jaw were then removed. These consist of the premaxilla, the maxilla and in some species one or two supramaxillae. The premaxilla was be disengaged at the symphysis from its counterpart on the other side. The maxilla, which articulates with the premaxilla anteriorly, was easily

removed. The supramaxilla/e (when present) were removed next.

7. Once the opercular series and the upper jaw were removed, a series of bones known as the palatoquadratum (consisting of the palatine, ectopterygoid, entopterygoid, metapterygoid, quadrate, hyomandibular and the symplectic) were revealed. To remove these, the palatine was detached from the ectethmoidal part of the neurocranium and the hyomandibular articulation with the sphenotic and pterotic broken. The whole complex, together with the articular, angular and dentary were then lifted once the two dentaries were separated at the symphysis.

The lower jaw (dentary, articular and angular) were detached from its articulation with the quadrate. The dentary and articular separated by pulling them apart along the longitudinal axis of the fish.

8. The paired bones of the hyoid arch (excluding the hyomandibular and the symplectic) and the branchiostegal rays were next removed. The hyoid bones comprise the stylohyal, the epihyal, the ceratohyal and 2 hypohyals. The number of branchiostegal rays varies in different fishes. These bones were separated from the basihyal.

9. The urohyal (an unpaired element) was next removed, once the musculature of the throat had been dissected. The urohyal is found ventro-medially beneath the branchial apparatus.

10. The skeletal elements of the shoulder girdle and of the pectoral fin were removed next. The shoulder girdle is composed of the following bones: the post temporal, usually a forked bone

attached to the cranial roof; the supracleithrum, usually a robust straight bone which connects the posterior part of the post temporal and the cleithrum; the postcleithra (when present); the scapula; and the coracoid. The pectoral fin comprises the radials, small bones which allow the fin rays to articulate; and the fin rays (these may be spines - acanthotrichs - or they may be soft flexible rays - the lepidotrichs.

The processes of the post temporal were freed from their connections with the hind part of the neurocranium. The post temporal was removed, often with the supracleithrum. Next the postcleithra, cleithrum and the entire pectoral fin were detached from the body with their associated musculature. Particular attention was paid to any postcleithra for they often tended to fall off. Once removed, the musculature was removed from the bones.

11. The elements of the pelvic fin were removed next. These consist of the basipterygium and the fin rays. The basipterygium, together with the rest of the pelvic fin was taken from the body of the fish with any surrounding muscles. The bony parts were then freed from skin, muscles and other soft tissue.

12. The branchial apparatus (basket) was removed next. This is composed of a large number of elements: basihyal; the basibranchials, the hypobranchials; the ceratobranchials, the epibranchials; the pharyngobranchials; infrapharyngeals and suprapharyngeals; and the gill rakers. In some large fish, for example the gadids, the principal bones of the branchial arches bear small toothed plates which are found in the tissue adhering

to the main bones. The various elements were picked out from the soft tissue, cleaned and dried.

13. The neurocranium was next cleaned. An attempt was made to keep one neurocranium of each species entire and to disarticulate one into its constituent elements.

The neurocranium was removed from the vertebral column at its occipital contact with the first vertebra. It was often necessary to use a scalpel or sharp knife to sever the basioccipital from the first vertebra. The neurocranium was then freed by bending and gently pulling it from the vertebral column. The soft tissue on the outer surface of the neurocranium was washed from the bone. The brain flushed out of the cerebral cavity using a jet of water. Brain fragments were collected in a sieve to collect otoliths. Alternatively, otoliths were collected by shaking the washed neurocranium.

14. The vertebral column, ribs, intermuscular bones and the elements which support the unpaired fins were next collected. The skin and the side muscles of the trunk were removed and the radial muscles of the median fins kept to one side.

The ribs were carefully freed from the musculature. Where they were present, some intermuscular bones (epicentrals and epineurals) were collected and preserved.

The elements of the dorsal and anal fins next received attention. It was simplest to remove the whole fin with its musculature and then separate the hard parts from the musculature, preserving their natural sequence. Some fins of the more common fishes were preserved as whole preparations; cleaning off the skin and the majority of the soft tissue but allowing the fin to dry entire.

Pterygiophores were also carefully removed.

The fin rays of the caudal fin were next removed from the caudal end of the vertebral column leaving epurals, the hypurals and the urostyle of the ultimate vertebra with the vertebral column.

Once the fins had been removed from one side of the fish, the vertebral column, together with the remaining ribs was freed from the musculature. The vertebral column was washed clean of any muscle fragments, parts of kidney etc. and dried.

In some specimens vertebrae were picked out one by one and preserved in sequence.

A much more rapid way to prepare a fish skeleton was adopted for the bulk of the skeletons prepared. The fish was weighed, measured and gutted in the manner described above. The fish was placed in a fine nylon-meshed bag with a label bearing its skeleton number. In order to keep the vertebrae in their natural sequence, a nickel alloy wire was passed through the spinal foramen or through the neural arches of the vertebrae. The bag containing the fish was placed in a tank of water until digestion is complete. It was found that if the temperature of the tank was maintained at 35-40 degrees Centigrade digestion was complete in 2-3 weeks. The bag of fish was then washed in clean running water and the bones picked out and dried. (This technique was extremely malodorous.)

2.4.4 Storage of Fish Reference Material

Once the bones had been prepared they were stored in a manner that they could be readily used for identification. Very large specimens were stored in stout cardboard. Stationery cabinets with shallow drawers (5/8ths of an inch - roughly 16 mm) were found to be a convenient container for small and medium sized clear plastic boxes containing the comparative anatomical collection. Deeper drawers (2 inch - roughly 5 cm) were necessary for the larger elements of big fish, for example dentaries and cleithra of large cod, and for storing bags or boxes of vertebral centra.

In order to speed up the identification of archaeological specimens two separate modern reference collections were prepared: a comparative anatomical collection and a taxonomic collection. In the comparative anatomical collection the various skeletal elements (dentaries, cleithra etc.) from different species were stored in taxonomic order side by side. This arrangement was necessary because it was often possible to know what element the archaeological specimen was, but it would have been grossly inefficient to search through boxes containing all elements. Using the comparative anatomical collection all specimens of a particular element could be examined rapidly.

The comparative anatomical collection was accumulated over a number of years by placing boxes containing the same element from a number of fishes into the same drawer. It was not considered necessary to box every bone from a fish separately, some, for example vertebrae, intermuscular bones, branchiostegal and fin rays, were grouped into the same box. Bones that can readily be assigned to species (or other taxonomic level) were boxed separately.

In the taxonomic collection the specimens were arranged in a recognized systematic sequence with all elements of a individual kept together, either in a box, in bags within a box or attached to card using plastic adhesive material. The taxonomic collection was used to check for variability within the species, and to look for age-related changes to the morphology of the particular element when the collection contained several specimens of a species.

Specimens not needed for the comparative anatomical or taxonomic collections were placed in labelled clear plastic boxes and stored by species in large cardboard boxes.

2.5 BONE NOMENCLATURE

Over a hundred years ago the great ichthyologist A. C. L. G. Günther stated: 'The bones of the skull of the fish have received so many different interpretations that no two accounts agree in their nomenclature, so that their study is a matter of considerable difficulty to the beginner' (Günther 1880). This state of confusion still exists because scientists studying fish bones have either carried out comparative studies of recent forms or examined fossils in order to understand the problems of homology and evolution of the fish skeleton. Many of these problems have still not been sufficiently well understood and there remains a number of subjective ideas which strongly influence the terminology of different workers.

Many zoologists have been aware of the difficulties with the nomenclature of fish skeletal elements and a number have attempted to give standard lists with synonyms. One of the first to do this was Starks (1901). This work was referred to by Casteel (1976) and many fish bone workers are familiar with it. However, it suffers from many deficiencies, most of which have emerged as fish osteology has developed over the last few decades. It can no longer be considered a useful starting point, though as a work of reference its value is assured.

A much quoted paper in osteological circles is that of Harrington (1955) which discussed the osteocranium of the American cyprinid Notropis bifrenatus. Another classic study is that of Topp and Cole (1968) on the sciaenid genus Sciaenops. These papers have strongly influenced ichthyologists, yet their terminology has not readily been adopted by those examining archaeological material. Jollie (1986) has produced a primer for the names of bones of the teleost skull. Whether or not this work may become a seminal paper followed assiduously in the future is in doubt. The absence of illustrations may hamper its adoption. Furthermore, many of the terms for common elements are so different from those currently used that urging osteologists and archaeologists to use it will probably cause confusion.

Attempts to clarify fish bone nomenclature for those working with archaeological material have not always succeeded in their aims. For example, Olsen (1968) gives a fine illustration entitled the 'Generalized articulated fish skeleton' in which many of the elements which are recognisable in archaeological assemblages are clearly labelled. Yet the text refers to the bones of the opercular series, labelled as opercular, preopercular, subopercular and interopercular, as the operculum, pre-operculum, suboperculum and interoperculum. This lack of consistency in nomenclature is poor science and most misleading. More recently Lepiksaar (1981) has privately circulated a most useful document on fish osteology from which a list of terms can be derived. These terms are almost all latinized and are not catholically acceptable. Cannon (1987) produced a guide to the osteology of four fishes intended for archaeologists. While her illustrations are generally excellent and many of the bone names widely used, several terms (e.g. 'opercle' for opercular) make it unacceptable.

In an attempt to clarify the confusion which has developed Wheeler and Jones (1989, 122-4) gave a list of recommended names which is, with a few additions, adopted here. This list was based on terms used in the works of a German anatomist, Dr Wilhelm Harder, who wrote an anatomy of European fishes which was first published in German in 1964 and later translated and published in English in 1975 (Harder, 1964, 1975). A few additional terms indicated with an asterisk (*) have been added to include all the material from Freswick.

Table 5. List of anatomical terms and codes used during identification

Region and anatomical term	Mnemonic code
NEUROCRANIUM	
Olfactory region	
ethmoid	E
nasal	N
prefrontal	PF
prevomer	PV
Orbital region	
frontal	F
lacrimal	LA
pterosphenoid	PTS
Otic region	
epiotic	EOT
exoccipital	EX
opisthotic	OPO
parietal	PL
post temporal	PT
prootic	PRO
pterotic	PTO
sphenotic	SPH
supraoccipitcal	SOC
Basicranial region	
basioccipital	B
basisphenoid	BSP
parasphenoid	PAR
BRANCHIOCRANIUM	
Oromandibular region	
angular	AN
articular	A
dentary	D
ectopterygoid	ECP
entopterygoid	ENP
maxilla	MX
metapterygoid	MTP
palatine	PA
premaxilla	PX
quadrate	QD
Branchial region	
basibranchial	BB
ceratobranchial	CB
epibranchial	EB
gillraker	GR
hypobranchial	HB
infrapharyngeal	IP
suprapharyngeal	SP

Table 5 (cont.).

Region and anatomical term	Mnemonic code
Hyoid region	
basihyal	BH
branchiostegal	BRR
ceratohyal	CH
epihyal	EH
hyomandibular	HY
hypohyal	HH
interhyal	IH
interopercular	IO
opercular	O
preopercular	PO
subopercular	SO
symplectic	SY
urohyal	UH
VERTEBRAL COLUMN	
abdominal vertebra	AV
caudal vertebra	CV
1st vertebra	FV
* ultimate vertebra	UV
rib	RB
intermuscular	IM
* mineralized vertebral core	MVC
MEDIAN FINS	
acanthotrich	FS
pterygiophore	PTY
lepidotrich	FR
CAUDAL SKELETON	
epural	EP
hypural	HP
urostyle	US
APPENDICULAR SKELETON	
radial	RA
basipterygium	BPT
cleithrum	CL
coracoid	CD
postcleithrum	PCL
scapula	SCP
supracleithrum	SCL
OTHERS	
otolith	OT
scale	SC
scute	SCT
* tooth	T
1st anal pterygiophore (flatfish)	AP

Chapter 3

INVESTIGATIONS INTO THE DURABILITY OF MODERN FISH BONES AND OTOLITHS

3.1 INTRODUCTION TO TAPHONOMY

The term 'taphonomy' was coined by Efremov to describe the events intervening between death of an organism and its fossilization and can be defined as the process of transition during which animals and plants pass from the 'biosphere to the lithosphere' (Efremov, 1940). Modern archaeological usage has extended the meaning of taphonomy to include events occurring during excavation and analysis (Rackham, 1983). Many factors influence the survival of fish remains in the period between the death of the fish and the analysis of excavated bones. Animal hard tissues are not equally robust or diagnostic and a host of processes can fragment them rendering them unidentifiable or irretrievable. Bones may be damaged or lost when fish are caught. Decapitation, gutting, descaling, filleting, butchery and heat may all adversely affect fish hard tissues. Fish waste, cooked or uncooked, may be gnawed or ingested by scavengers. Discarded fish remains may be trampled, buried, thrown into water or fires or left on the surface to weather. The bones that survive in archaeological deposits are likely to be a small and probably biased sample of those brought onto the site.

On excavation taphonomic processes have not ceased to operate, for the methods used in excavation affect what is recovered. The final factor affecting what is examined is human error. Bags are mislabelled, boxes of bone mislaid and other events may cause material to be lost or damaged after the excavation has ceased.

Thus the animal remains analysed from an archaeological site are rarely more than a small sample of the bones in thatarchaeological site. Clear indications of the amount of fish bones absent in archaeological assemblages can be seen in reports where the numbers of elements identified for each taxon and the percentage representation of each element based on the minimum number of individuals are given. For example Noddle (1980) presents the number of mammal bone fragments per individual for cattle, sheep and pig and shows that in some groups of bones only 3 identifiable fragments are present for each individual. A number of archaeological fish bone reports list the numbers of elements of each taxon and calculate percentage representation for each element (e.g. Lepiksaar and Heinrich, 1977; Heinrich, 1985; 1987, and Brinkhuizen, 1989). These accounts show that for all but a few elements of most fish taxa less than 10% of the expected number of bones was present.

In the early 1970s two influential critiques discussed the methods used in osteoarchaeology and elucidated the difficulties and challenges of dealing with archaeological bone assemblages (Payne, 1972; Uerpmann, 1973). Although these papers were primarily concerned with mammal bone assemblages, the points made are relevant to fish bone assemblages. Payne and Uerpmann pointed out that it is never possible to recover all of the bone debris from a site, no matter how careful and how extensive the excavation may be. There is always an unknown quantity which is not collected. Factors affecting this missing quantity include the consumption of meat beyond the limits of the site, the consumption and removal of bones by dogs, the use of bone as a raw material, and the destruction of bone by trampling and weathering.

In recent years attention has focussed on this 'missing quantity'. Taphonomy has become an increasingly important aspect of archaeological research as archaeozoologists have attempted to interpret their data in addition to describing what they have found. Many investigators have carried out controlled experiments and detailed observations on how animal carcasses are processed, in order to understand patterning in archaeological assemblages. Shipman (1981, 11) stated that 'the present is the key to the past', and that a past event (e.g. butchery) can only be unequivocally identified by demonstrating that its effects differ from those of other events (e.g. scavenging). Binford stressed the need for 'actualistic studies' and for 'middle range research' (Binford, 1981, 29) designed to investigate the effects of mechanical and chemical processes on bone assemblages.

Payne and Munson (1985) noted that in 1862 Steenstrup recognized that the weaker parts of mammal skeletons were consistently under-represented in bone assemblages from Danish Mesolithic midden sites. Steenstrup examined collections of bones from contemporary Eskimo middens and fed bones to dogs to see what was destroyed. Despite this pioneering work, the field of taphonomic research saw little progress until the 1960s.

Seminal papers culminating in a book by Brain (1967, 1969, 1981) explored bone samples from Hottentot villages and modern carnivore dens and concluded that representation of the various elements of antelope skeletal elements at the important palaeolithic site of Makapansgat, South Africa, was typical of any bone assemblage 'chewed-over' by carnivores. Binford (1981) discussed in great detail the kinds of carnivore damage that can be seen on bones. He also studied marks made by Nunamuit peoples as carcasses were skinned and butchered (Binford, 1978). Furthermore, Binford examined the element distribution of mammal bone assemblages from wolf kill sites, dog yards and human occupation sites. Behrensmeyer and Hill (1980) edited papers presented on the subject and Shipman (1981) drew much of the scattered literature together. Walters (1984) recorded the animals brought onto a temporary campsite in Australia and discovered that over 98% of the bones had disappeared from the site in 6 months. Most recently Payne and Munson (1985) described a series of experiments where squirrels and goats were fed to large dogs. These important contributions have helped to show that the patterning seen in many bone groups is not caused directly by human activity and that some of the conclusions drawn by early workers concerning how animal populations were exploited are now untenable.

In contrast to the amount of taphonomic work on mammal bones, fishes have received scant attention. As part of this study experiments were carried out to investigate the properties of fish bones in order to assess their ability to survive the processes which occur on human habitation sites. Assemblages of modern fish remains deposited on land by animals other than humans were studied. In addition, this chapter discusses the innate and environmental factors that influence which fish remains survive in archaeological deposits.

3.1.1 Inherent Factors Influencing the Survival of Fish Remains

There are important inherent factors, notably the nature and composition of the hard tissue, which influence whether a bone, tooth, otolith or scale will survive in archaeological deposits. Some kinds of fish hard tissues are more resistant than others. Thus, the only archaeological finds of jawless fishes (agnathans) are chitinous teeth, preserved in anoxic organic deposits and recovered on fine meshed (500 um aperture) sieves. Teeth plates, identified as lampern, Lampetra fluviatilis, were recovered from medieval deposits at Coppergate, York (Jones, 1986b; O'Connor, 1989).

Elasmobranch skeletons consist primarily of cartilage, a material that does not persist for long periods in a recognizable form in soils and sediments. Although cartilage is often mineralized with crystals of apatite (a mixture of calcium phosphates and carbonates), in most species only the cores of vertebrae are sufficiently well mineralized to survive in archaeological deposits. The cartilage of the chondrocranium, jaws and pectoral skeleton of sharks is reinforced with an external layer of apatite crystals set in a matrix of collagen, rather than being mineralized throughout. Consequently, in neutral or alkaline conditions the collagen and other organic components are readily degraded, leaving minute prismatic mineral particles too small to be recovered using archaeological methods.

Elasmobranch dermal structures, teeth, denticles and spines are extremely well-mineralized and are composed of dentine covered with a layer of enameloid tissue. The dentine of sharks and rays has been termed 'osteodentine' (Halstead, 1974) because it is organized into vertical units reminiscent of the Haversian system of mammal bone.

Fish bone, though little studied compared with mammal bone, consists of a mixture of woven lamellar bone (Moss, 1961). It is peculiar in being acellular (i.e. lacking osteocytes) in most families, including the Gadidae, and cellular in other families (e.g. the Salmonidae). Because fish are not subject to the effects of gravity in the same way as terrestrial vertebrates, their bones are more fragile than mammal and bird bone. It is also noteworthy that unlike mammals, fish bone grows throughout life (Pitcher and Hart, 1982) and that articulations are separated from the growth points by cartilage.

Bony fishes do not all produce the same number of bones, and some species have more highly mineralized and resistant elements than others. Some families produce bones which are extremely fragile. For example the box-fishes, Ostraciontidae, sun fish, Mola mola, and lumpsucker, Cyclopterus lumpus, have bones which are light and extremely flimsy. Rather more robust are the bones of the salmon family, Salmonidae, and the mackerel, Scomber scombrus, and tunnies, Thunnus spp. Bones of these fishes, when found are often recovered as broken fragments from archaeological sites. The pike, Esox lucius, the carp family, Cyprinidae, the cod family, Gadidae, perch family, Percidae, and many other spiny-finned fishes have strong bones which often survive relatively well in archaeological deposits.

In addition to differences in the mechanical properties of fish hard tissues between families, there is considerable variation in the robustness of elements within a single species. This is related to the function the element performs in the animal's skeleton.

Although fish bone is noticeably more fragile than mammal or bird bone little work appears to have been carried out on its mechanical properties. An undergraduate thesis examining ribs from several European fishes (Chasler, 1972) established that the bone was considerably less tough than mammal bone. To investigate this further an experiment was designed to compare the resistance of fish and mammal bone to mechanical damage (see section 3.3.).

3.1.2 Environmental Factors Influencing the Survival of Fish Remains

Two important factors influencing which fish remains survive in archaeological deposits are the chemical environment and the kind of sediment surrounding fish remains. Archaeological sites on acid subsoils rarely produce fish remains. Neutral and alkaline soil conditions are most conducive for fish bone survival, although Beeley and Lunt (1980) showed that hydrolysis of collagen can occur in these conditions.

While the soil pH is probably the major factor, the nature of the sediment burying ancient remains is also important. Layers composed mainly of mineral particles are more likely to cause post-burial abrasion than layers rich in organic debris. Stratified waterlogged sites, often produce fish remains that are exceptionally well-preserved, for here delicate bones are rapidly buried and cushioned by large volumes of organic refuse which protect the remains from mechanical damage. Weathering of bone which is left exposed on the ground surface takes place surprisingly quickly (Binford and Bertram, 1977). There are often marked differences in the state of preservation of bone from different parts of the same site (Chaplin, 1971, 17).

3.2 EFFECTS OF THE MAMMALIAN DIGESTIVE SYSTEM ON FISH BONES AND OTOLITHS

Details of experiments in which fish was fed to human and porcine subjects have been published (Jones, 1986a; Wheeler and Jones, 1989, 69-74, plates 5.1 & 5.2). Additional feeding experiments were carried out during the course of this study with the assistance of the animals' owners and the staff of the Animal House, Department of Biology, University of York. Bones and otoliths recovered during these experiments were identified using the criteria and assumptions employed when examining archaeological assemblages.

3.2.1 Feeding Experiments with Dogs, Canis familiaris

The first experiment was carried out by Sebastian Payne and Pat Munson and the author examined the resulting bone assemblage. Payne and Munson fed a large dog two whole red snappers (Lutjanus campechanus) and collected bones which were not swallowed and those present in the animal's faeces (Jones, 1984a).

In a second experiment fish were fed to a cross-bred female collie dog. 'Sally', whose normal diet was tinned dog-food, was fed a herring and a haddock. Details were given in Jones (1986a) and Wheeler and Jones (1989, 69-74). Plates 1-3 show some of the bones and otoliths after the experiment.

A third experiment was carried out with 'Fay', also a female cross-bred collie. This dog frequently and eagerly ate fish. The experiment was carried out in an attempt to establish which elements of a herring's head survived digestion best.

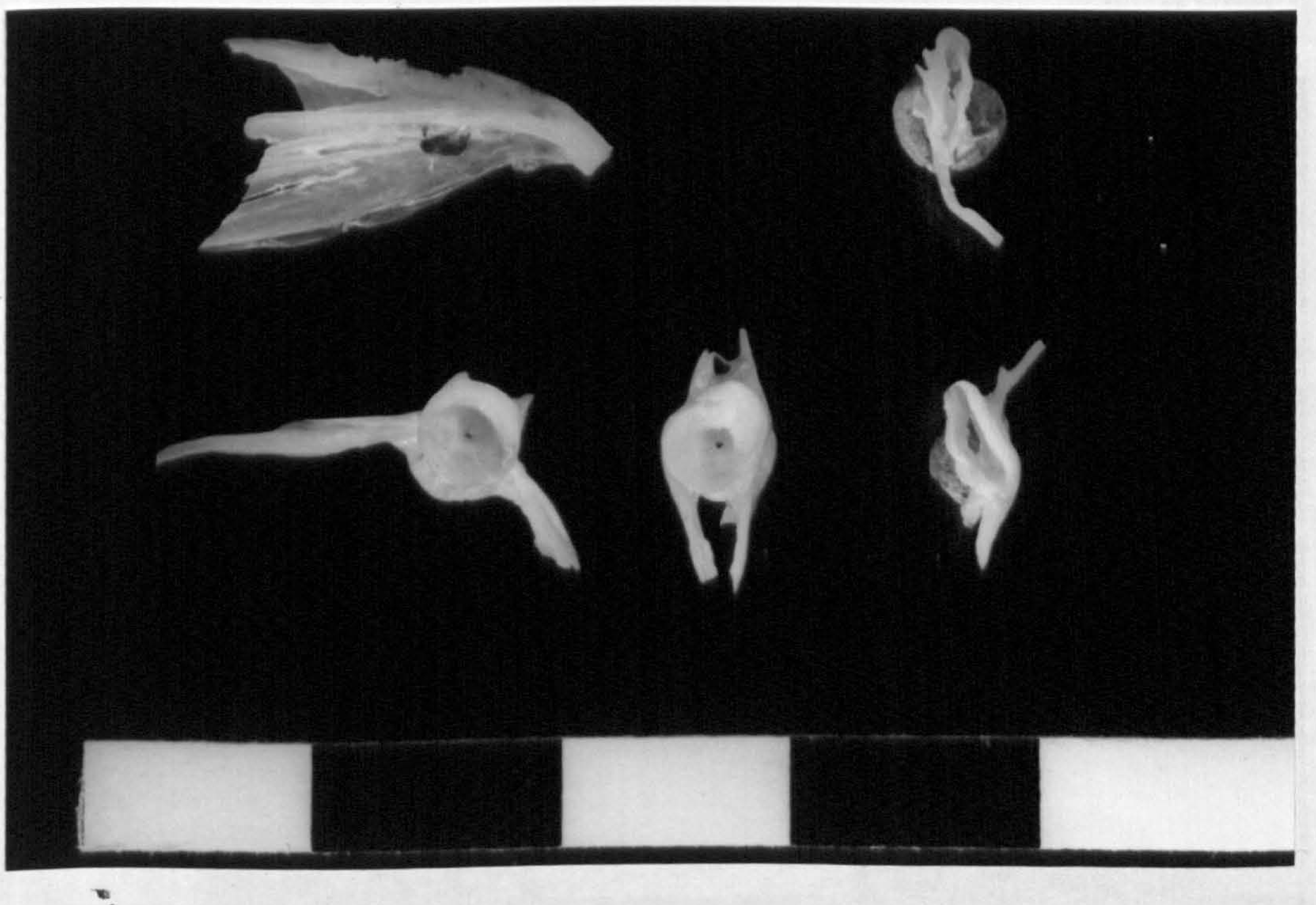


Plate 1. Fragments of modern haddock, Melanogrammus aeglefinus, bones rejected by Border Collie dog (Sally) during feeding experiment. Top row: dentary; vertebra fragment. Bottom row: three vertebrae. All bones have been deformed during mastication; most show tooth marks.

Plate 2. Fragments of modern haddock, Melanogrammus aeglefinus, bones and sagittal otoliths (inner surface) collected from faeces of Border Collie dog (Sally) during feeding experiment. Left to right: crushed vertebra; left hand otolith showing glossy surface and irregular outline caused by acid solution; right hand otolith showing severe signs of acid solution; crushed caudal vertebra.

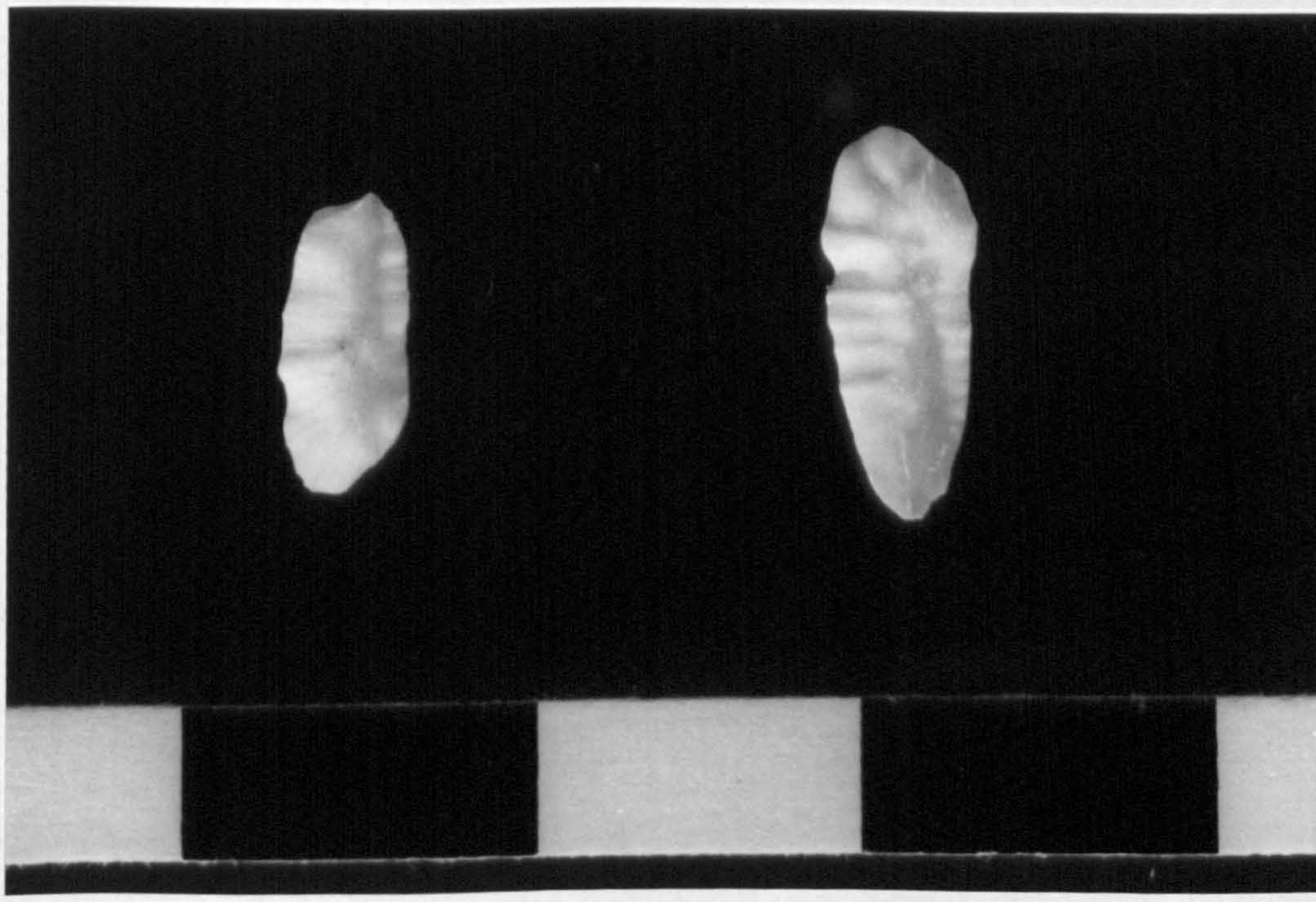


Plate 3. Fragments of modern haddock, Melanogrammus aeglefinus, sagittal otoliths (outer surface) collected from the faeces of a Border Collie dog (Sally) during feeding experiment.

Ten herring heads, from fishes 230-270 mm total length, were fed (in two batches of 5, over 24 hours) to the dog. Faeces were collected for one week and bones extracted following the procedure of Jones (1986a). Thus 20 bones of paired elements, and 10 unpaired elements, numerous branchial bones and gill rakers were ingested. Table 6 shows the head bones recovered from faeces.

Eye lenses and otic bullae were the best preserved remains, while maxillae, dentaries, basioccipitals and other bones were completely absent. The condition of the bones and lenses recovered from faeces showed considerable variation. Some otic bullae were reduced to thin-walled part spheres while others, although clearly eroded, were almost entire. 'Fay' digested more of the herring bones than 'Sally' indicating that there is variation in the amount of bone destroyed by different animals of the same species.

Table 6. Remains of 10 herring, Clupea harengus, heads recovered from dog faeces.

Paired elements	
Eye lenses	15
Otic bullae	13
Quadrate	4
Otoliths	3
Sphenotic	2
Stylohyal	2
Ceratohyal	1
Unpaired elements	
Parasphenoid	1
Prevomer	1
Other bone fragments	
Gill rakers	16
Branchiostegal ray	1
Circumorbital	2
Neurocranium frags	11
Unidentified frags	66

All three feeding experiments with dogs gave broadly consistent results and showed that when dogs eat fish they digest or fragment most of the bone, rendering it unidentifiable or irretrievable. The small amount of bone and otoliths that survived the experiments was usually characteristically eroded and larger fragments bore tooth marks. These results are consistent with observations of recent Eskimo fishing camps where fish waste was fed to dogs and no fish bones were observed (Binford, 1978, 256).

3.2.2 Feeding Experiments with Rats, *Rattus norvegicus*

Adult laboratory rats (Wistar strain) were fed whole herring and plaice (Wheeler and Jones, 1989, 70-71) and left no recognizable fish remains when allowed free access to fish. (Some damaged bones were recovered after 48 hours and photographed (Wheeler and Jones, 1989, plate 5.1).

A further experiment was carried out to investigate whether rats are able to consume the bones of large cod. To this end the principal head bones and three vertebrae from a large cod (total length 840 mm) were roughly dissected and fed, 2 or 3 bones at a time, to a colony of 6 adult Wistar strain laboratory rats. Throughout the experiment the rats were also fed pelleted food. Table 7 shows the bones fed, the length of time the rats had access to them and their determination using criteria for identifying archaeological material. Samples of rat faeces were disaggregated and no identifiable bone fragments were recovered.

Table 7. Bones of cod, Gadus morhua, (total length 840 mm) fed to laboratory rats

Element	Time in cage	Archaeological determination
Otolith	144 hours	cod (part missing)
Dentary	72 "	?cod
Cleithrum	"	large gadid (cod or pollack)
Articular	"	large gadid
2nd vertebra	"	"
3rd vertebra	"	"
Branchiostegals	"	"
Caudal vertebra	"	No trace
Premaxilla	"	"
Maxilla	"	"
Coracoid	"	"
Nasal	"	"
Preopercular	"	"
Hyomandibular	"	"
The neurocranium (including prevomer, basioccipital and parasphenoid)	144 hours	"

All recovered bones were clearly gnawed. Only the otolith could be identified to species with certainty.

3.2.3 Discussion of Feeding Experiments

Although only the experiments with rats were carried out under controlled laboratory conditions, there is little chance that any faeces containing fish bones were not examined. There is no chance that any bones were lost from the human faeces and every effort was made to ensure that none were lost from the pig or dog faeces. It is also extremely unlikely that bones were overlooked or lost during the washing and sorting process.

It is clear that large numbers of bones which might be expected to have survived passage through the mammalian guts were absent. The three non-rodents gave broadly similar results - only a small percentage of the ingested bones was recovered in recognizable form. Some of those fragments were characteristically damaged. Crushed vertebrae were recovered from human/dog faeces, while indentations made by conically tipped teeth were present on a few bones rejected by one of the dogs. The rats were even more destructive to fish bone and destroyed almost all bones.

Suffice it to say that these experiments show that a vast majority of bones from small to medium-sized fish (150-350 mm total length) do not survive passage through the mammalian gut. Fish hard tissues are either dissolved by the process of digestion or they are so fragmented when they are eaten, that most cannot survive passage through the mammalian gut. These results are entirely consistent with those obtained by Prime (1979) who studied fish otoliths fed to a young captive common seal, *Phoca vitulina*, and discovered that 14% of gadid otoliths were totally digested.

It is important to point out that in these experiments fish bones have been passed through one gut only. On many sites it is likely that excrement was eaten by pigs, rats and dogs. Presumably any bones that survived the first digestion would have been vulnerable to destruction by the second.

3.3 EFFECTS OF TRAMPLING AND OTHER MECHANICAL DAMAGE TO FISH BONES AND OTOLITHS

Gifford & Behrensmeyer (1978) studied a camp site made during a foraging expedition by a group belonging to the Dassaneth in Kenya. The site was occupied by eight men for four days during which 14 catfishes and two Nile perch, *Lates* *niloticus* were eaten, in addition to crocodiles, terrapins and scavenged zebra meat. When the site was abandoned, bones were mapped. The authors found that although bones were scattered over the site, they were concentrated round the hearth. The site was left for a year and the position of the bones replotted. By this time most of the large bones had disappeared, and only small bones and fragments which had been trampled below the surface survived. These were thought to have been protected from rain and scavenging because of their size and burial.

An investigation into the robustness of the bones of the cod, *Gadus morhua* was carried out by Bron (1987) who used a garden roller to crush bones. Bron showed that some elements would fragment into a large number of identifiable fragments (Bron, 1987, 50). The dentary broke into a maximum of eight identifiable fragments, the premaxilla and cleithrum into five and the sagittal otolith into two. He also observed that the anterior vertebrae (those with no lateral processes or horizontal lateral processes) and the ultimate and penultimate vertebrae survived better than other trunk and caudal vertebrae. Other bones which survived well included the dentary, premaxilla while the otoliths fared badly. Overall he found that flat bones (ceratohyal, symplectic, urohyal, lacrimal, opercular, coracoid, scapula) survived better than he had expected and suspected that the 'unnatural' methodology of lying the bones on a board accounts for their survival.

3.3.1 Resistance to Abrasion

To compare the resistance of fish and mammal bone to mechanical abrasion the following experiment was performed. Pieces of cod parasphenoid (from a fish 1050 mm total length, prepared by enzyme digestion) and an adult sheep metacarpal (prepared by dissection) were sawn and ground into pieces measuring approximately 20 x 2 x 2 mm. Two marked and weighed bone fragments of each species were then placed in an 100 mm diameter gemstone tumbler revolving 50 revolutions per minute with rounded limestone pebbles 15-25 mm in size. The bones were weighed at 5 hour intervals. After 15 hours in the tumbler the fish bones were greatly reduced in weight while the sheep bone fragments were only slightly polished (see Figures 14 and 15). This experiment verifies that fish bone is more vulnerable to mechanical abrasive forces than mammal bone.

3.3.2 Resistance to Trampling

To investigate the effects of trampling on the bones and otoliths of a cod, Gadus morhua, the following experiment was carried out. The aims of the experiment were to monitor the gradual disintegration of the principal bones in a cod skeleton and to classify the elements according to their robustness.

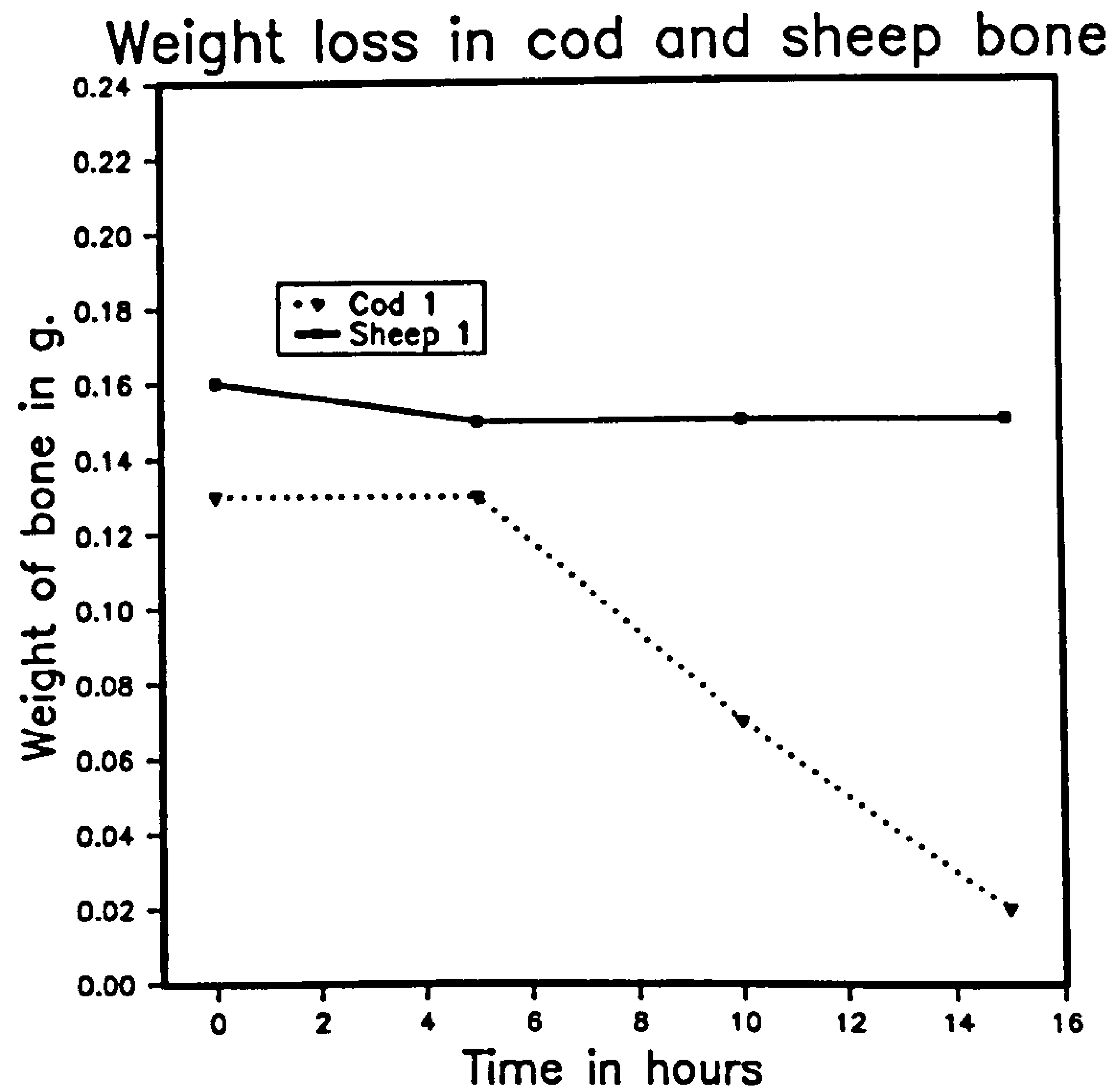


Figure 14. Weight loss of a piece of cod, Gadus morhua parasphenoid and a piece of sheep Ovis metapodial in a gemstone tumbler.

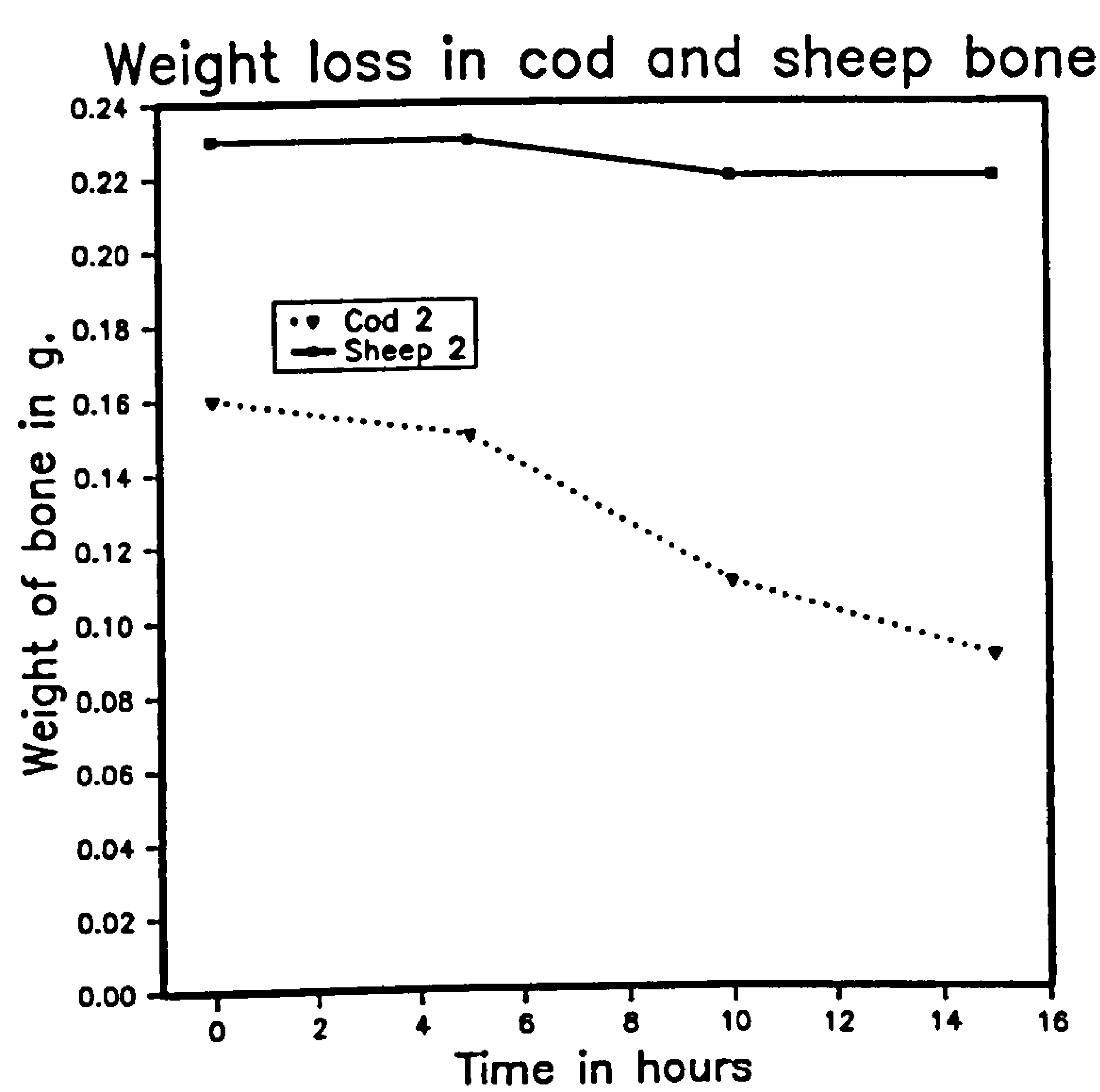


Figure 15. Weight loss of a piece of cod, Gadus morhua parasphenoid and a piece of sheep Ovis metapodial in a gemstone tumbler.

A large cod (total length 1090 mm) was prepared by maceration and the bones rinsed and air dried. Fin rays, branchiostegal rays, intermuscular bones, pterygiophores and other undiagnostic elements were excluded.

The remaining bones and sagittal otoliths were weighed and placed in a nylon mesh bag. The bag was placed on a vinyl covered concrete floor and an adult male weighing 75kg walked on the bones for 25 paces. The bones were examined, recorded, weighed and replaced in the bag. The bones were again placed on the floor and walked on for an additional 50 paces when they were re-examined and recorded. The bones were rebagged and subjected to a further 100 paces, recorded and subjected to a final 200 paces. Thus the bones were examined after 25, 75, 175 and 375 paces. As the aim of the experiment was to break the bones, the noise made during the walking was closely monitored. During the 100 and 200 pace walks, the amount of cracking diminished after 20 or 30 paces. To increase bone breakage the bag was shaken in order to reorientate the bones so that further walking would cause damage. At all times the bones were identified using criteria employed for recognizing archaeological material. After each stage in the experiment the bones were recorded. For paired elements the right (R) and left (L) bones were recorded separately. The frontal bone broke into recognizable left and right sides after 25 paces and were recorded separately thereafter. Asterisks denote the presence of mid-line bones.

The results for the midline and left-hand-side cranial elements are presented pictorially in Figures 16-20 and for all elements in Table 8. As is clear from the figures some bones quickly became so damaged that they were not recognizable, while others persisted as identifiable fragments until the end of the experiment. (The results for the right-hand-side were similar).

It was possible to determine an 'Index of Robustness (IR)' for the bones in this experiment. Bones that remained identifiable after the experiment were assigned the value 1. Those which disappeared from the record after 175 paces trampling were assigned an IR of 5. Intermediate gradings were assigned for other elements. Vertebrae were divided into 6 groups: first vertebra; precaudal group 1 (those anterior vertebrae with no horizontal processes); precaudal group 2 (anterior vertebrae with horizontal processes); precaudal group 3 (precaudal vertebrae with lateral processes angled ventrally; caudal group 4 (anterior caudal vertebrae with neural and haemal arches complete); caudal vertebrae group 5 (posterior caudal vertebrae with haemal and neural processes angled at less than 30 degrees to the axis of the vertebral column. The index of robustness for vertebrae was assigned by considering the numbers of identifiable vertebrae of each group at each stage of the experiment.

Developing the Index of Robustness (IR) has provided a method for judging the condition of assemblages of cod bones from archaeological excavations. An assemblage consisting only of the most robust bones (i.e. those with an IR of 1) are less well preserved than assemblages which contain bones with the higher IR. Here we have an objective way of categorizing the completeness of an assemblage.

Figure 16. Left hand side elements of cod skull recorded at beginning of trampling experiment.

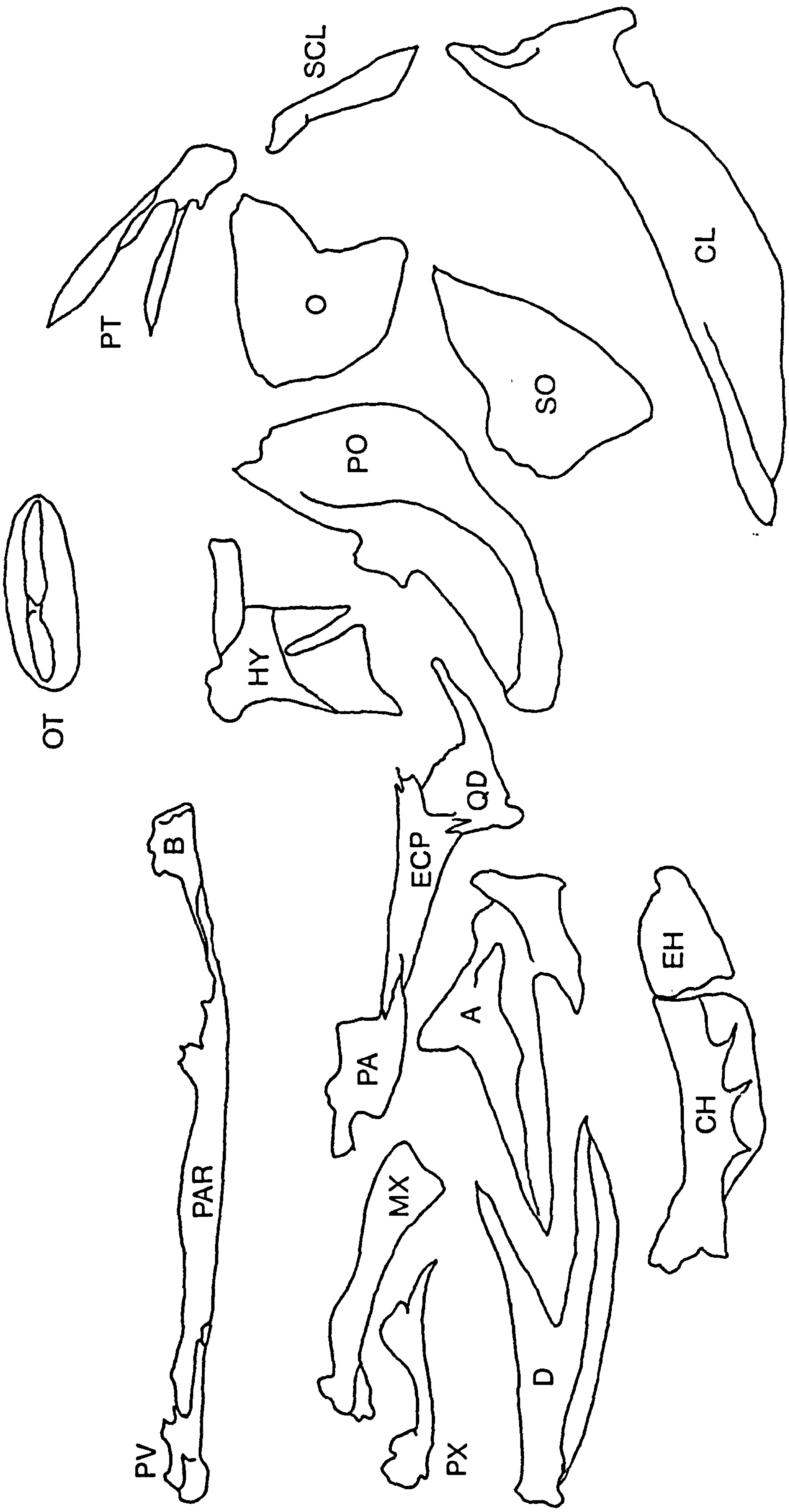


Figure 17. Left hand side elements of cod skull recorded after 25 paces of trampling experiment.

Figure 18. Left hand side elements of cod skull recorded after 75 paces of trampling experiment.

Figure 19. Left hand side elements of cod skull recorded after 175 paces of trampling experiment.

Figure 20. Left hand side elements of cod skull recorded after 375 paces of trampling experiment.

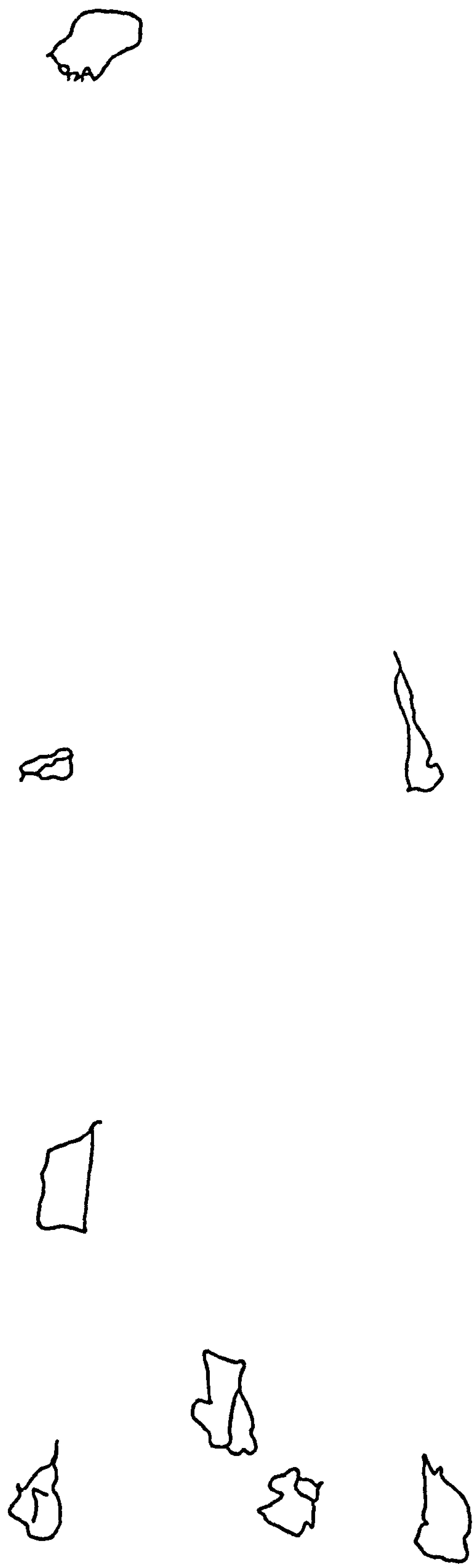


Table 8. Breakage patterns of selected elements of a trampled cod, <u>Gadus morhua</u>, total length 1090 mm.

Name of bone	25P	75P	175P	375P	IR
Neurocranium					
Basioccipital	*	*	*	*	1
Ethmoid	*	*			5
Frontal	*	LR	LR		3
Opisthotic	LR	LR			5
Otolith (sagittal)	LR	LR	LR	R	2
Parasphenoid	*	*	*	*	1
Prefrontal	LR	LR			5
Squamosal	LR	LR			5
Supraoccipital	*	*	*		3
Prevomer	*	*	*	*	1
Suspensorium					
Angular	LR	LR			5
Articular	LR	LR	LR		3
Dentary	LR	LR	LR	LR	1
Ectopterygoid	LR	LR	L		4
Entopterygoid	LR	LR			5
Metapterygoid	LR	LR			5
Maxilla	LR	LR	LR	LR	1
Palatine	LR	LR	L		4
Premaxilla	LR	LR	LR	LR	1
Quadrate	LR	LR	LR	L	2
Cleithrum and Pectoral fin support					
Cleithrum	LR	LR	LR		3
Coracoid	LR	LR			5
Post cleithrum	LR	LR			5
Post temporal	LR	LR	LR	L	2
Scapula	LR	LR			5
Supracleithrum	LR	LR	LR		3
Opercular bones and other lateral elements					
Interopercular	LR	LR	L		4
Lacrimal	LR	LR			5
Nasal	LR	LR			5
Opercular	LR	LR	LR	L	2
Preopercular	LR	LR			5
Subopercular	LR	LR			5

Table 8 (cont.). Breakage patterns of selected elements of a cod, Gadus morhua, total length 1090 mm.

Name of bone	25P	75P	175P	375P	IR
Hyomandibular and hyoid bones					
Ceratohyal	LR	LR	L		4
Epihyal	LR	LR			5
Hyomandibular	LR	LR	R		4
Hypohyal	LR	LR	R		4
Stylohyal	LR	LR	LR		3
Symplectic	LR	LR			5
Urohyal	*	*			5
Branchial region					
Suprapharyngeals	LR	LR	L		4
Infrapharyngeals	LR	LR			5
Vertebrae					
First vertebra	*	*	*	*	1
Precaudal Group 1	4	4	3	3	2
Precaudal Group 2	6	5	*	*	4
Precaudal Group 3	10	7	2	0	5
Caudal Group 4	19	19	8	4	3
Caudal Group 5	10	8	7	6	2

The final patterning apparent in the assemblage after 375 paces is of interest. This consisted of a small number of cranial elements, a few anterior vertebrae and a few extreme caudal centra. The cleithrum and almost all the trunk vertebrae were absent at 375 paces. If such an assemblage were recovered from an archaeological site it could be interpreted as the remains of a fish which had been decapitated and had its tail removed prior to being transported elsewhere. Such an interpretation would be in error. If account is taken of which bones survive and their robustness, it is clear that the assemblage consists entirely of robust bones, and that decay processes are as likely as human action to have produced the assemblage.

These experiments show that some elements are more resistant to trampling and other mechanical damage than others and illustrate how elements fragment into several identifiable pieces. By using the results it is possible to assess whether archaeological remains are well preserved or poorly preserved. This is a vital prerequisite to interpreting fish remains. For well preserved assemblages can be interpreted with much greater confidence than poorly preserved ones.

3.4 FISH REMAINS DEPOSITED BY ANIMALS OTHER THAN HUMANS

Human beings are assumed to be responsible for the accumulation of most assemblages of fish remains recovered from archaeological sites. However, other animals also cause fish remains to be incorporated into archaeological deposits. At sites close to large fish populations, both inland or coastal, birds and other piscivores can drop fish bones, which may then be mixed with human occupation debris. Birds, seals and otters often deposit bones at selected locations and local concentrations of fish and other animal remains can accumulate. In an attempt to investigate which fish remains may be deposited by seabirds and otters limited amounts of recent material were collected and examined in order to determine the species and size of fishes taken by piscivores.

Accumulations were collected from a small island in Millport Harbour, Gt. Cumbrae in the Firth of Clyde, Scotland. An area of limestone roughly 20 square metres in extent produced the assemblage of fish bones listed in Table 9. It was dominated by bones and otoliths of gadid fishes. Observations of the site showed it to be used by gulls, Laridae, the bones being the more resistant parts of regurgitated pellets.

The assemblages, which were hand collected, also contained a number of small (maximum centrum width 4.8 mm) gadid vertebrae and other gadid skeletal elements.

Eight otter spraints were collected from a prominent stone located on Freswick beach where Freswick Burn ran into the sea during the period 24th August, 1982 until the 8th September, 1982. The spraints were washed on a 500 um aperture meshed sieve and were identified. Table 10 lists selected elements found in these droppings.

These two studies demonstrate that identifiable fish bones of species commonly exploited by human groups are present in faeces and pellets of other animals. Other potential sources of fish bones in the archaeological deposits include remains of fishes scavenged by dogs at the seashore, bones from other piscivorous animal faeces, and bones and otoliths of dead fishes blown onto the site during storms.

Table 9. Selected fish remains collected from gull pellets on Outer Eilean, Millport, Gt Cumbrae, collected during July 1983 and May 1984.

Element	Number	Measurement/size of fish	Determination
Cleithra	8	300-350 mm TL	Gadidae indet
Supracleithrum	1	300-350 mm TL	Melanogrammus aeglefinus (haddock)
Otolith	33	min width 3.3 max width 4.2	Trisopterus ?luscus (?bib)
	1	11.2 x 4.7	Gadus morhua (cod)
	1	10.9 x 4.8	"
"	1	width 4.6	? Merlangius merlangus (whiting)
"	3	width 3.7	Pollachius sp
"	3		Gadid indet.
Dentary	1	3.1, 3.7	Pollachius virens
"	1	2.5, 2.6	" (saithe)
"	1	- 3.1	Pollachius sp.
"	1	2.6, 2.6	Gadus morhua
"	1	2.7, 1.8	Trisopterus luscus
"	1	2.2, 2.0	" "
Premaxilla	1	3.4	Trisopterus sp.
"	1	4.8, 2.8	Gadus morhua
"	4	c. 300-400 mm TL	Gadidae indet
Maxilla	2	c. 600 mm TL	Merluccius merluccius (hake)
Dentary	1	c. 700 mm TL	Conger conger (conger eel)
Vertebrae	12	3.4 mm	Clupea harengus (herring)
Precaudal vertebra	1	7.1	Mugilidae
Caudal vertebra	1	4.8	Pleuronectidae (flatfish)

Measurements are in millimetres. Dentary, otolith and premaxillae with 2 measurements are those taken on archaeological specimens (see Chapter 2). Vertebral measurements are the maximum width of the articulating surface of the centrum.

Table 10. Fish remains recovered from otter spraints

Element	Number	Measurement	Determination
Premaxilla	5	1.2 mm	Ciliata mustela (5 bearded rockling)
Maxilla	2		Anguilla anguilla (eel)
Dentary	2	7.8 mm	"
Fin spine	5		Gasterosteus aculeatus (stickleback)
Premaxillae	2	1.1 mm	Pholis gunnellus (butterfish)
Dentary	2		"

Chapter 4

THE RELATIONSHIP BETWEEN FISH LENGTH AND ELEMENT SIZE

4.1 GROWTH OF FISHES

It has long been known that the size of fish bones, otoliths and scales can be used, with differing degrees of accuracy, to estimate the length or weight of the whole animal because fishes, like most organisms, grow allometrically (Imbrie, 1956). This kind of growth pattern can be closely approximated by the following equation:

$$y = bx^a$$

where y and x stand for the measured variables e.g. fish total length and otolith length respectively, and a and b are mathematical parameters that take on particular values for different curves. Fisheries biologists, palaeontologists and other zoologists frequently make use of the relationship between bone, scale and otolith size and fish length to gain data for managing fish stocks (Templeman and Squires, 1956; Carlander, 1969; 1977, and Blacker, 1974) and to investigate the prey of piscivorous predators (Mann and Beaumont, 1980; Härkönen, 1986).

The relationship between length and weight is also allometric and can be expressed as follows:

$$W = aL^n$$

W = weight; a is a constant for each measurement of each species; L = length; n is an exponent which varies between 2.4 and 4, but is usually 3. Thus, as the fish grow they increase in weight roughly to the cube power of their length.

4.2. REVIEW OF WORK ON ARCHAEOLOGICAL FISH REMAINS

In recent years similar studies have been published as part of reports on archaeological material. The value of these studies is that they can be used to calculate the size of ancient fishes from archaeological specimens, assuming accurate measurements can be taken from the ancient material.

The earliest studies assumed that the relationship between bone size and fish size was linear and directly proportional, but it became apparent that other forms existed including: linear but not directly proportional ($y = a + bx$); curvilinear ($y = ax^b$) which can be transformed logarithmically to a straight line ($\log y = \log a + b \log x$); and sigmoid in which the relationship varies at different stages of life.

Estimating the size of fishes from measurements of ancient bones can be achieved in several ways. The quickest and simplest way is to compare archaeological specimens with bones from a fish of known size. In its crudest form the archaeological bones can be said to be from fish larger or smaller than the size of the bones of a modern comparative specimen. A refinement is to compare archaeological bones with two or preferably three modern specimens of different sizes, say large medium and small individuals. Thus it is possible to determine if the ancient fishes were large, medium or small. The value of this approach is its simplicity, speed and the need for relatively small amounts of modern reference material. The information obtained may not be as accurate as that theoretically possible, but in practice it is usually adequate. Van Neer (1986) used this approach to examine the sizes of fish from Wadi Kubbaniya, a Late Palaeolithic site in Upper Egypt, while Colley (1983b) and Jones (1984b) used it while examining fish bones from Orkney sites and Freswick Castle respectively. Estimating fish size by eye is appropriate where small assemblages of poorly preserved bones are present. The method has the advantages of being rapid and requiring only a few modern reference specimens of each species.

There are, however, archaeological assemblages which warrant detailed study, and here regression analysis is the most appropriate technique to use in fish size estimation. Casteel (1976) discussed the five methods used in archaeological research to estimate animal size or weight. The methods were:

1) single regression
2) double regression
3) the proportional method
4) White's method
5) Cook and Treganza's method

Single regression uses bone size as the independent variable (X) and fish size as the dependent variable (Y). Plotting X against Y usually results in a curvilinear relationship between the two variables. This can be straightened by logarithmic transformations of the raw data and the application of simple linear regression techniques. Least squares regression was used as it minimizes the sum of squares of the vertical distances from the data points to the fitted regression line.

The double regression method also uses the regression equation. It is used when attempting to estimate weight by using fisheries data. Thus regression analysis is first used to acquire estimates of fish length, these data are then regressed with modern fisheries data to estimate fish weight. Clearly such a procedure compounds errors.

The proportional method assumes that there is a linear proportional relationship between bone size and fish size. Data presented in section 4.4. show that for the bones and species considered in this study such an assumption cannot usually be made.

Both White's, and Cook and Treganza's methods were not designed to make estimates of fish size from individual elements. They are used to determine meat weight from bone data by using a single value which represents the 'average size' of an individual of a particular species. Estimating the 'average size' clearly is the weak point of these methods.

It is hardly surprising that Casteel concluded that the best of the five methods is the single least squares regression analysis (possibly better described as simple regression using one predictor variable) for it requires only a single regression equation for each bone of each species and it is highly accurate. This method has been widely adopted by archaeozoologists studying fish remains.

4.3. A REVIEW OF WORK ON MODERN SPECIMENS

4.3.1. Studies on Fish Bones

Size estimation is most accurate if a large number of modern specimens of the species is available for study; 30 has been suggested as a standard by Desse (1984). The modern fishes should be selected to represent the exploited size range of each species and to include sufficient bones to take account the natural variation in bone size for the species. For some species it may be necessary to measure the bones of rather more than 30 specimens if there is considerable variation in bone size.

In recent years several modern studies showing the relationship between fish bone size and fish size (usually length) have been published. These investigations can be divided into two groups: those which simply plot a graph showing the relationship between bone size and fish length; and those which use least squares regression analysis to describe this relationship.

Studies of the fish length/bone size relationship by simply drawing a best fit line by eye include a small group (10) of cod, Gadus morhua, dentaries and premaxillae studied by Wheeler and Jones (1976), small-mouthed wrasse, Centrolabrus exoletus, pharyngeal bones by Wheeler (1979a) and opercular bones of the sardine, Sardina pilchardus, studied by Wheeler and Locker (1985).

A detailed example of an investigation showing the relationship of bone size and fish length is given by Desse (1984) for Salpa salpa, the sarp. In this account clear illustrations are given showing the measurement points of several bones and plots showing the linear relationship between bone size and fish length are also presented. Desse, Desse-Berset and Rocheteau (1987a) examined the bones of 22 perch, Perca fluviatilis and gave a detailed account of the relationship of fish and bone size for this species. Other species for which published examples relevant to archaeological material include Liza ramada (Desse, et al, 1987) and Lates niloticus (Van Neer, 1989).

Examples using simple linear regression analysis include a study of the first vertebra of the herring, Clupea harengus, (Höglund 1972); pike, Esox lucius, dentaries by Noe-Nygaard (1983); cod, Gadus morhua, and whiting, Merlangius merlangus, first vertebrae by Enghoff (1983); and the ultimate vertebra of the Sacramento squawfish, Ptychochelus grandis, (Casteel 1976). Rojo (1986) explored the relationship between fish length, dressed (gutted) weight, and round (total live) weight and measurements on 10 bones (premaxilla, dentary, maxilla, hyomandibular, articular, quadrate, opercular, preopercular, cleithrum and postcleithrum) of the cod. He showed that there was no statistically significant difference between bone size of male and female fishes. Regrettably, some of the bone measurements suggested by Rojo are impractical for archaeological specimens because few are sufficiently complete in archaeological assemblages.

Heinrich (1987) used linear regression analysis on logarithmically transformed data to determine the length of the following elements: pike, Esox lucius, dentaries and cleithra; roach, Rutilus rutilus, infrapharyngeal; tench, Tinca tinca, operculars; bream, Abramis brama, operculars and preoperculars; cod, Gadus morhua, operculars, dentaries, cleithra and precaudal vertebrae; perch, Perca fluviatilis, from operculars, preoperculars and cleithra. Archaeological specimens were recovered from excavations at Schleswig, Germany. Brinkhuizen (1989) employed linear regression on raw data and logarithmically transformed data to investigate the relationship between bone measurements fish length and fish weight. He studied the preopercular, opercular, infrapharyngeal, supracleithrum, cleithrum, and basipterygium of bream, Abramis brama; preopercular, opercular, infrapharyngeal, and cleithrum of rudd, Scardinius erythrophthalmus; the preopercular, opercular, infrapharyngeal, and cleithrum of roach, Rutilus rutilus; the mesethmoid, frontal, first vertebra, and cleithrum of wels catfish, Siluris glanis; parasphenoid, basioccipital, dentary, articular, preopercular, quadrate, palatine, ceratohyal, cleithrum of pike, Esox lucius; parasphenoid, basioccipital, prevomer, first vertebra, preopercular, opercular, post temporal, supracleithrum, cleithrum and basipterygium of perch, Perca fluviatilis; and the first anal pterygiophore (os anale), caudal vertebra, and preopercular of plaice, Pleuronectes platessa, flounder, Platichthys flesus, and dab, Limanda limanda.

While these studies are of value as they provide some objective evidence of the size of the fishes they do not give statistically calculated confidence or prediction intervals to allow others to use the data for size estimation with accuracy.

4.3.2. Studies on Sagittal Otoliths

Härkönen (1986) provided confidence intervals in his study of otoliths of northern European marine fishes, however as he was interested in the fishes taken by seals, he rarely examined fishes larger than 60 cm total length. He tested four models on data gathered from modern otoliths of 103 species fishes of the most common species in the north east Atlantic. These models were as follows:

1. Linear	$y = a + bx$
2. Power	$y = a\ x^b$
3. Exponential	$y = a\ e^{bx}$
4. Log	$y = a \ln x - b$

where y = fish length or weight
x = otolith length
a and b are constants.

In choosing which model to adopt for each analysis he considered the value of the coefficient of determination (r^2), the shape of the curve relative to the data points (judged by eye as the best fit) and the width of the 95% confidence intervals (calculated as 1.96 standard deviations of the fitted values) for each model. He concluded that the power model gave the best result in about 90% of the data sets.

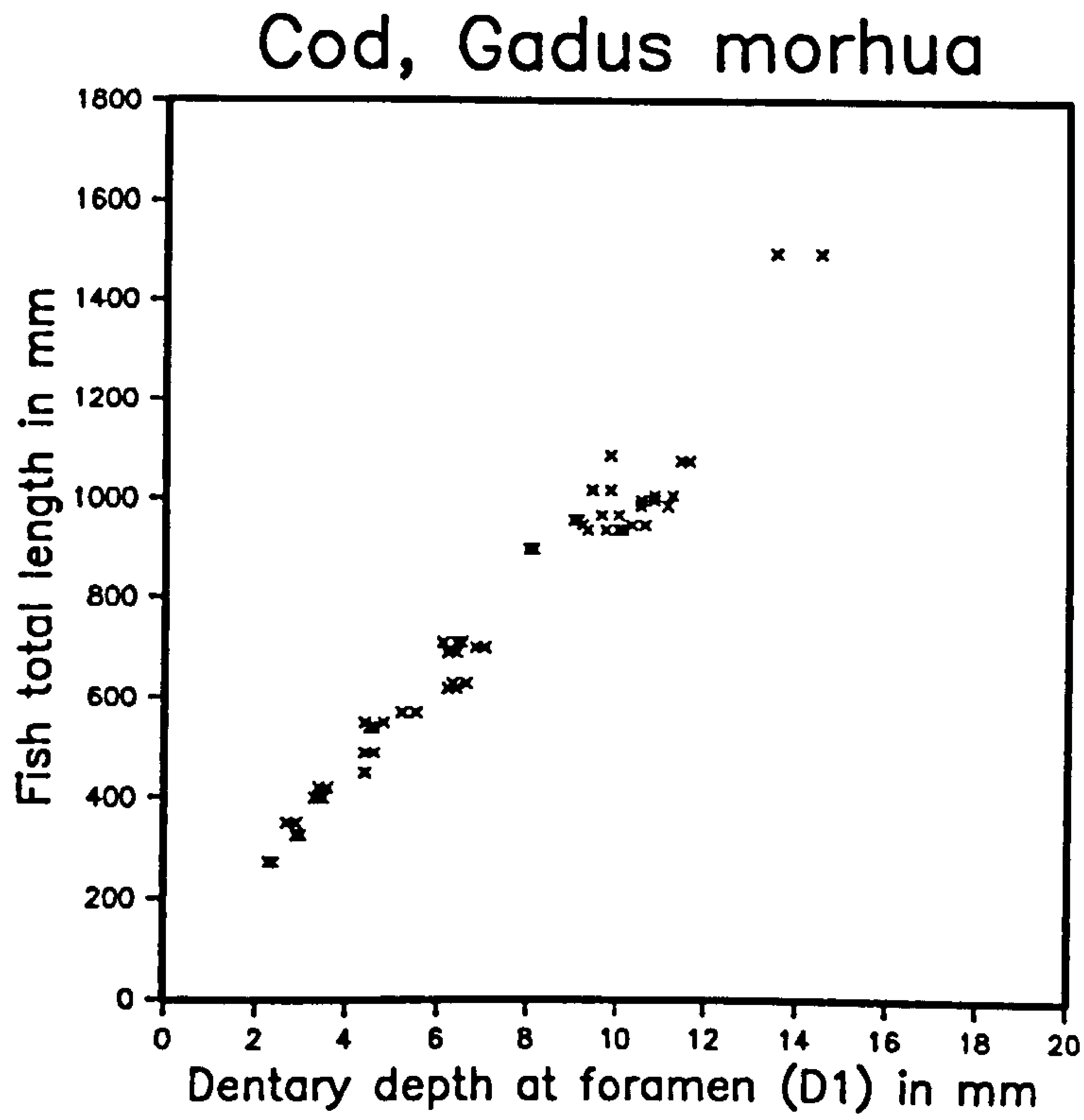
Most of the examples cited above (including Härkönen's extensive study) showed the relationship of element size to fish length for small to medium-sized individuals: the largest specimens of the species present at Freswick Links were rarely included. This is seen as a major limitation for two reasons. First, the bones and otoliths of large fishes are common in archaeological deposits. Second, the ratio of bone size and fish length is more variable in large animals. This phenomenon is described in statistical works as heteroscedasticity.

4.4. AN INVESTIGATION OF THE RELATIONSHIP BETWEEN FISH LENGTH AND ELEMENT SIZE IN SELECTED GADID FISHES

To investigate the relationship of fish length and element dimension measurements of cleithra, dentaries, premaxillae and otoliths of modern cod Gadus morhua, saithe, Pollachius virens, pollack, P. pollachius, haddock, Melanogrammus aeglefinus, and ling, Molva molva, were recorded from fish of known size. As archaeological assemblages frequently contain the remains of large individuals considerable efforts were taken to obtain large specimens. Using the element measurements as the predictor variable the measurements were plotted against the total length of the fishes. Figures 21-42 shows the relationship between element dimension and the total length of the modern fishes.

A classical (least squares) regression analysis was carried out on the raw data and the regression equations, multiple correlation coefficient (r), and the number of cases are given in Table 11. Three important results emerged from this work. First, it was clear that bone and otolith size was strongly correlated with fish total length (r usually >0.95). Second, large fish produce bones and otoliths which are more variable

Figure 21. Scatter diagrams showing the relationships of dentary measurements and fish total length for cod.



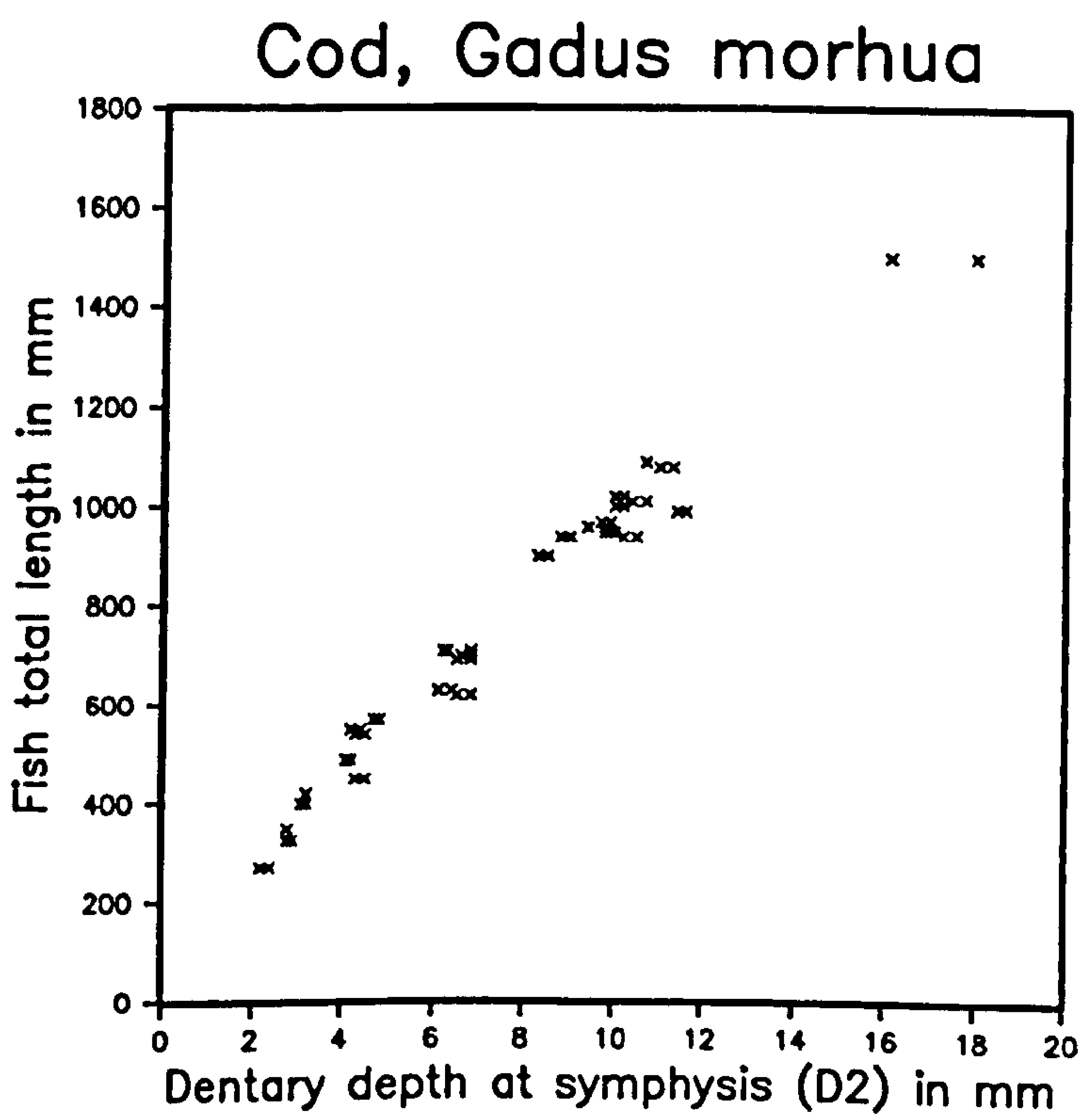
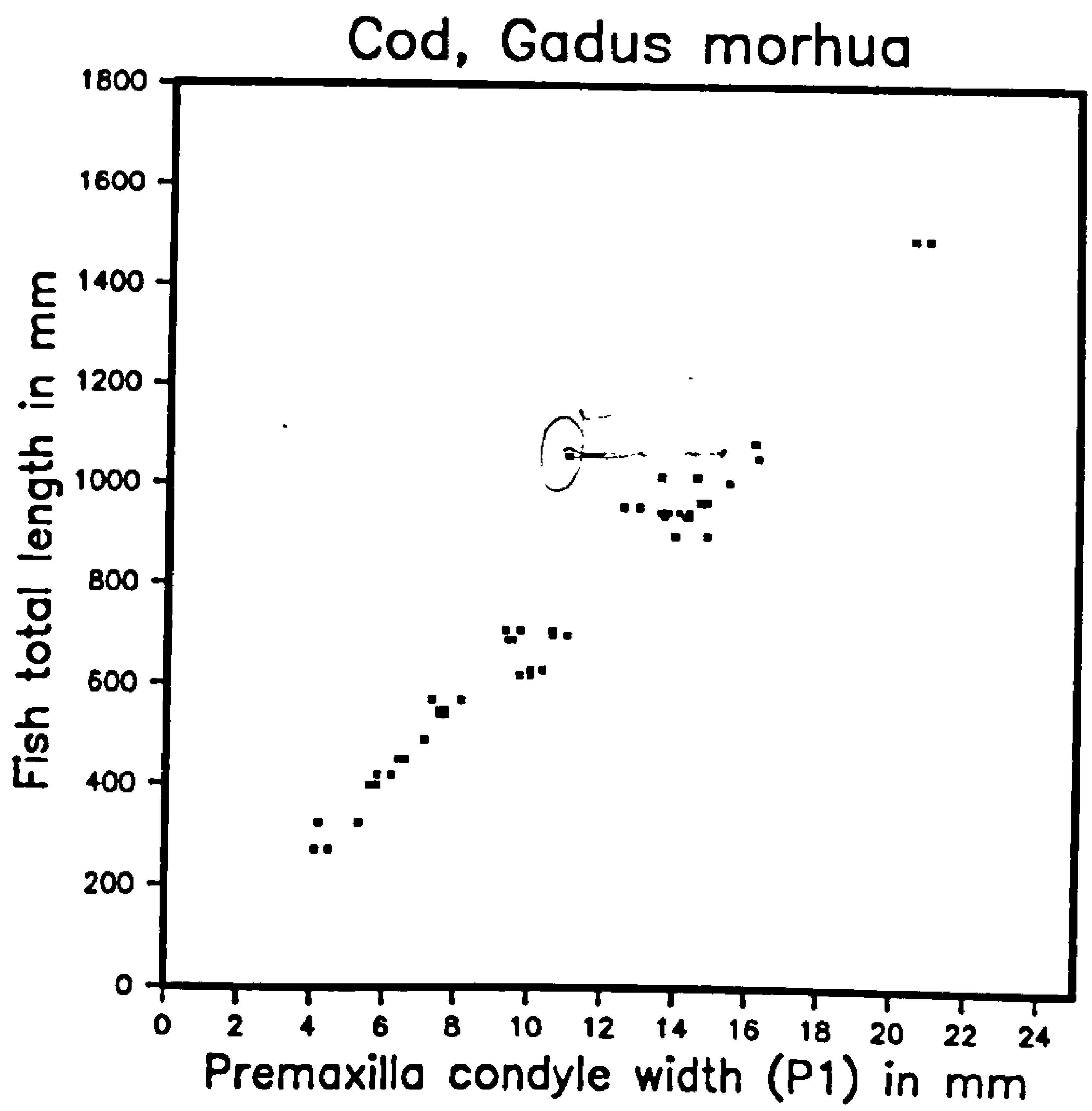


Figure 22. Scatter diagrams showing the relationships of premaxilla measurements and fish total length for cod.



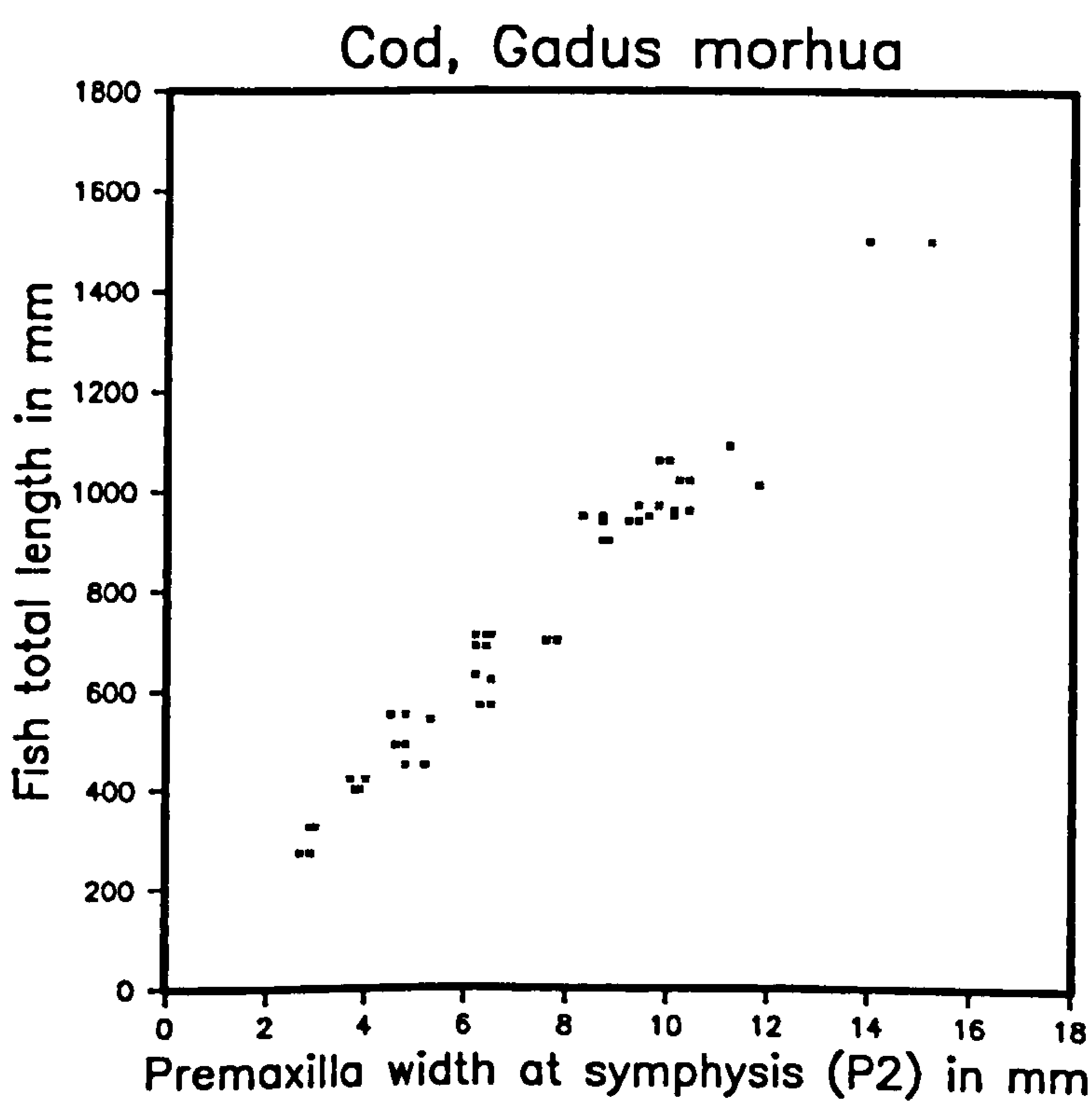
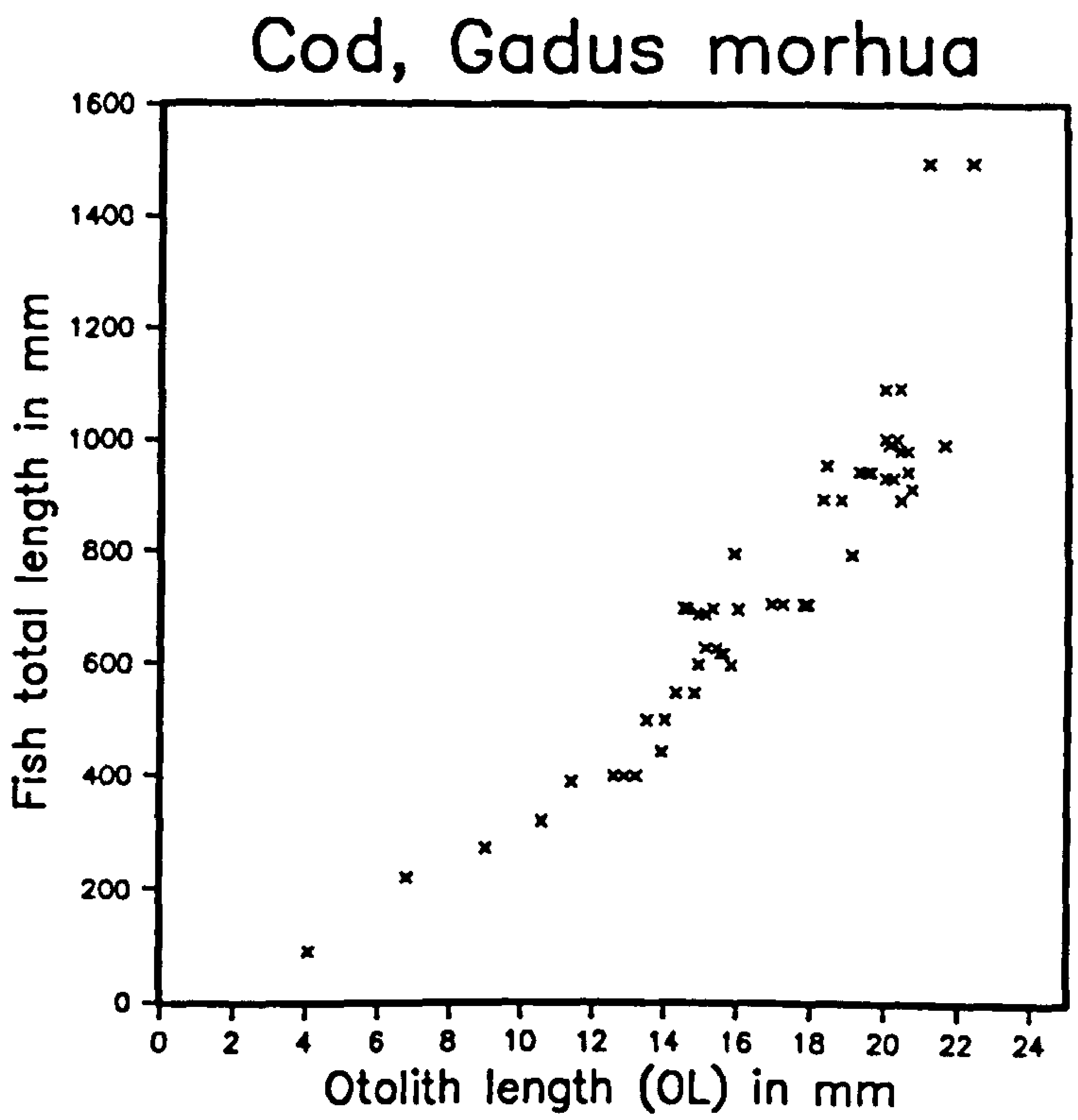


Figure 23. Scatter diagrams showing the relationships of otolith measurements and fish total length for cod.



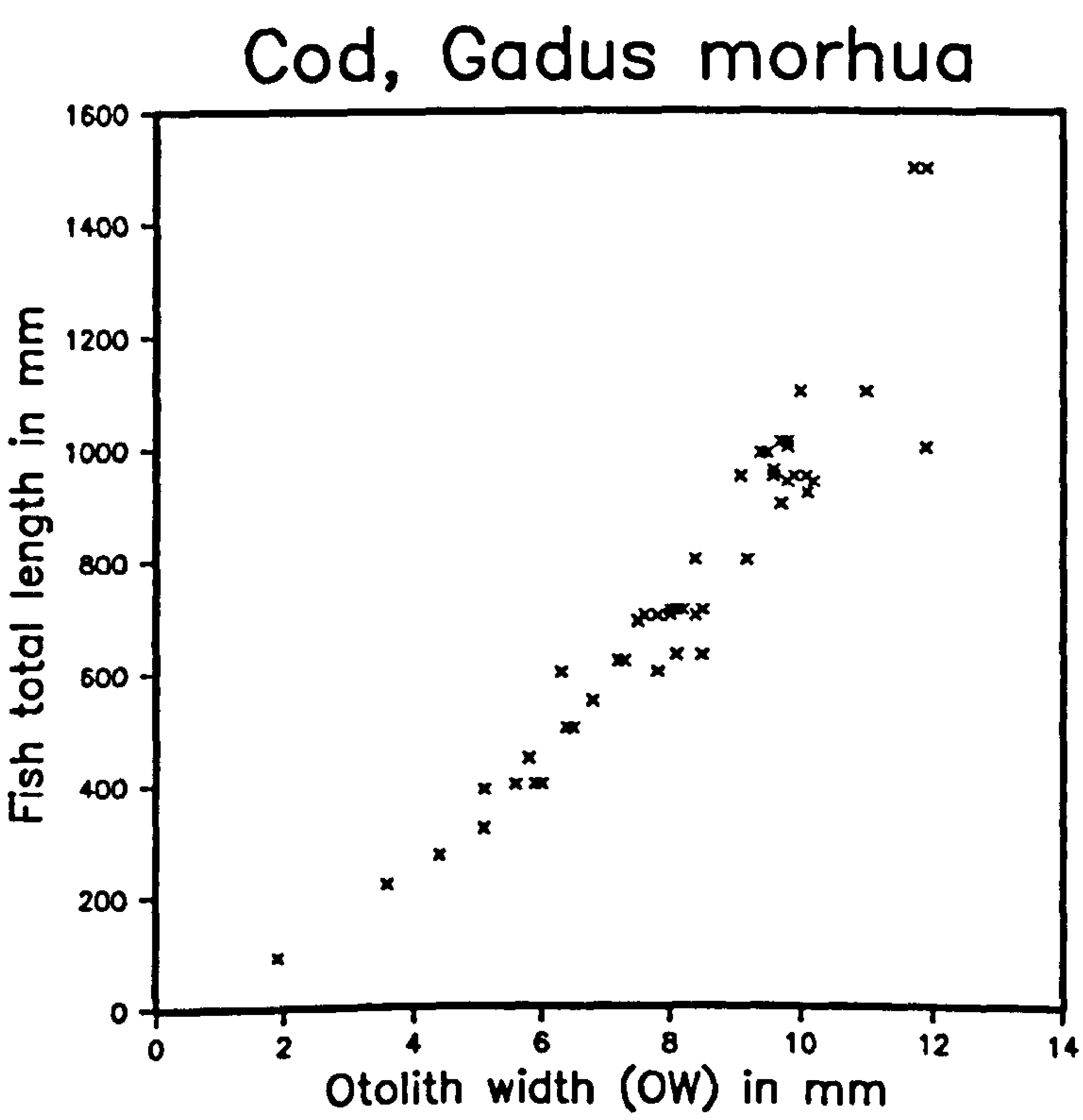
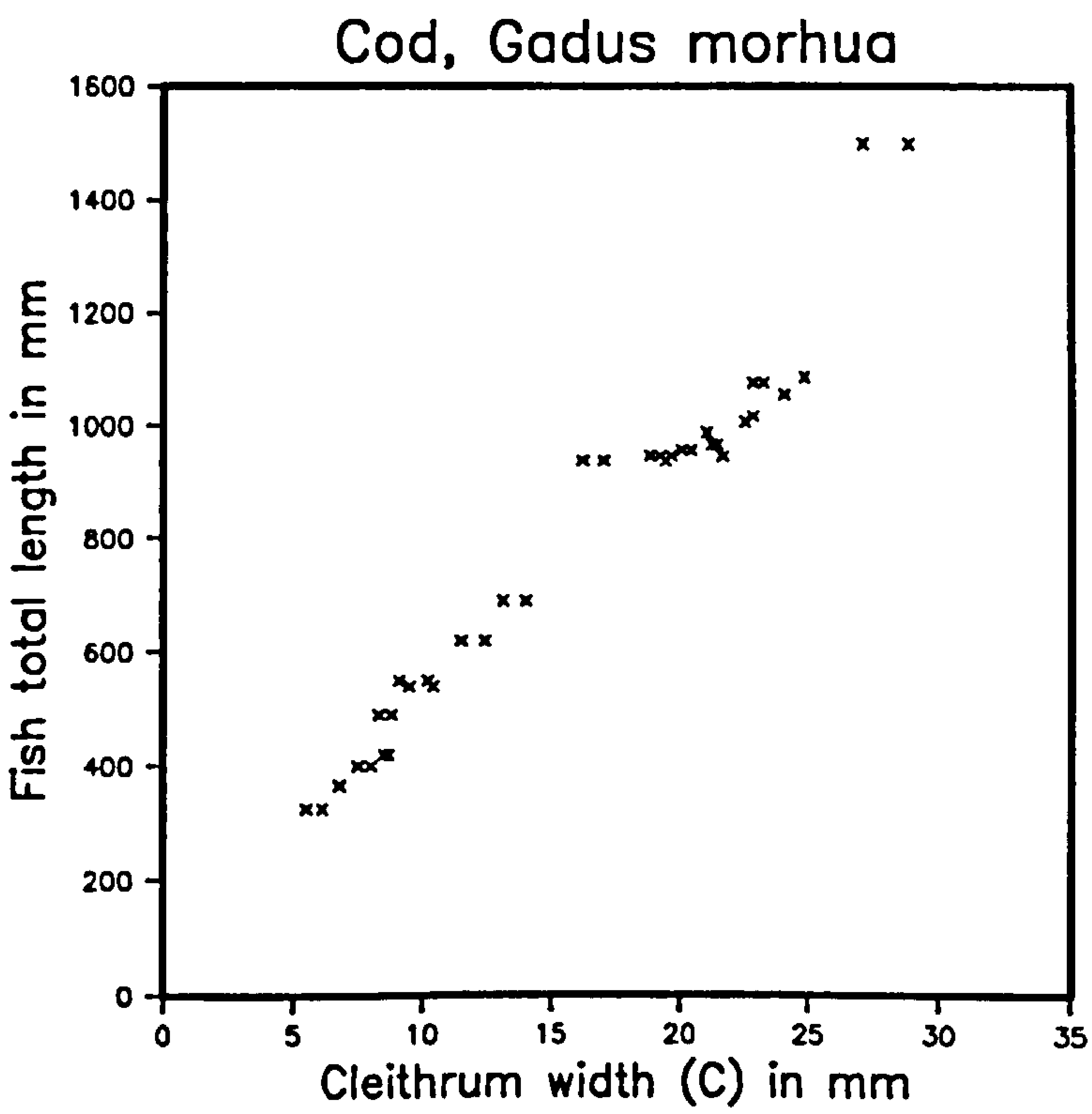


Figure 24. Scatter diagrams showing the relationships of cleithrum measurements and fish total length for cod and ling.



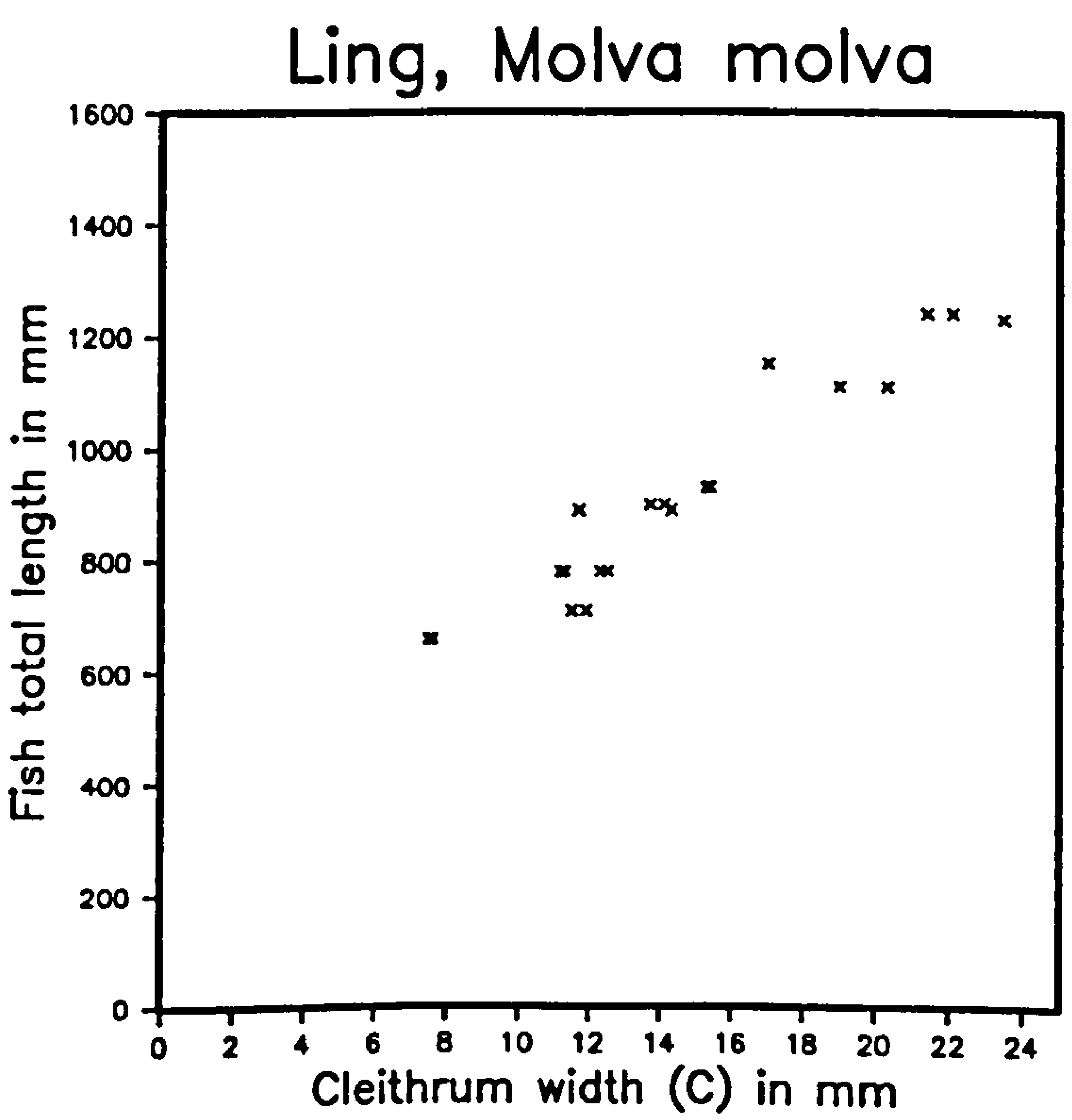
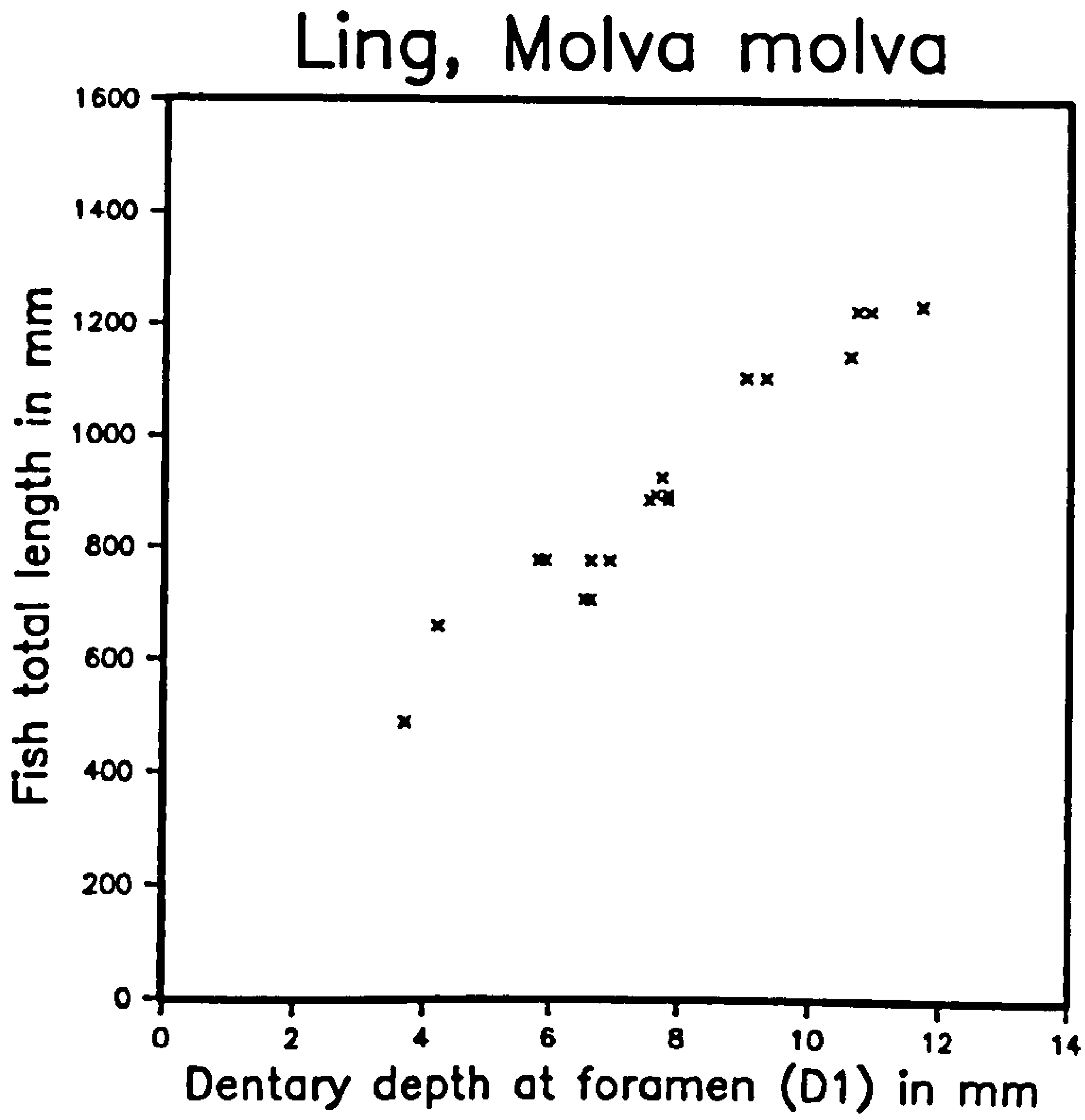


Figure 25. Scatter diagrams showing the relationships of dentary measurements and fish total length for ling.



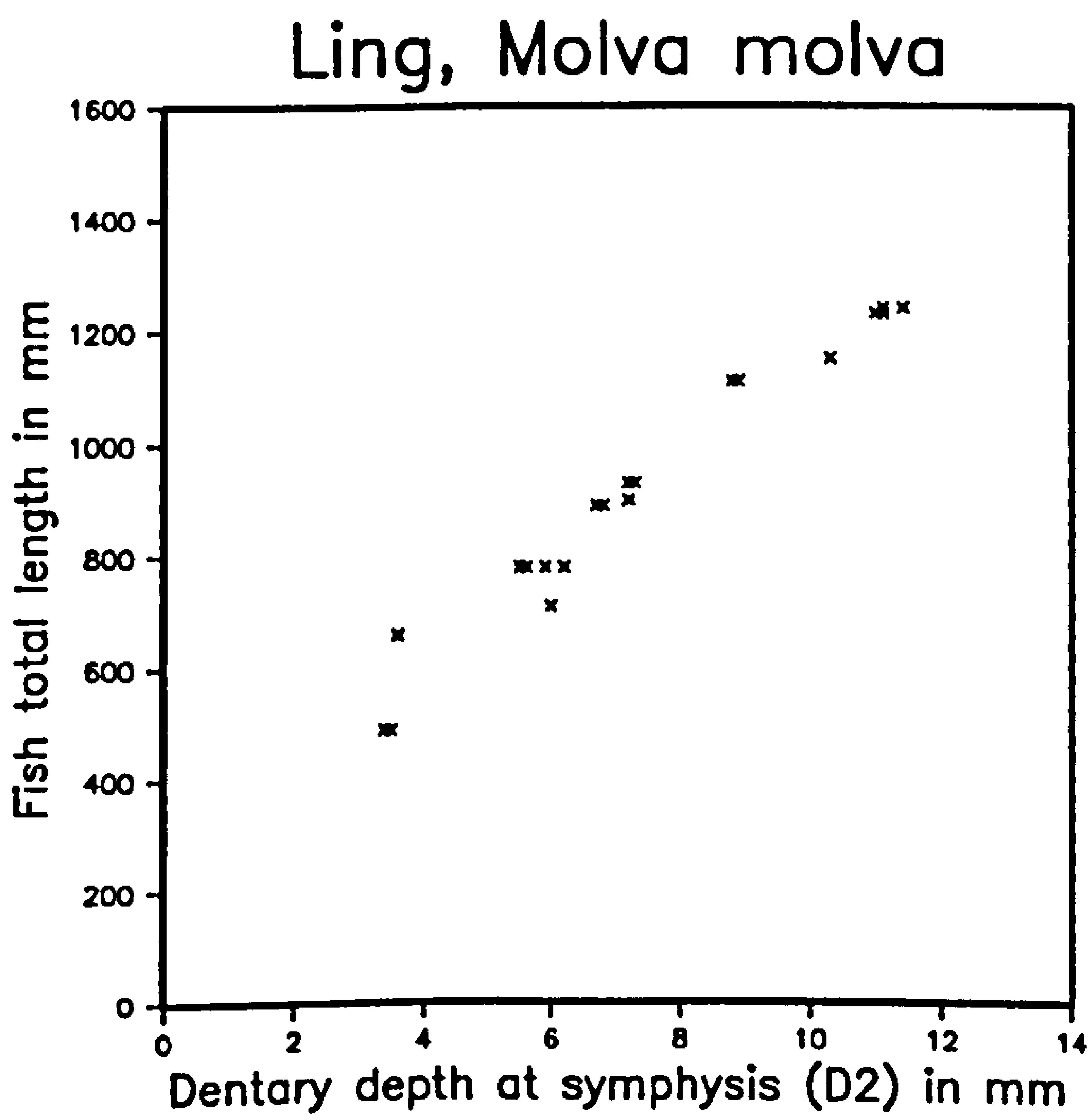
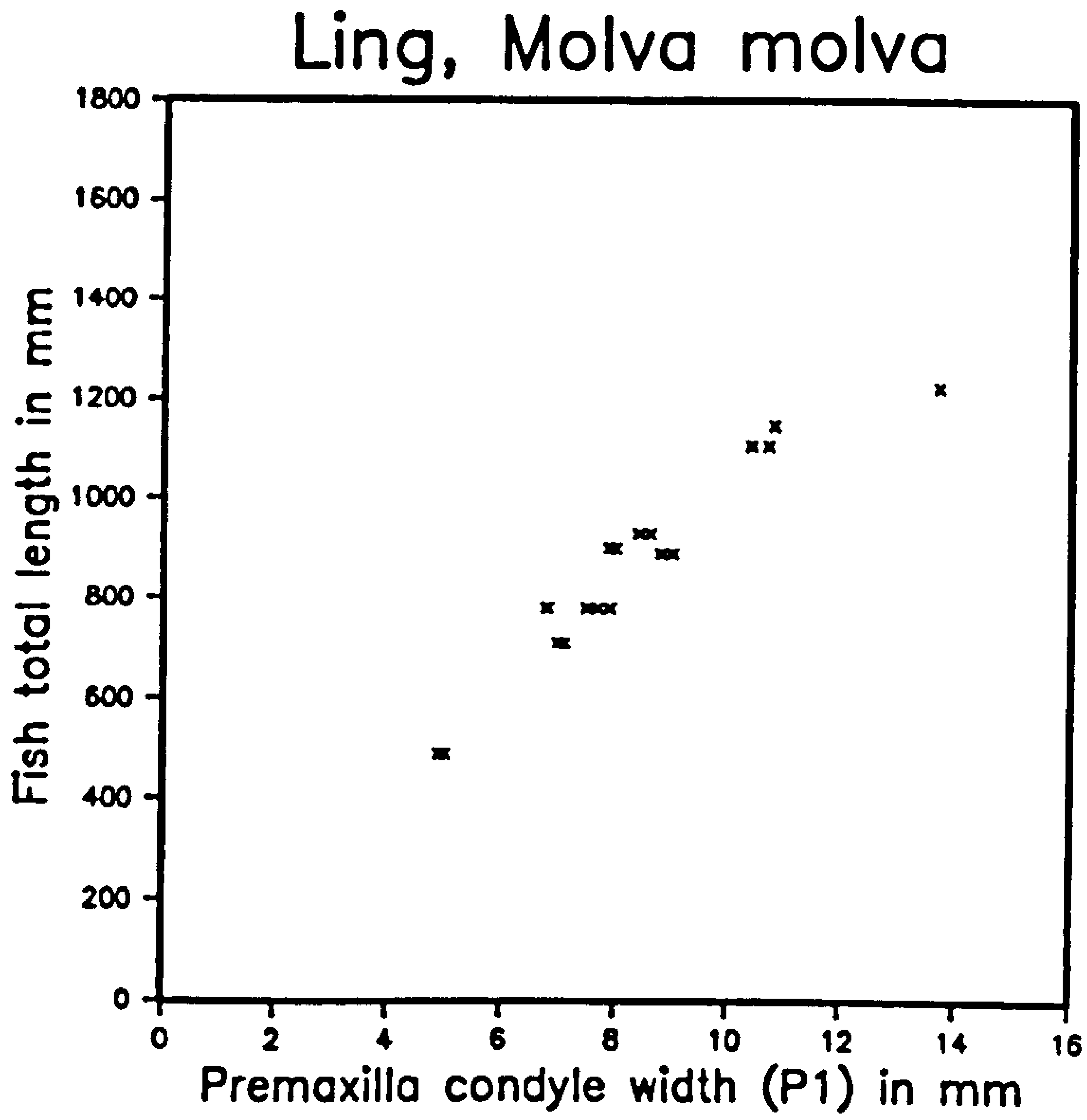


Figure 26. Scatter diagrams showing the relationships of premaxilla measurements and fish total length for ling.



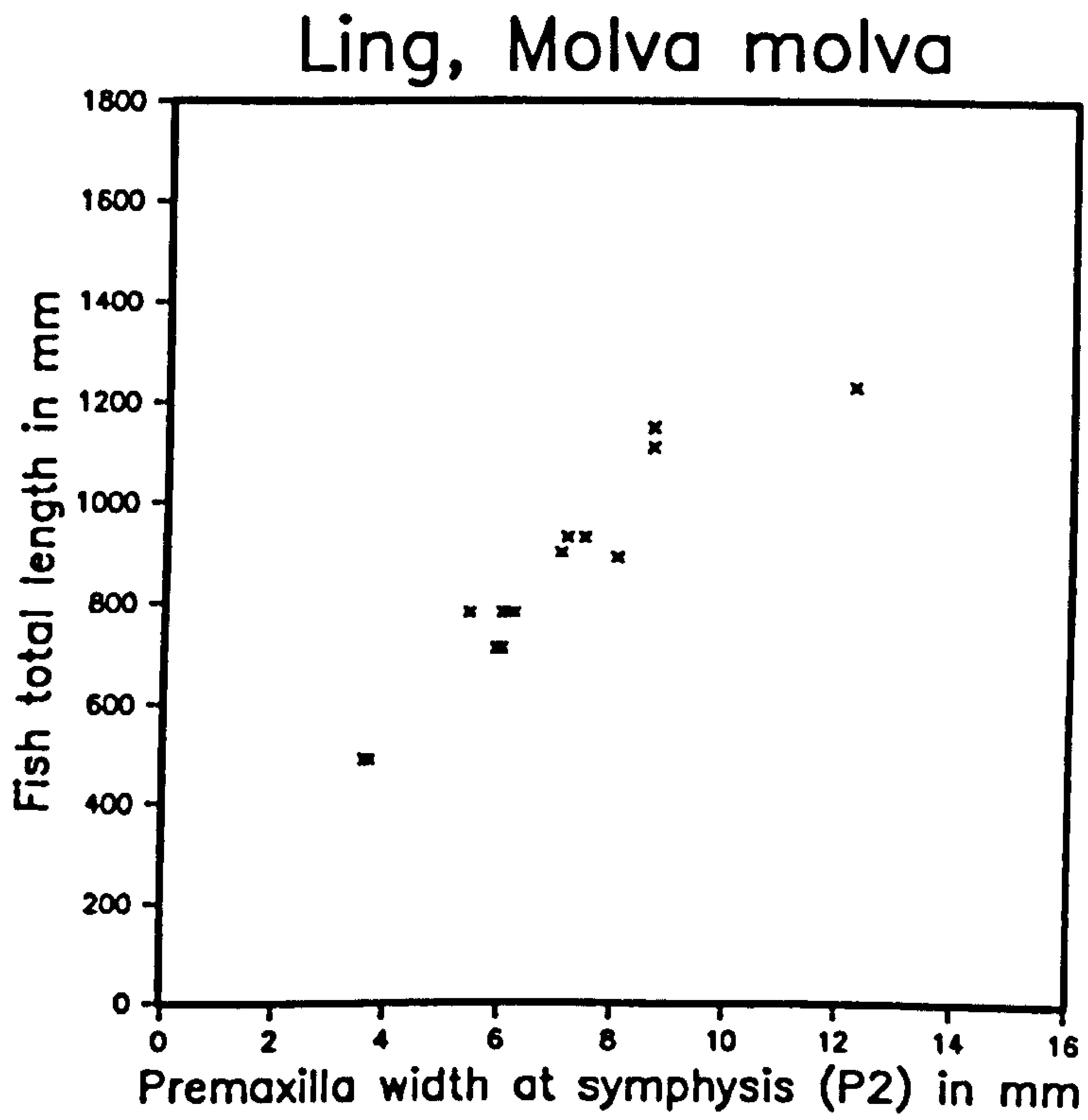
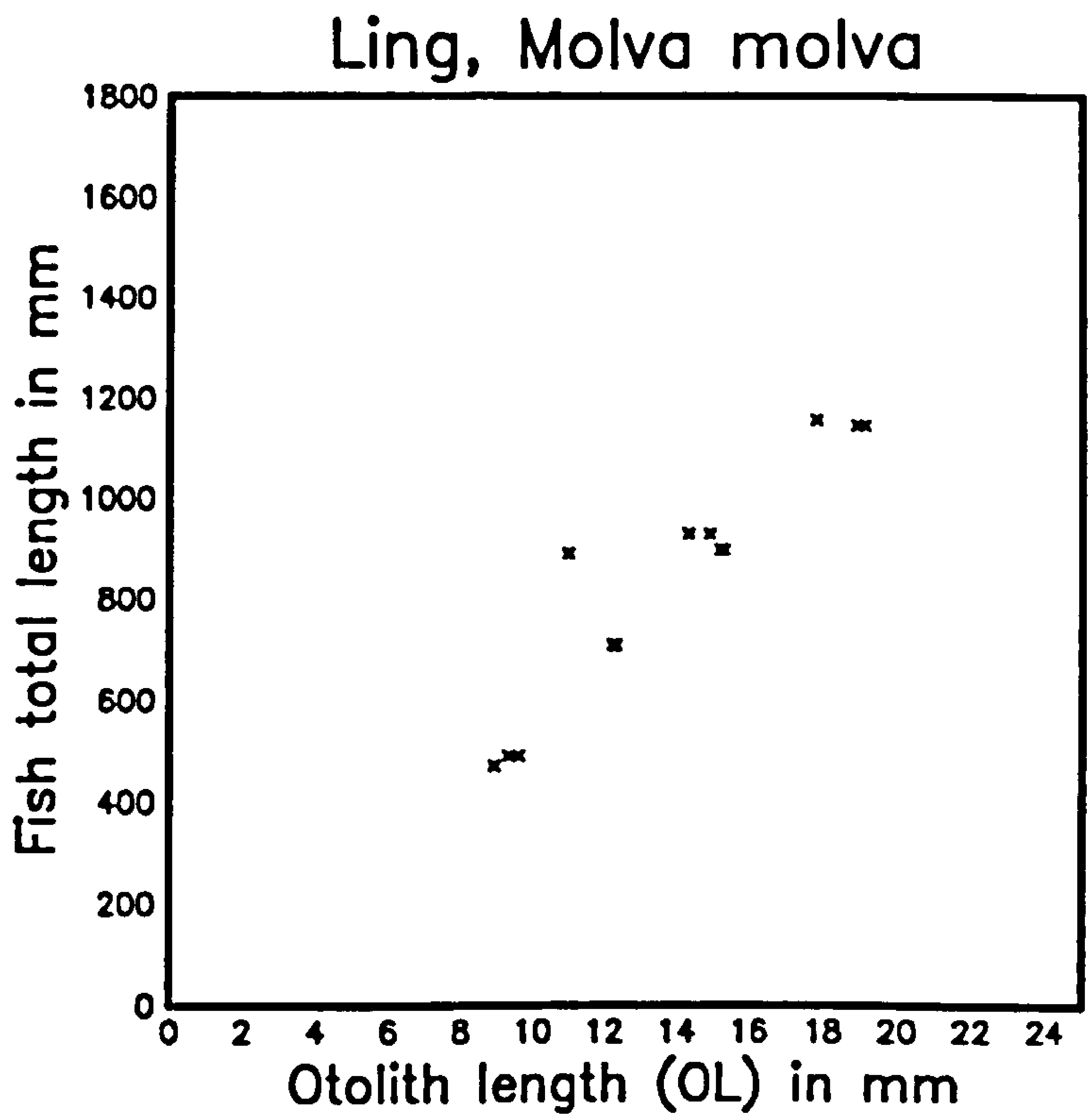


Figure 27. Scatter diagrams showing the relationships of otolith measurements and fish total length for ling.



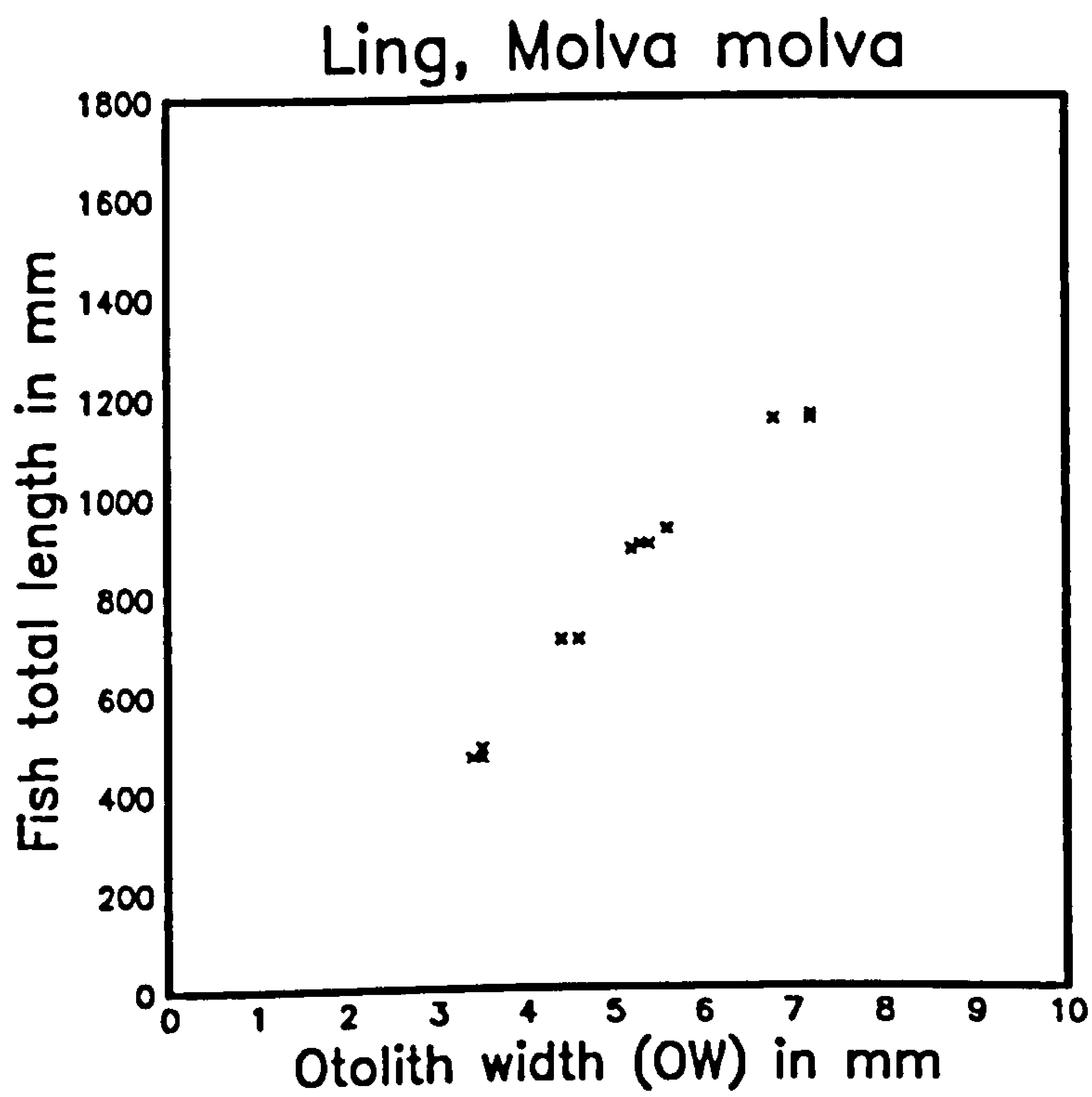
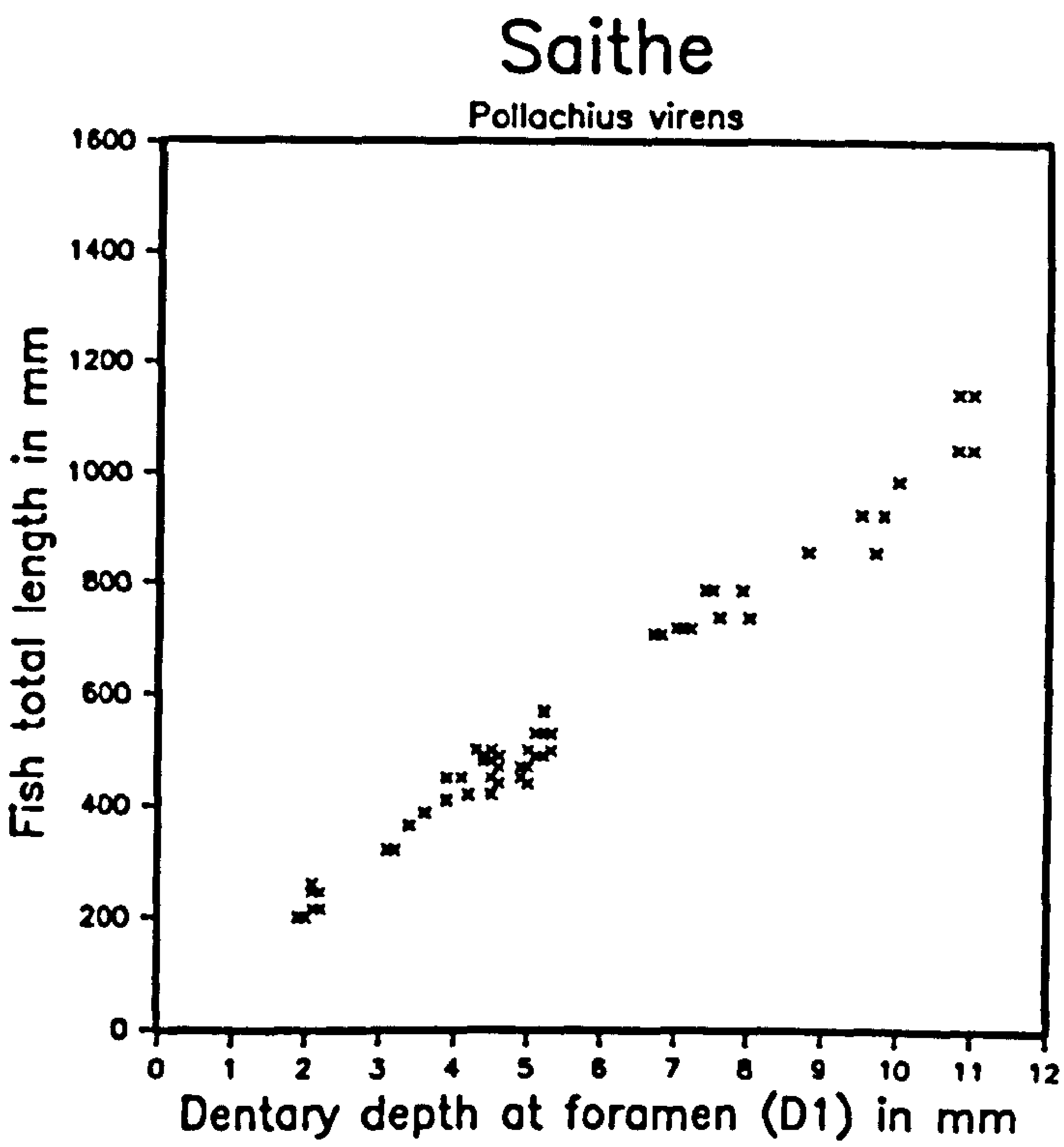


Figure 28. Scatter diagrams showing the relationships of dentary measurements and fish total length for saithe.



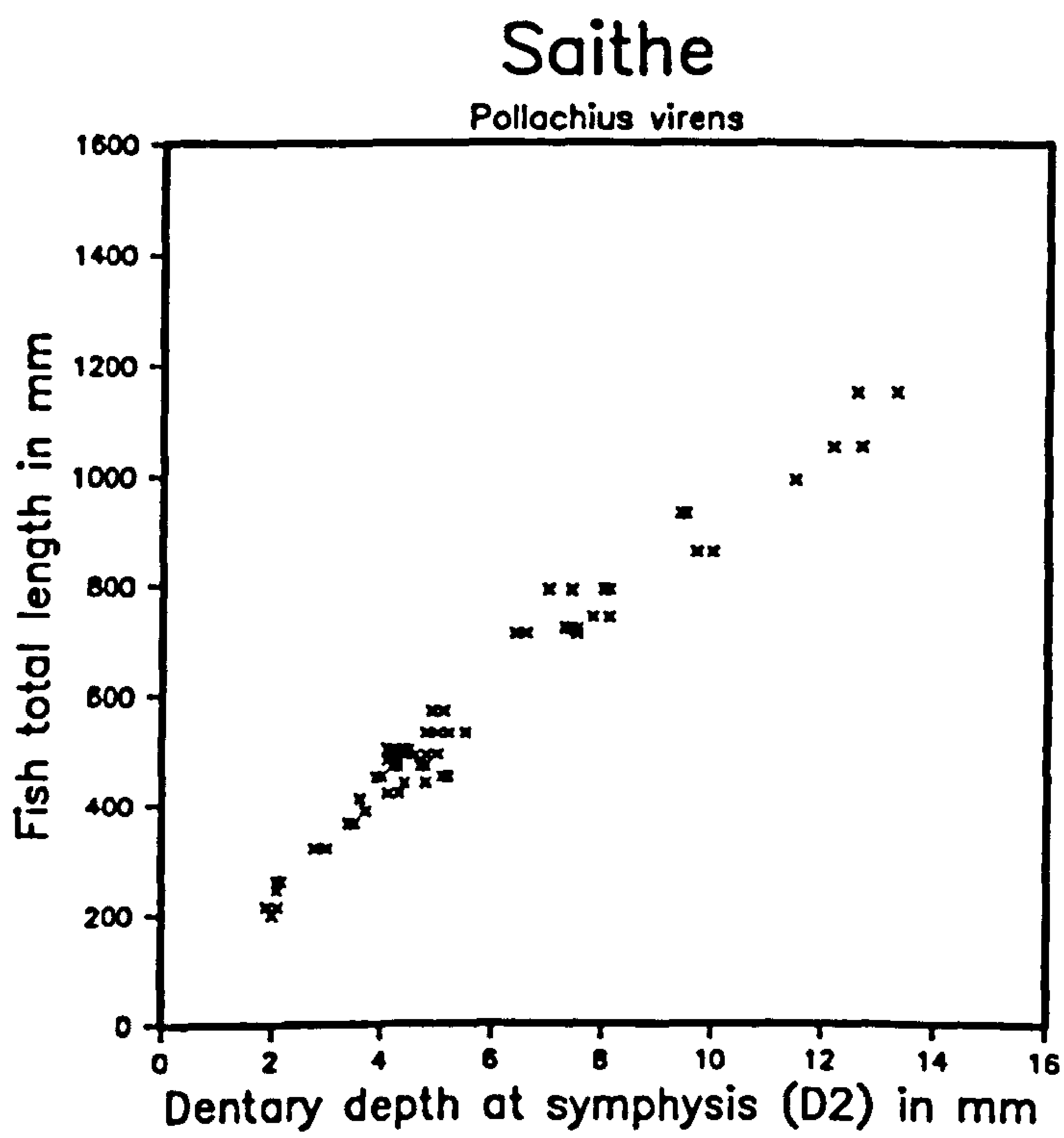
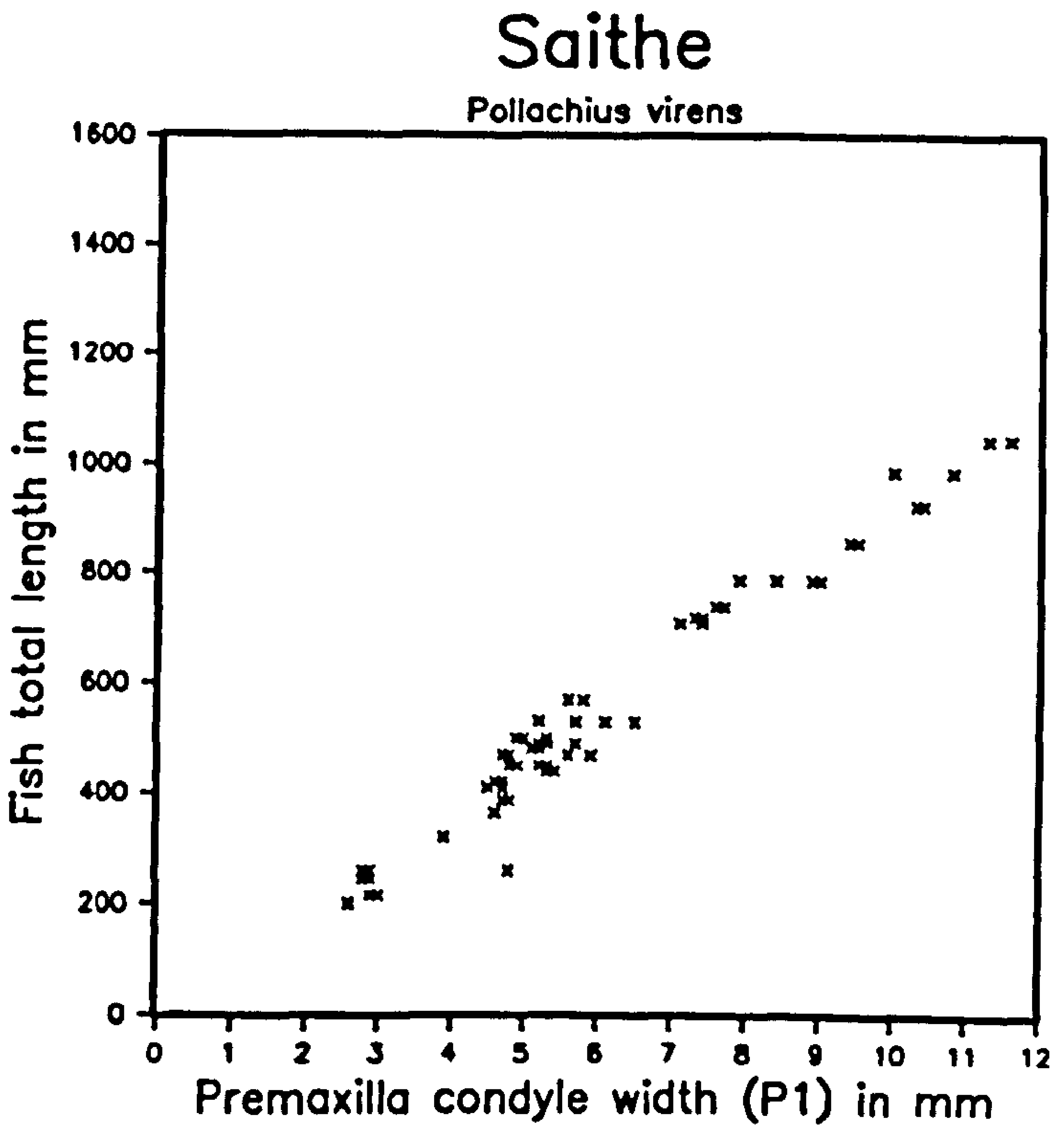


Figure 29. Scatter diagrams showing the relationships of premaxilla measurements and fish total length for saithe.



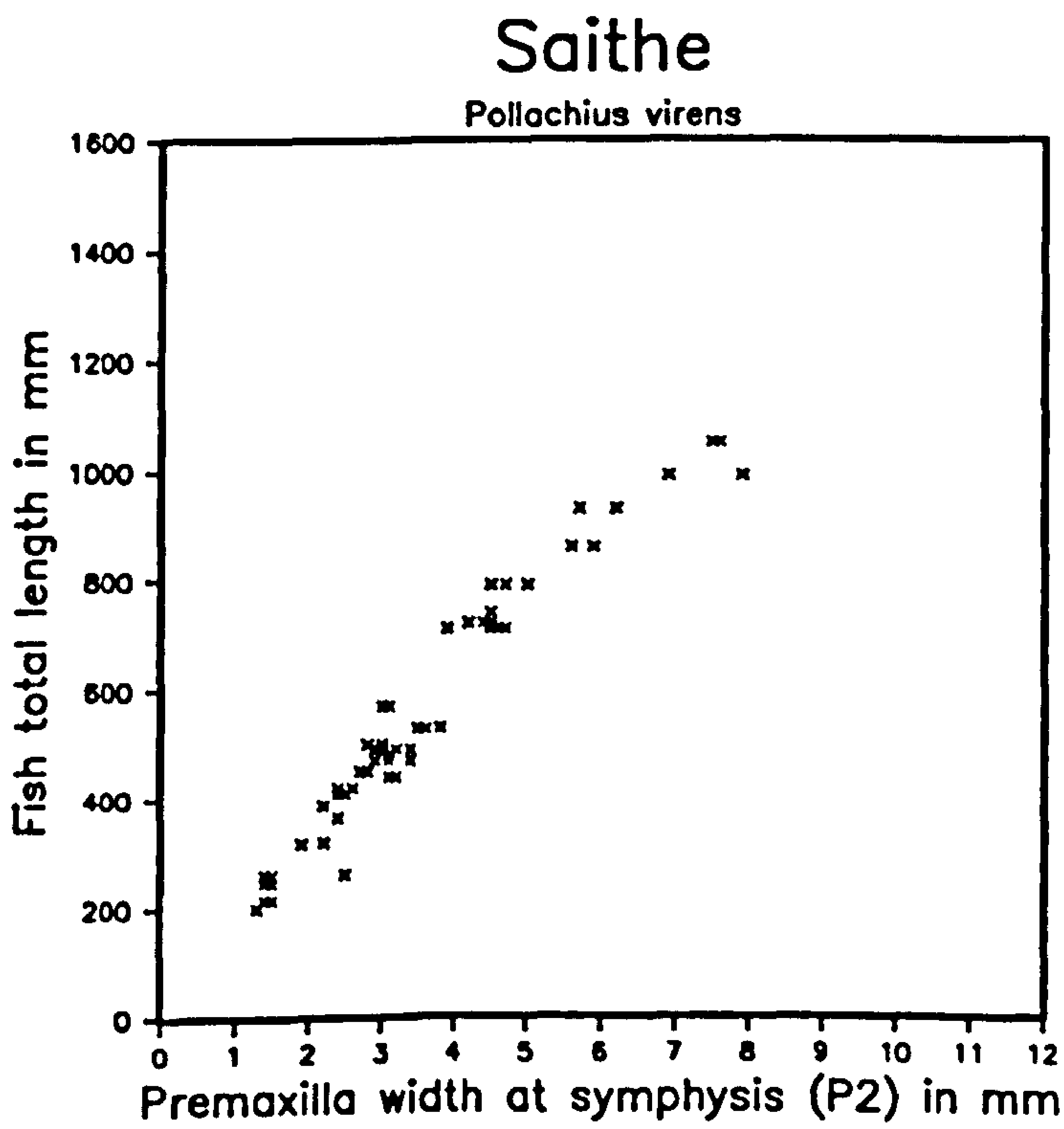
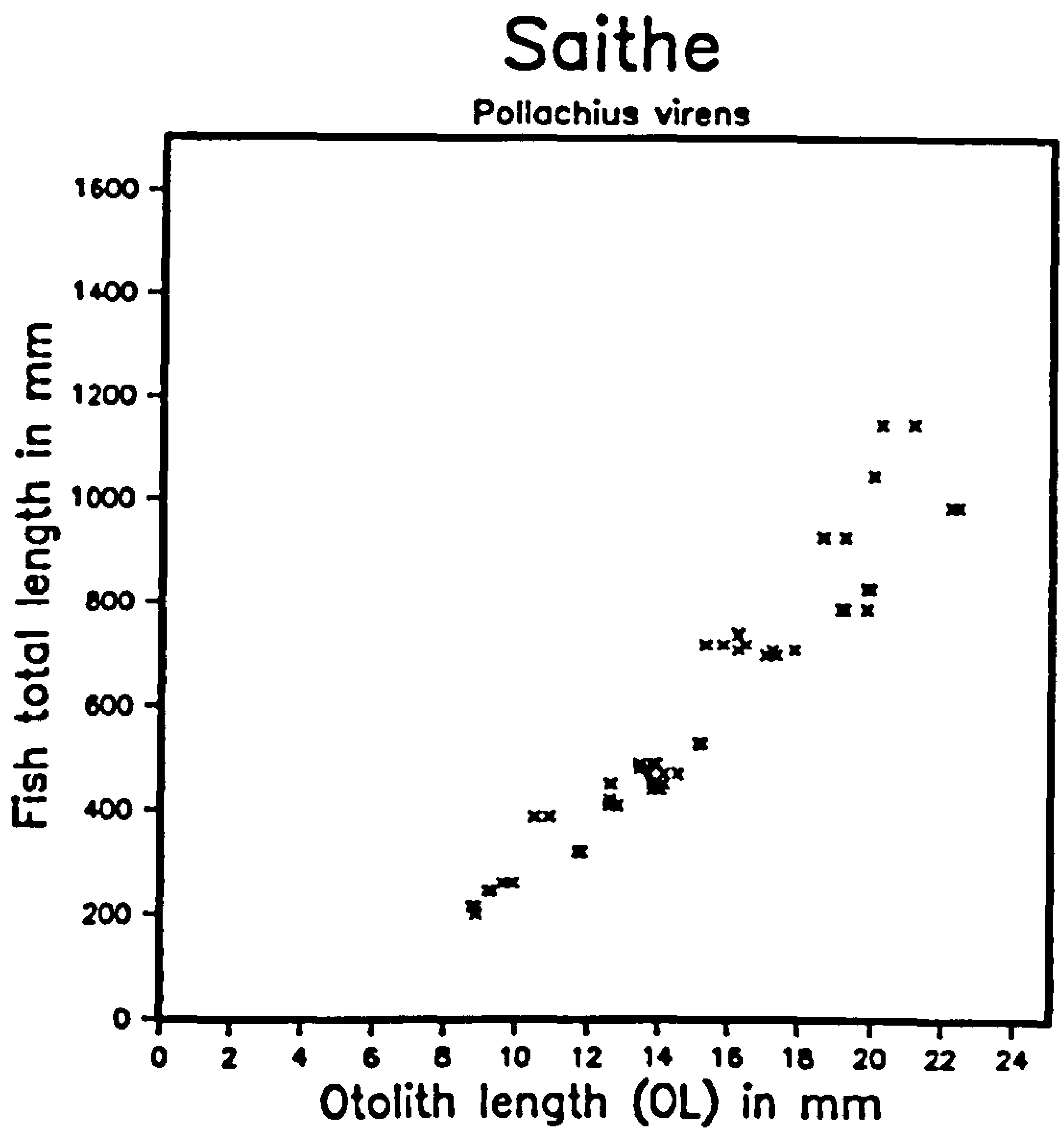


Figure 30. Scatter diagrams showing the relationships of otolith measurements and fish total length for saithe.



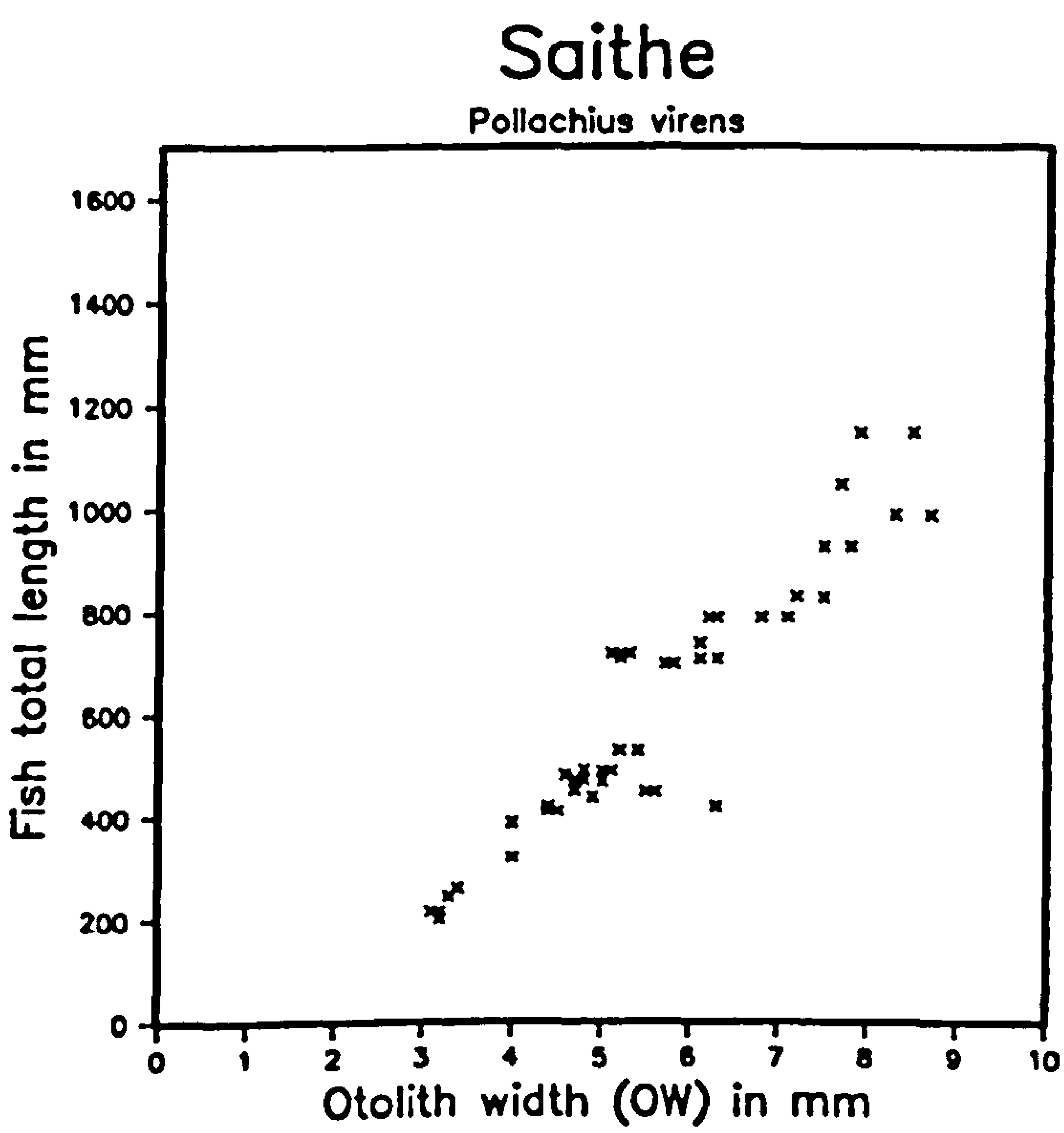
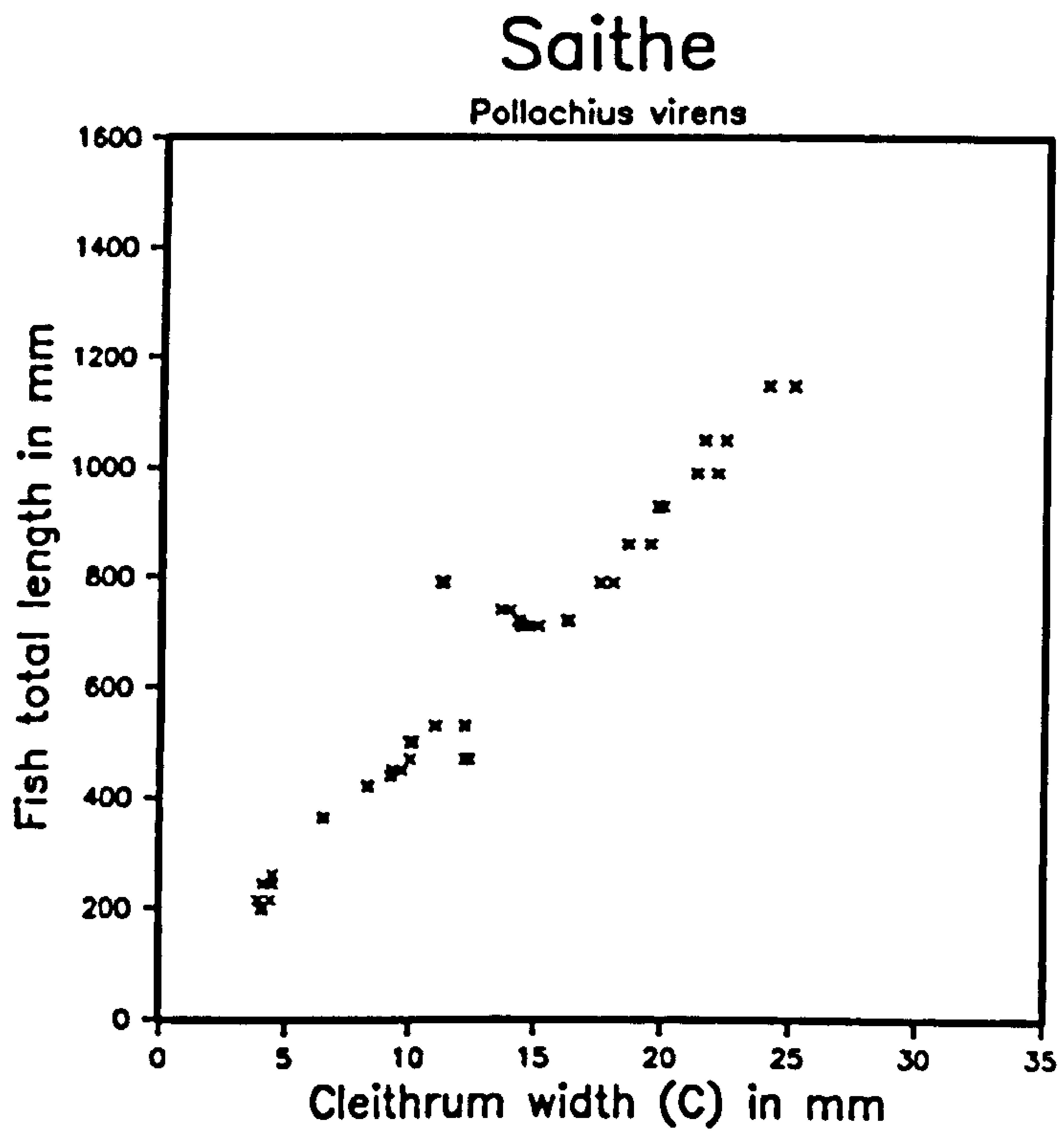


Figure 31. Scatter diagrams showing the relationships of cleithrum measurements and fish total length for saithe and pollack.



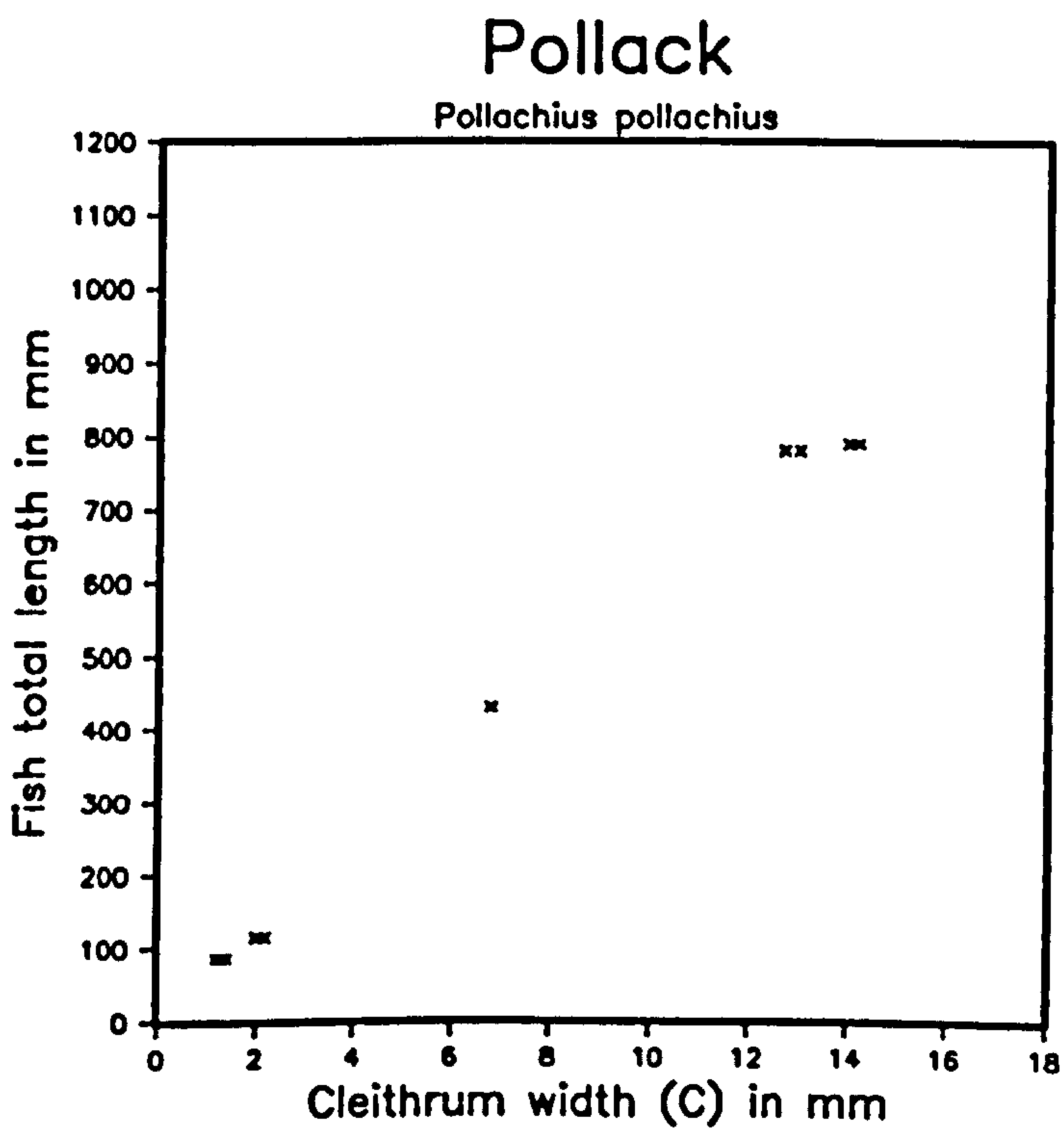
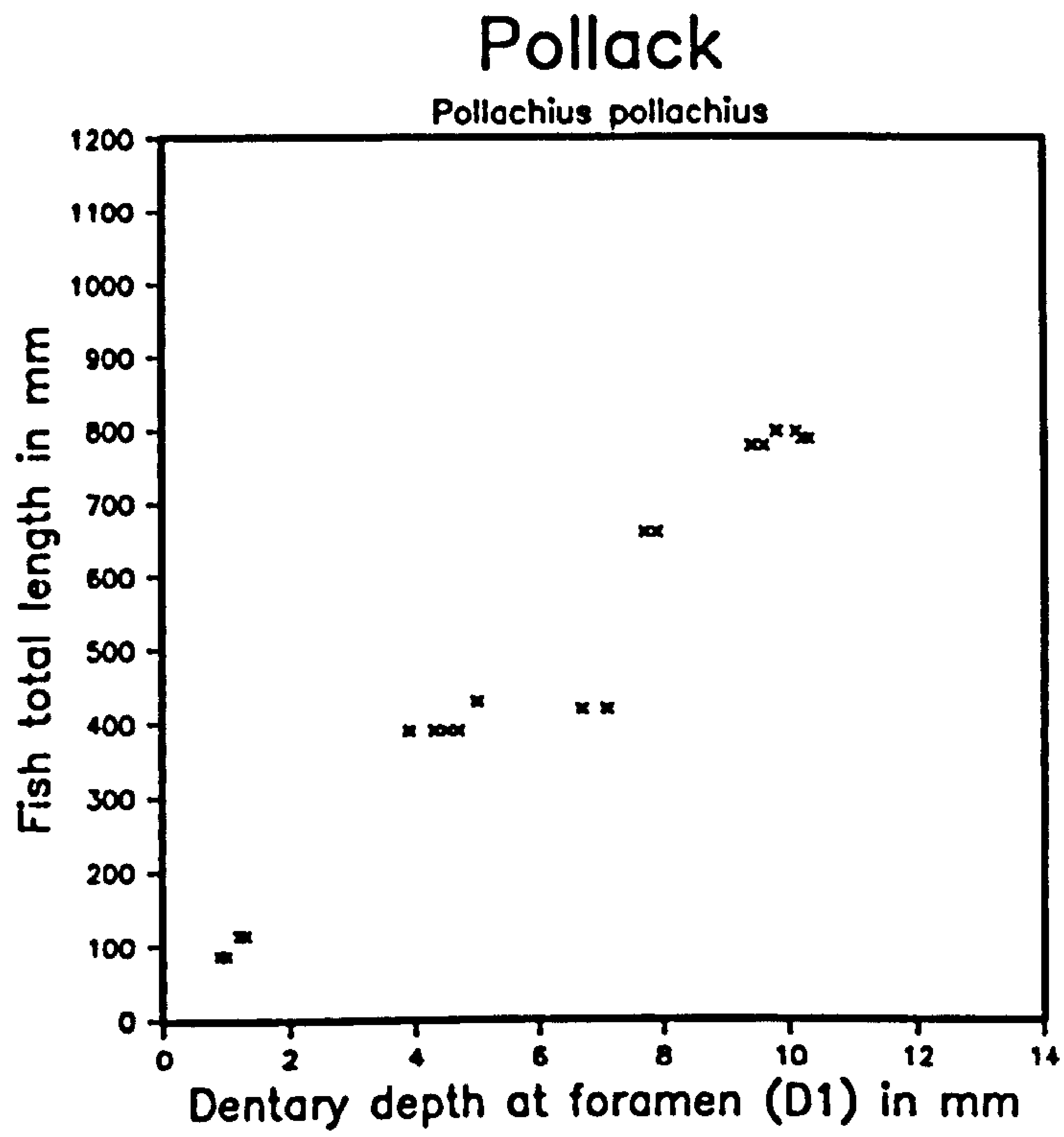


Figure 32. Scatter diagrams showing the relationships of dentary measurements and fish total length for pollack.



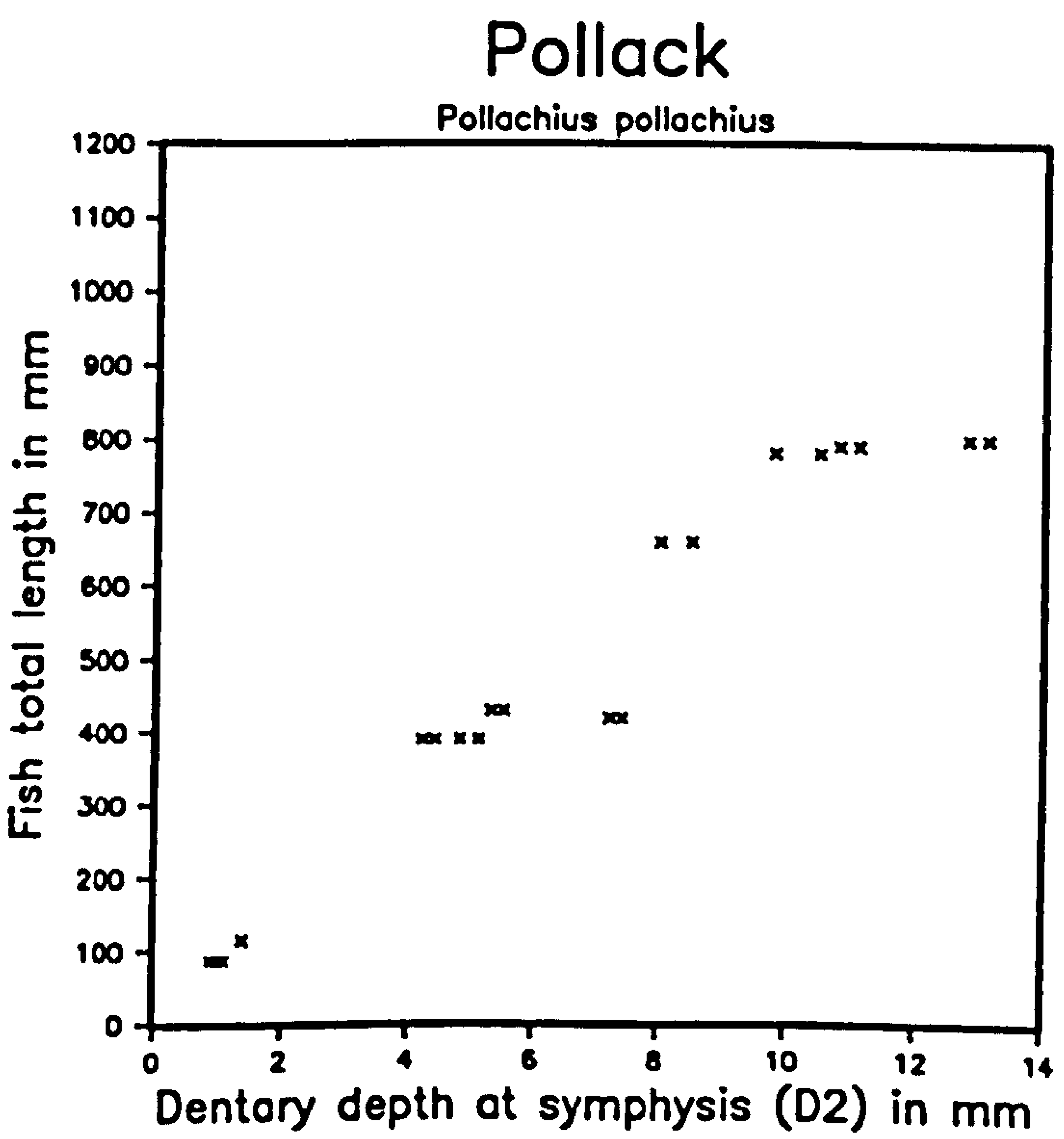
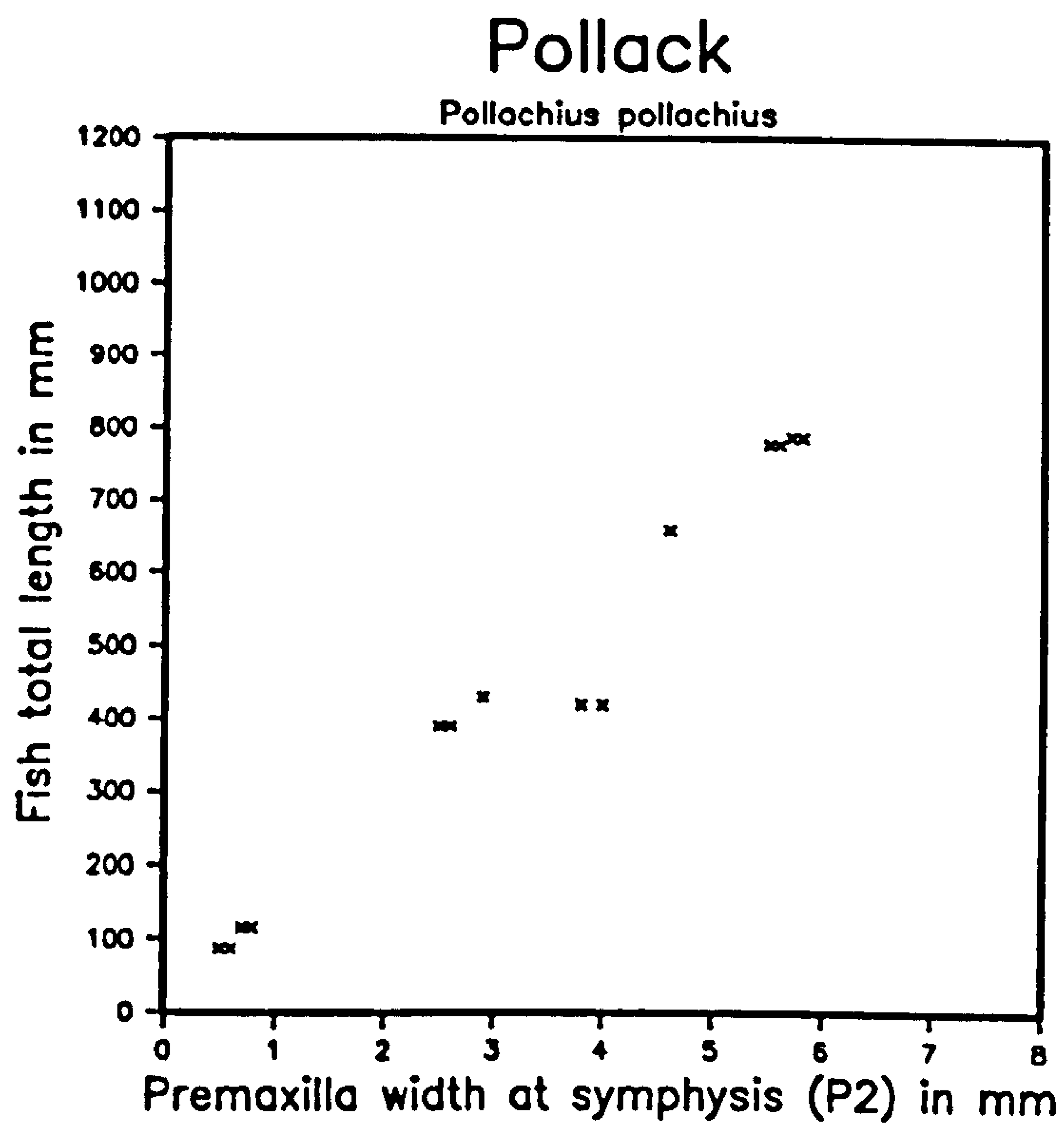


Figure 33. Scatter diagrams showing the relationships of premaxilla measurements and fish total length for pollack.



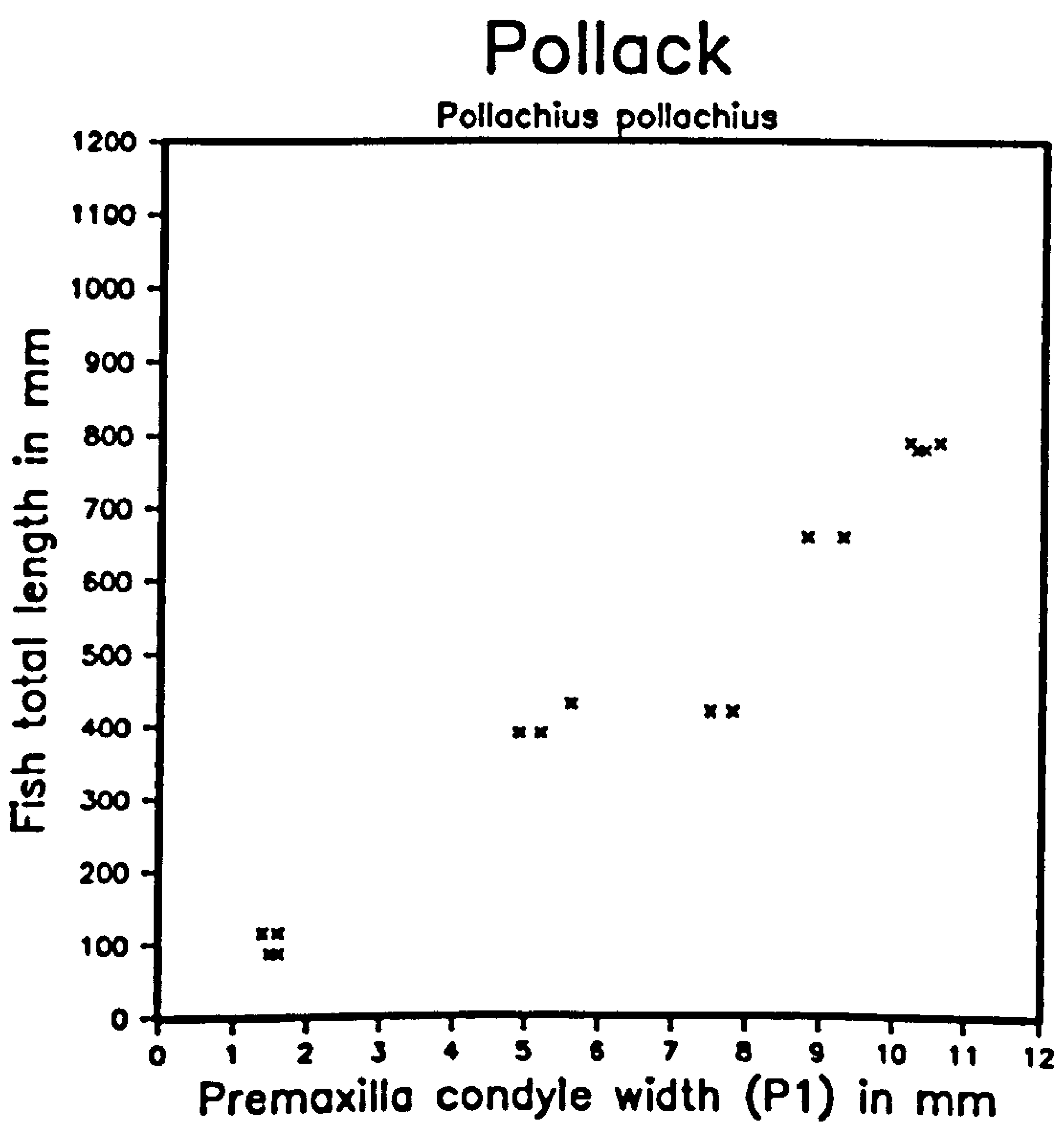
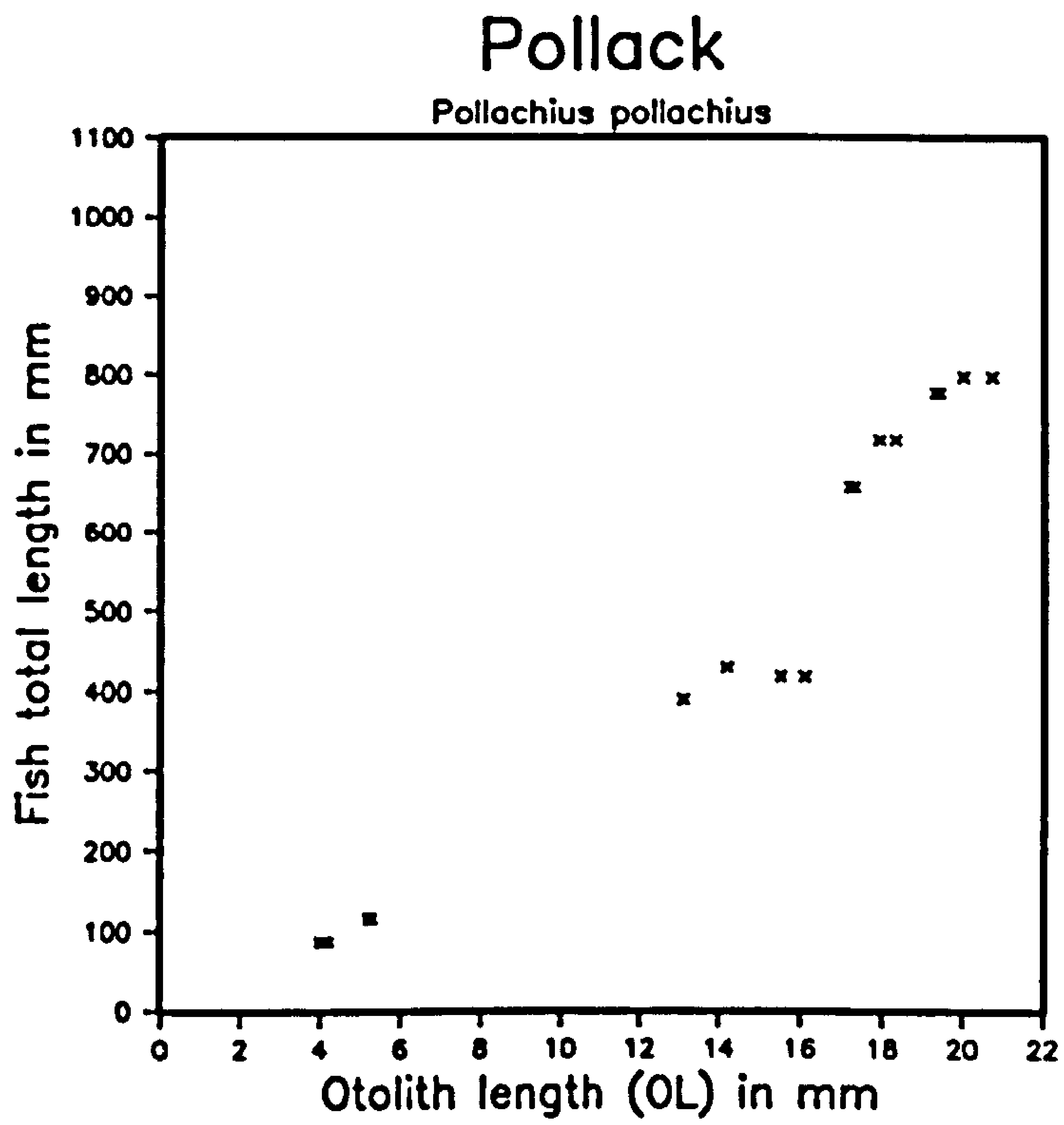


Figure 34. Scatter diagrams showing the relationships of otolith measurements and fish total length for pollack.



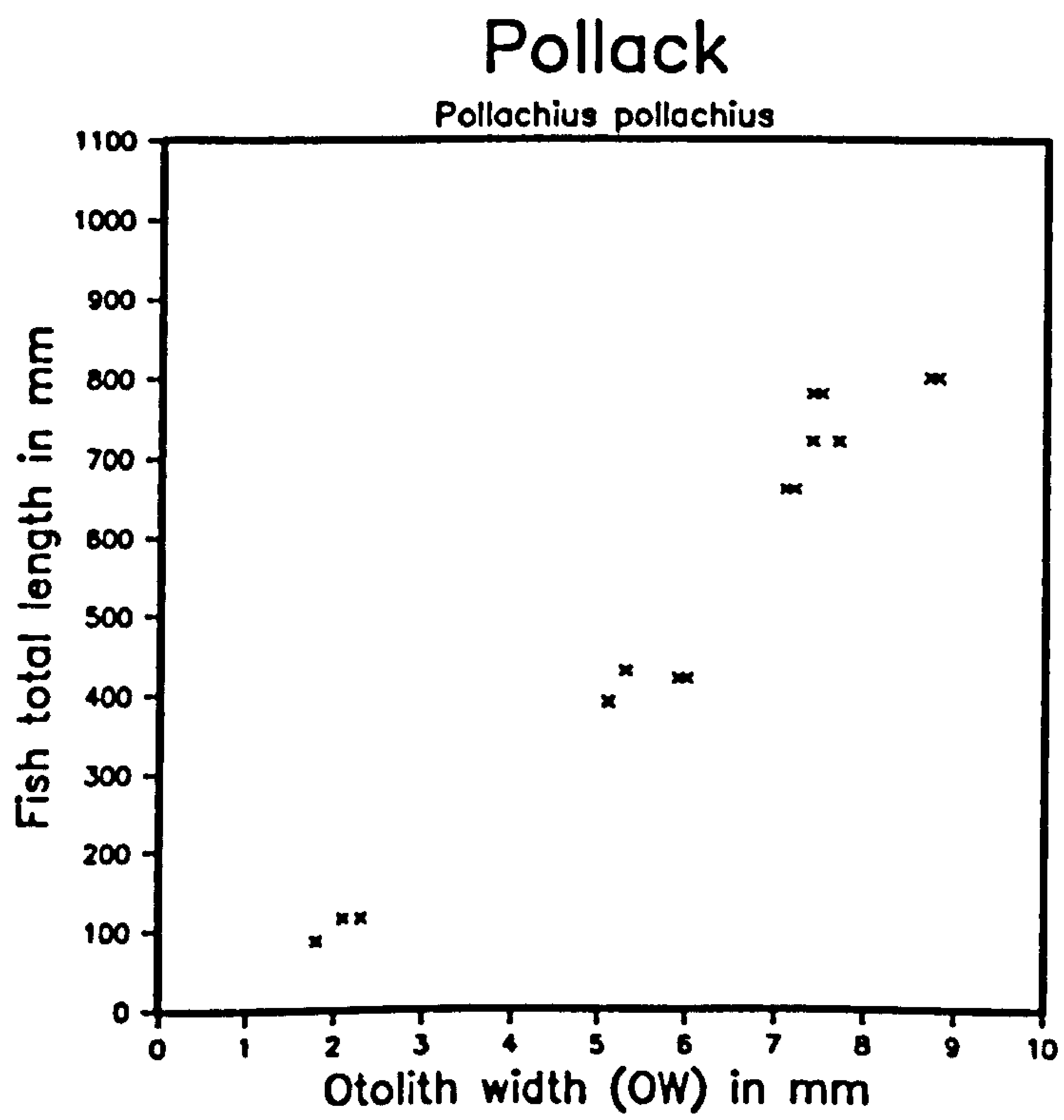
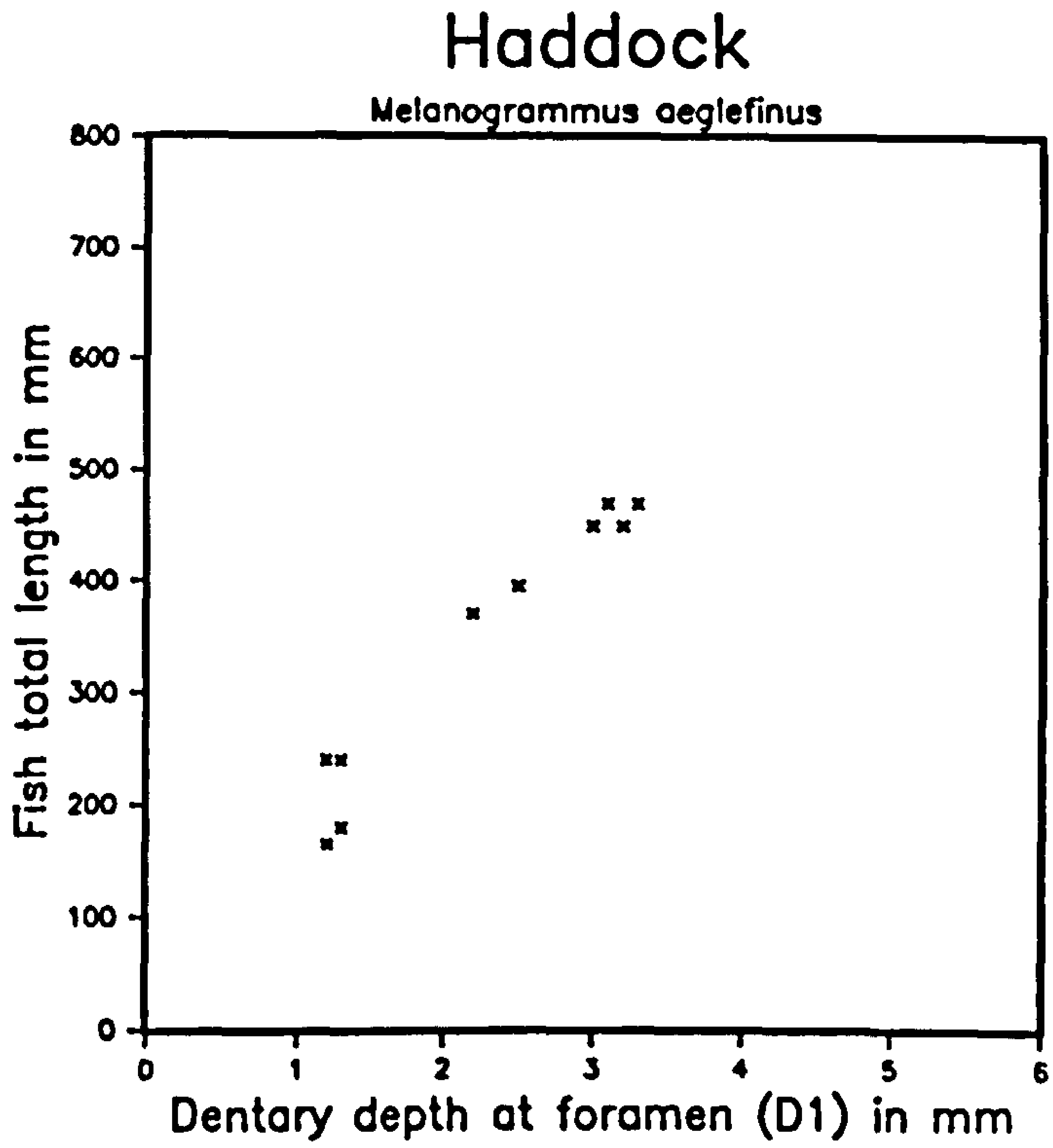


Figure 35. Scatter diagrams showing the relationships of dentary measurements and fish total length for haddock.



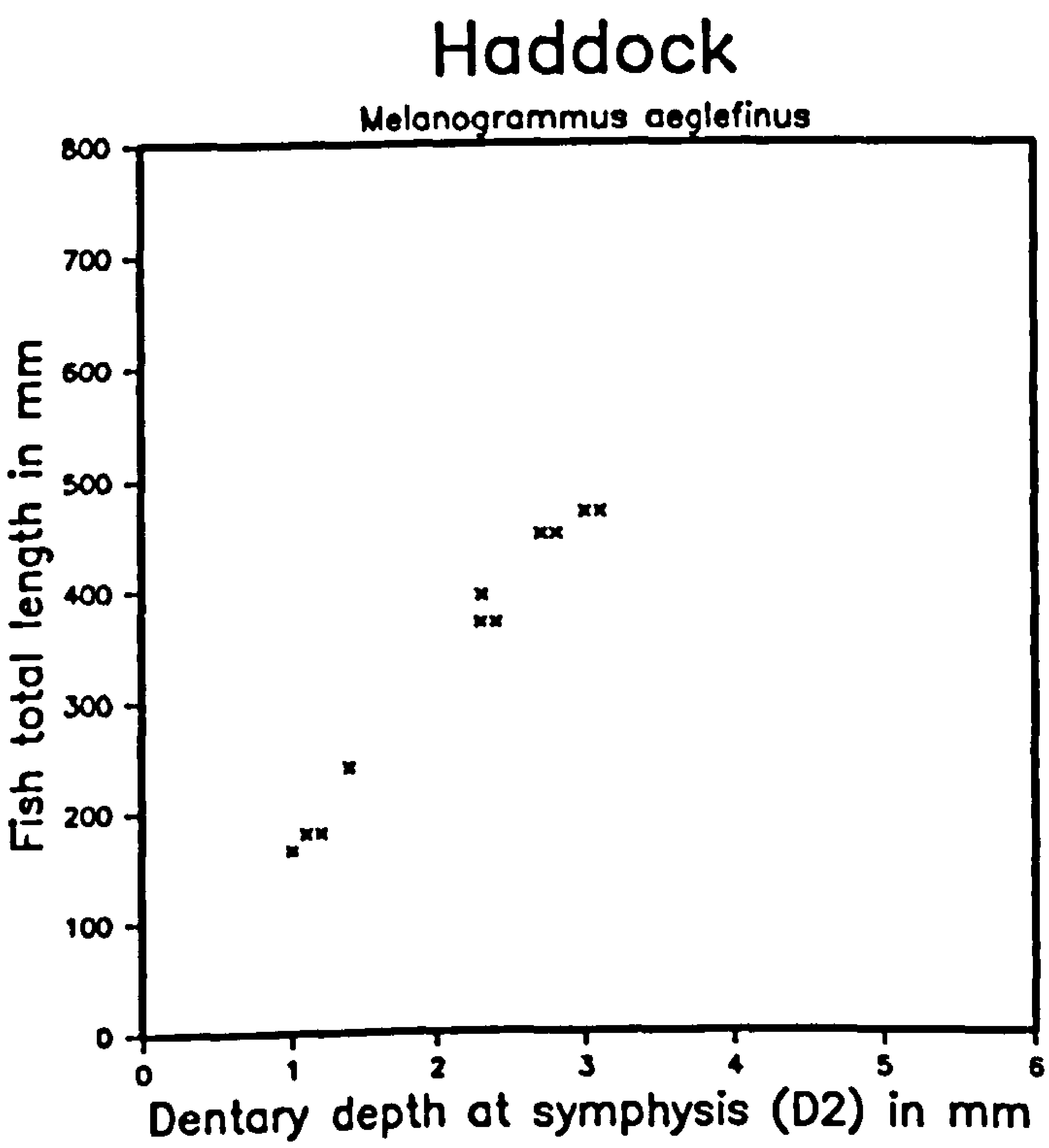
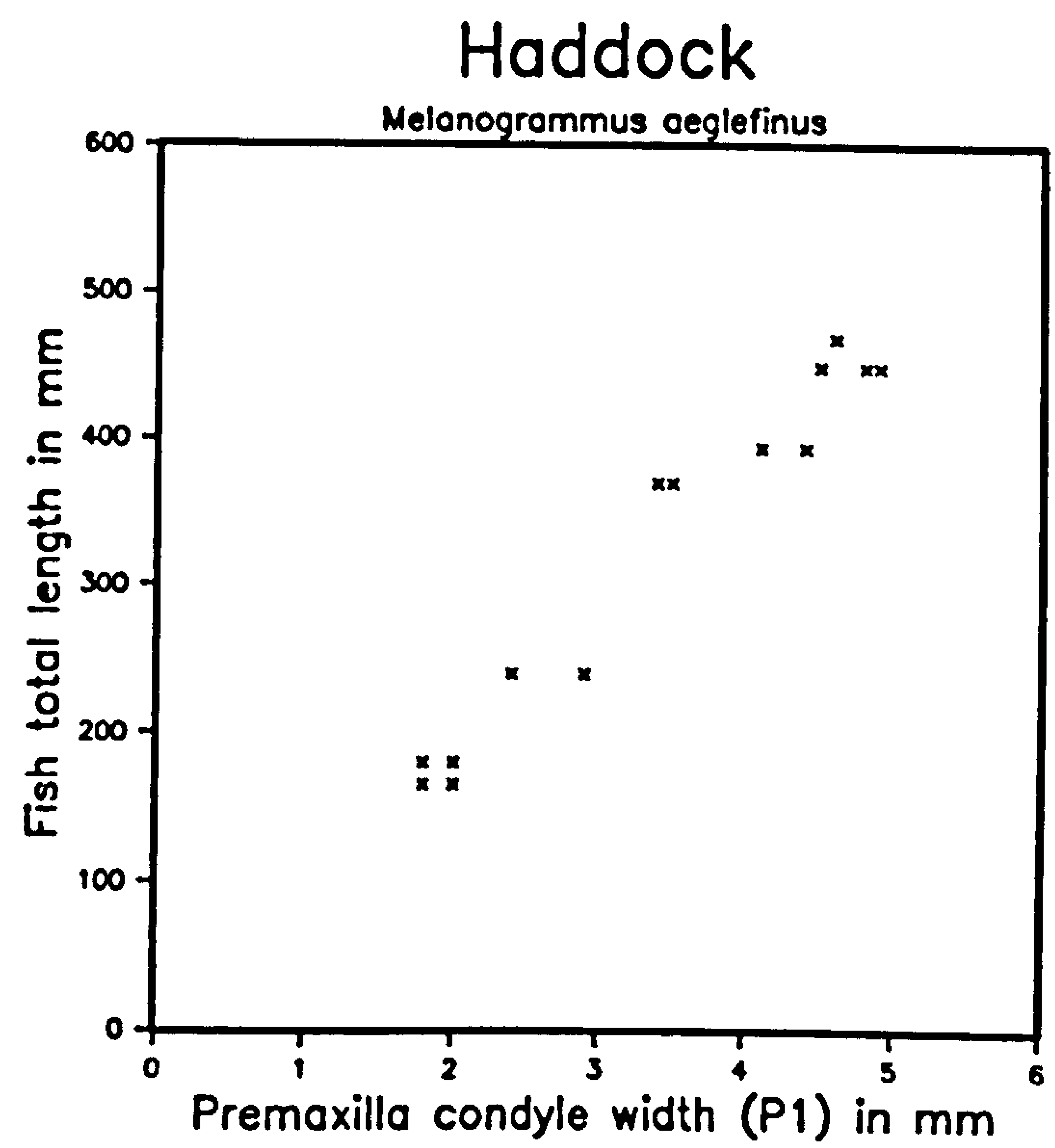


Figure 36. Scatter diagrams showing the relationships of premaxilla measurements and fish total length for haddock.



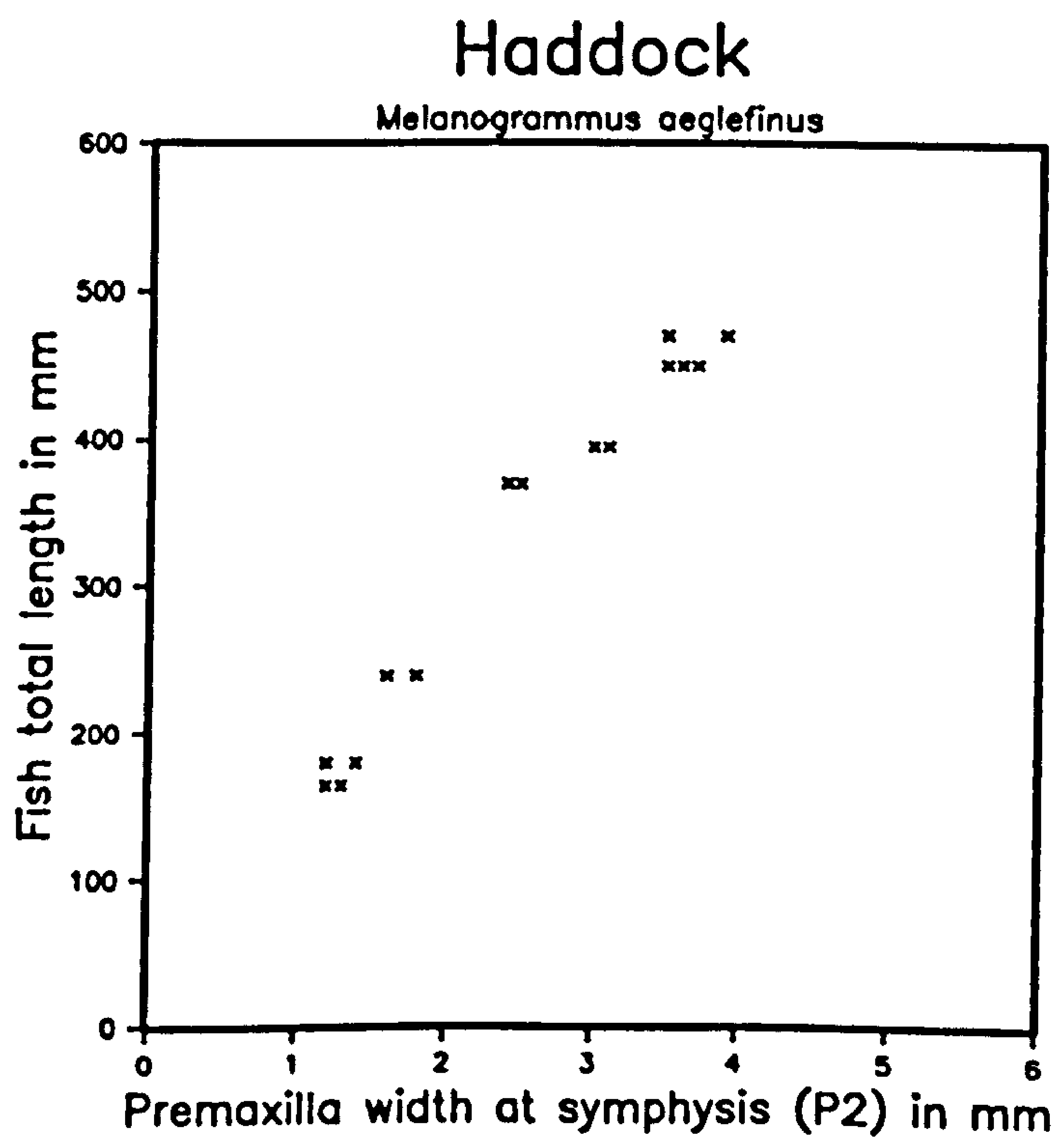
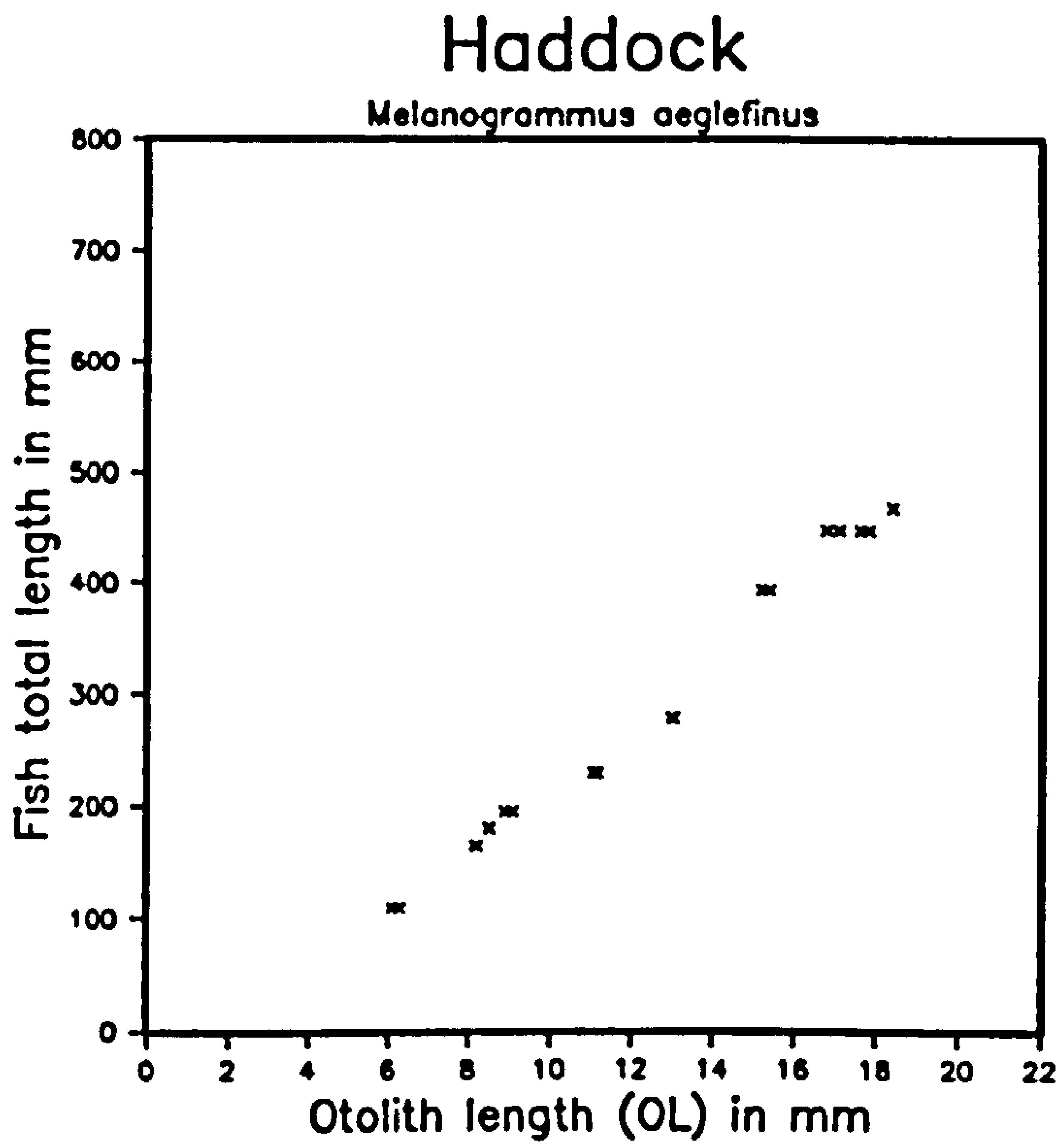


Figure 37. Scatter diagrams showing the relationships of otolith measurements and fish total length for haddock.



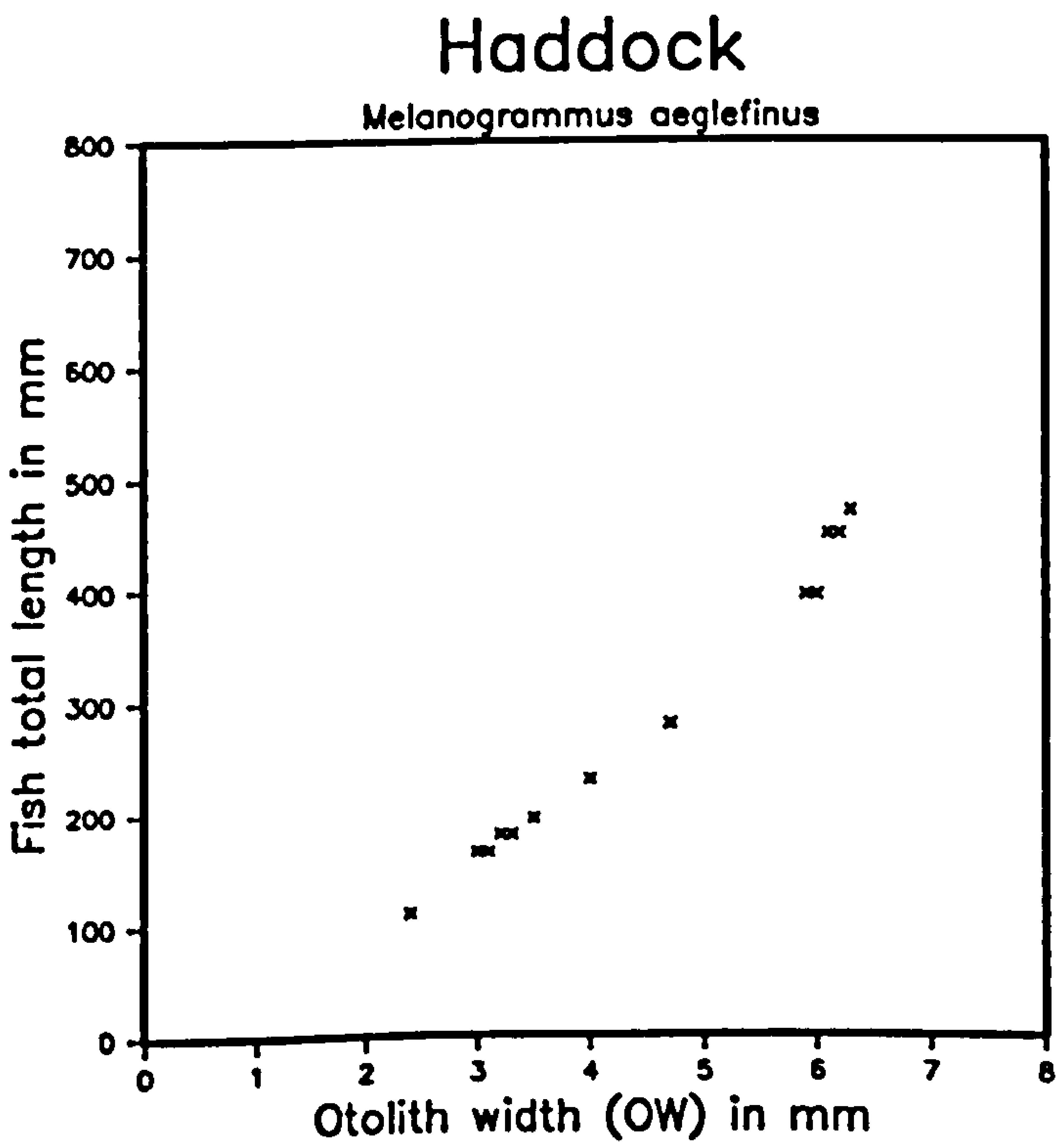
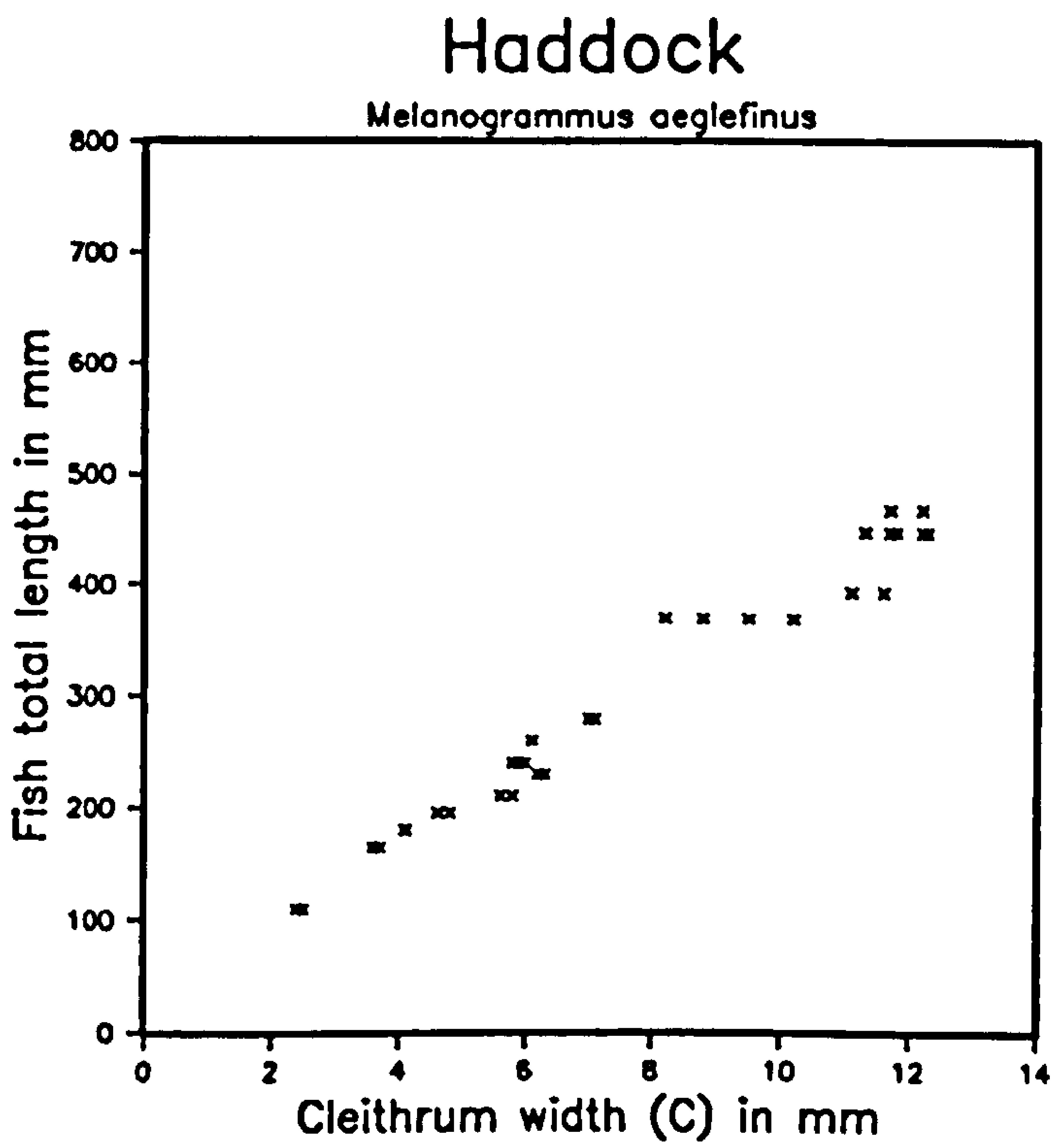


Figure 38. Scatter diagrams showing the relationships of cleithrum measurements and fish total length for haddock, cod and pollack (combined data).



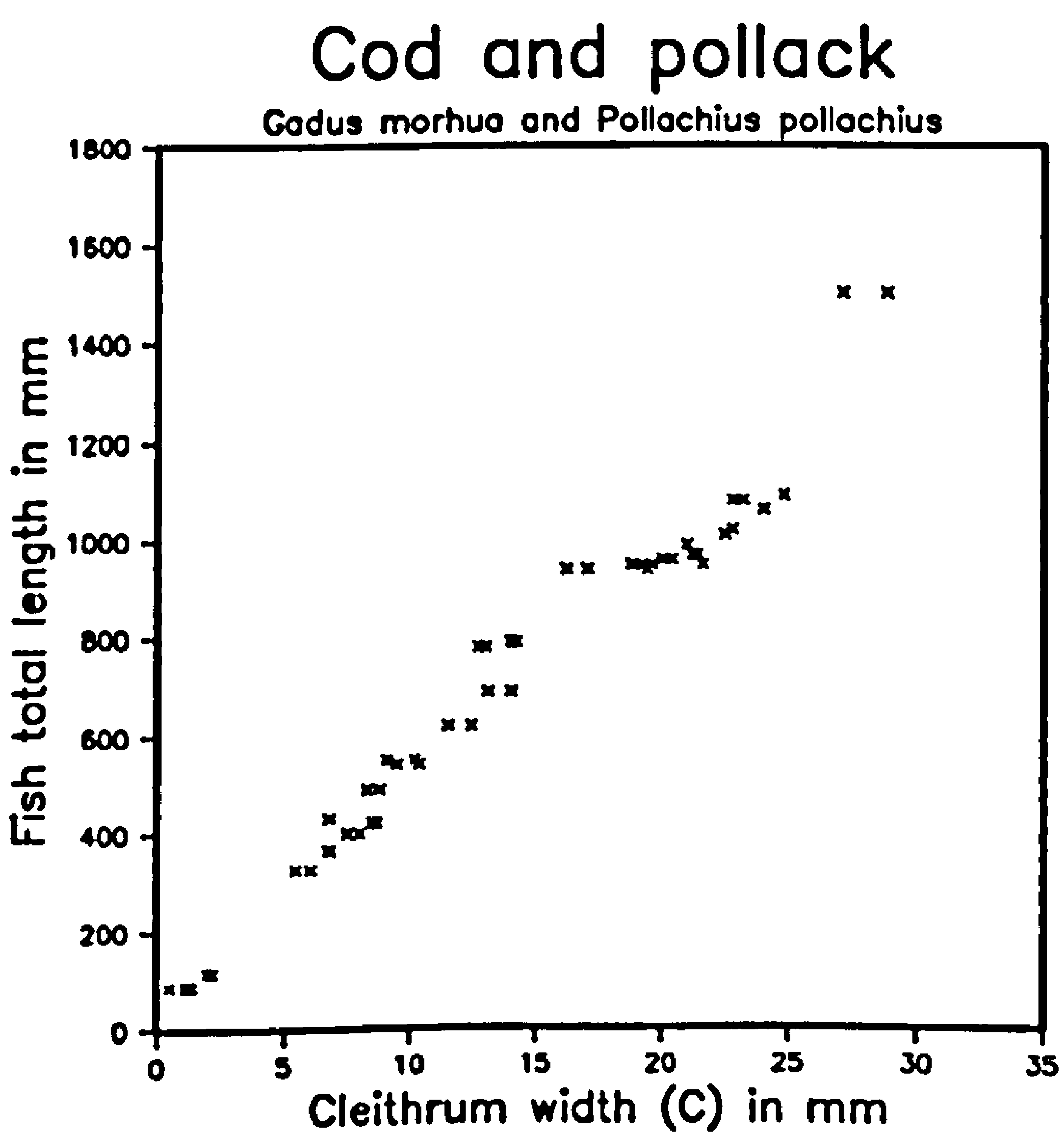
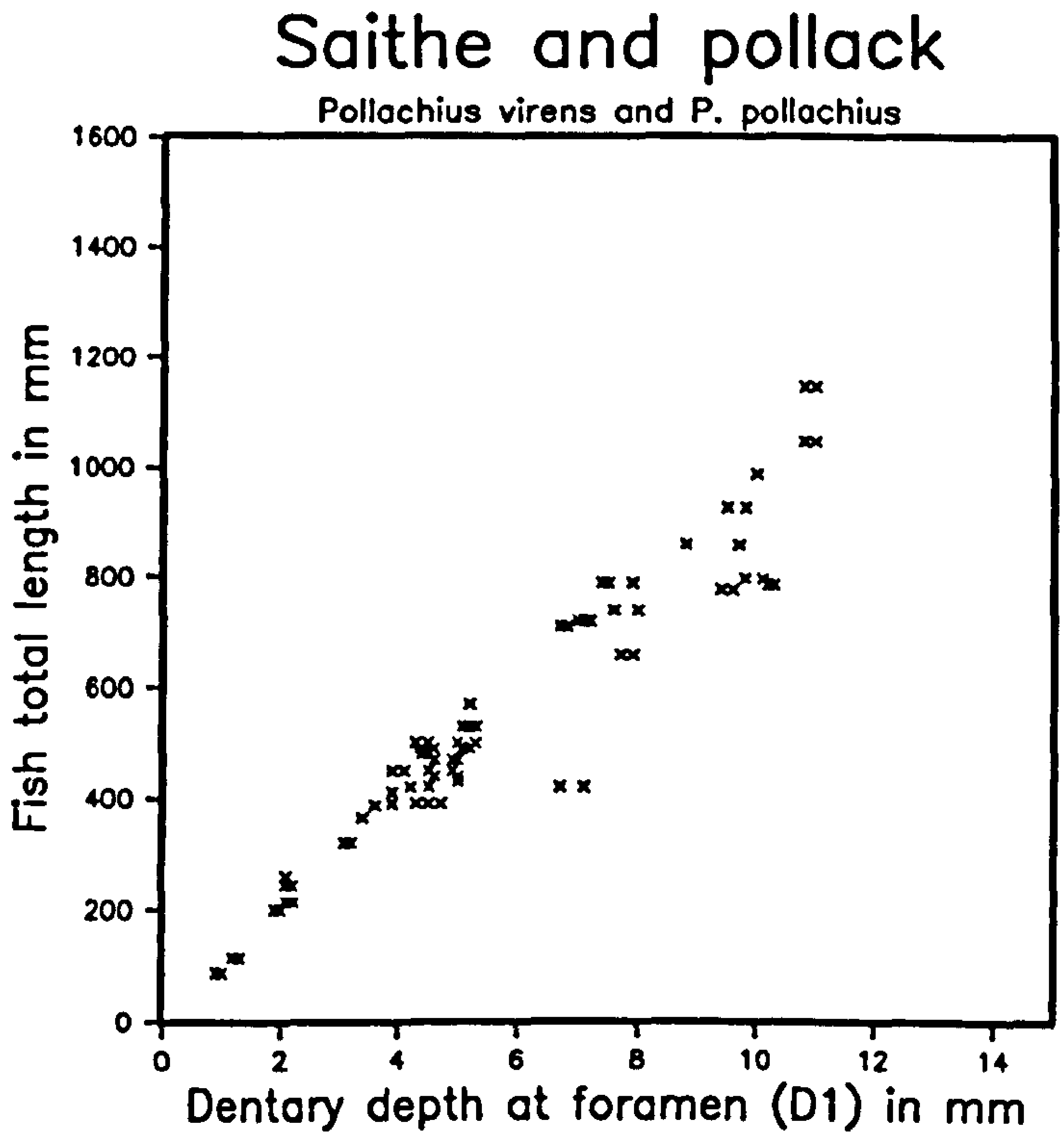


Figure 39. Scatter diagrams showing the relationships of dentary measurements and fish total length for saithe and pollack (combined data).



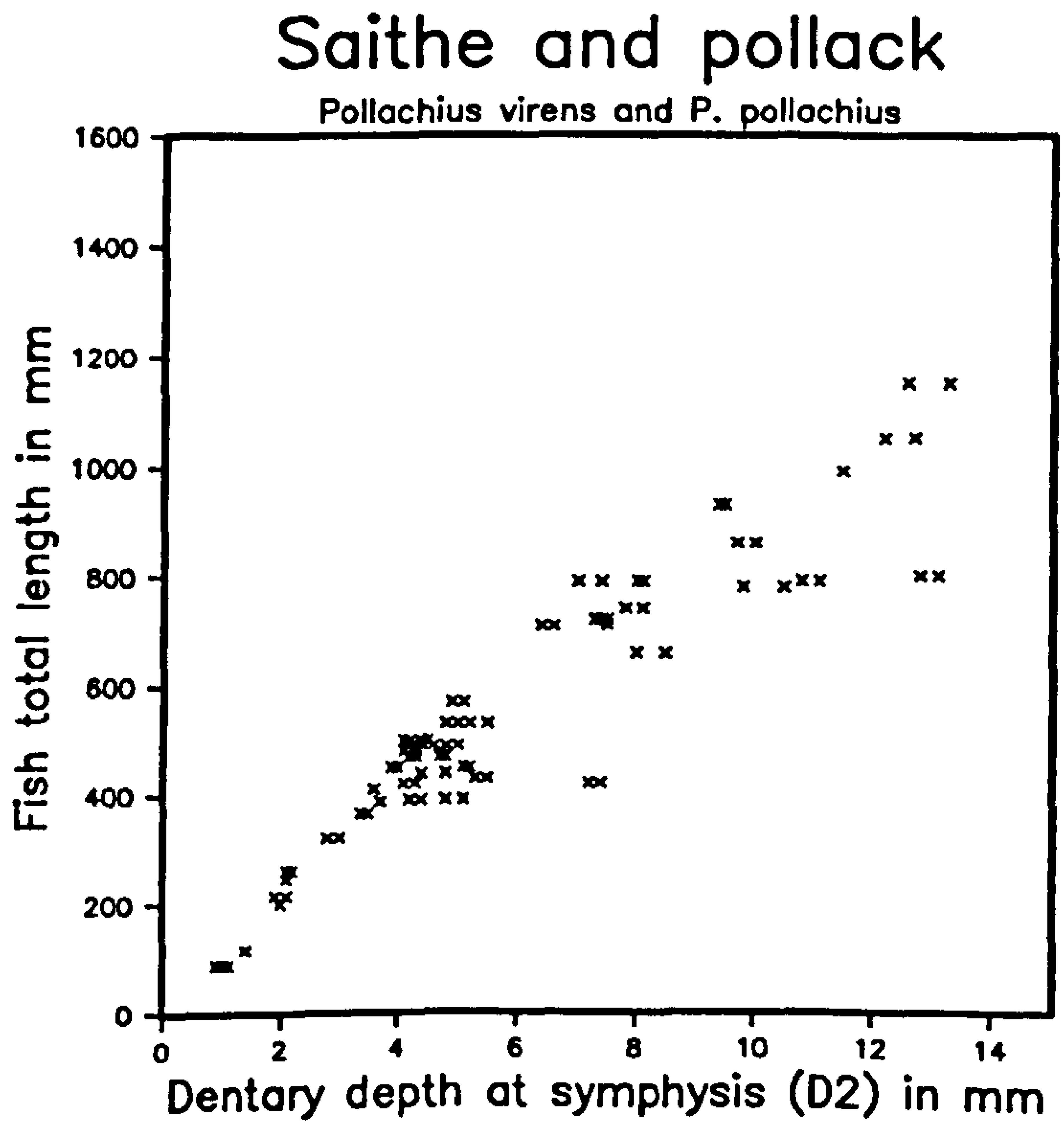
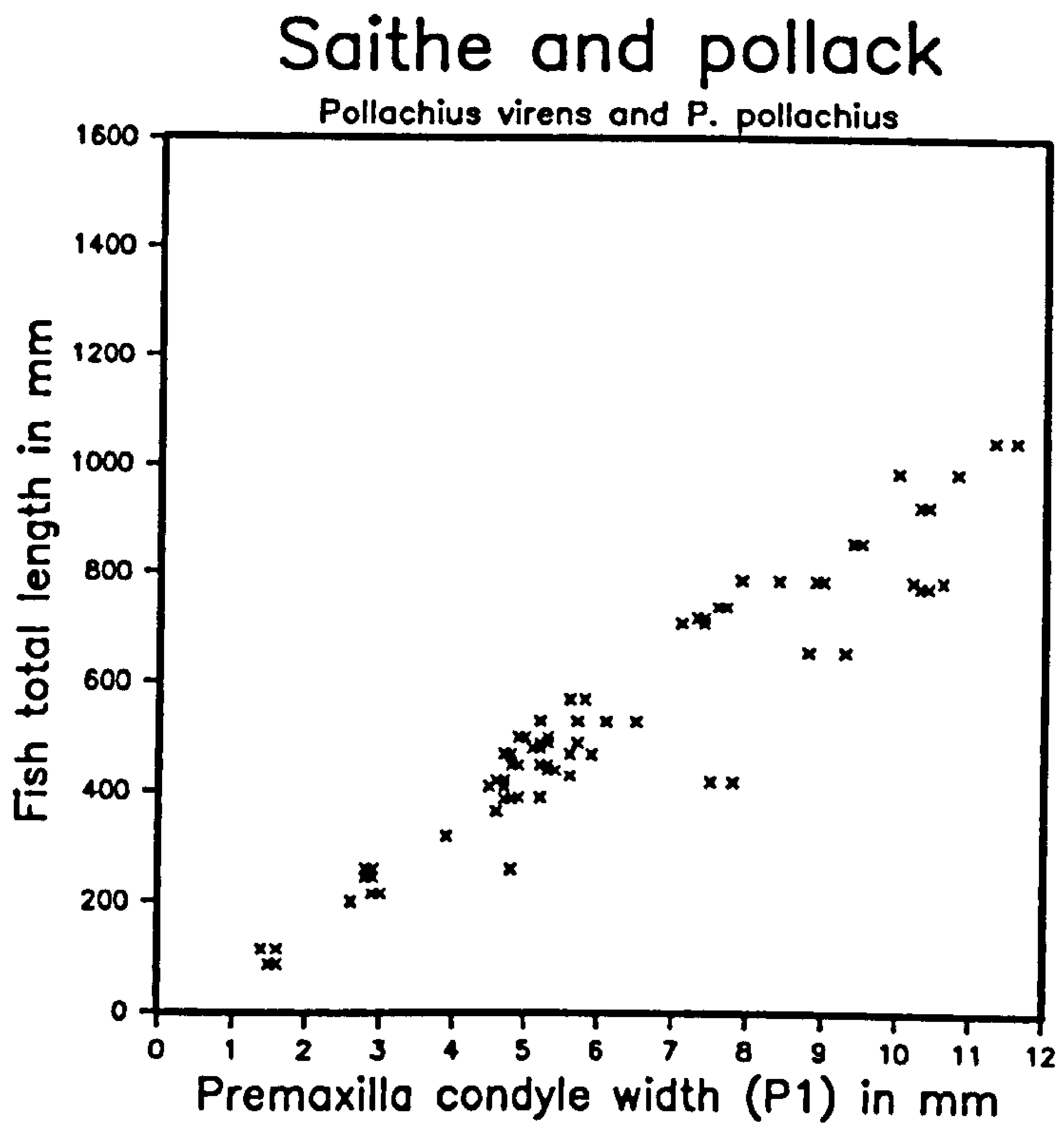


Figure 40. Scatter diagrams showing the relationships of premaxilla measurements and fish total length for saithe and pollack (combined data).



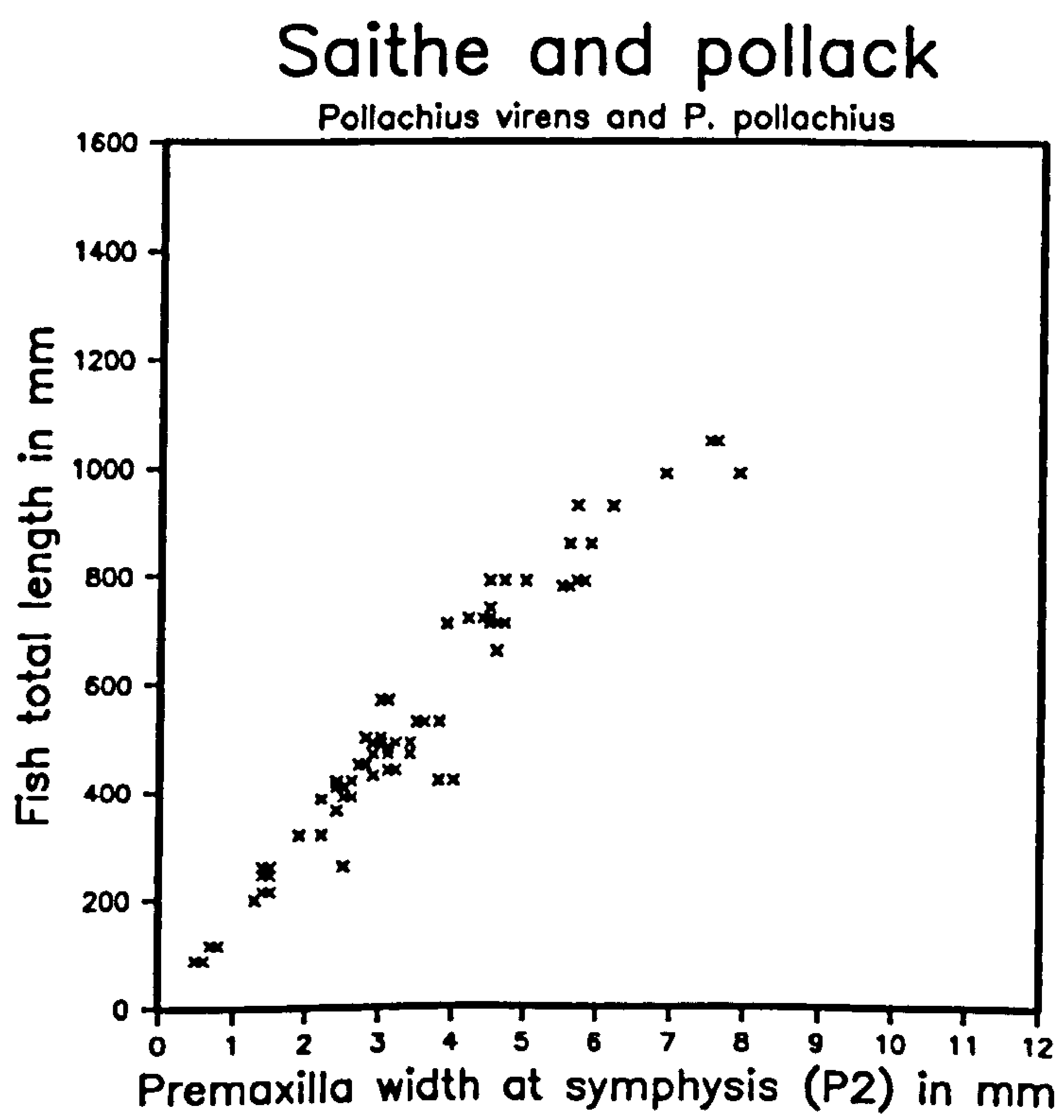
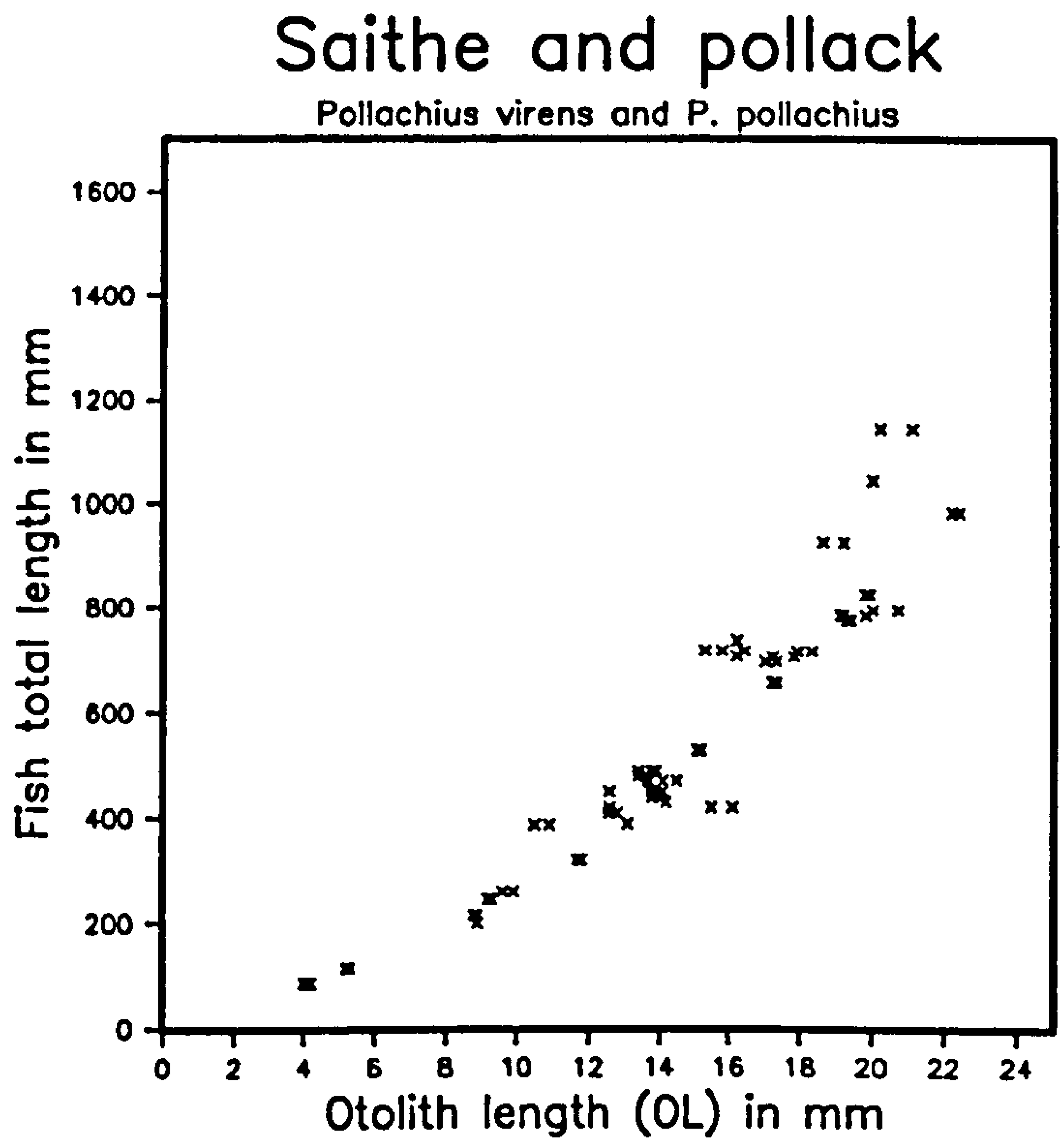


Figure 41. Scatter diagrams showing the relationships of otolith measurements and fish total length for saithe and pollack (combined data).



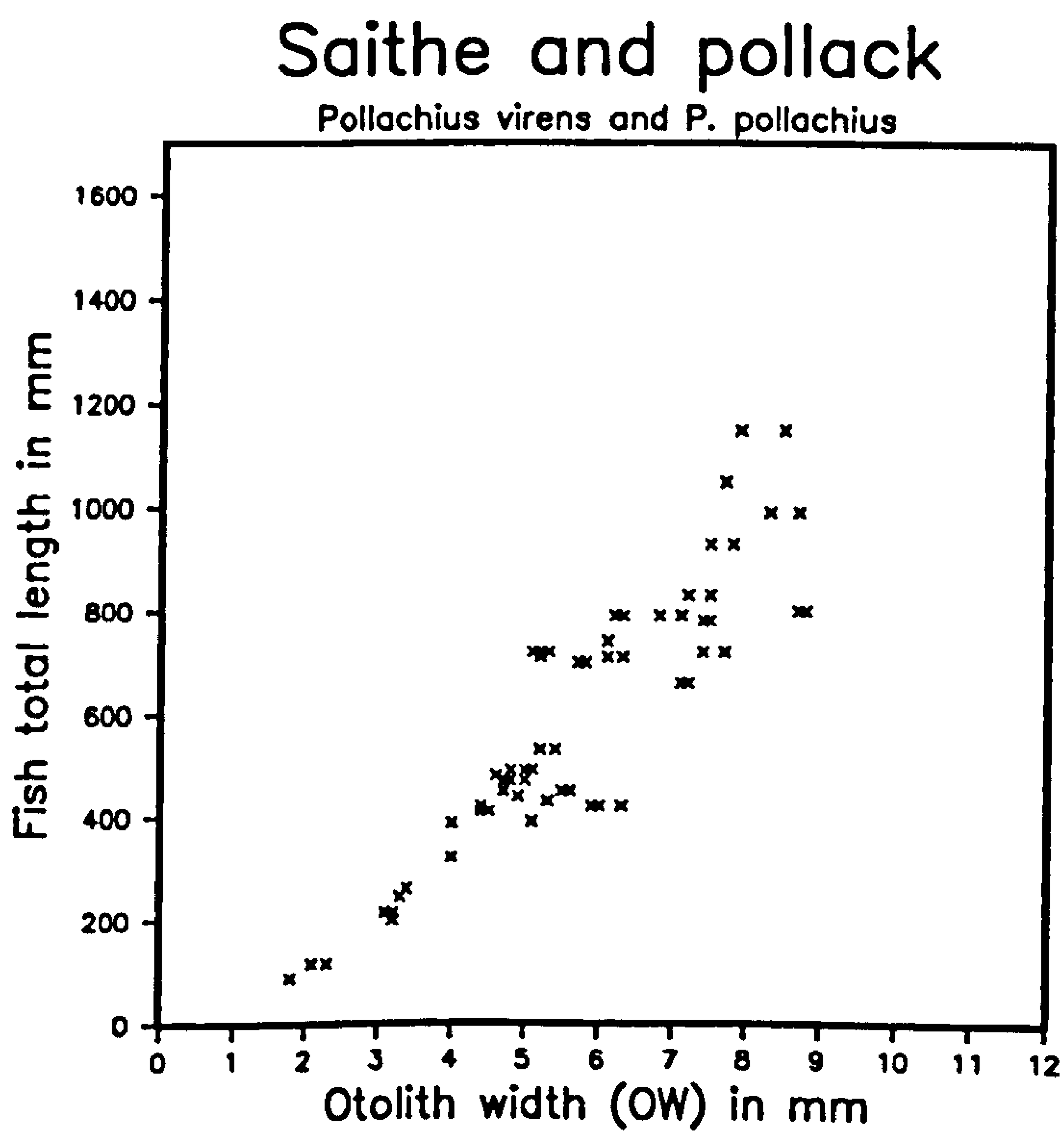
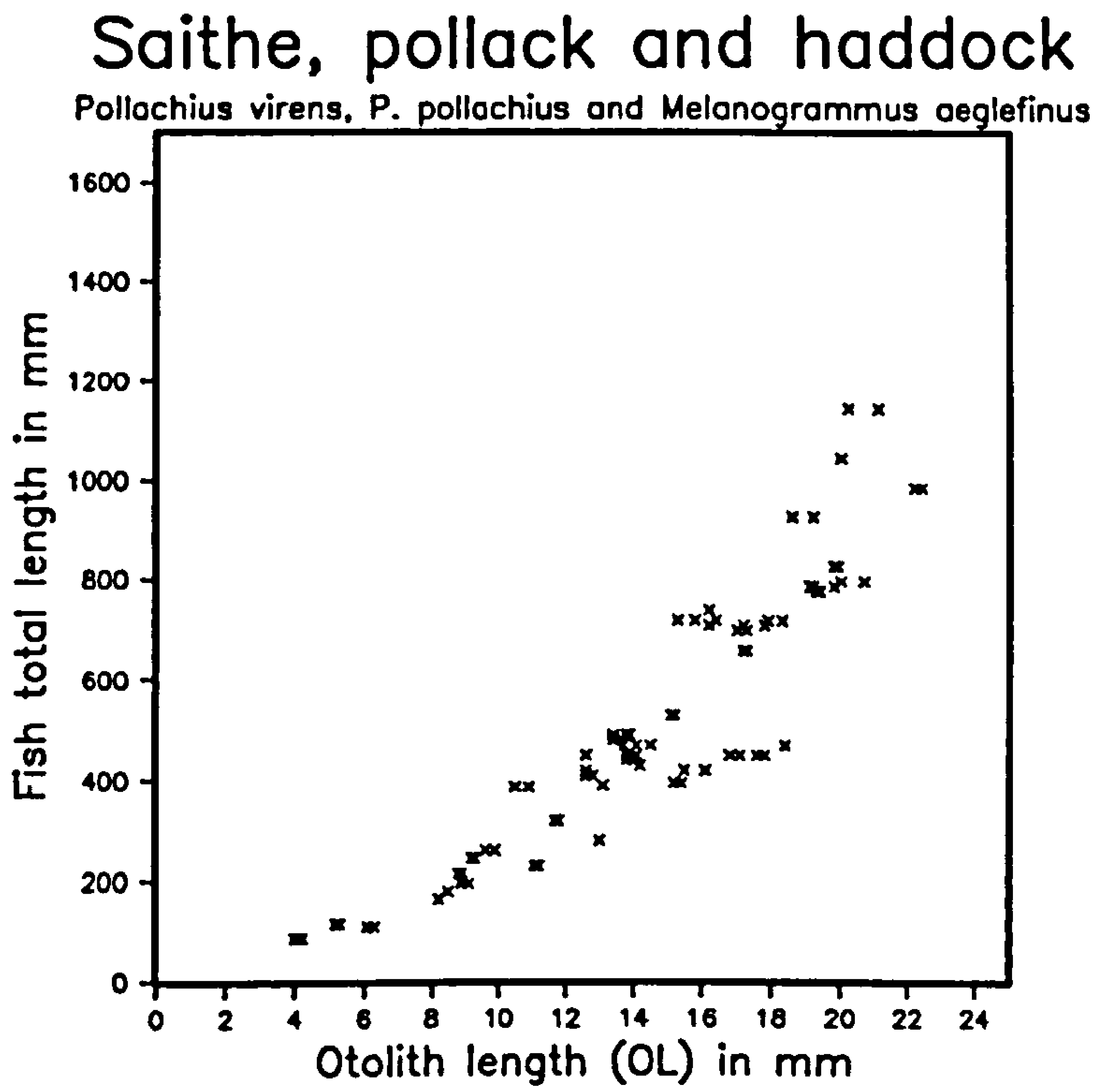
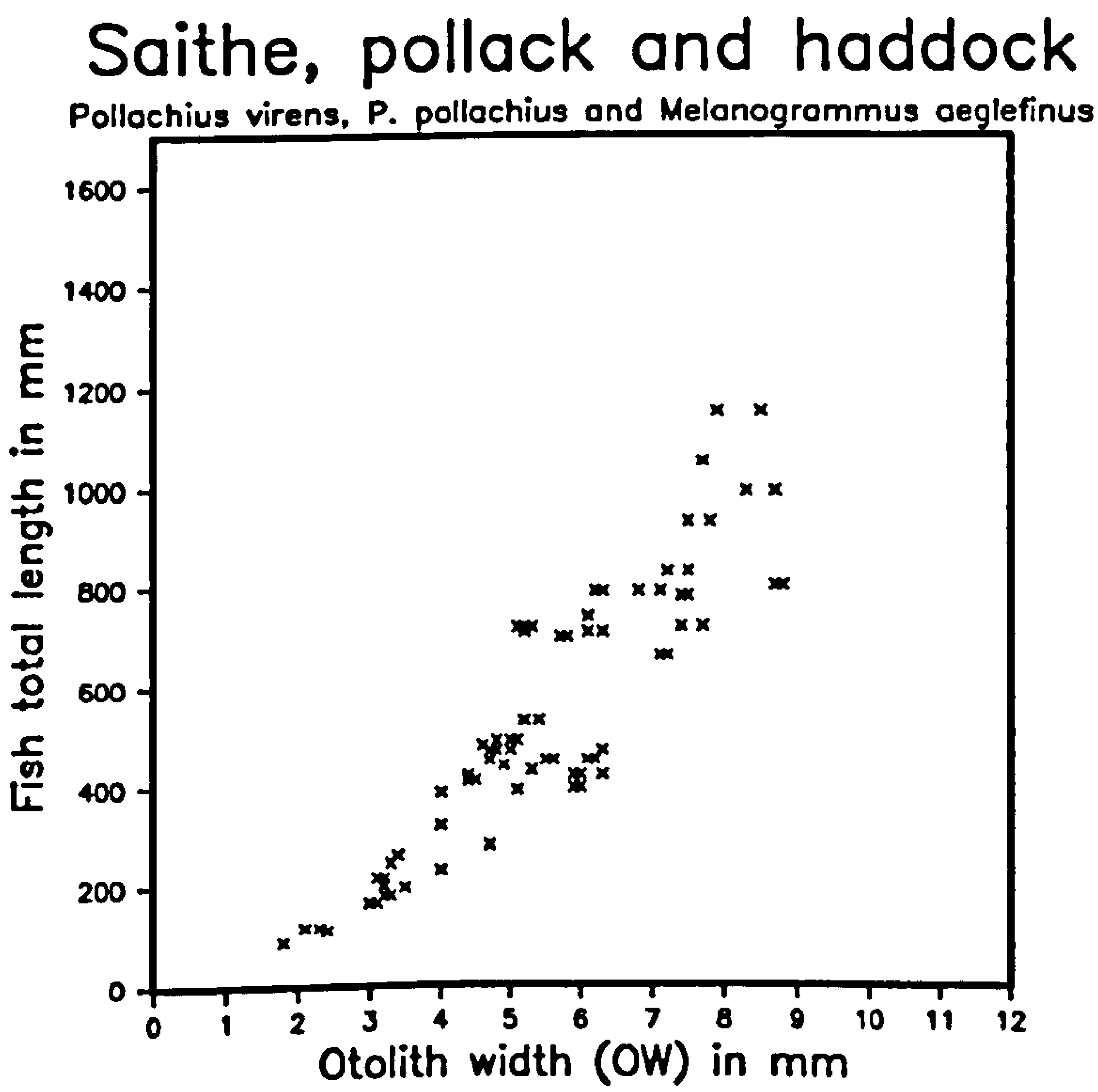


Figure 42. Scatter diagrams showing the relationships of otolith measurements and fish total length for saithe, pollack and haddock (combined data).





in size than those of small fishes. A plot of the fitted values against the residuals gave a clear indication that the heteroscedasticity visible in the plot of raw data was a real feature of the data. Third, for most elements the relationship was not linear but curvilinear.

Two mathematical transformations of the raw data were undertaken in order to reduce the spread and curvilinearity of data plots. Square root and logarithmic transformations were made on data for both element dimension and fish length and regression analysis carried out with raw and transformed data for each axis, separately (e.g. otolith length and square root fish length and square root otolith length and fish length) and with transformed data in both axes (i.e. square root otolith length and square root fish length). The analyses were assessed by considering the coefficient of determination and the shape and spread of the plot. Logarithmic transformations of both element measurement and fish total length were found to both reduce spread in the data and straighten the plot of fitted values in almost all cases, in addition, the coefficient of determination increased to its maximum value.

Having determined that logarithmic transformations of data of both element dimension and fish length gave the straightest relationship between the variables, prediction intervals (confidence intervals for predictions based on the fitted model) were obtained by the following procedure.

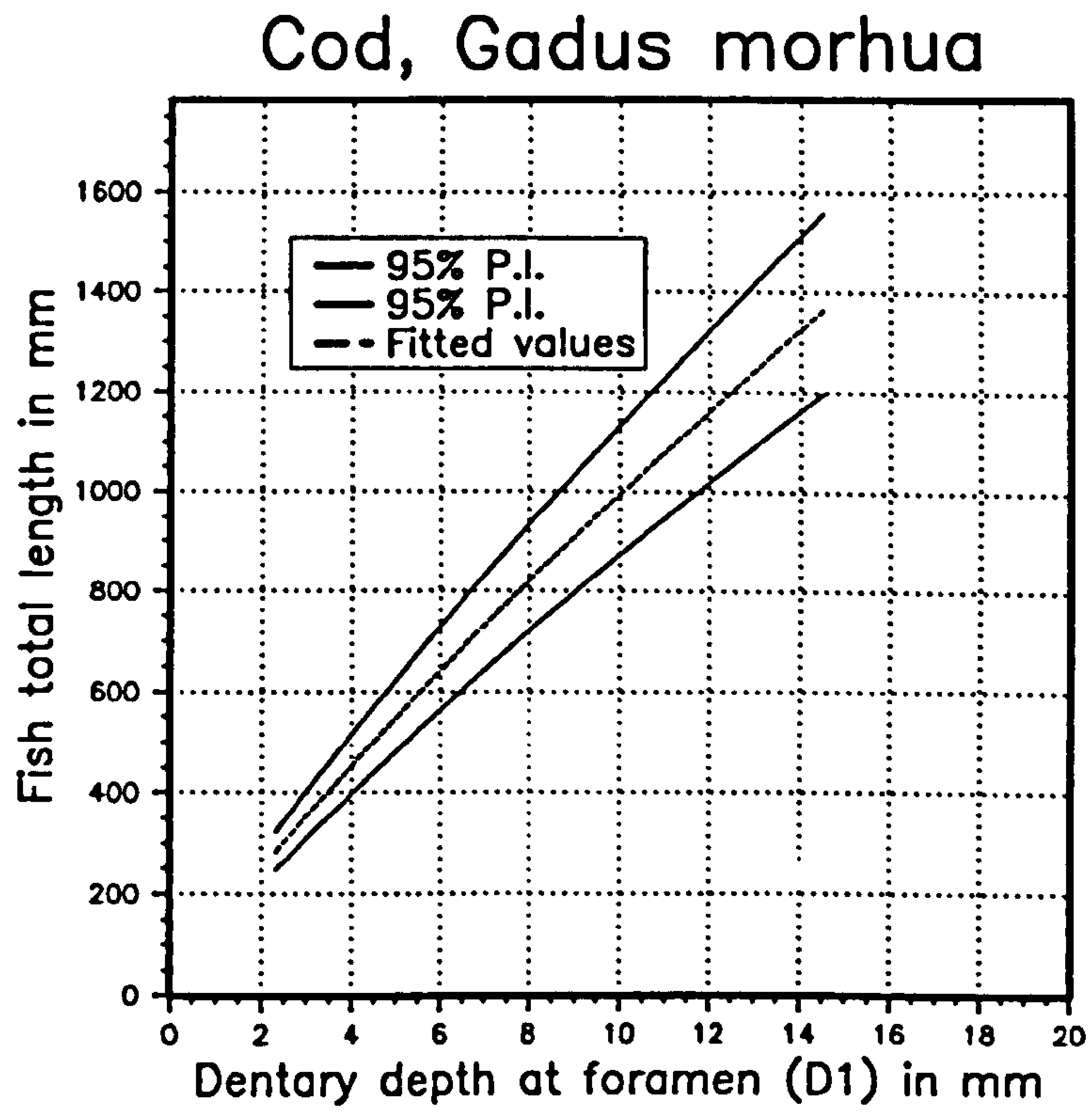
Logarithms (log 10) of fish length (in mm) and bone dimensions were taken and classical regression analysis carried out using the statistical package MINITAB. (Details of the regression equations and multiple correlation coefficient are presented in Table 12).

The regression analysis routine of MINITAB produced both confidence intervals and prediction intervals. The fitted values and the 95% prediction intervals were back transformed to raw data units (mm) and plotted. The resulting graphs (Figures 43-65) clearly show that large bones can be sized with less accuracy than small bones and that some measurements provide more accurate estimates of fish total length than others.

In addition to considering the bones of each species, the data for the same element of different species were analysed together in Table 13. This was included because species determination for the element is often impossible or very difficult. It should be noted that when this has been done all data were considered together. Thus species for which large collections of bones were available contribute more to the graphs than those species for which only a few measurements were available.

It is clear from this investigation that the prediction intervals for some elements and species are much smaller than for others.

Figure 43. The 95% prediction intervals and fitted values for cod dentary measurements.



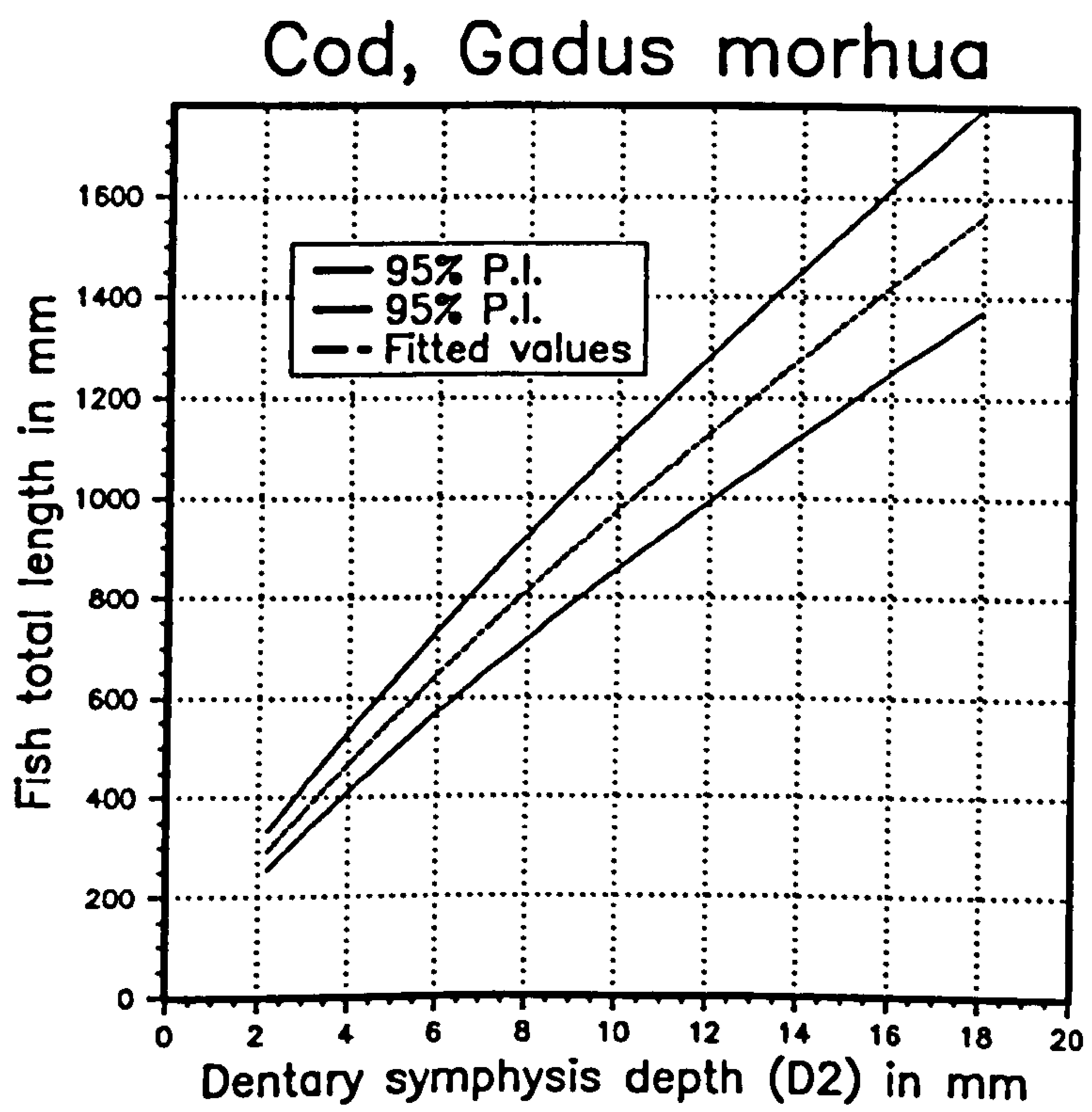
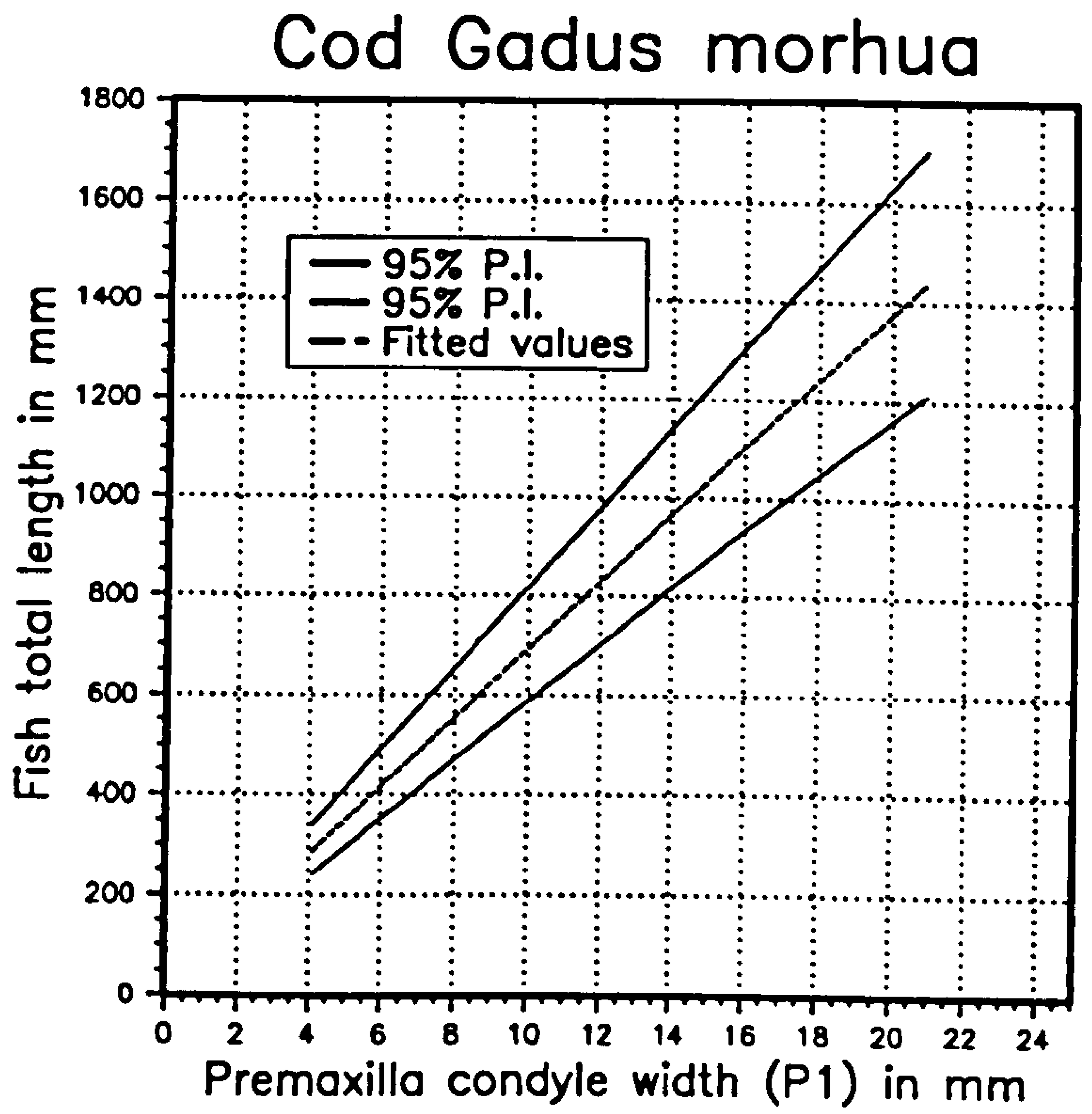


Figure 44. The 95% prediction intervals and fitted values for cod premaxilla measurements.



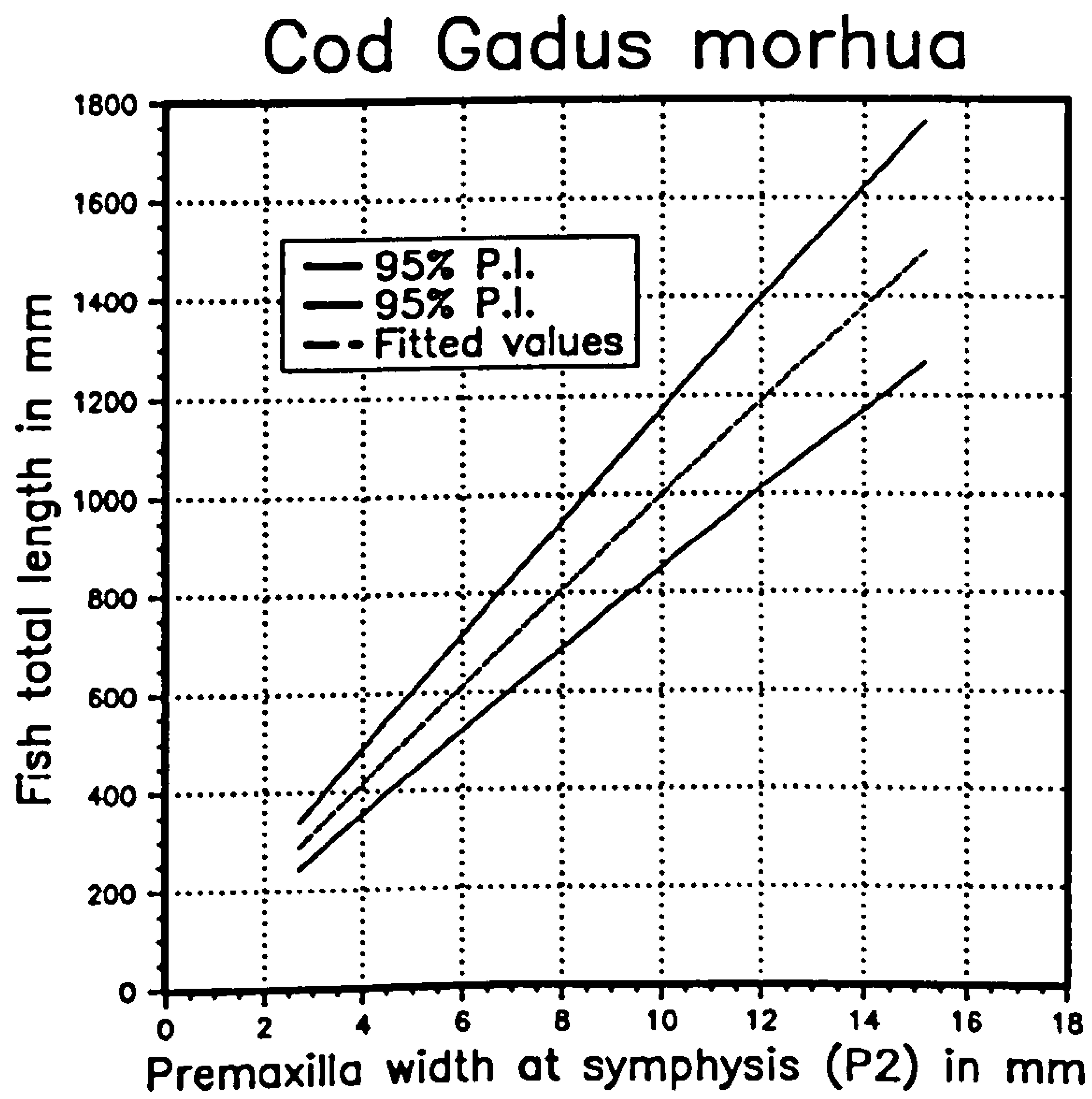
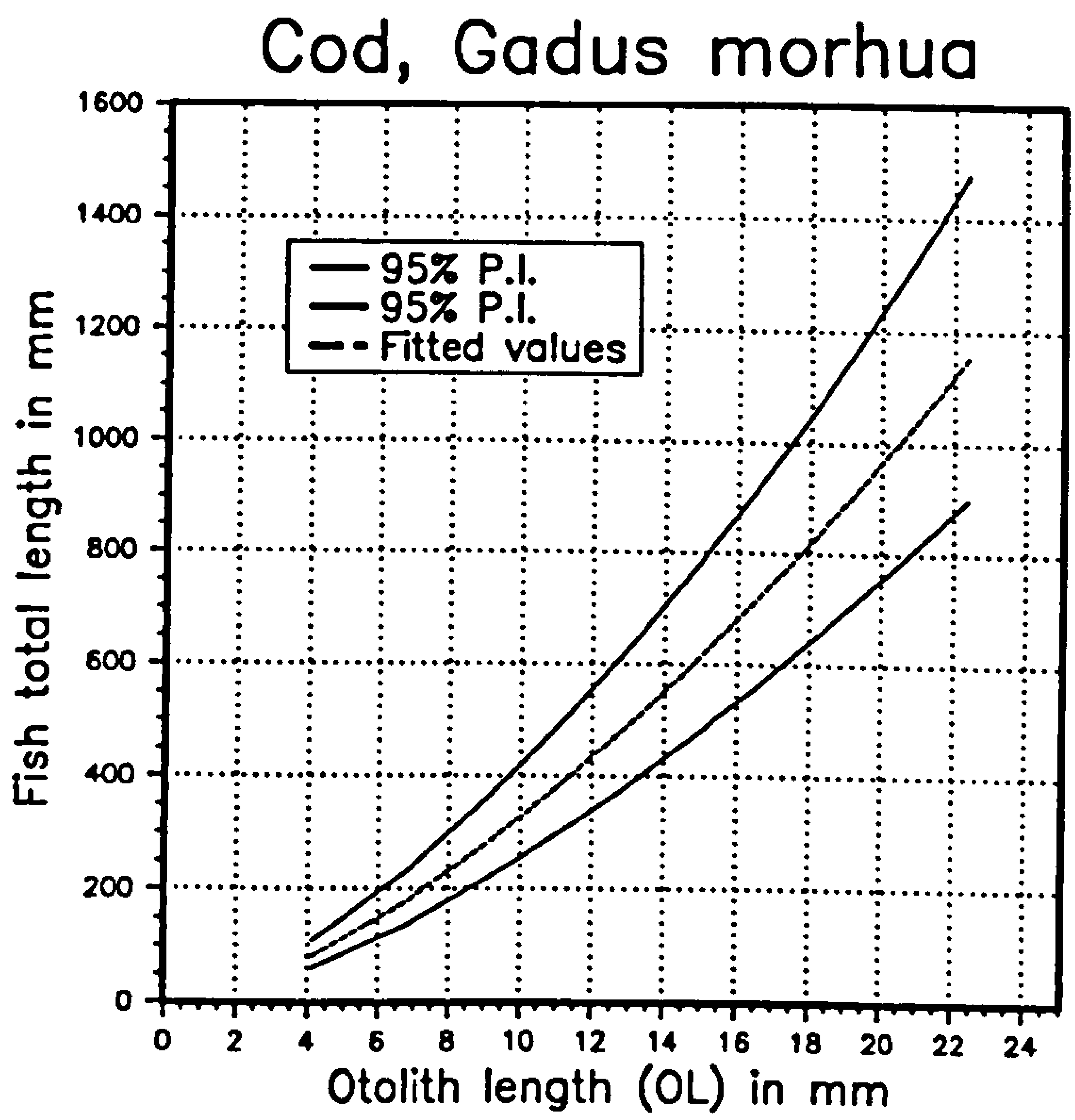


Figure 45. The 95% prediction intervals and fitted values for cod otolith measurements.



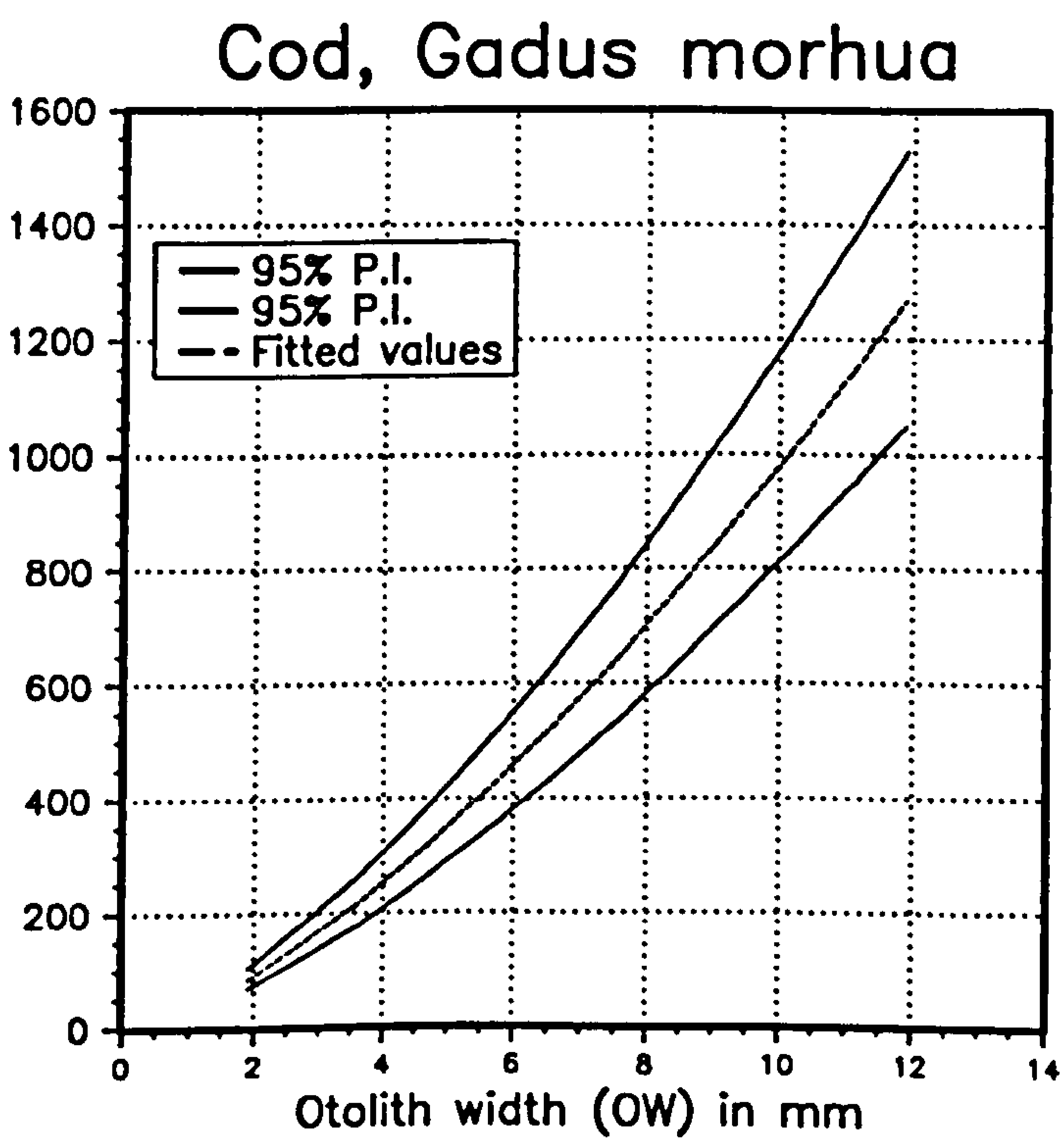
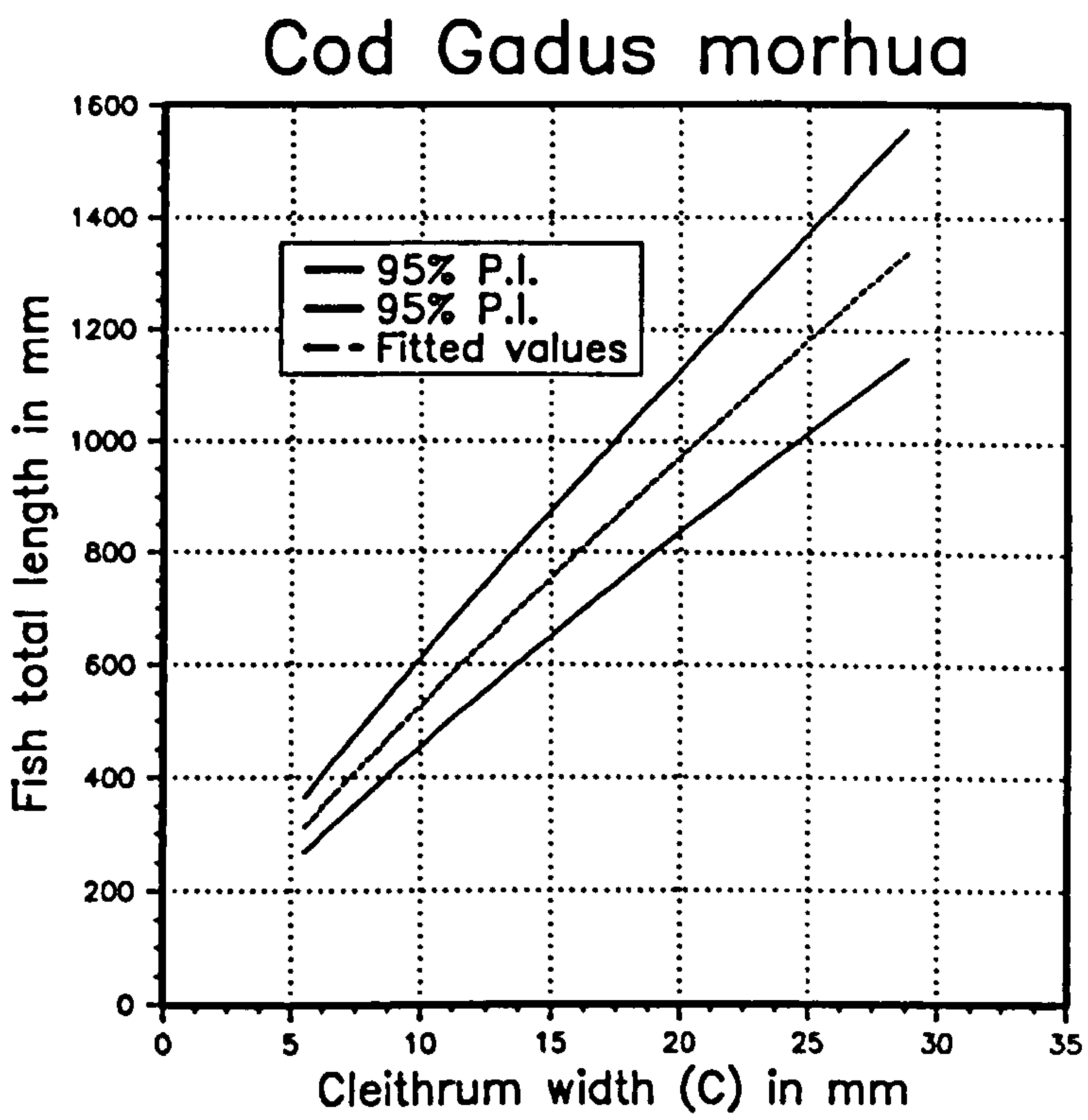


Figure 46. The 95% prediction intervals and fitted values for cod and ling cleithra measurements.



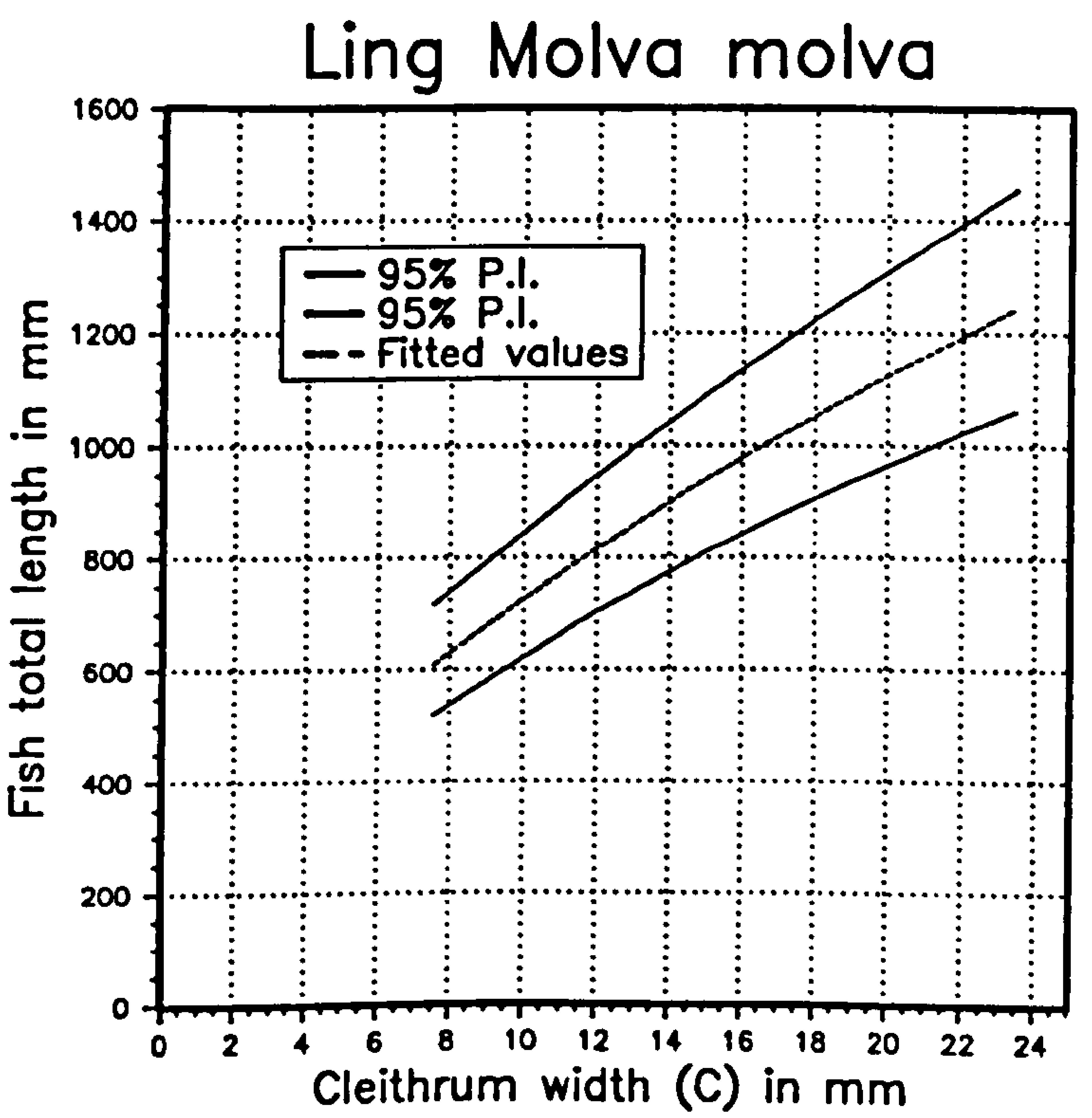
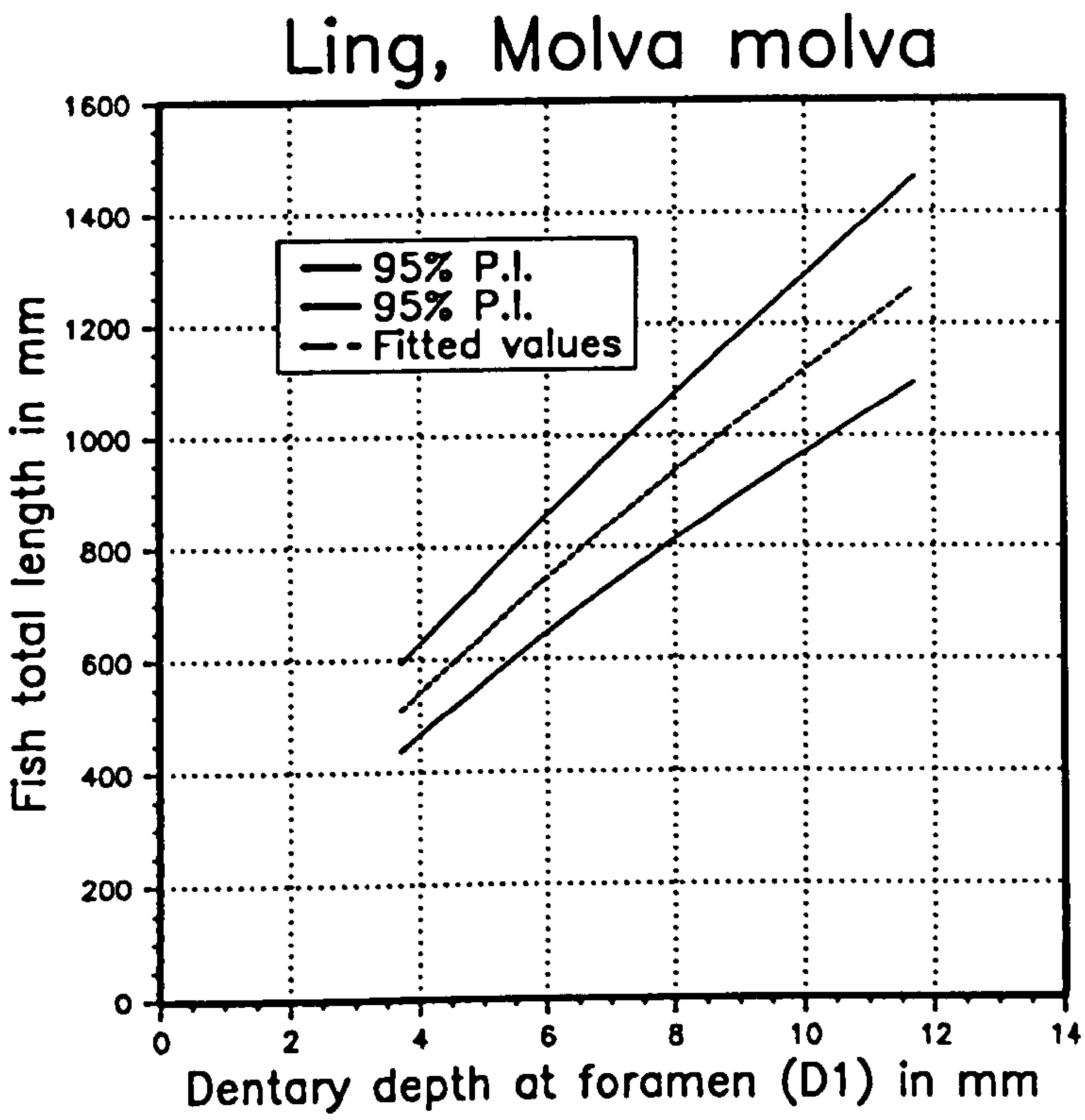


Figure 47. The 95% prediction intervals and fitted values for ling dentary measurements.



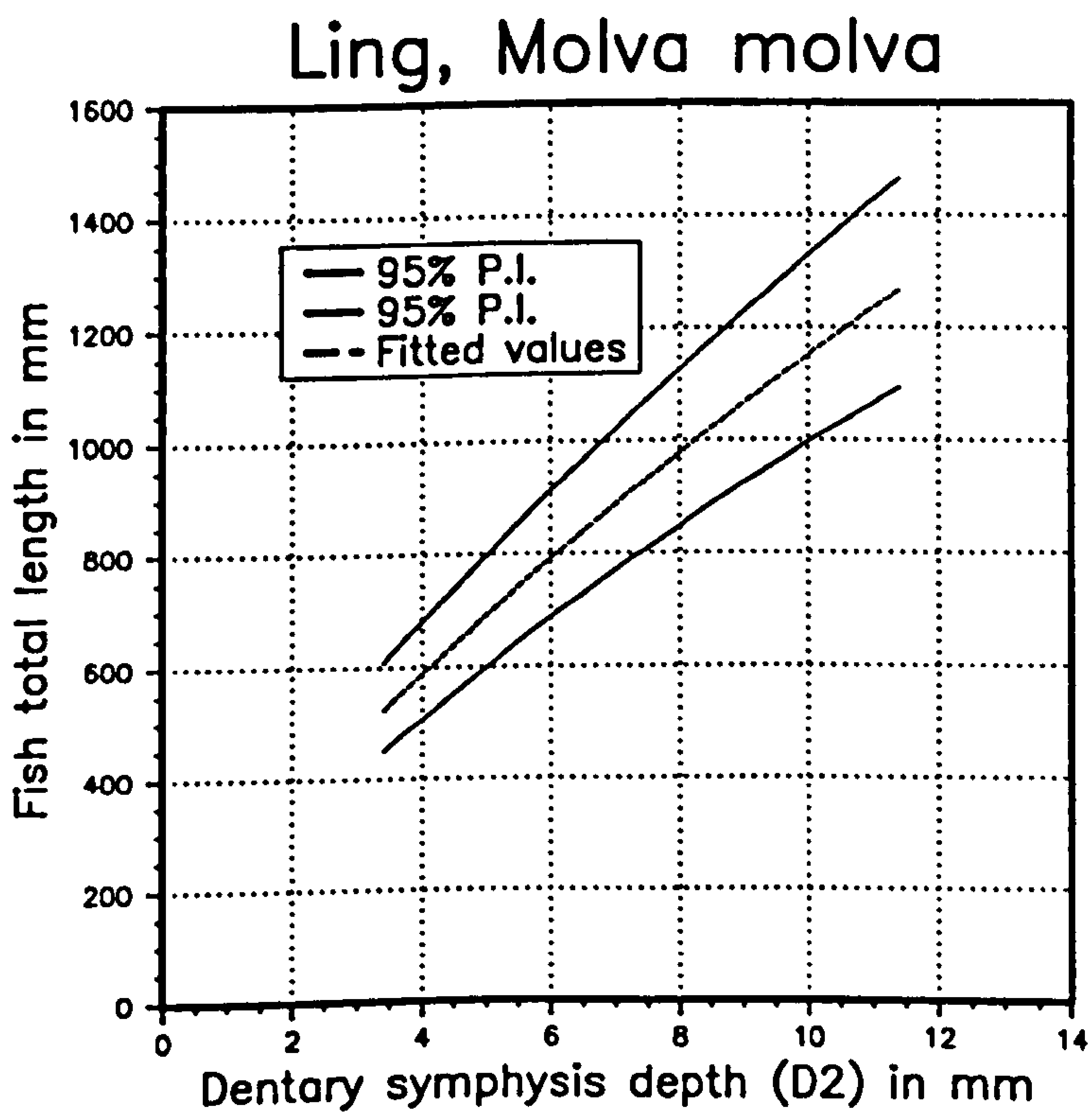
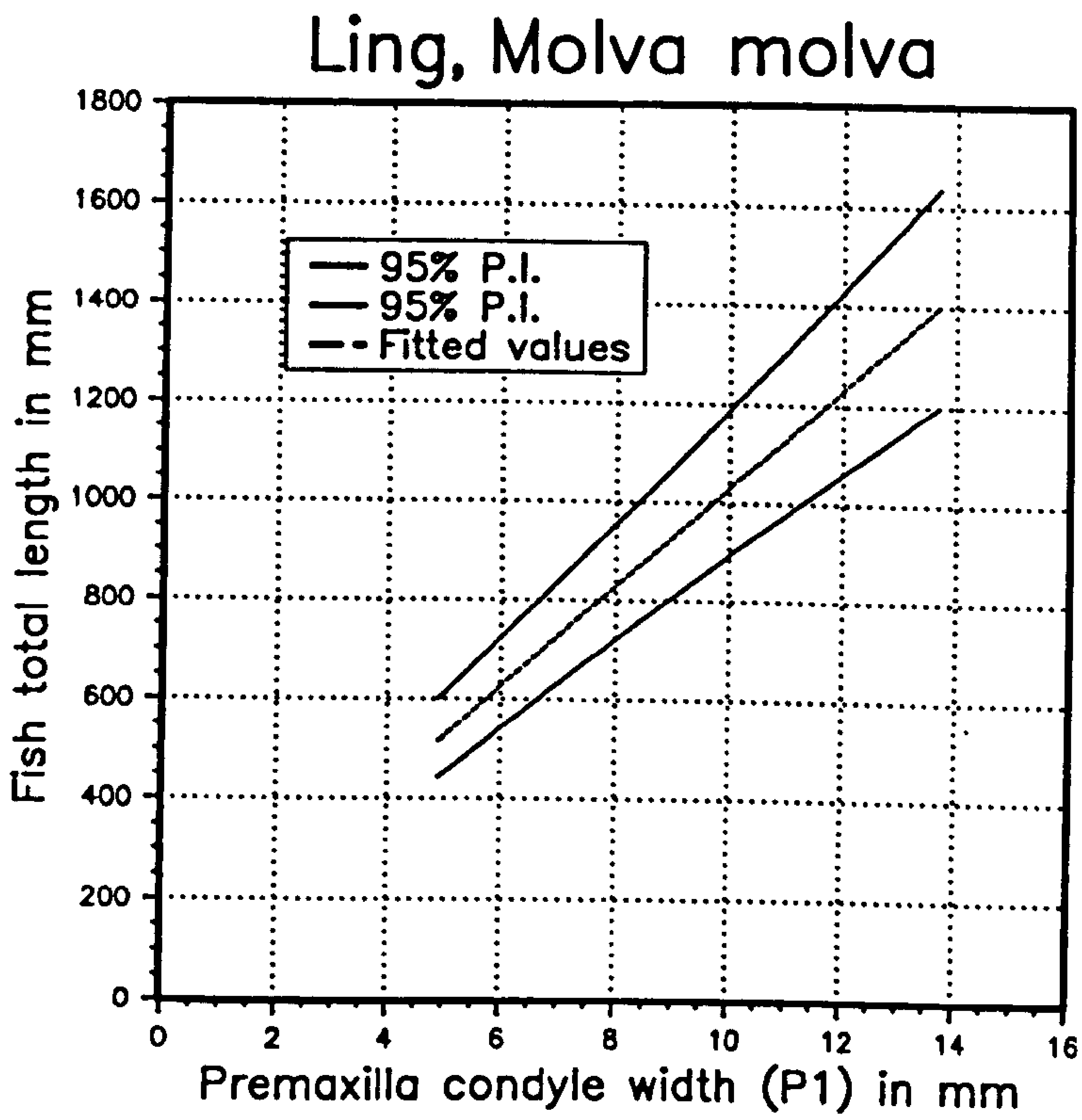


Figure 48. The 95% prediction intervals and fitted values for ling premaxilla measurements.



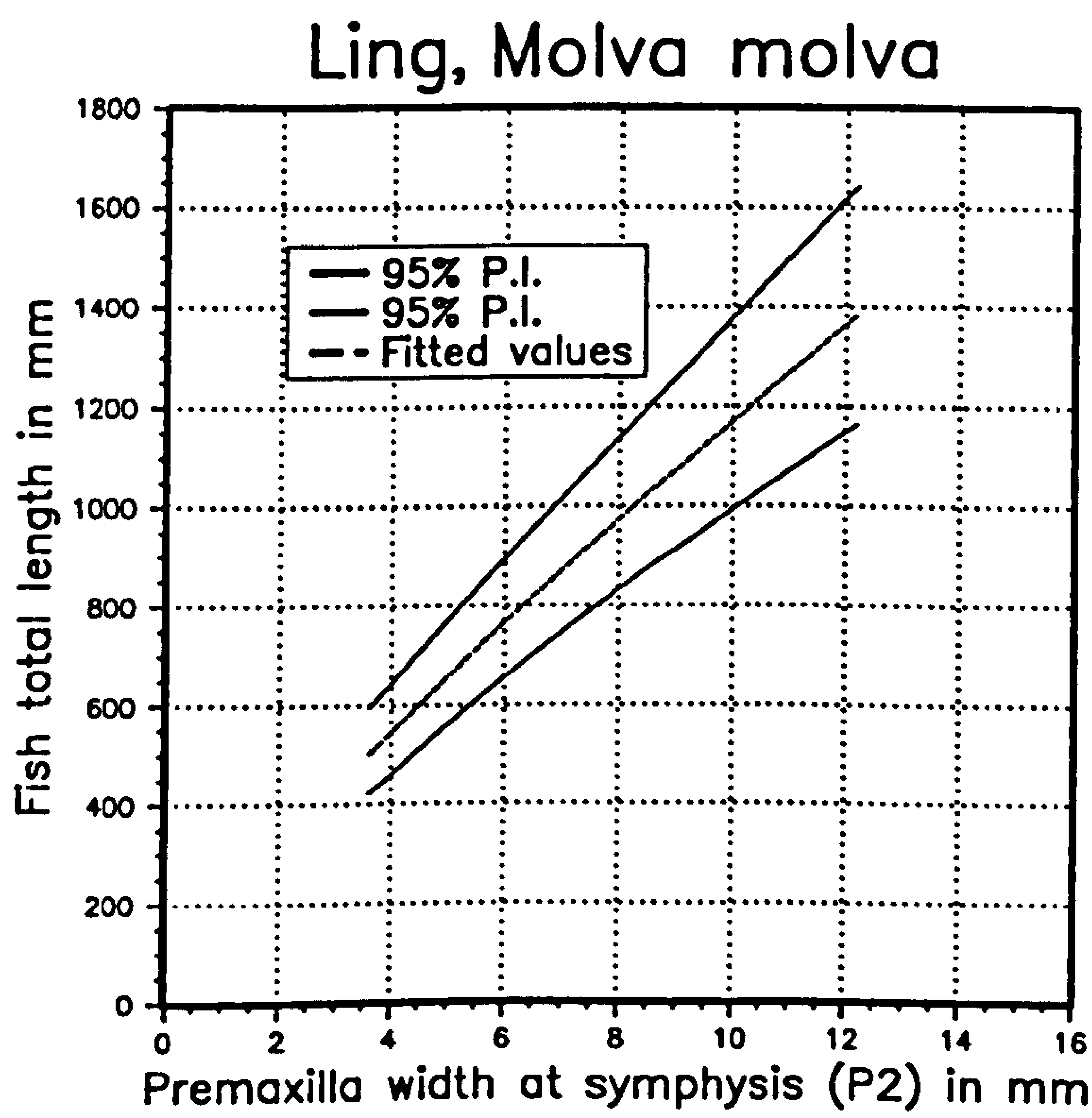
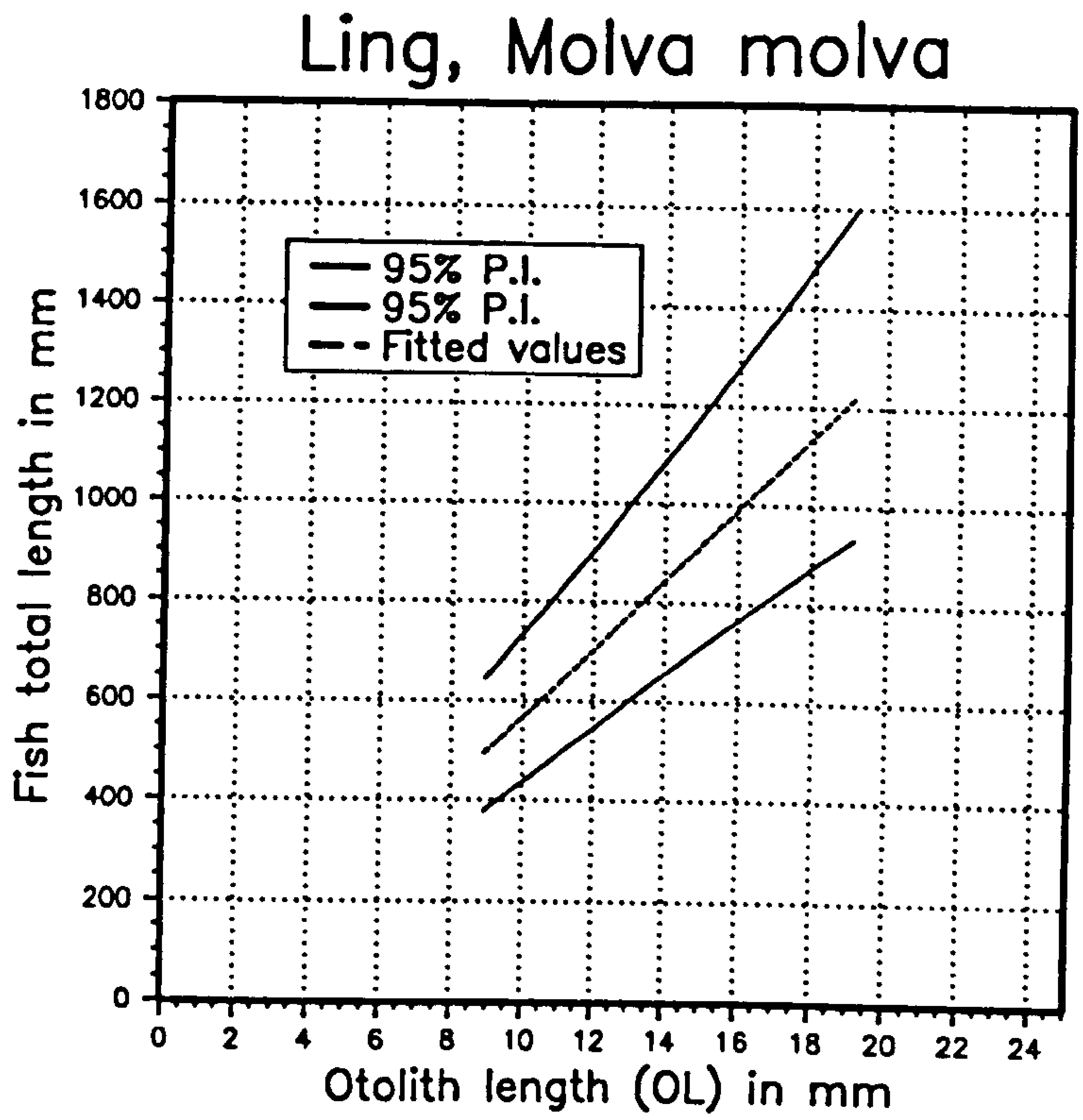


Figure 49. The 95% prediction intervals and fitted values for ling otolith measurements.



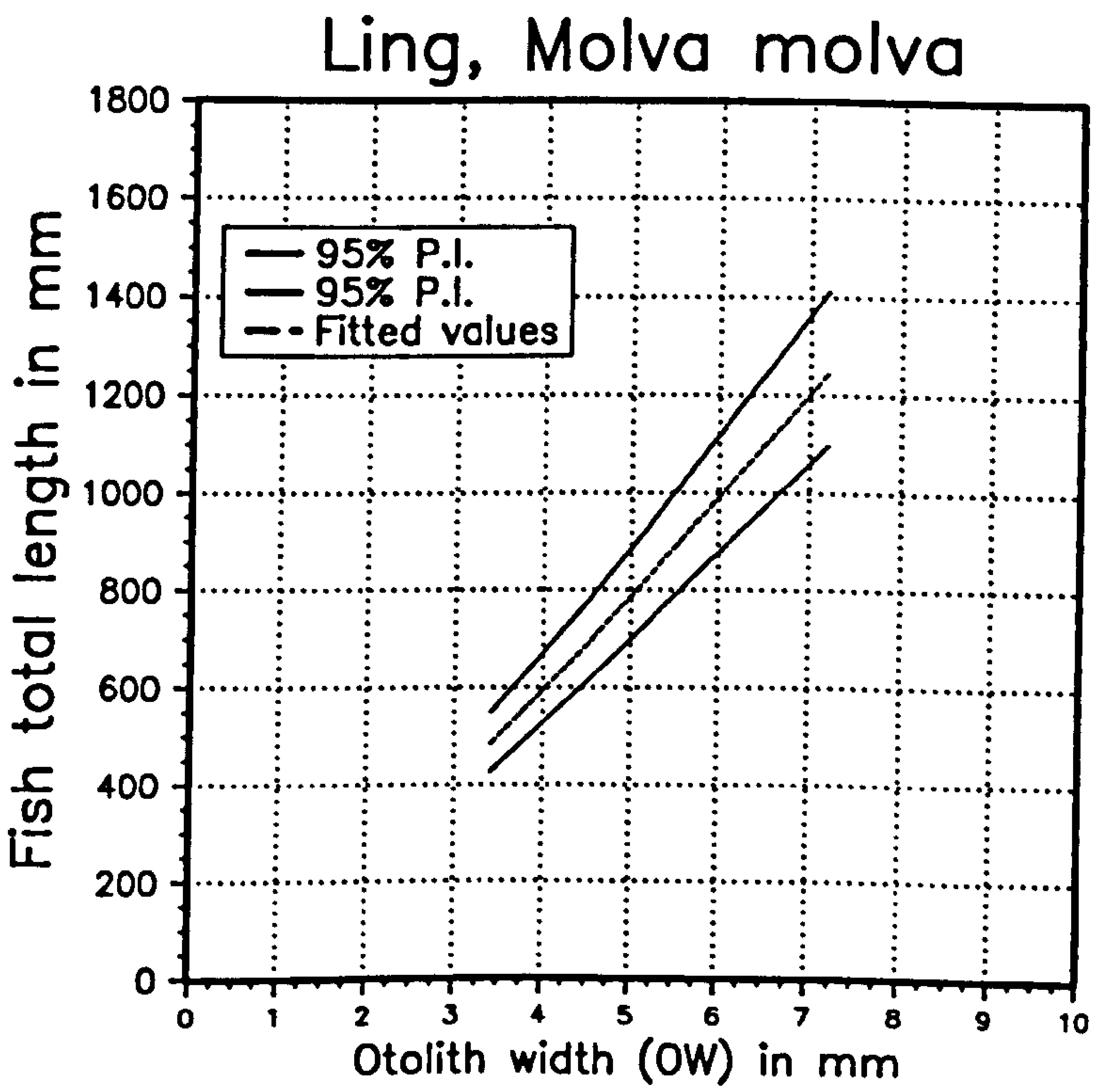
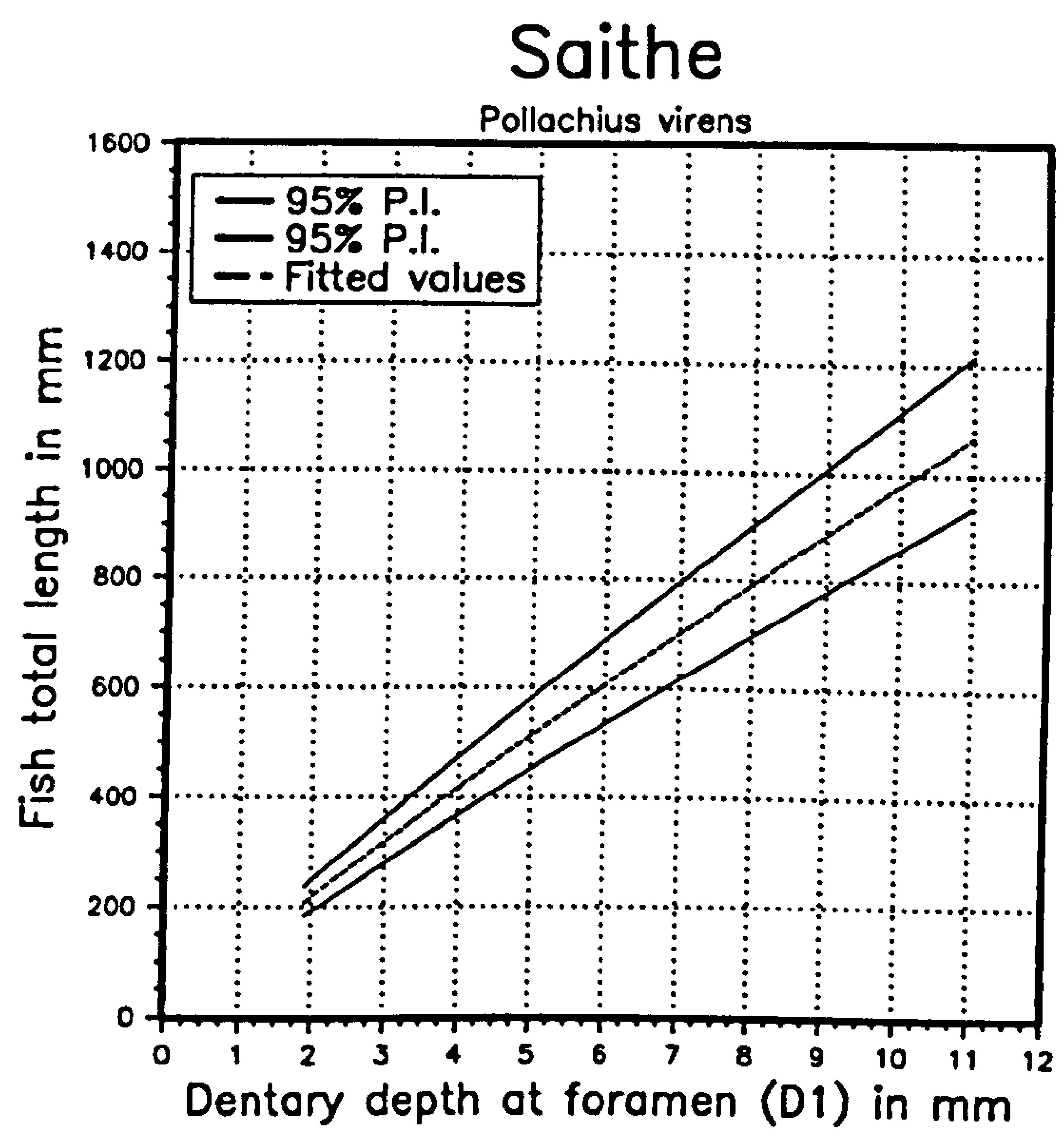


Figure 50. The 95% prediction intervals and fitted values for saithe dentary measurements.



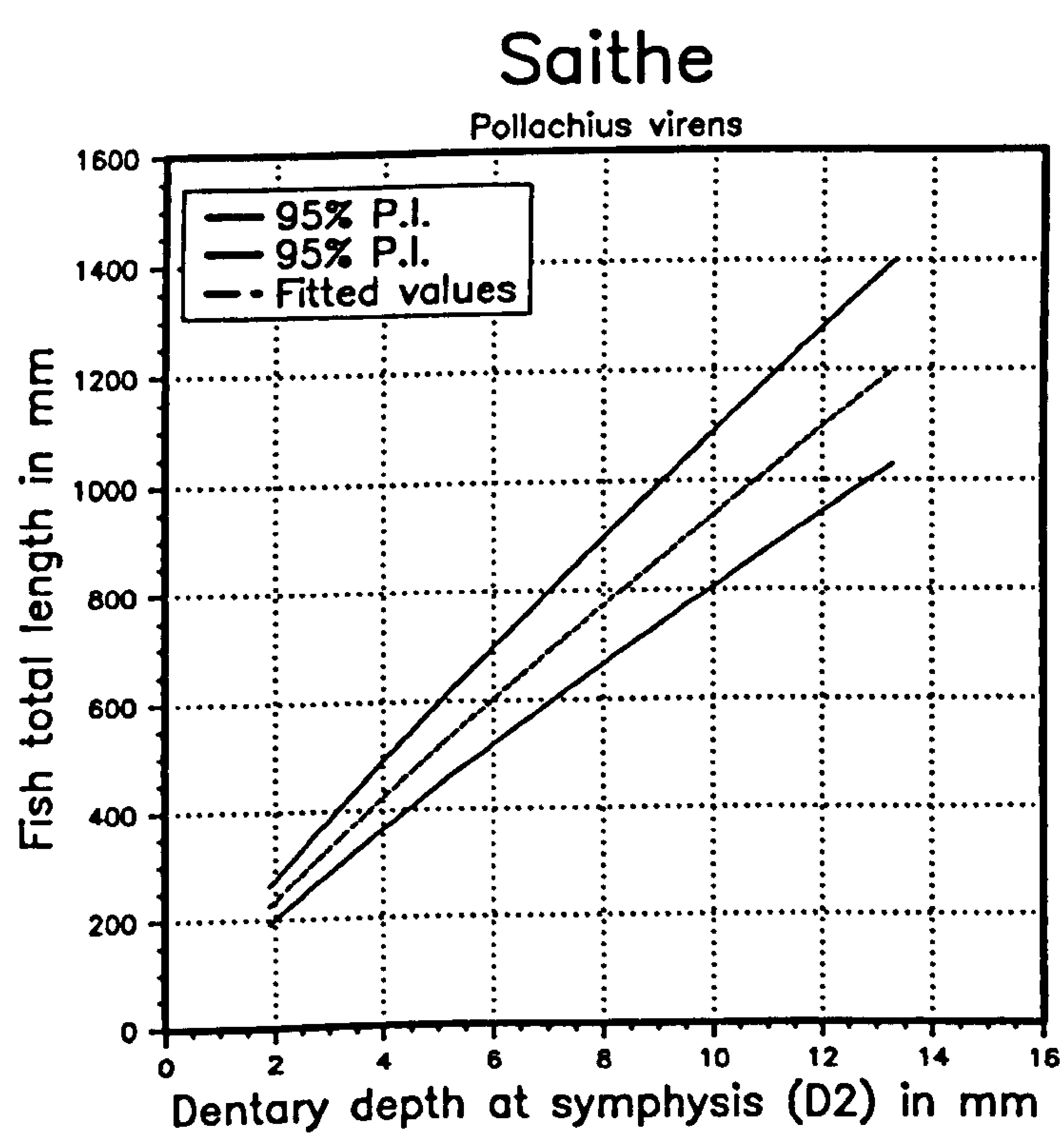
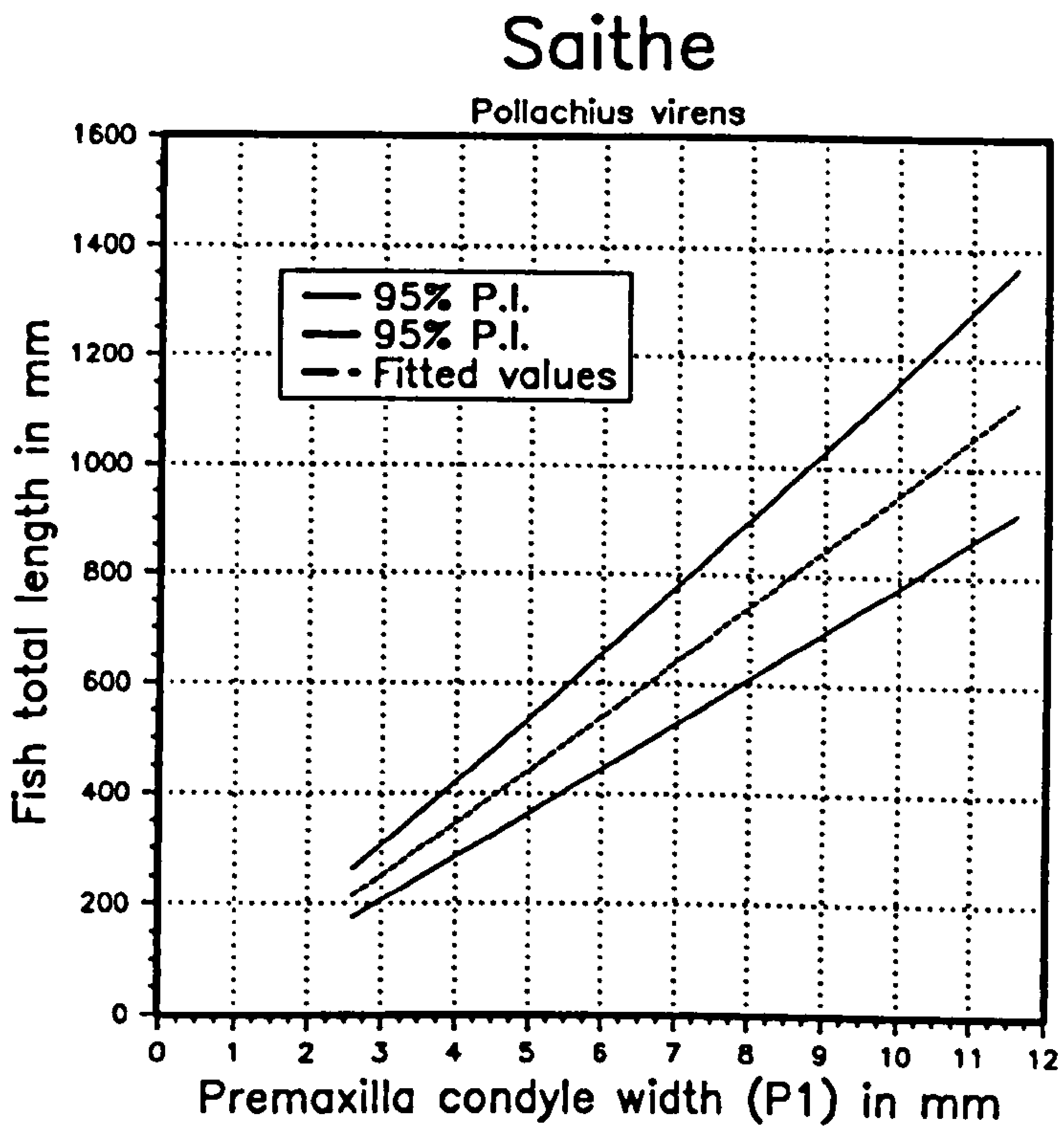


Figure 51. The 95% prediction intervals and fitted values for saithe premaxilla measurements.



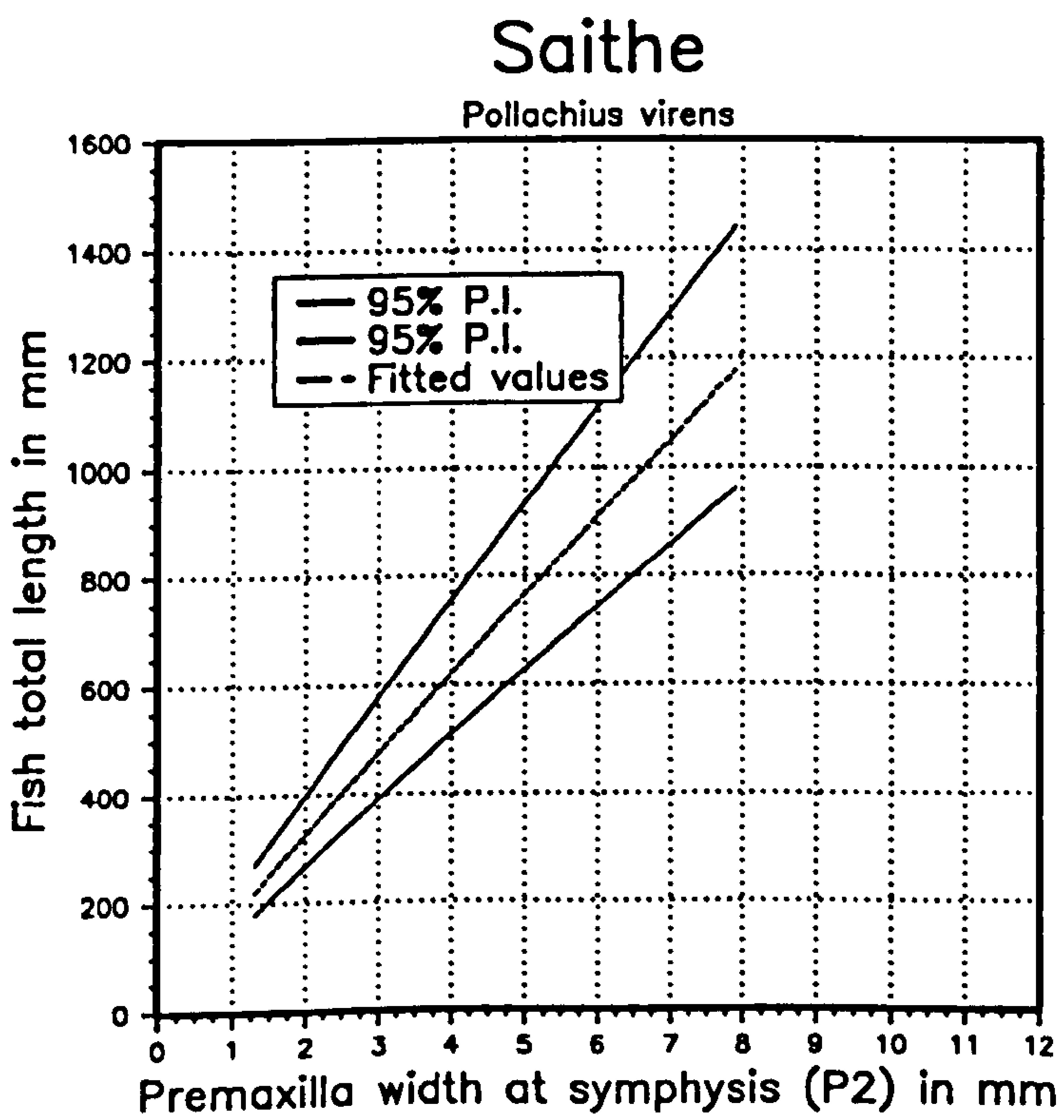
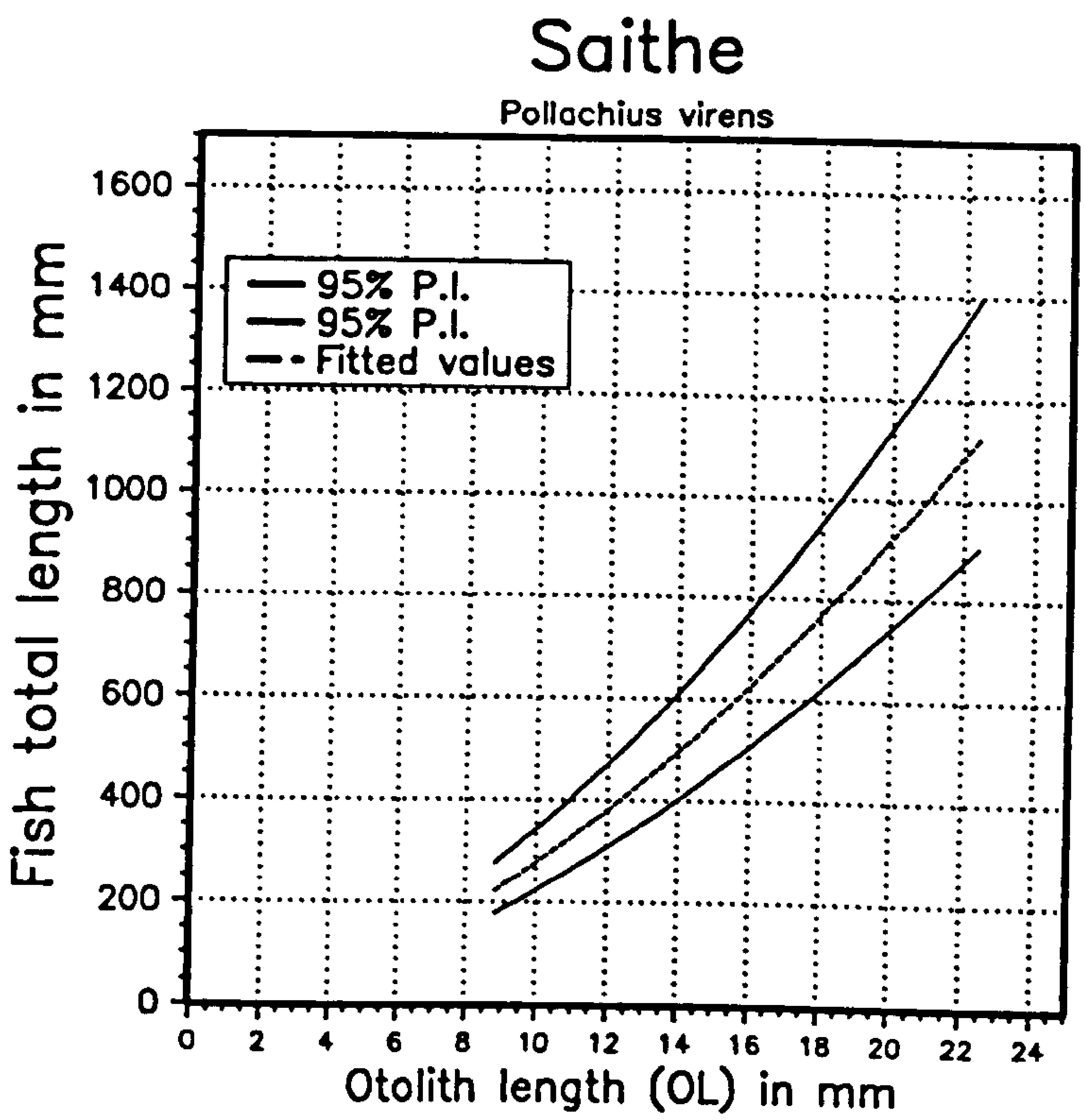


Figure 52. The 95% prediction intervals and fitted values for saithe otolith measurements.



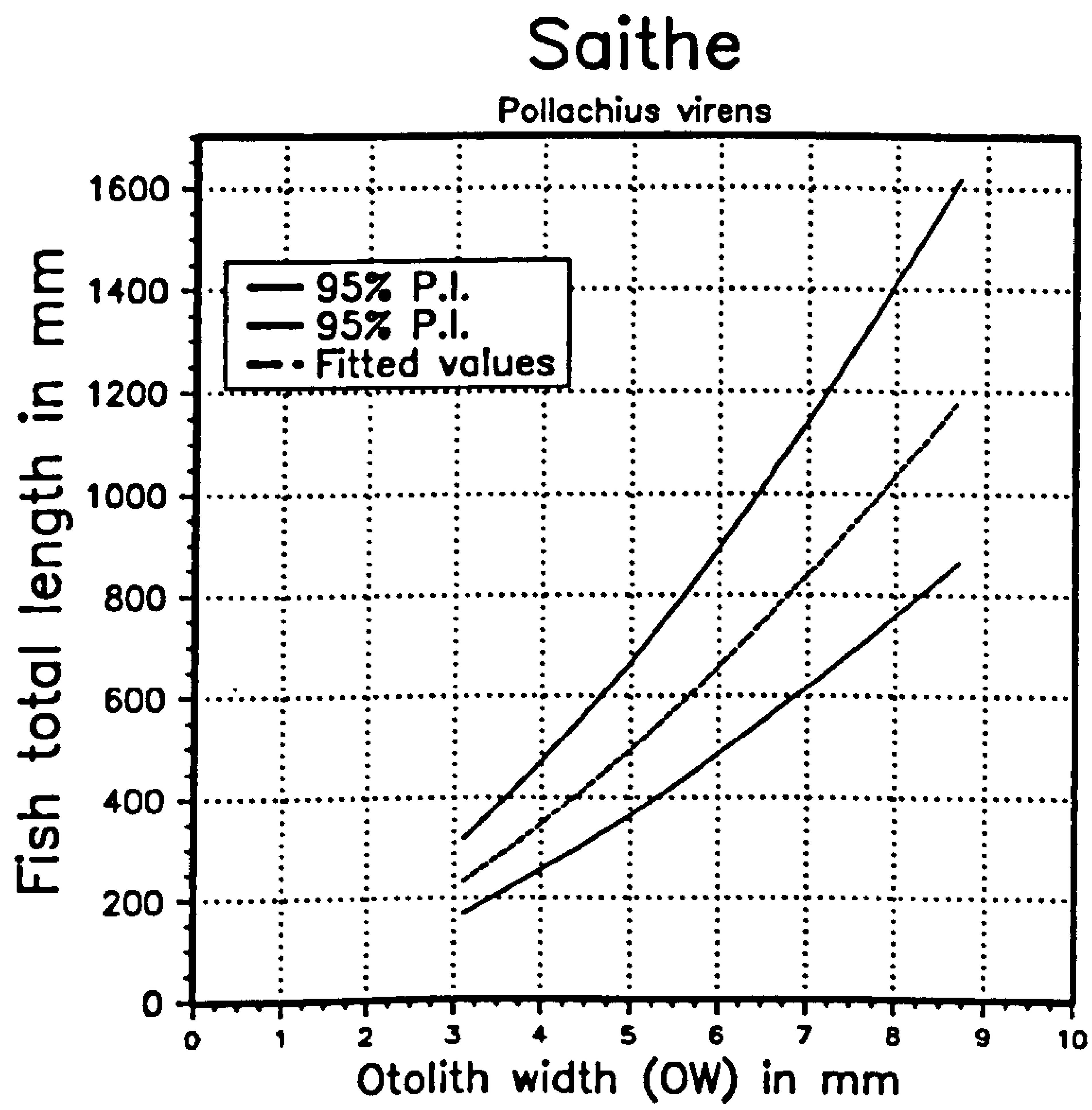
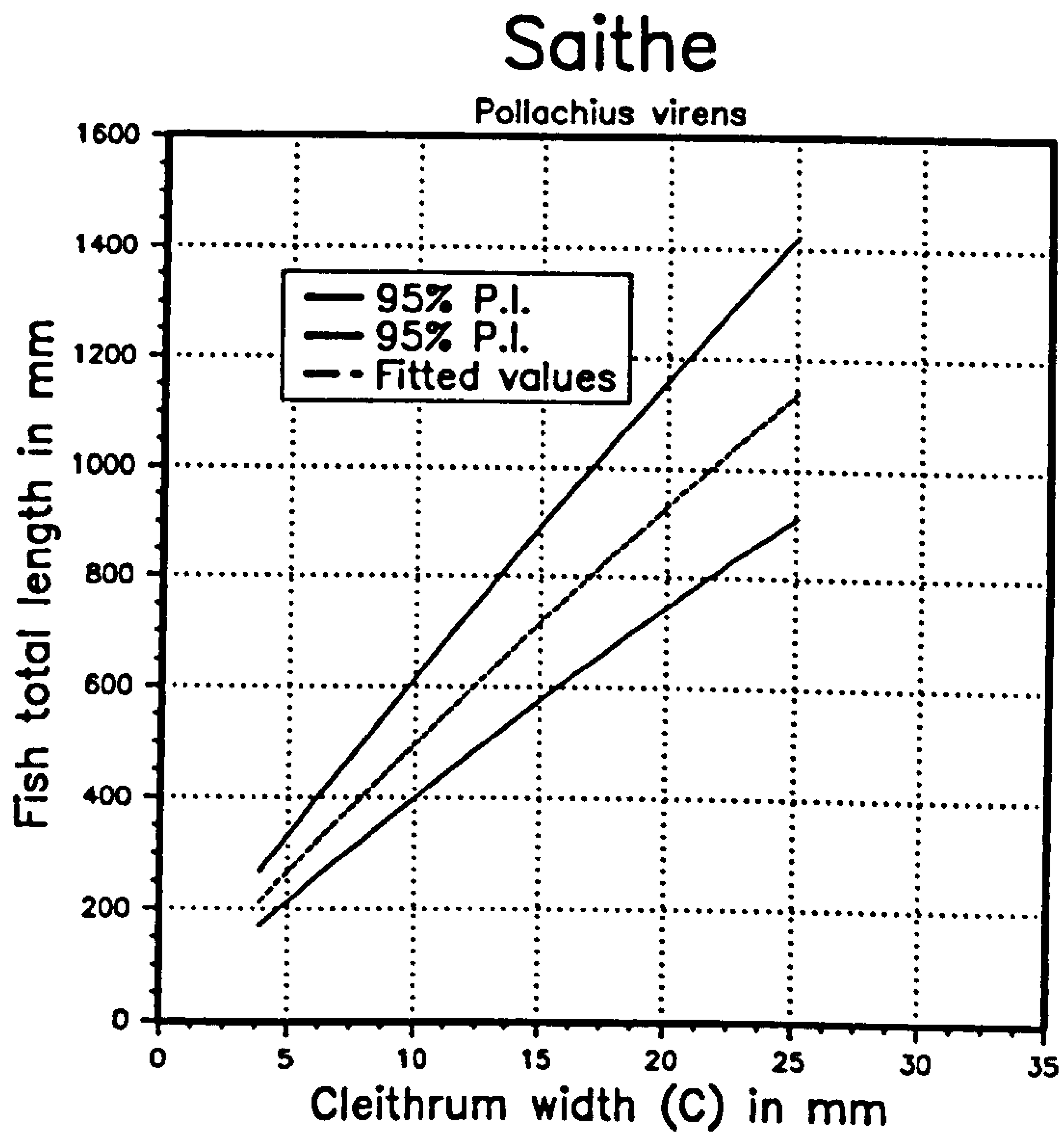


Figure 53. The 95% prediction intervals and fitted values for saithe and pollack cleithra measurements.



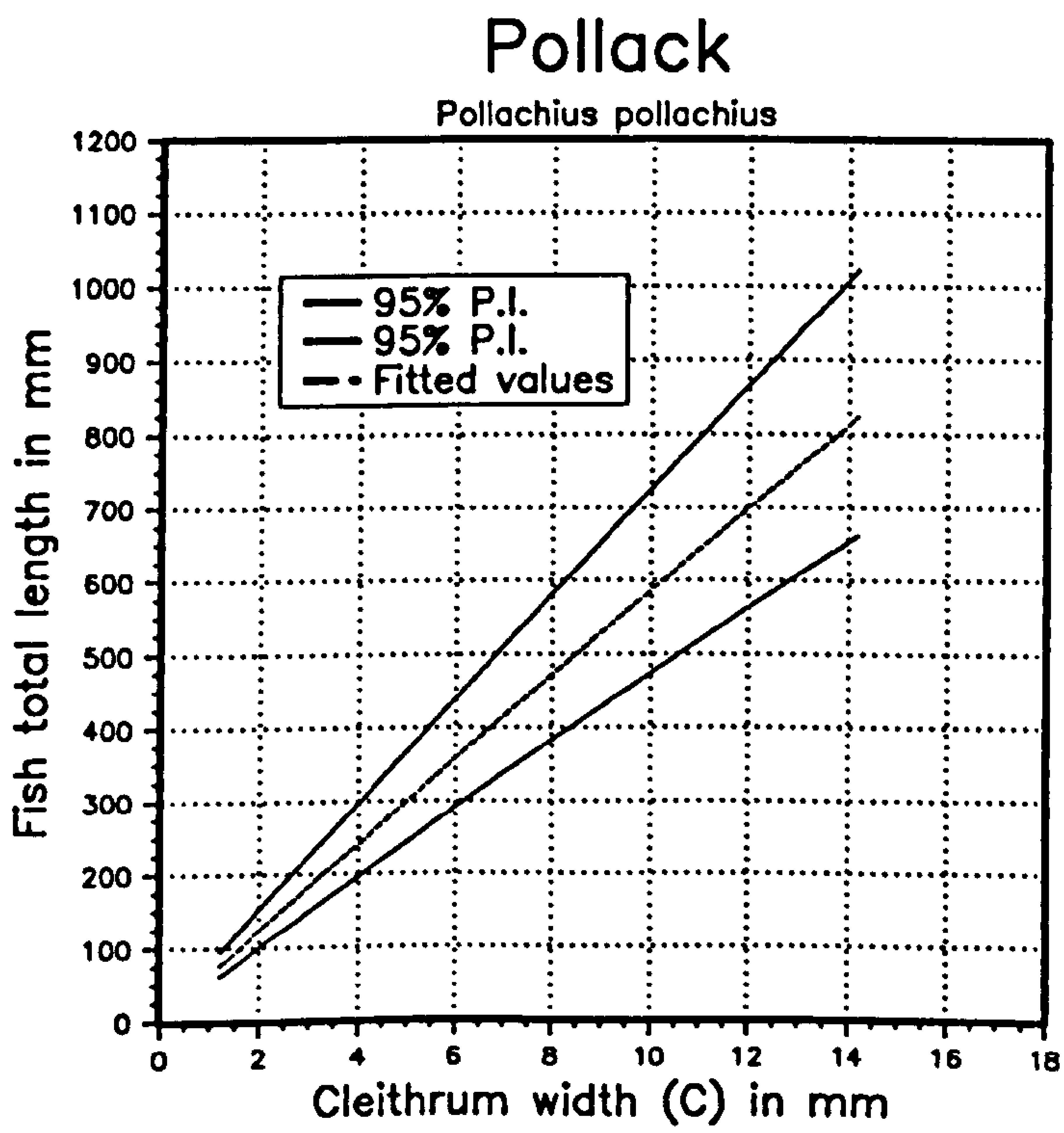
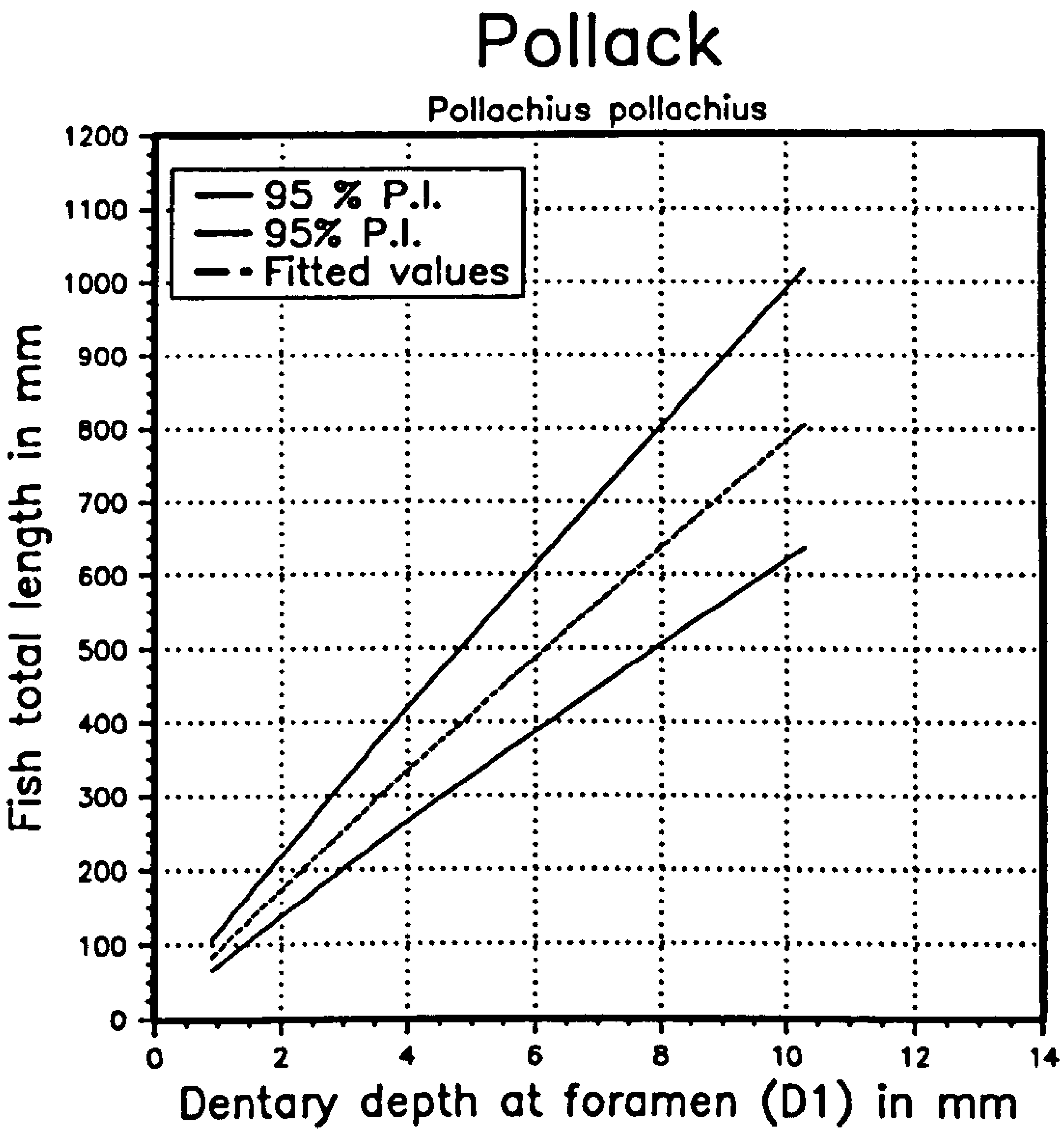


Figure 54. The 95% prediction intervals and fitted values for pollack dentary measurements.



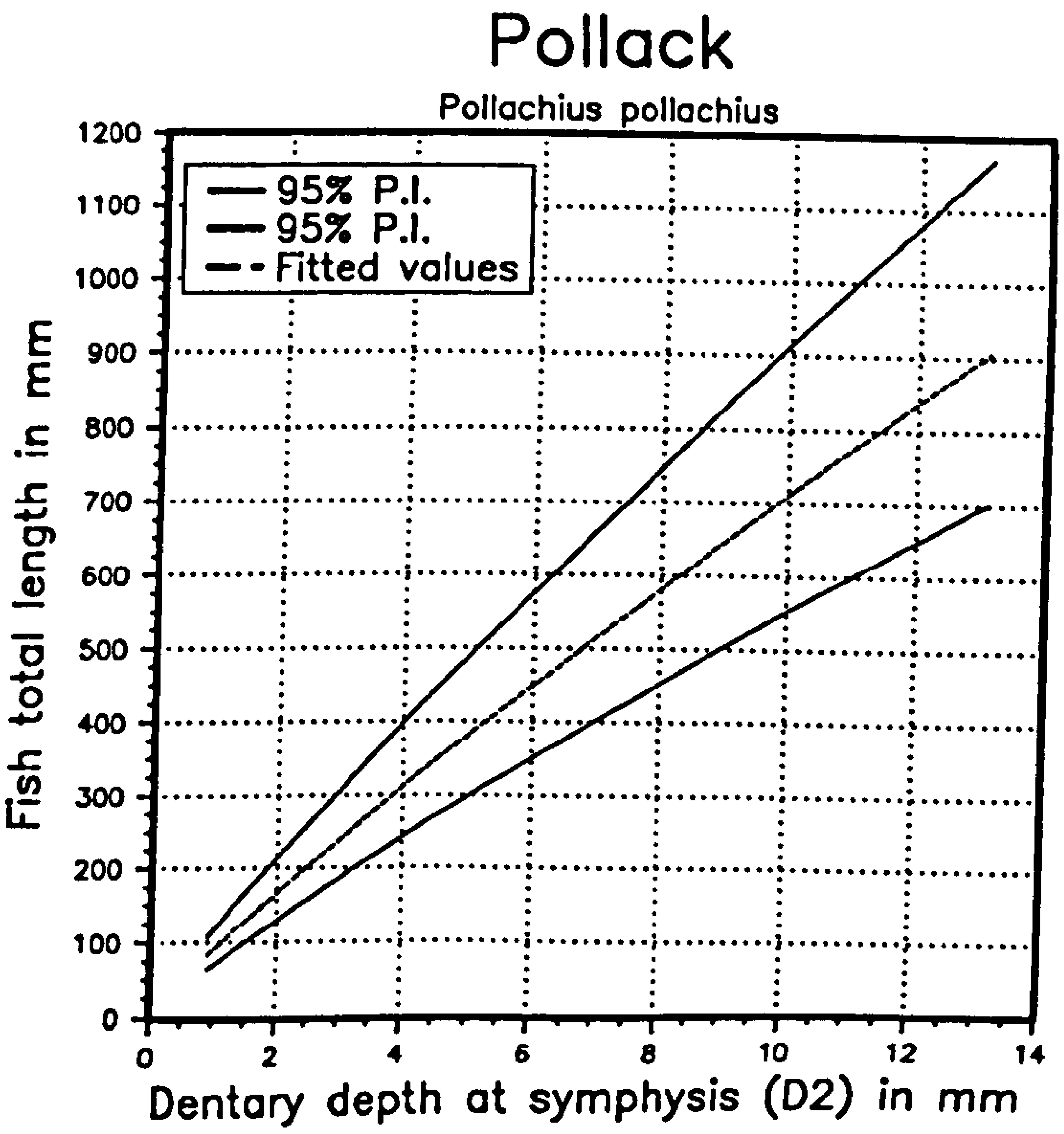
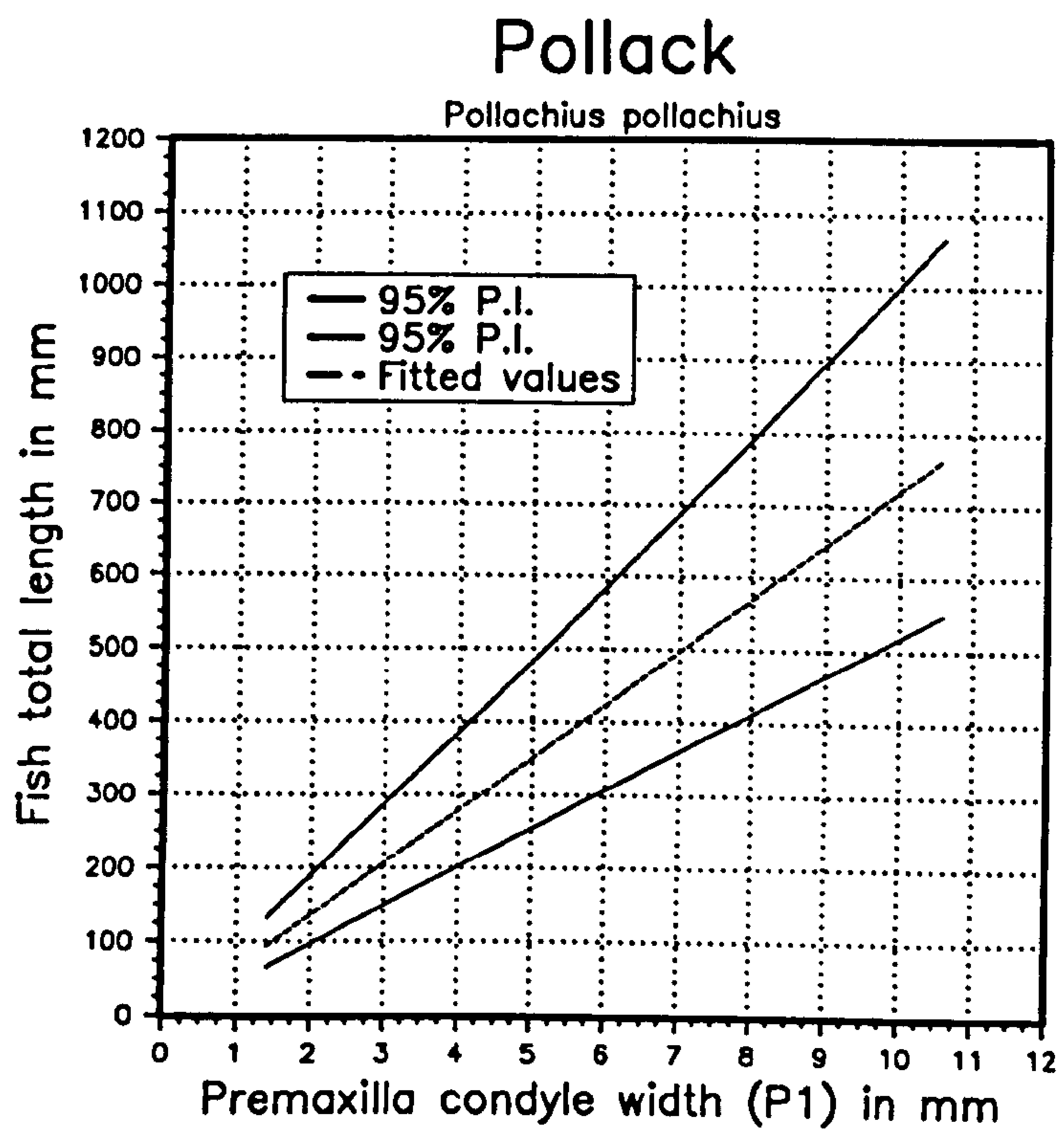


Figure 55. The 95% prediction intervals and fitted values for pollack premaxilla measurements.



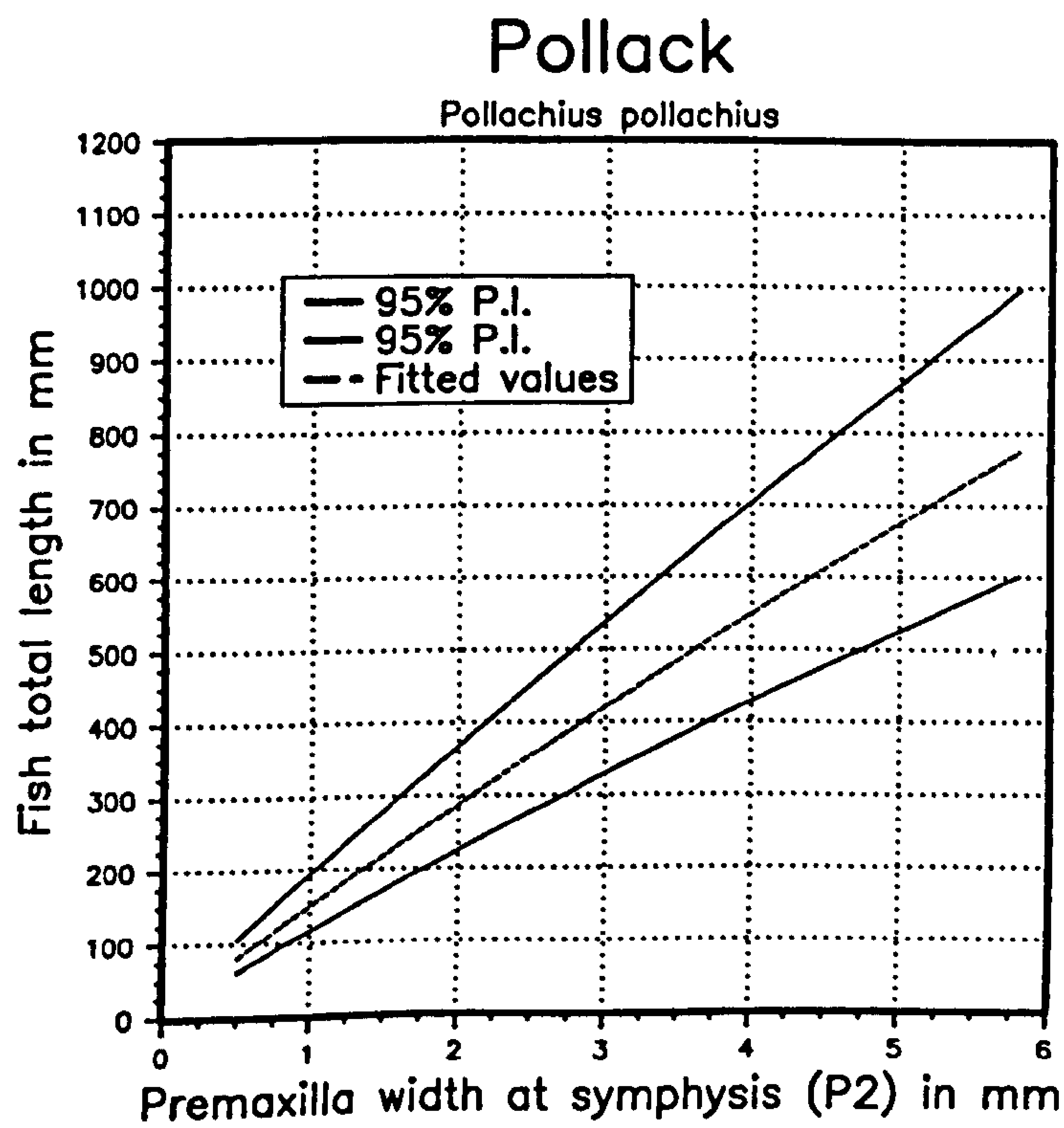
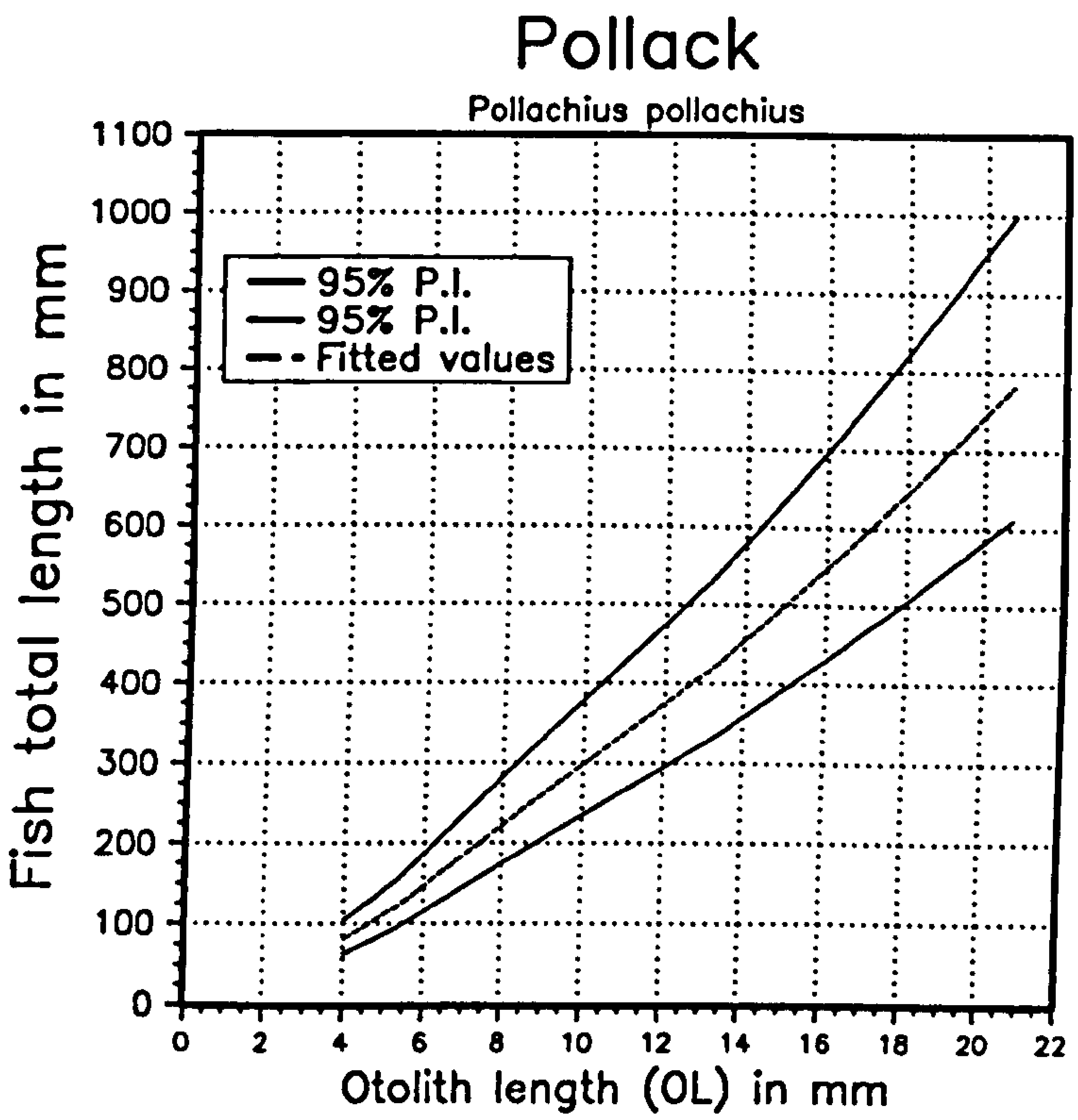


Figure 56. The 95% prediction intervals and fitted values for pollack otolith measurements.



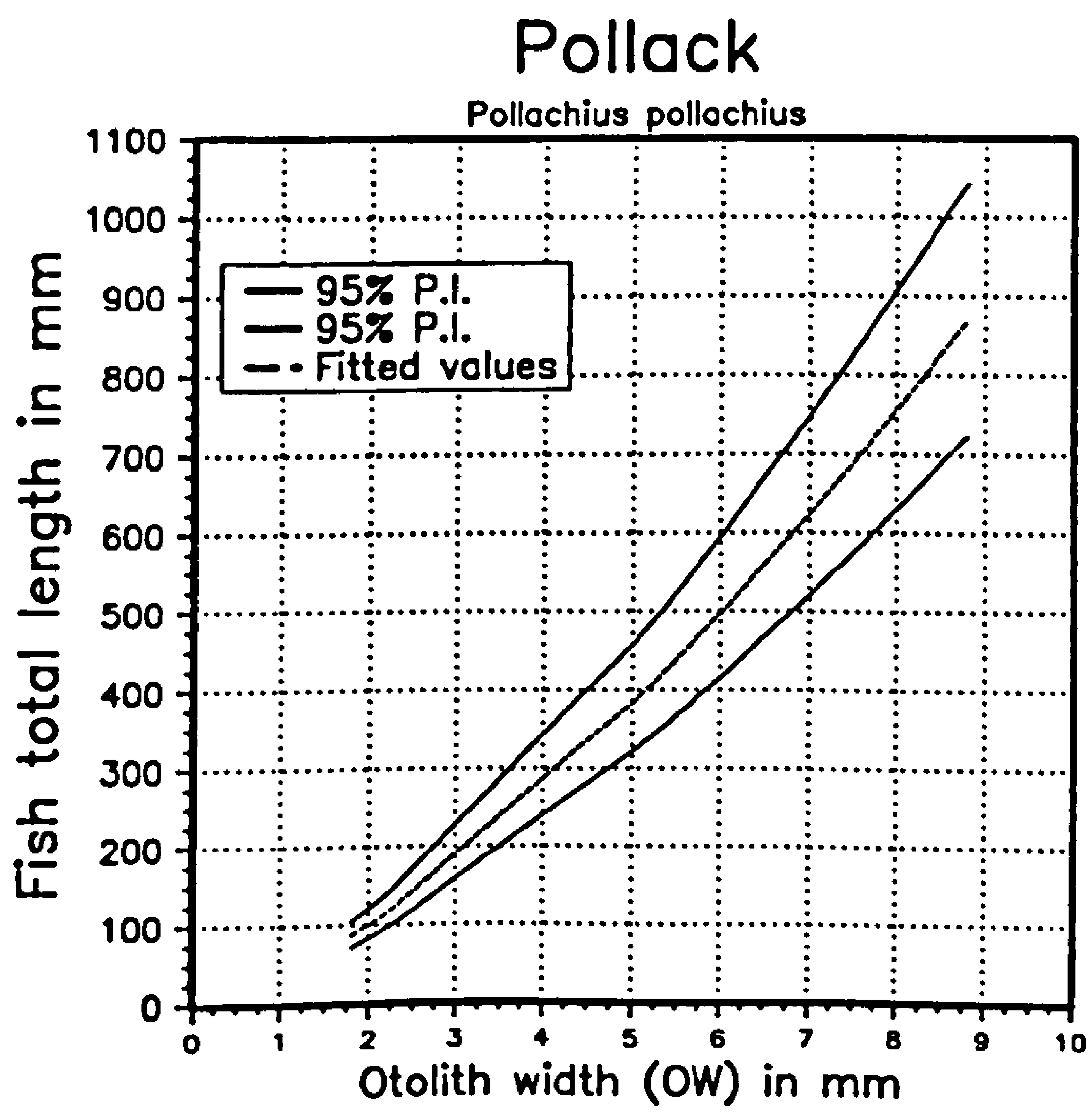
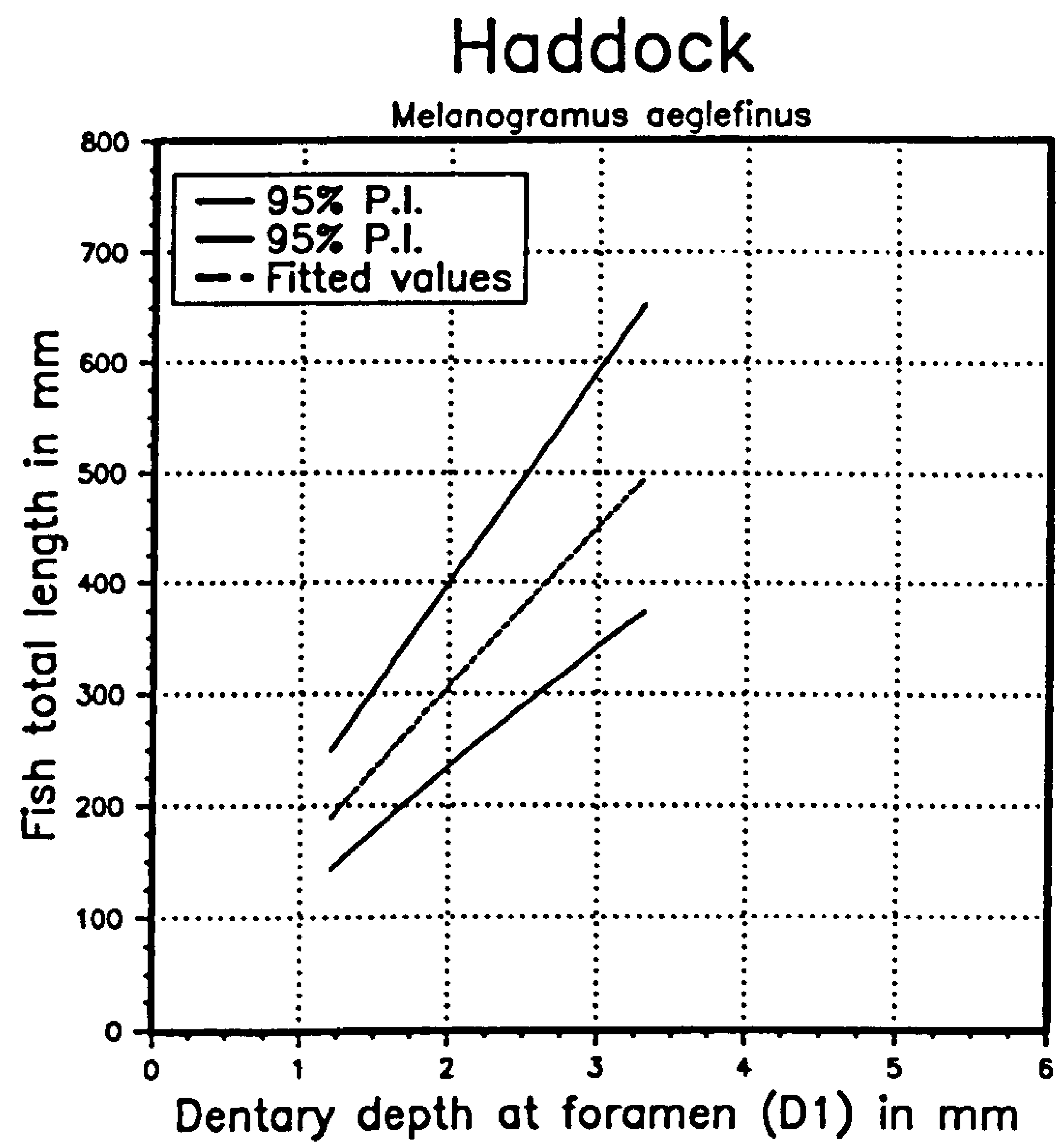


Figure 57. The 95% prediction intervals and fitted values for haddock dentary measurements.



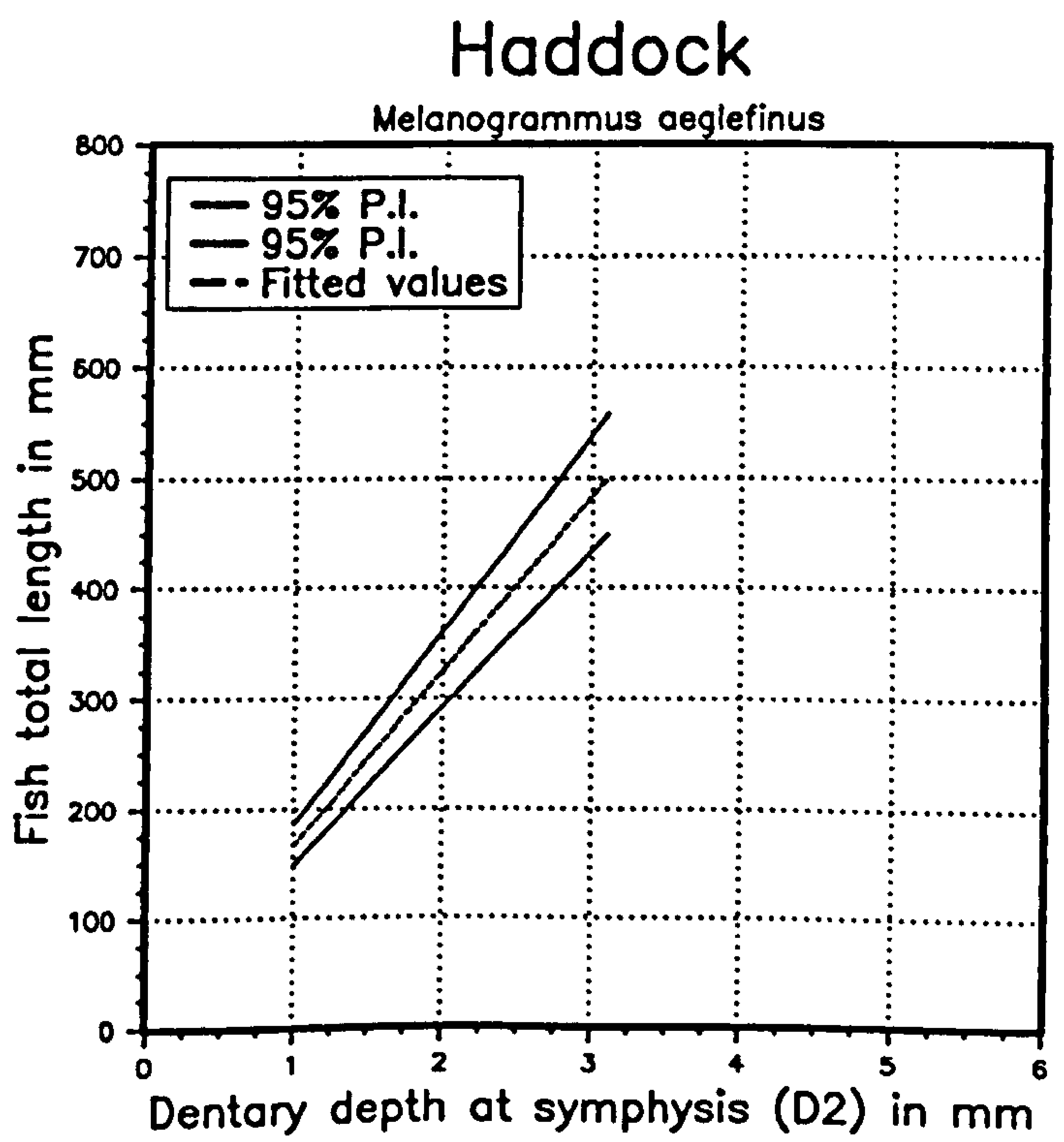
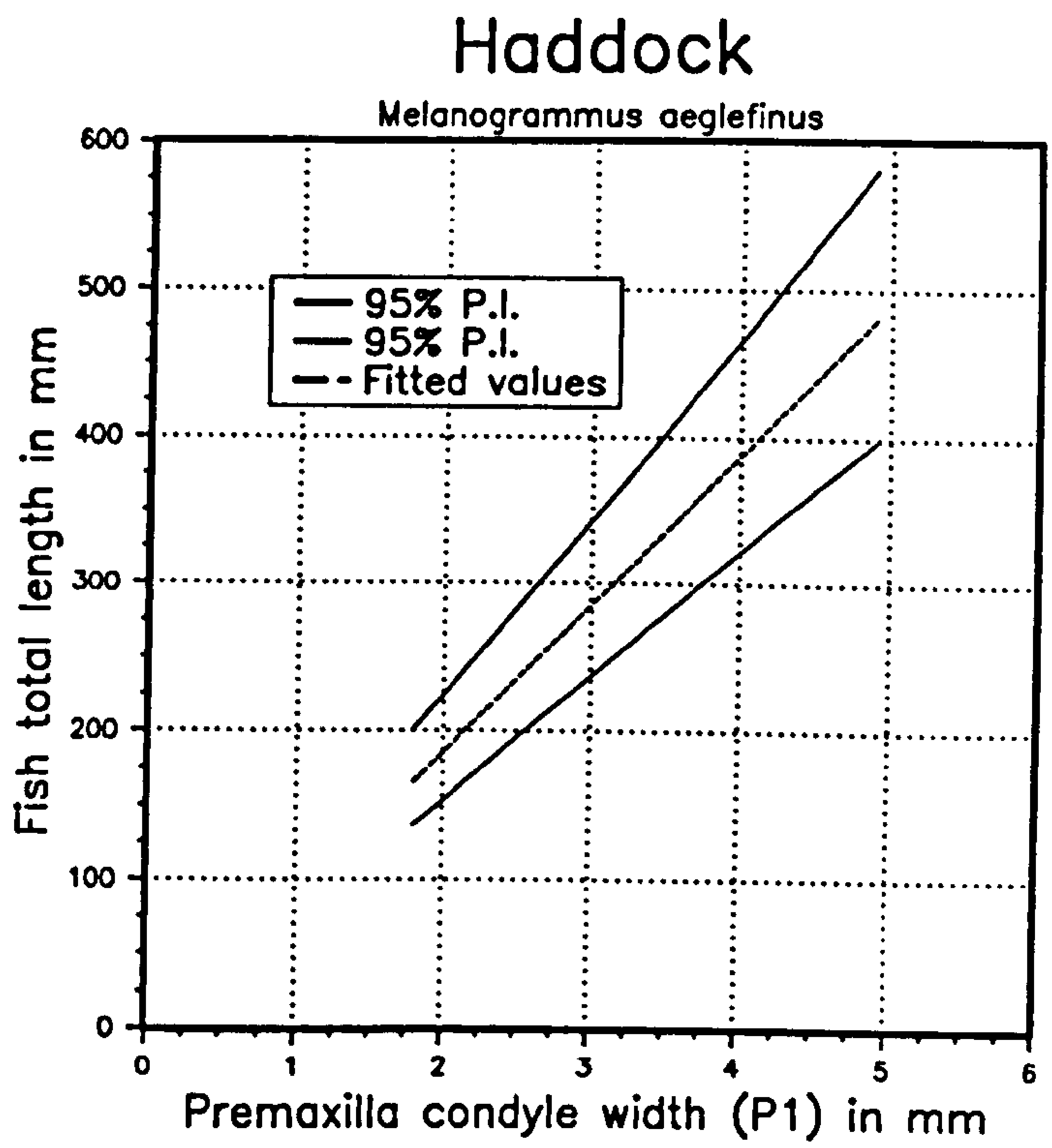


Figure 58. The 95% prediction intervals and fitted values for haddock premaxilla measurements.



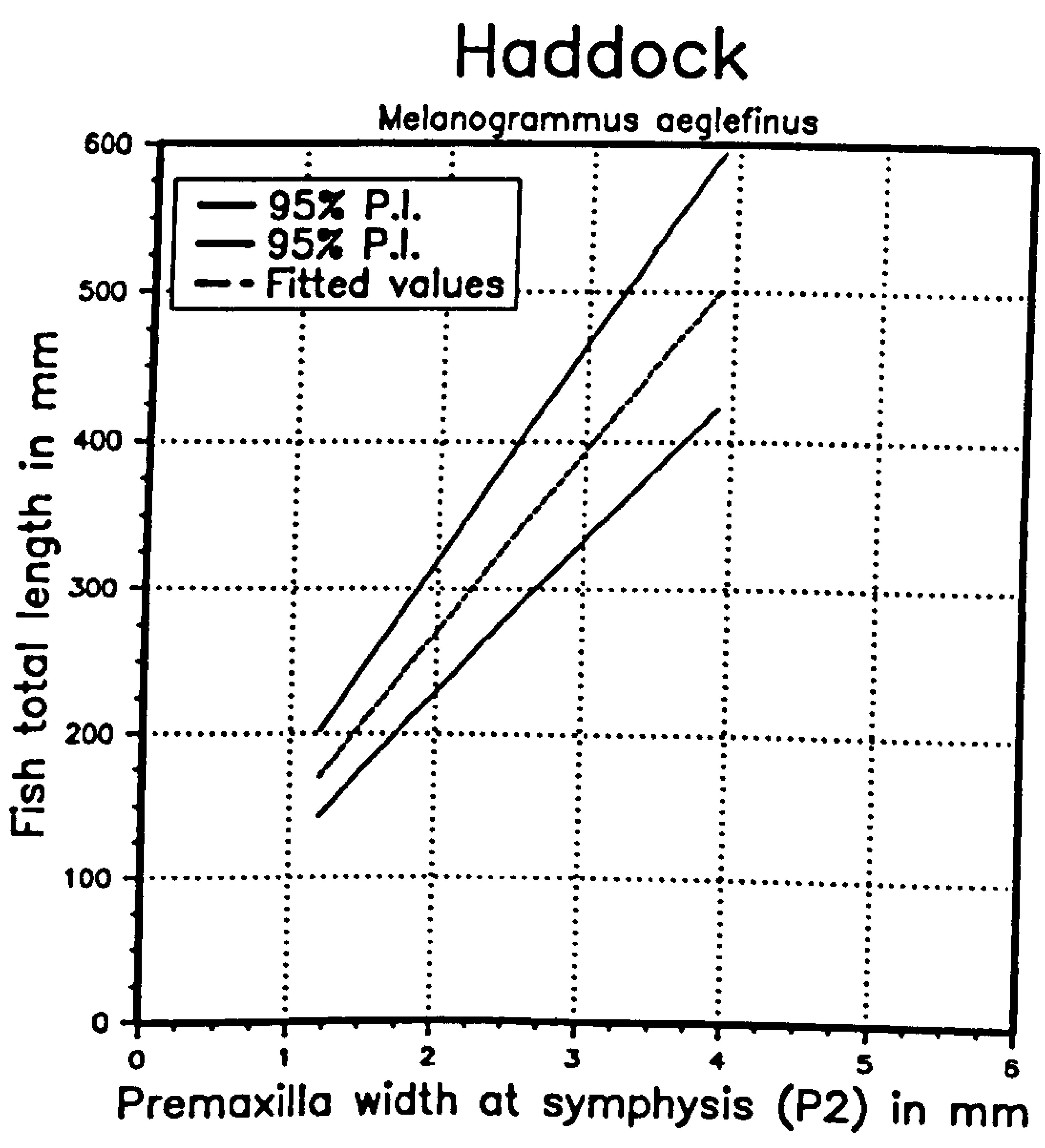
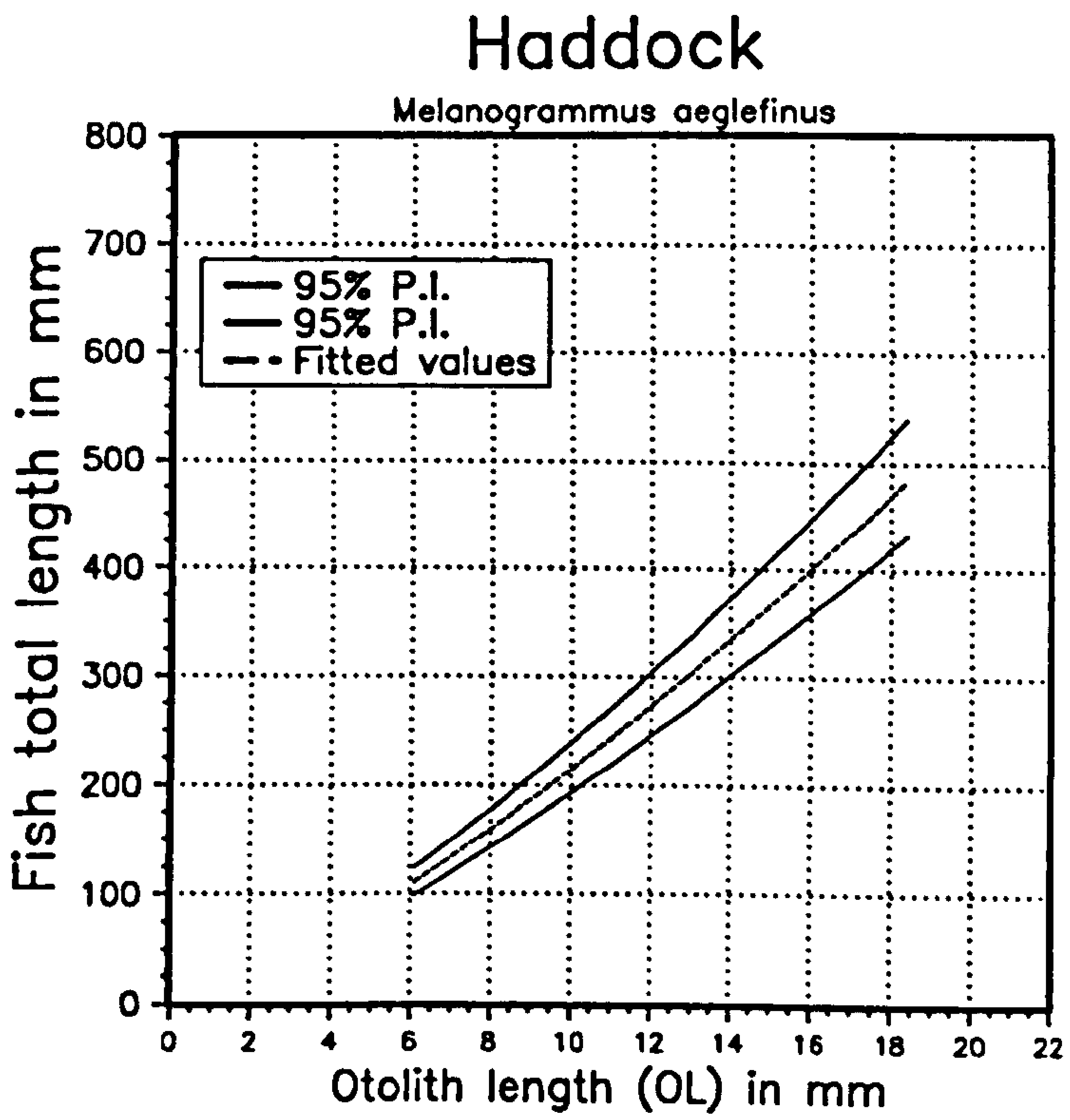


Figure 59. The 95% prediction intervals and fitted values for haddock otolith measurements.



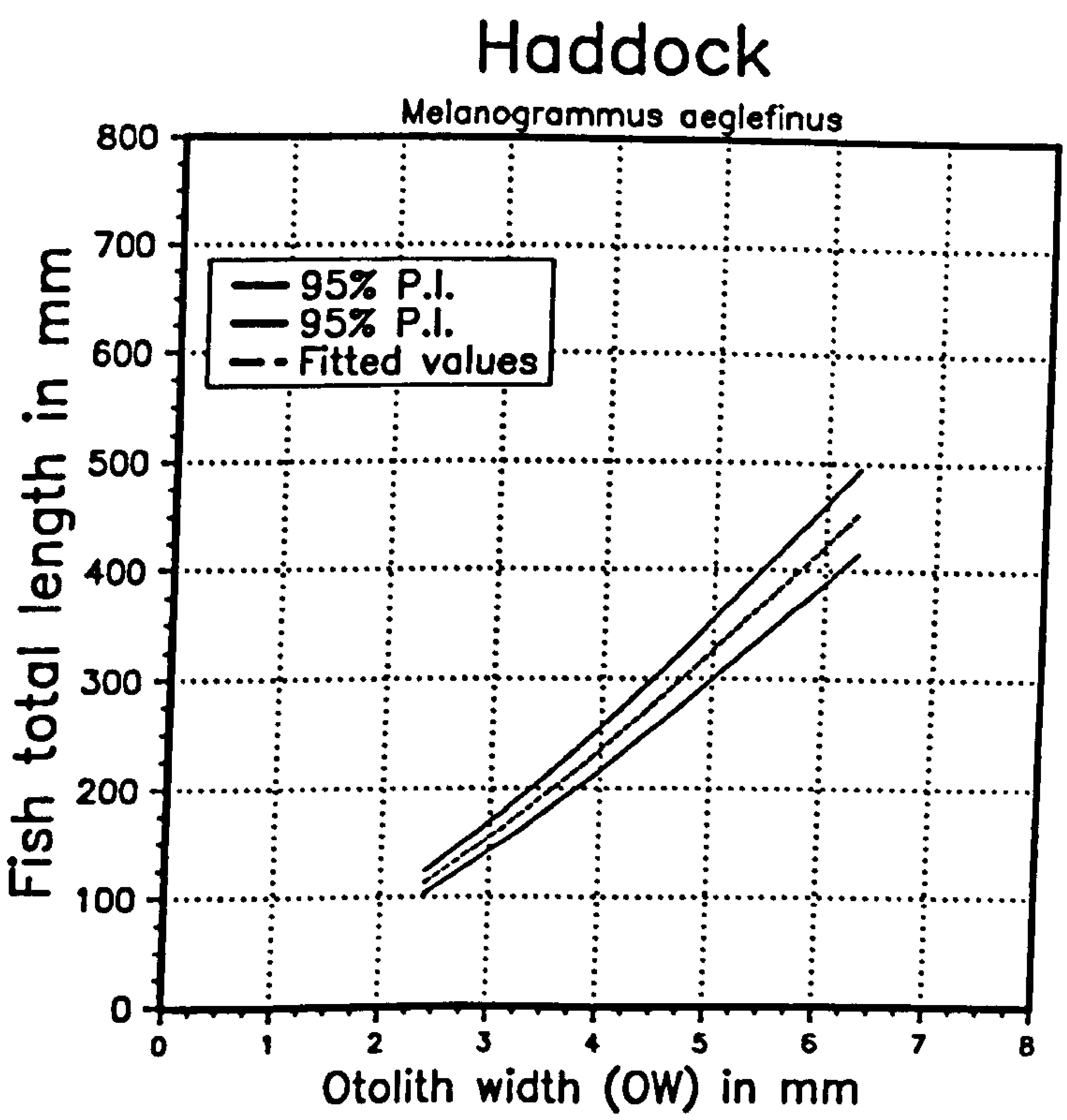
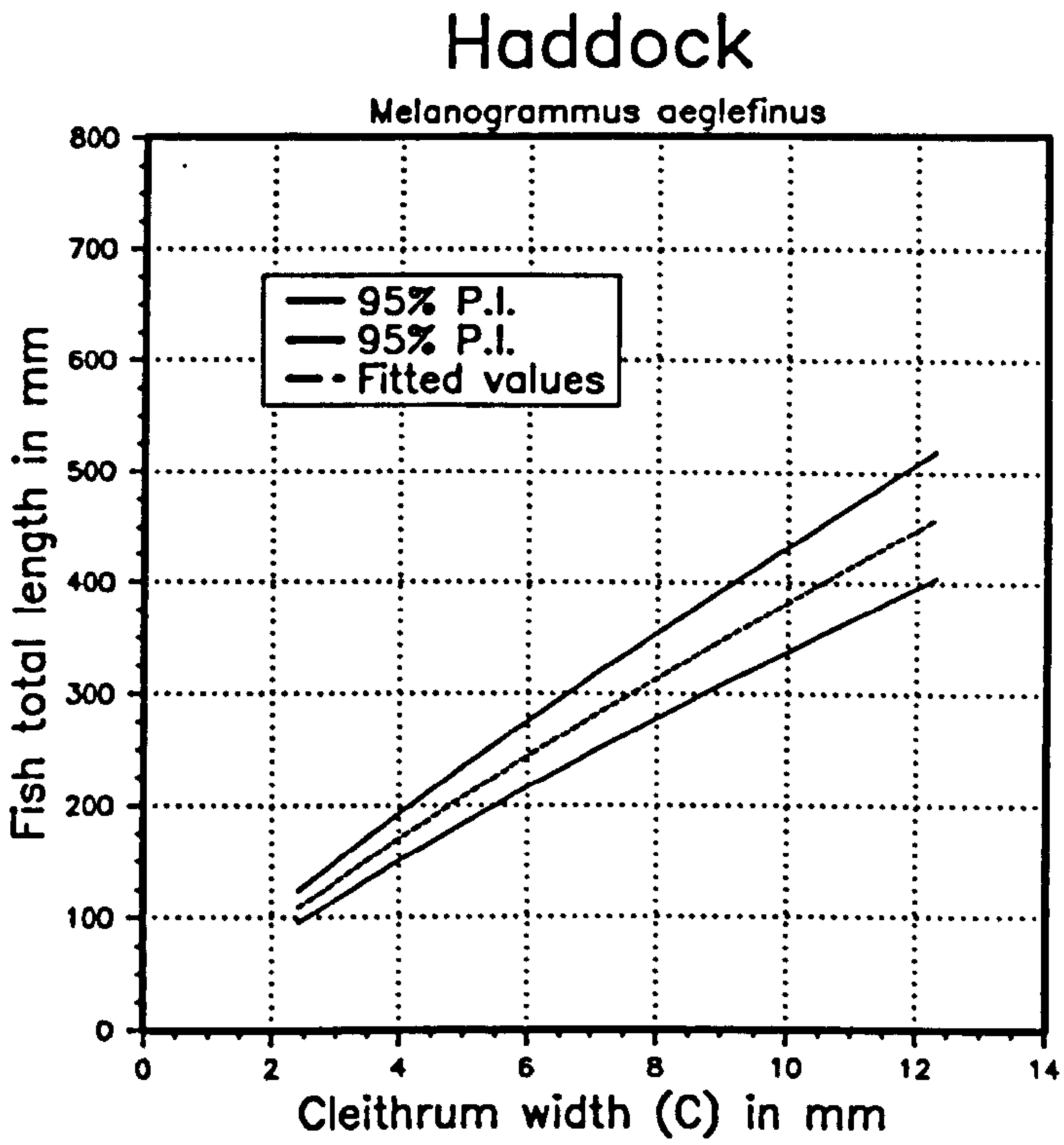


Figure 60. The 95% prediction intervals and fitted values for haddock and cod and pollack (combined data) cleithra measurements.



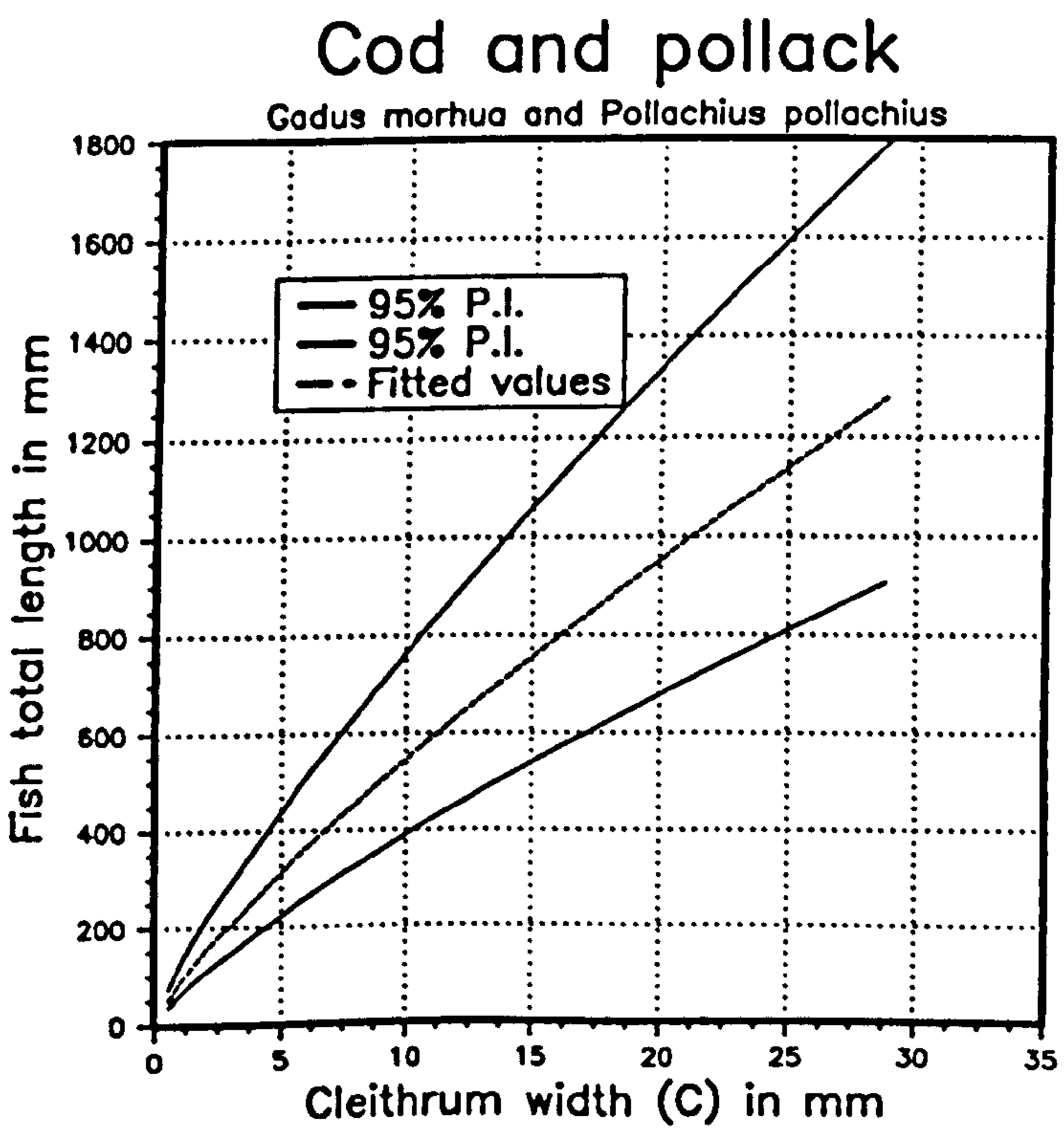
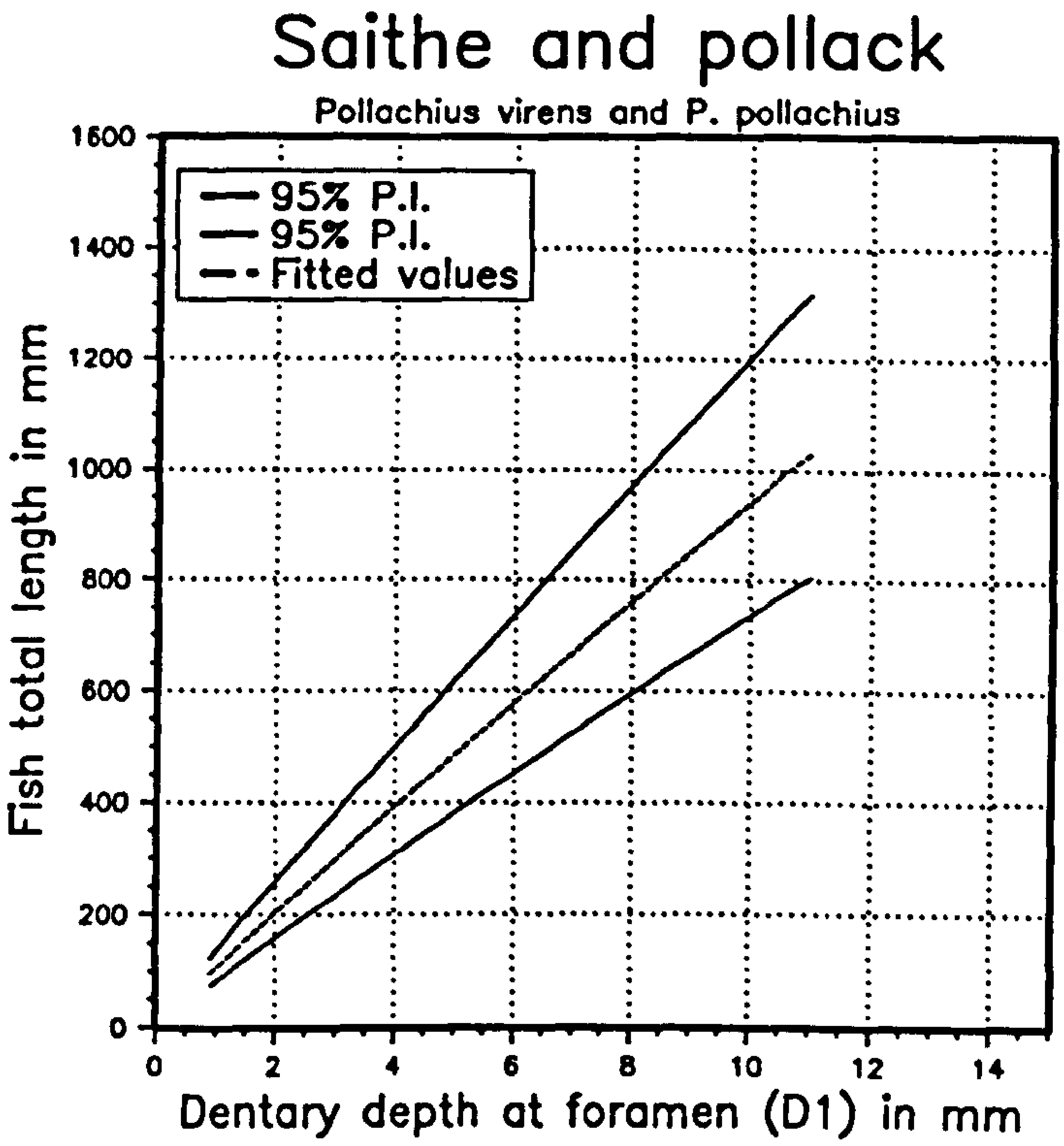


Figure 61. The 95% prediction intervals and fitted values for saithe and pollack (combined data) dentary measurements.



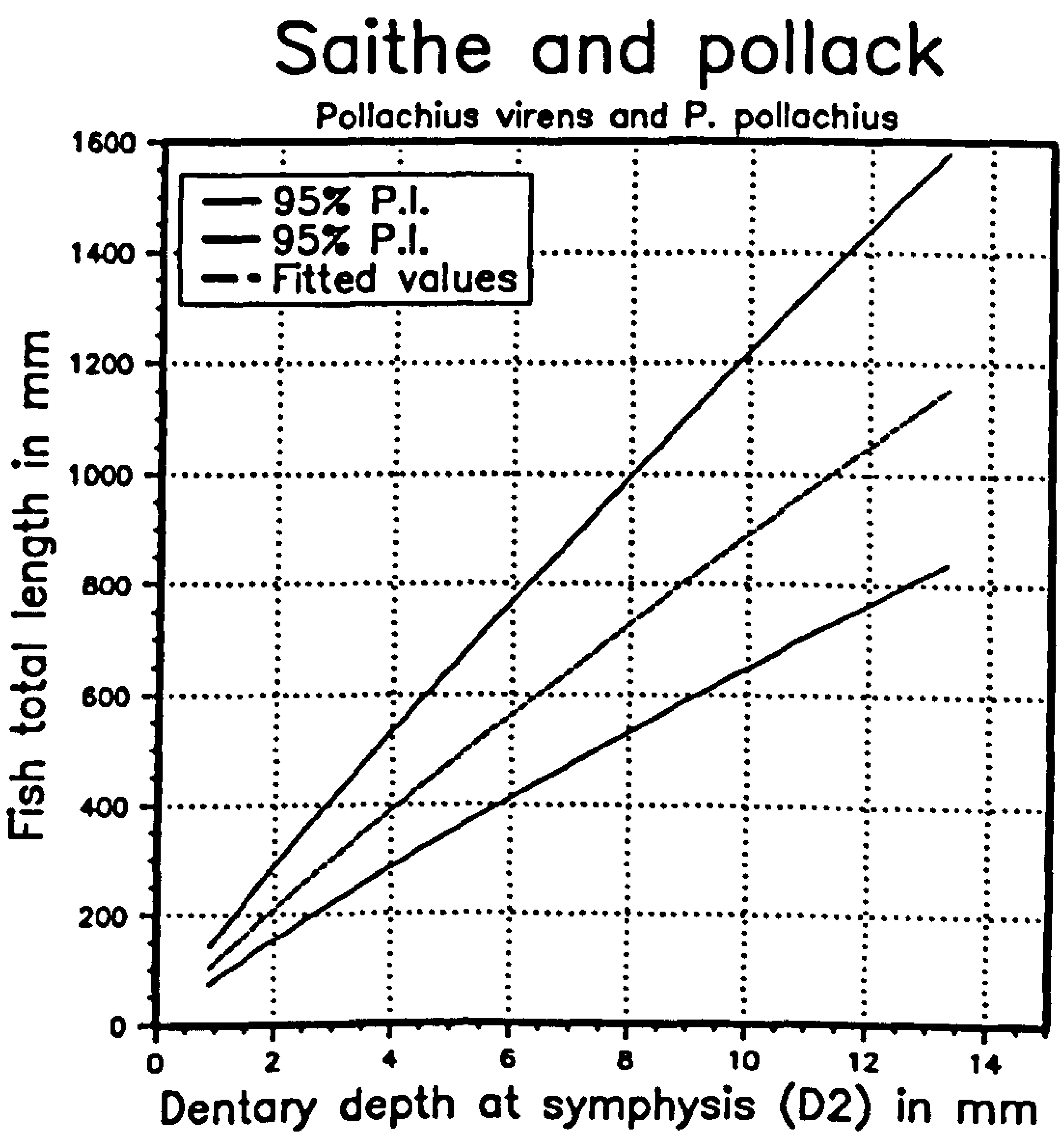
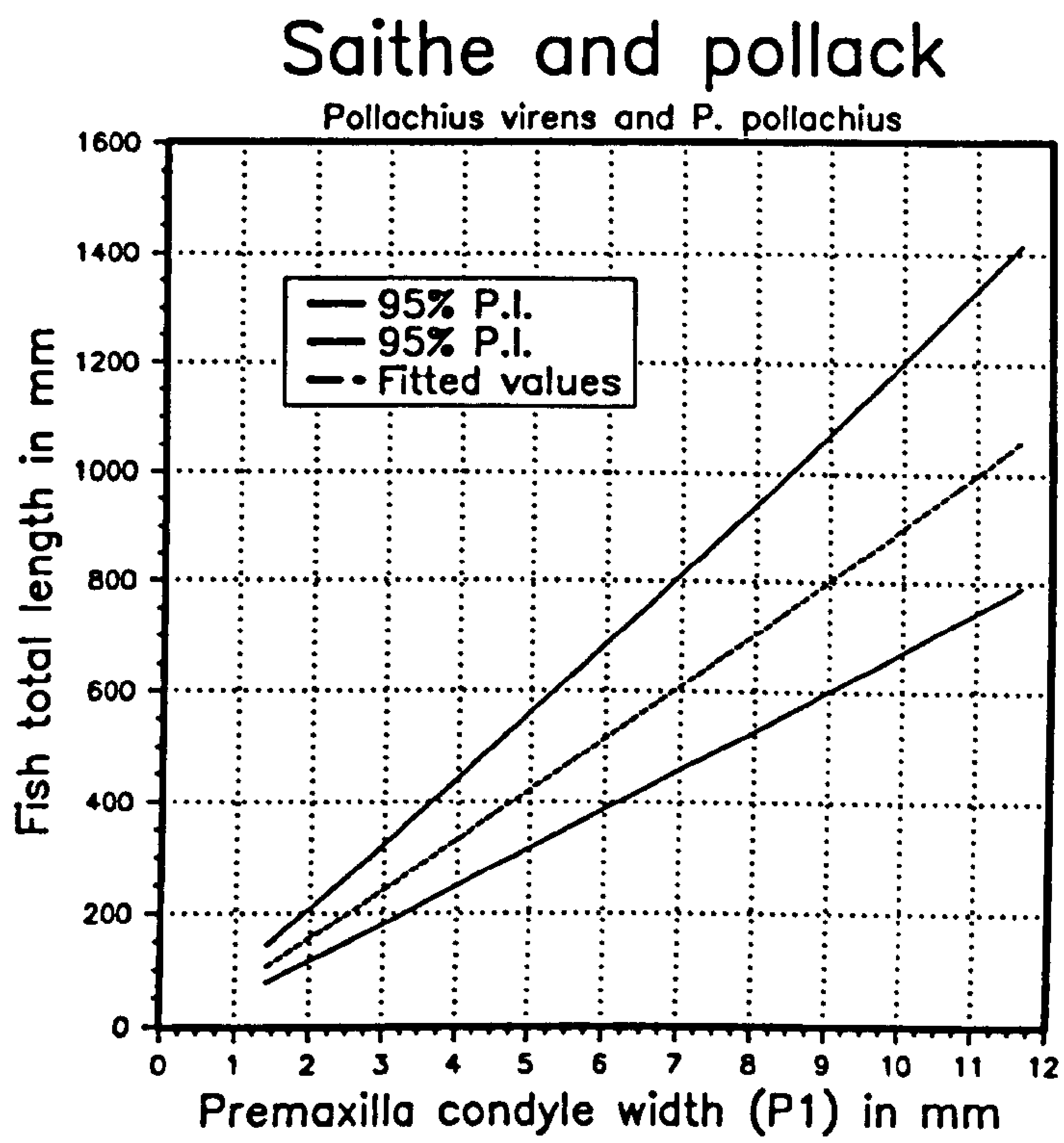


Figure 62. The 95% prediction intervals and fitted values for saithe and pollack (combined data) premaxilla measurements.



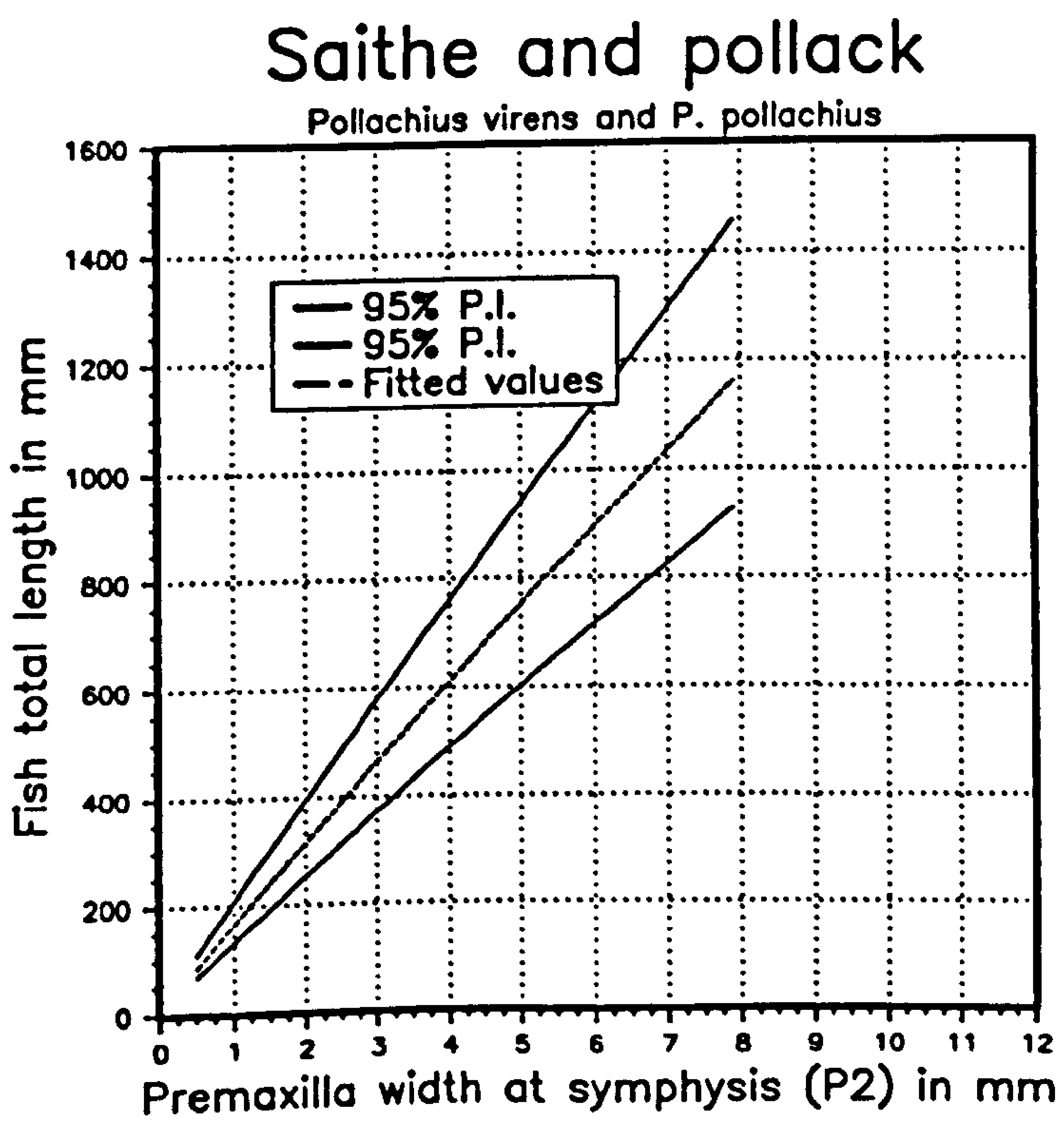
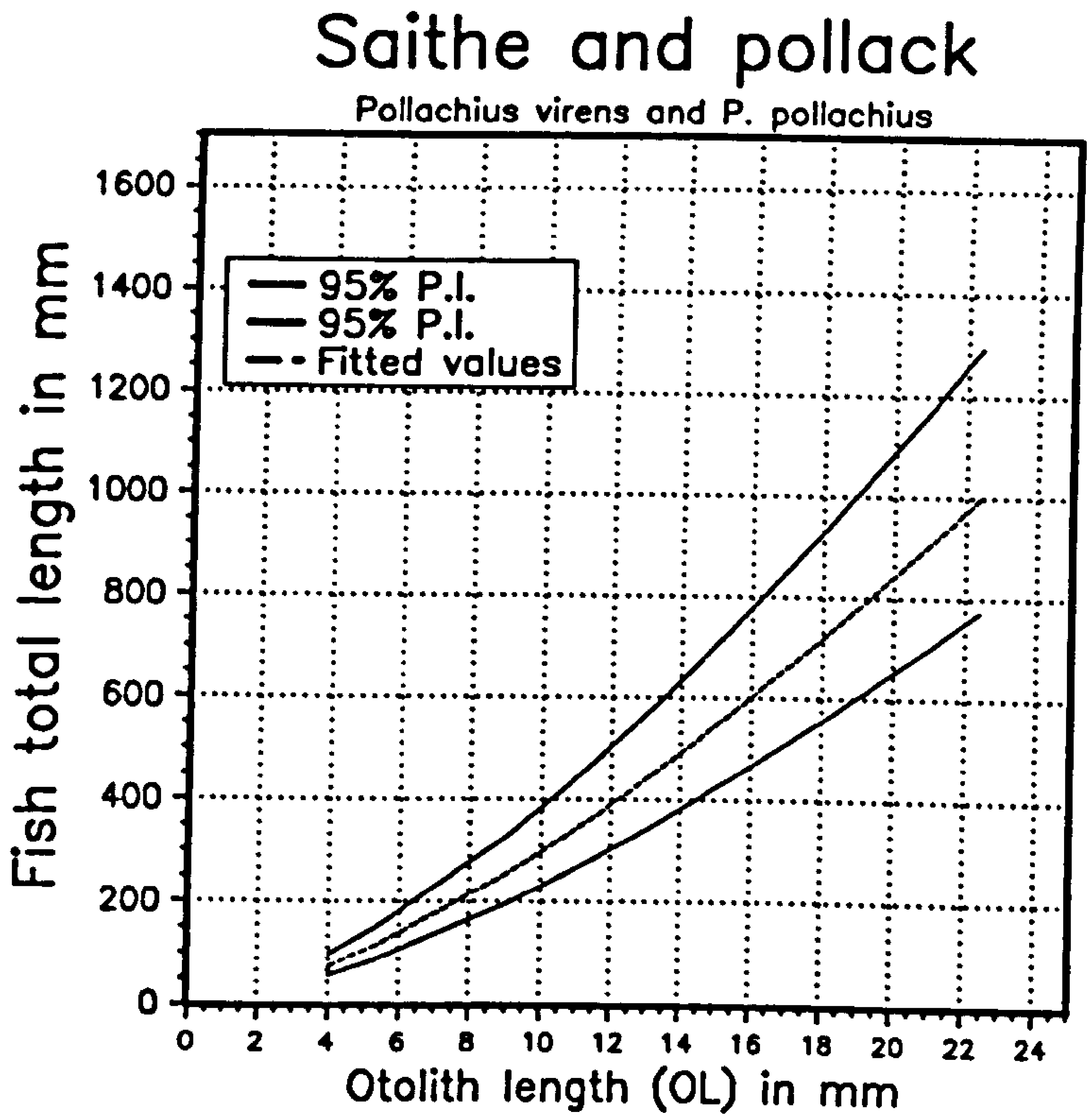


Figure 63. The 95% prediction intervals and fitted values for saithe and pollack (combined data) otolith measurements.



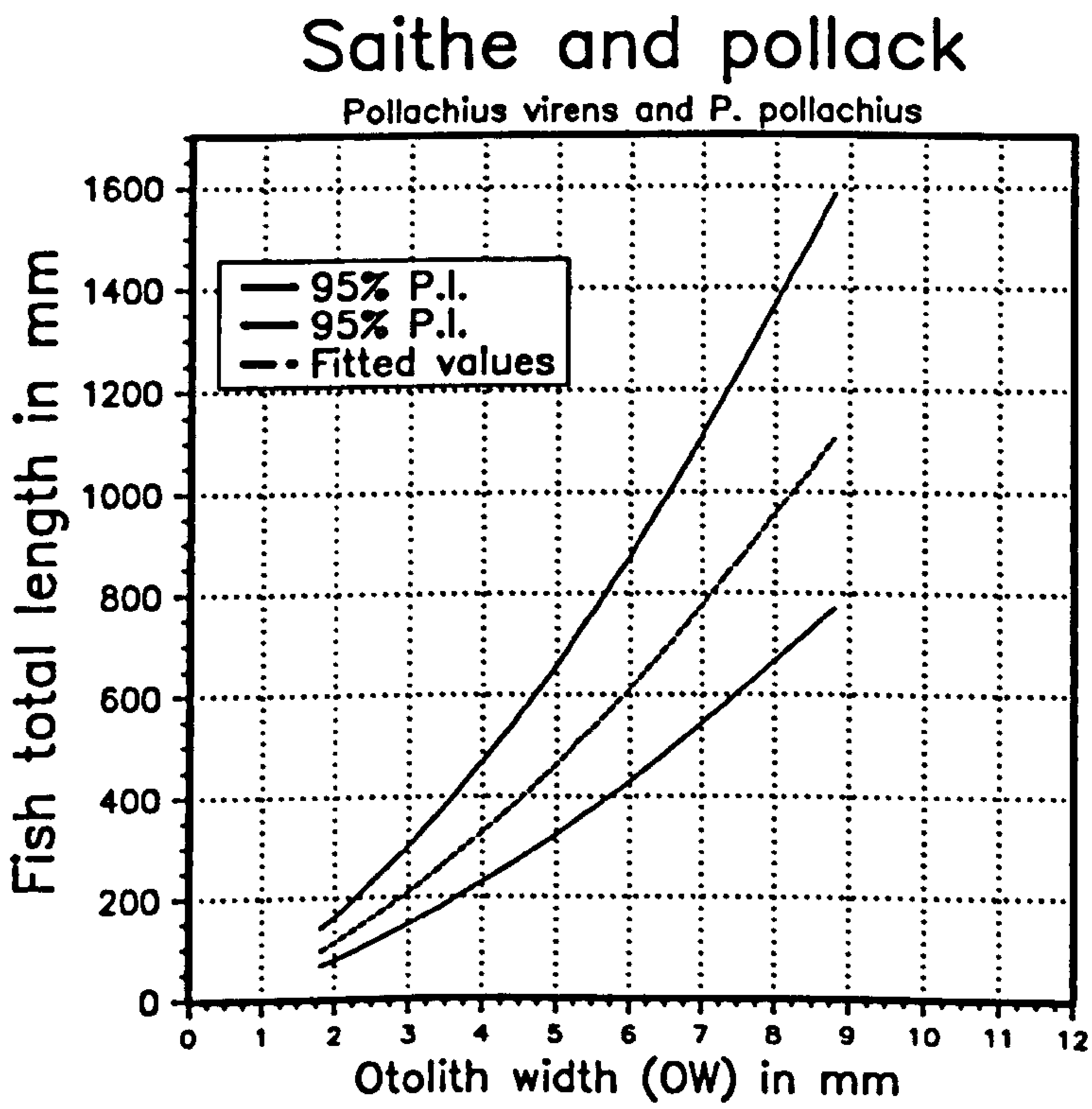
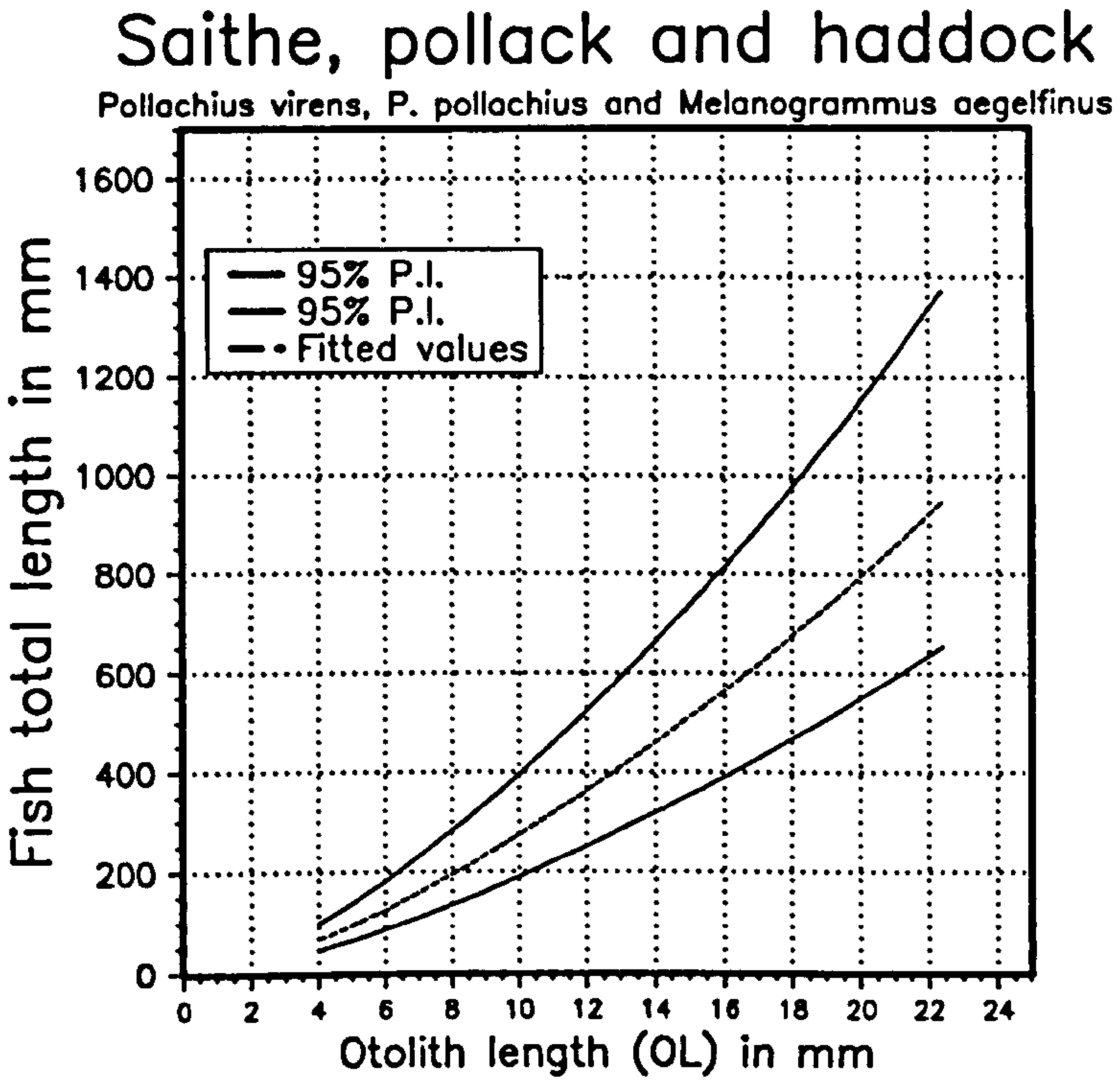


Figure 64. The 95% prediction intervals and fitted values for saithe pollack and haddock (combined data) otolith measurements.



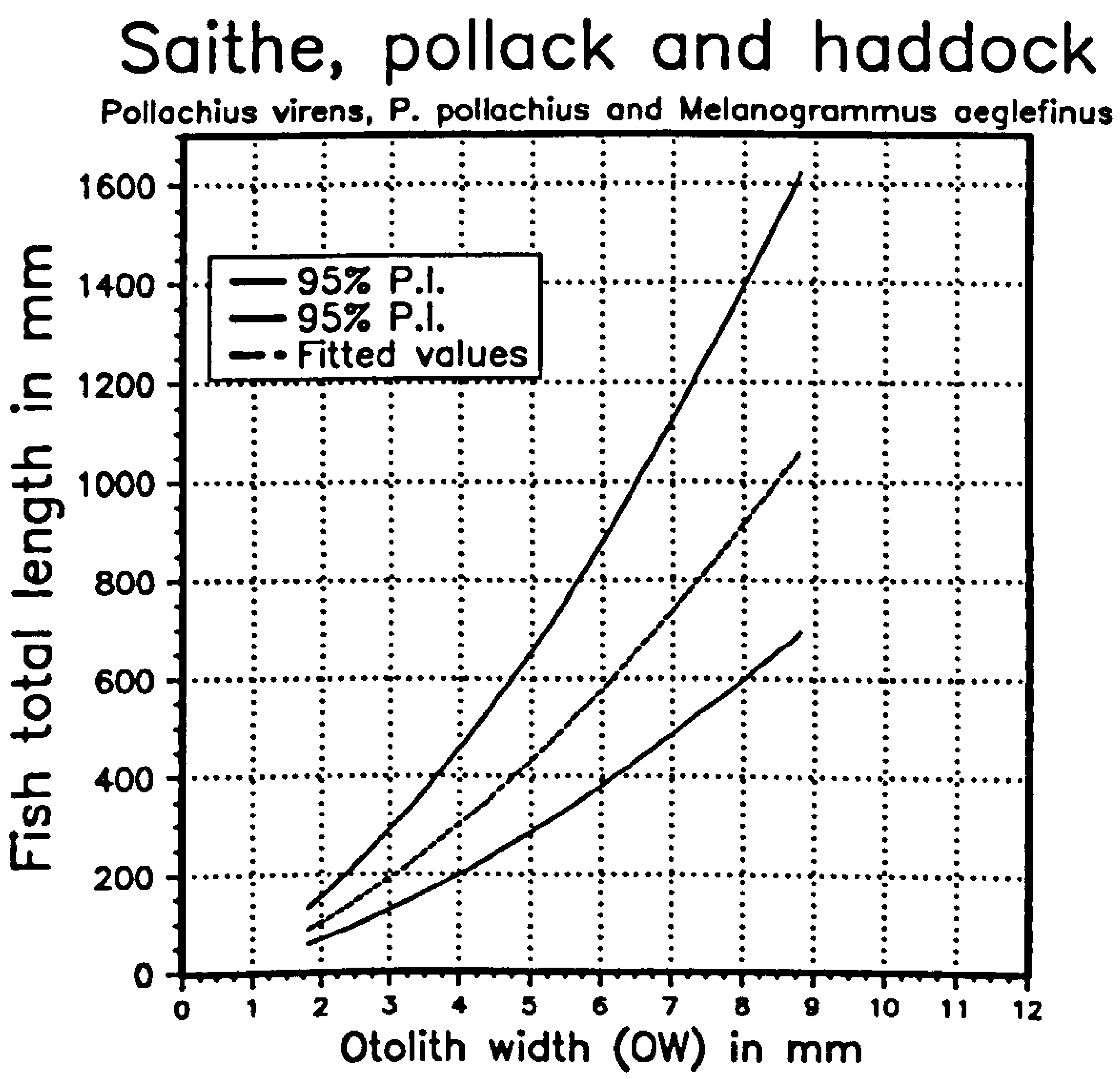


Table 11. Relationship between element measurement in mm (M) and fish total length in mm (TL). Fish TL = a + b M

Cod, Gadus morhua

Bone measurement	Code	a	b	r	n
Cleithrum width	C	78.0	44.7	0.98	37
Dentary depth	D1	90.0	90.6	0.98	61
" symphysis	D2	146.0	82.0	0.99	61
Otolith length	OL	-385.0	68.3	0.92	52
" width	OW	-312.0	130.0	0.95	52
Premaxilla width	P1	9.4	68.5	0.98	51
" breadth	P2	34.2	96.7	0.98	51

Pollack, Pollachius pollachius

Cleithrum width	C	9.2	57.7	0.99	11
Dentary depth	D1	22.8	76.6	0.98	22
" symphysis	D2	48.7	65.3	0.98	22
Otolith length	OL	-119.0	43.4	0.97	19
" width	OW	-126.0	109.0	0.98	19
Premaxilla width	P1	-13.9	74.0	0.98	16
" breadth	P2	15.1	134.0	0.98	16

Saithe, Pollachius virens

Cleithrum width	C	54.8	44.0	0.97	47
Dentary depth	D1	32.1	95.7	0.99	67
" symphysis	D2	101.0	82.0	0.98	67
Otolith length	OL	-388.0	64.8	0.96	52
" width	OW	-278.0	159.0	0.94	52
Premaxilla width	P1	-35.7	97.0	0.98	65
" breadth	P2	64.8	138.0	0.97	65

Ling, Molva molva

Cleithrum width	C	315.0	41.1	0.96	20
Dentary depth	D1	17.4	9.47	0.98	22
" symphysis	D2	24.1	9.11	0.98	22
Otolith length	OL	-92.2	67.3	0.95	14
" width	OW	-149.0	189.0	0.99	14
Premaxilla width	P1	92.2	92.5	0.96	18
" breadth	P2	192.0	96.5	0.94	18

Haddock, Melanogrammus aeglefinus

Cleithrum width	C	30.4	35.2	0.98	33
Dentary depth	D1	29.6	139.0	0.97	15
" symphysis	D2	11.9	157.0	0.99	15
Otolith length	OL	-86.5	30.6	0.99	18
" width	OW	-115.0	89.7	0.99	18
Premaxilla width	P1	-12.5	100.0	0.98	15
" breadth	P2	36.5	118.0	0.98	15

Table 12. Relationship between log 10 element measurement (in mm) (M) and log 10 fish total length (in mm). Log TL = a + b log M.

Species and Bone measurement	M Code	a	b	r	n
Cod, Gadus morhua					
Cleithrum width	C	1.84	0.88	0.99	37
Dentary depth	D1	2.14	0.86	0.99	61
" symphysis	D2	2.19	0.80	0.99	61
Otolith length	OL	0.95	1.57	0.97	52
" width	OW	1.51	1.49	0.98	52
Premaxilla width	P1	1.85	0.99	0.98	51
" breadth	P2	2.05	0.95	0.98	51
Pollack, Pollachius pollachius					
Cleithrum width	C	1.80	0.96	0.99	11
Dentary depth	D1	1.96	0.93	0.99	22
" symphysis	D2	1.96	0.90	0.99	22
Otolith length	OL	1.08	1.38	0.99	19
" width	OW	1.57	1.45	0.99	19
Premaxilla width	P1	1.82	1.04	0.98	15
" breadth	P2	2.18	0.93	0.99	15
Saithe, Pollachius virens					
Cleithrum width	C	1.79	0.90	0.98	47
Dentary depth	D1	1.96	0.93	0.99	67
" symphysis	D2	1.96	0.89	0.99	67
Otolith length	OL	0.70	1.74	0.98	52
" width	OW	1.59	1.58	0.95	52
Premaxilla width	P1	1.87	1.10	0.97	65
" breadth	P2	2.23	0.93	0.97	65
Ling, Molva molva					
Cleithrum width	C	2.24	0.63	0.95	20
Dentary depth	D1	1.26	0.79	0.97	22
" symphysis	D2	1.33	0.73	0.97	22
Otolith length	OL	1.57	1.18	0.95	14
" width	OW	2.01	1.26	0.99	14
Premaxilla width	P1	2.04	0.97	0.97	18
" breadth	P2	2.24	0.83	0.96	18
Haddock, Melanogrammus aeglefinus					
Cleithrum width	C	1.70	0.88	0.99	33
Dentary depth	D1	2.20	0.95	0.96	15
" symphysis	D2	2.22	0.98	0.99	15
Otolith length	OL	1.00	1.34	0.99	18
" width	OW	1.50	1.44	0.99	18
Premaxilla width	P1	1.95	1.06	0.98	15
" breadth	P2	2.16	0.92	0.99	15

Table 13. The relationship between element measurement and fish total length for species with almost identical bones.

Bone measurement	Code	a	b	r	n
Cod and pollack, Gadus morhua and Pollachius pollachius					
Cleithrum	C	64.7	45.9	0.98	50
Saithe and pollack Pollachius virens and P. pollachius					
Dentary	D1	45.8	88.1	0.96	89
	D2	109.0	73.9	0.94	89
Otolith	OL	-242.0	54.5	0.95	71
	OW	-174.0	134.0	0.92	71
Premaxilla	P1	-2.7	87.6	0.95	81
	P2	53.1	138.0	0.97	81
Saithe, pollack and haddock Pollachius virens, P. pollachius and Melanogrammus aeglefinus					
Otolith	OL	-247.0	52.9	0.92	89
	OW	-206.0	135.0	0.91	89

Log 10 fish TL : log 10 element dimension for elements of two or more species which cannot always be determined to species

Cod and pollack Gadus morhua and Pollachius pollachius					
Cleithrum	C	1.94	0.80	0.98	50
Saithe and pollack Pollachius virens, P. pollachius					
Dentary	D1	2.02	0.96	0.98	89
	D2	2.05	0.90	0.96	89
Otolith	OL	0.96	1.51	0.98	71
	OW	1.59	1.54	0.96	71
Premaxilla	P1	1.86	1.09	0.96	81
	P2	2.22	0.95	0.98	81
Saithe, pollack and haddock Pollachius virens, P. pollachius and Melanogrammus aeglefinus					
Otolith	OL	0.90	1.54	0.96	89
	OW	1.52	1.59	0.95	89

Chapter 5

IDENTIFICATION

5.1 OVERVIEW

While every attempt was made to identify bones and otoliths to species, specific determinations were only made when clear criteria for distinguishing a species from closely related taxa could be found. After considerable study of modern reference material, and discussion with other archaeozoologists and zoologists who study fish remains in piscivores' faeces, it was decided that very large numbers of remains could not be definitely identified to species. Many elements are not sufficiently diagnostic to be assigned to species either because they do not possess distinctive features or because distinctive features have been lost. A small number of elements, e.g. rockling bones, are not identified to species for lack of adequate reference material.

Some taxa were devised to include closely related species with similar bones, for example Pollachius/Gadus (cod, pollack and saithe). Question marks (?) are used to denote determinations which could not be assigned to species (or other taxon) with certainty. Consequently, the identified taxa include species, a small number of species from the same family, several species from a family and species from different families.

Identifications were made by comparing archaeological specimens with modern material in a number of reference collections. Most remains were identified using disarticulated modern material in the Environmental Archaeology Unit, University of York. In addition, skeleton and otolith collections housed at the following institutions were consulted: Fish Section of the Natural History Museum, London; Faunal Remains Project, University of Southampton; and Ministry of Agriculture Fisheries and Food Fisheries Laboratory, Lowestoft (otoliths only). Specimens from three private collections belonging to Sheila Hamilton-Dyer, Mike Wilkinson and Allison Locker were also consulted.

A few determinations were made by persons other than the author. John Prime identified tadpole fish *Raniceps*, ?sand eel Ammodytidae, bullrout *Myoxocephalus scorpius* otoliths and Sheila Hamilton-Dyer refined the determination of the sparid remains to ?Black Sea Bream, ?*Spondyliosoma cantharus*.

Although every effort was made to ensure that the criteria for identification remained constant throughout the study, and considerable efforts were made checking determinations, identification is not a completely objective process.

5.2 CRITERIA FOR SPECIFIC DETERMINATIONS

While detailed written accounts of the criteria used to identify all bones is impractical, the following notes were prepared during the analysis to ensure that the criteria for determining the bones of the principal species remained constant.

Apart from the excellent account of differences in the bones of cod, saithe and lythe, Pollachius pollachius (Williamson 1902), the only published accounts which have proved helpful in identifying archaeological material are a guide to otoliths (Härkönen, 1986) and an atlas of dentary and articular bones of Iberian teleosts (Izquierdo, 1988). Heinrich's useful account of differences in gadid vertebrae (Heinrich, 1987) does not include discussion of pollack, Pollachius pollachius and Nolf and Steurbaut (1989) make no mention of differences between species of the same genus for gadid otoliths. While the characters mentioned in these works can be used to make determinations, the fragmentary and eroded nature of much of the Freswick material made it necessary to find additional characters.

Fish remains cannot always be identified to species. Robust elements with distinctive features are more visible in the archaeological record than fragile featureless elements. To minimize this bias, only 4 elements (cleithrum, dentary, otolith and premaxilla) were selected for detailed recording for the most common fishes (cod, ling, haddock, saithe and pollack) in the assemblages.

Identifications were made by comparing the archaeological specimens with the same element from modern fishes of known size and species. Where possible bones were assigned to species. If insufficient diagnostic features were available to make a specific determination the fragment was assigned to genus or family.

5.2.1 The Cleithrum (see Plate 4)

Cod and pollack cleithra possess a very similar curvature at the ventral mid portion, particularly when fragmentary. Saithe can be distinguished by a ridge of bone which runs across the main curve of the ventral median portion of the bone. The degree of curvature of this region separates ling from other species. Haddock cleithra are particularly distinctive as in all but the smallest specimens the anterior part of the bone is heavily mineralized and has a swollen appearance.

As most of the cleithra from Freswick were small fragments few could be assigned to species. However, distinctively swollen

Plate 4. Modern right cleithra from (left to right) cod, Gadus morhua; saithe Pollachius virens; pollack P. pollachius and ling, Molva molva. Note splitting in ling cleithrum caused as bone dried at room temperature.

anterior portions of haddock cleithra were recognized. Fragments of ling cleithra were recognized by their relatively short radius of curvature in the mid-dorsal aspect. Many other cleithra fragments, almost certainly of cod, pollack or saithe were assigned to family.

5.2.2 The Dentary

The dentary was most readily identified in all five of the commonest species at Freswick. The left and right dentaries meet anteriorly at a symphysis to form the lower jaw. The dorsal surface bears tooth-sockets, the teeth are attached to the dentary by cartilage and connective tissue (Mummery, 1924).

The following features of the dentary were used to determine species: 1) the overall shape of the bone; 2) characteristics of the tooth-sockets (number of rows, shape and size); 3) shape and surface features of the most anterior part of the dentary near and at the symphysis.

These three features are explained more fully below:

1) The shape of the bone in cod, ling, pollack and saithe is illustrated in Plates 5 and 6.

2) Tooth row characters:

In the cod, *Gadus morhua*, there are two rows of tooth-sockets. The lingual row of sockets are somewhat unevenly spaced along the bone. The sockets are large (up to 2.4 mm in a specimen of 940 mm total length) and irregular in shape, ranging from sub-triangular, oval and sub-square. The height of the tooth-sockets is less than the tooth-socket diameter.

The buccal row, also somewhat uneven in distribution, is composed of teeth that are considerably smaller than those in the outer row (mostly 0.8 mm in the 940 mm total length specimen).

The ling *Molva molva* dentary also carries two rows of teeth, the lingual row consists of large (2.7 mm diameter in a fish of 1110 mm total length) widely spaced teeth. The tooth-sockets are approximately twice the height of the socket diameter. The buccal row consists of small closely spaced sockets which extend beyond the caudal limit of the lingual row. The size and distribution of tooth sockets of the Spanish ling, *Molva dypterygia macrophthalama*, are very similar to those of *Molva molva*. The most clear difference between the two species is that the buccal row is weakly developed and does not extend beyond the caudal limit of the lingual row in *M. dypterygia*.

The tooth row of the haddock, *Melanogrammus aeglefinus*, consists for most of its length of two rows of rather similarly sized tooth-sockets. Close to the symphysis the buccal row is uneven in distribution and in large specimens may be two rows deep. The sockets of the lingual row are slightly larger than those of the buccal row.

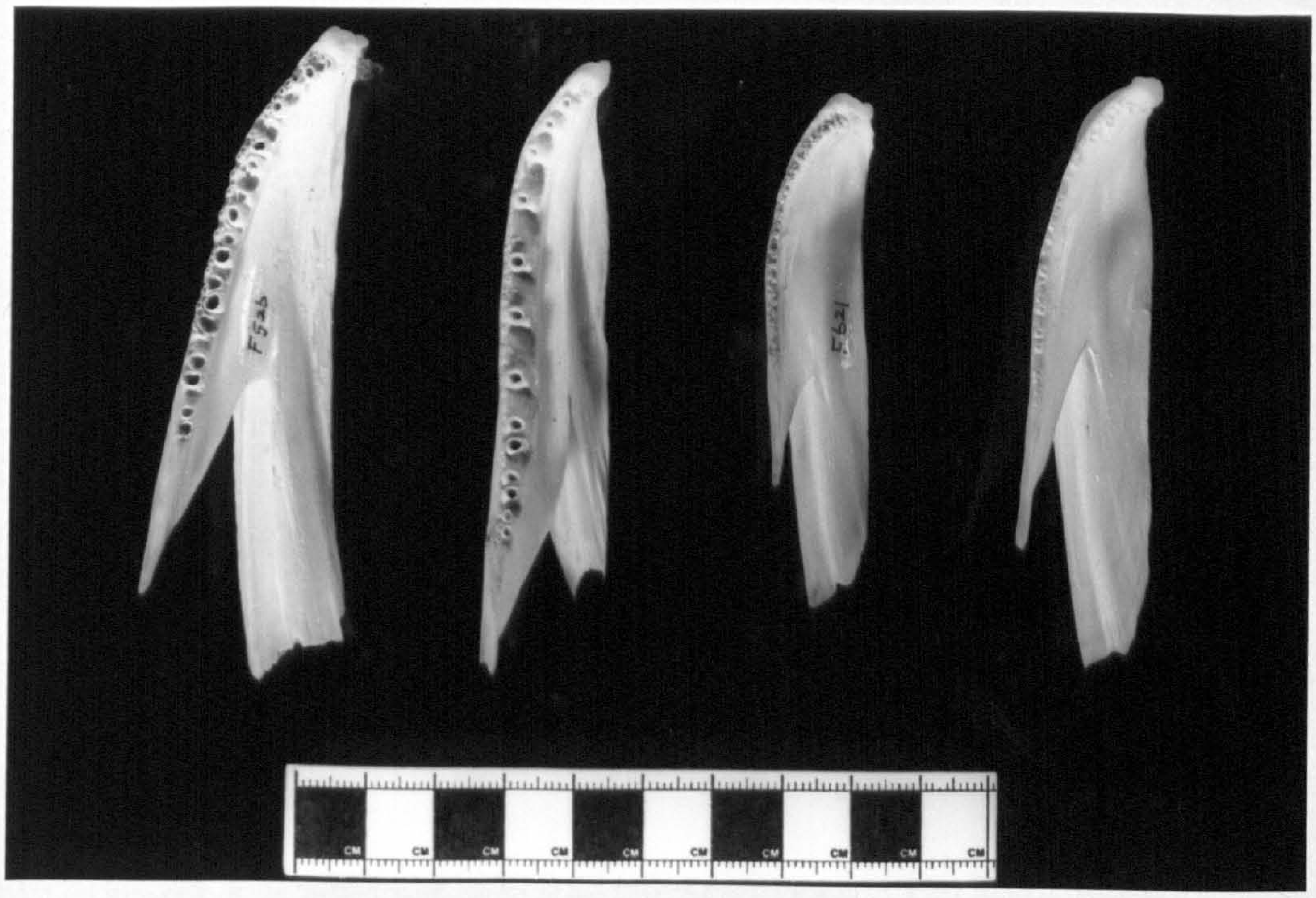


Plate 5. Dorsal view of modern left dentary bones of (left to right) cod Gadus morhua; ling Molva molva; saithe Pollachius virens and pollack P. pollachius.

Plate 6. Lateral view of modern left dentary bones of (left to right) cod Gadus morhua; ling Molva molva; saithe Pollachius virens and pollack P. pollachius.

The tooth row of the saithe, Pollachius virens, consists for most of its length as a double row of relatively small tooth-sockets (0.5 mm diameter in a fish 860 mm total length). Towards the symphysis three rows are present in large specimens.

In the pollack, Pollachius pollachius, a single row of tooth-sockets of small to medium sized teeth (approximately 1 mm diameter in a specimen of 790 mm total length) form a single uneven row for most of the length of the dentary. A double row is present anteriorly, just before the symphysis in large specimens. Occasional additional tooth-sockets are present along the buccal margin which may, at first sight, give the impression that there are two rows.

3) The shape of the dentary at the symphysis:

This region of the bone has important characters which can be used to distinguish pollack, saithe and cod. Williamson mentions that the 'tuberosities on the anterior end of the dentaries project in the saithe well in front on either side of the symphysis: in the lythe they are small, and in the cod even less conspicuous.' (Williamson 1902, 261).

A second feature of this part of the bone is the surface texture of the buccal part of the dentary which differs strikingly in saithe and pollack. In the saithe the bone, although often of irregular shape, is smooth and not evenly striated between the foramen and the symphysis. By contrast this region in the pollack is regularly striated (see Plate 7).

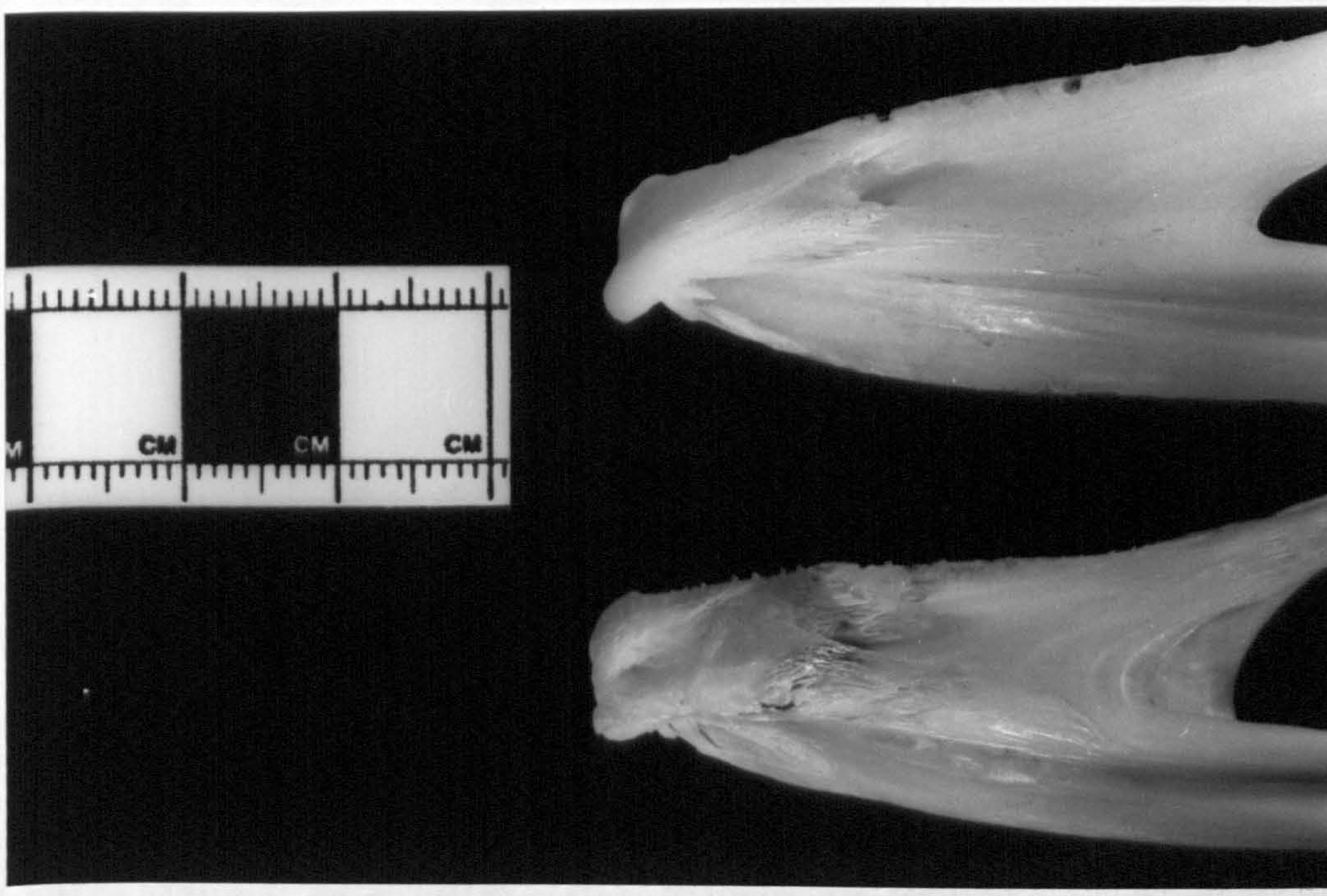


Plate 7. Lateral view of modern left dentary bones of (lower) saithe Pollachius virens and (upper) pollack P. pollachius.

5.2.3 Otoliths (see Plates 8 & 9)

Otoliths were recognized following criteria set out by Frost (1926) and Härkönen (1986). The latter describes (p. 90) cod otoliths from very large specimens (length > 700 mm) as 'skewed and triangular', while in smaller specimens the otolith length/otolith breadth ratio decreases

Ling otoliths are also highly characteristic with a 'weakly sine-wave' shape which resembles a 'twisted kidney' (p. 122). (The otoliths of Molva dypterygia have very different, slightly rhomboid, general shape.)

The otoliths of haddock, saithe and pollack are very similar in overall appearance (Plate 9).

'Härkönen states that an important character in distinguishing haddock is that 'the dorsal margin is usually linear or almost linear in mid-section' (p. 98). This description fits well with modern reference material and was used in the first phase of identification to separate ?haddock from ?Pollachius spp.

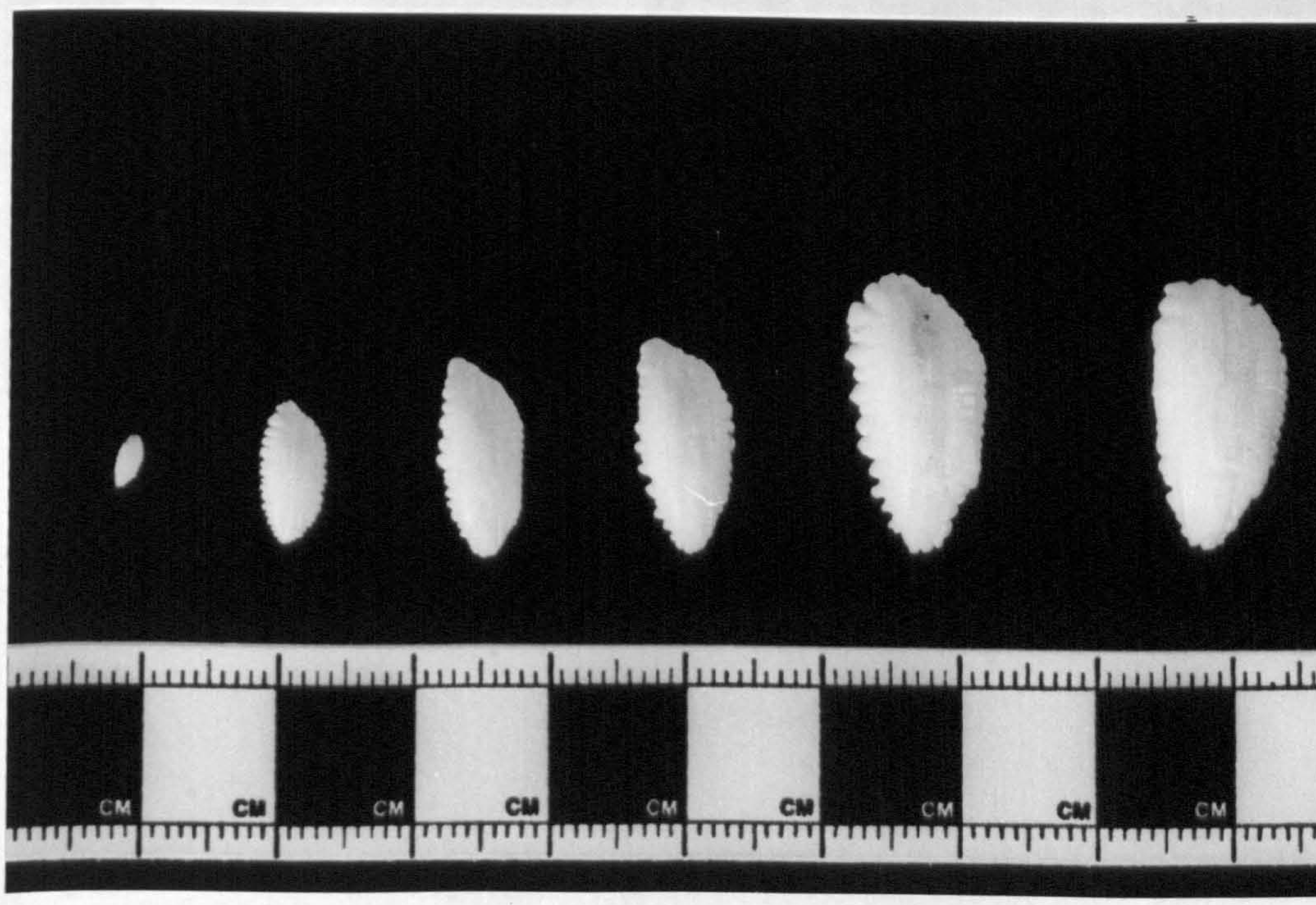


Plate 8. Modern cod Gadus morhua otoliths from fish ranging from 100-1090 mm total length.

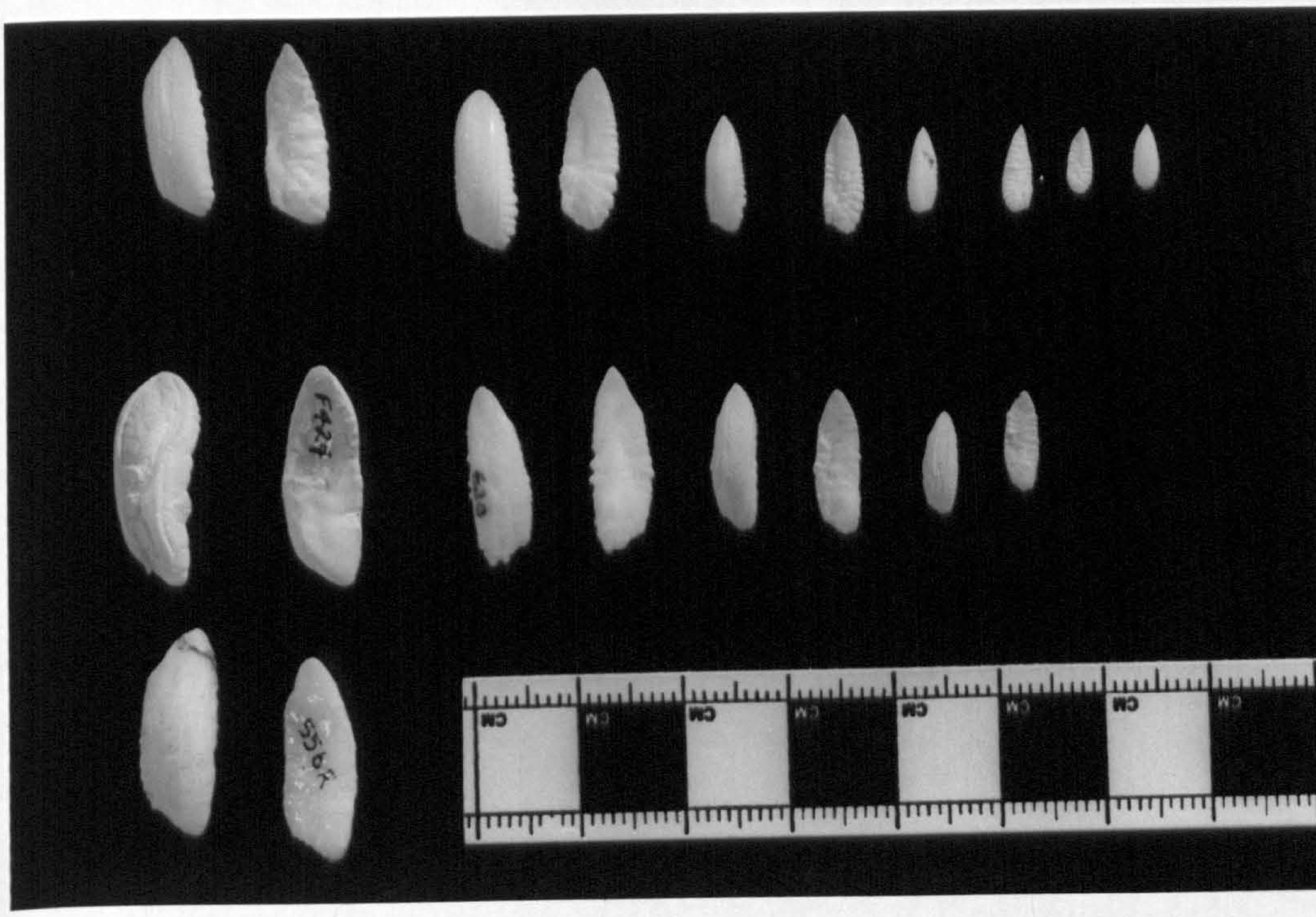


Plate 9. Pairs of modern otoliths from pollack Pollachius pollachius (top row); saithe P. virens (middle row) and haddock Melanogrammus aeglefinus (bottom row).

Distinguishing the otoliths of saithe and pollack is far from simple. The criteria given by Frost include a somewhat subjective difference in the 'brightness' of the surface of the outer side. He also states that the otolith outer surface is furrowed and umbonated as in haddock; that the cauda is less distended and that serrations are present on the ventral rim. These features were not found to be consistent with all the modern material examined during the course of this study. Furthermore, Härkönen states: 'There has not been found reliable characters to distinguish between small specimens of P. pollachius and P. virens and smooth large specimens give severe problems' (p. 100).

The similarity of otoliths of pollack and saithe was noted by Wilkinson (1981) who examined mesolithic otoliths from the Scottish Hebrides. He considered the length-breadth ratios of otoliths from a large number of young saithe otoliths and a smaller number of pollack. He concluded that this ratio cannot be used to determine the relative frequencies of the two species within a sample. In order to determine which species were present Wilkinson examined the number of tooth rows on the dentaries. 'Dentaries were examined in a number of samples from each site and only a couple clearly showed a single row of teeth out of a couple of hundred pieces; thus the bulk of the dentaries appeared to belong to saithe' (Wilkinson, 1981, 36). Later on the same page we read: 'The conclusion drawn from this study is that almost all the fish identified from the sites and assigned to Pollachius sp. belong to saithe (P. virens). To simplify discussion all this material will be described as saithe throughout this work, but the presence of some lythe should be noted'.

In order to test the objectivity of otolith determinations in the present study a blind trial was conducted with the assistance of John Prime, a zoologist who has identified many thousands of gadid otoliths from seal droppings in order to assess diet (Prime, 1979). A total of 100 otoliths in varying states of completeness, some burnt, others showing clear signs of acid erosion or mechanical abrasion, of a variety of sizes from the Freswick Links samples were individually packed in numbered bags were sent with a clearly marked sealed envelope containing the author's determinations. (The opportunity was taken to enclose several non-gadid otoliths that were only tentatively identified.) The results were as follows:

Table 14. A comparison of otolith determinations by two analysts

	A. Jones	J. Prime	
		Agree	Disagree
Cod	28	26	1pol, 1?hd
Saithe	21	5	5?s, 6?hd, 3hd, 2?pol
Pollack	3	0	1?pol, 2hd
Haddock	5	2	2?hd, 1pol
Ling	4	4	0
Whiting	1	1	0
<u>Trisopterus</u> sp.	2	2	0
?Cod	2	1	1cd
?Saithe	10	2	3?hd,3s,1?cd,1??cd
?Haddock	1	1	
?Pollack	3	0	2s, 1hd
Pol/Hd/S	5	1	1hd, 3?hd
S/Pol	6	0	2?s, 1s, 1hd, 1?hd, 1?pol
Gadid	6	0	1cd,1?cd,1hd/s,2?hd, ?sandeel

Abbreviations: cd = cod; s = saithe; hd = haddock; pol = pollack

Overall there was good agreement on most of the determinations. For cod, ling and the single whiting agreement was almost total. However, the determination of haddock, saithe and pollack otoliths was much more inconsistent between the two analysts. Prime tended to identify more haddock than saithe while the author determined more saithe than haddock otoliths. Consequently, it was decided to treat all otolith identifications of these species as a tentative determinations and preface each with a question mark.

5.2.4 The Premaxilla (Plates 10 & 11)

The premaxilla, which with the maxilla bone forms the upper jaw, bears tooth-sockets on its ventral surface in all five species. As in the dentary, the number, size and distribution of tooth-sockets are important characters in determining species.

In the cod, Gadus morhua, the buccal row, is composed of large tooth-sockets rather unevenly distributed along the margin. In very large specimens (1500 mm) a second row of large tooth-sockets may also be present. There are several lingual rows of distinctly smaller tooth-sockets (7 in a fish 1500 mm total length; 5 in a specimen 940 mm).

Ling Molva molva premaxillae bear up to 12 rows (depending on size) of tooth-sockets. The sockets gradually reduce in size from the buccal to lingual margin.

The tooth row of the haddock, Melanogrammus aeglefinus, consists for most of its length of four uneven rows of rather similarly sized sockets. The sockets of the buccal row are slightly larger than others and the lingual rows are uneven.

Plate 10. Lateral view of modern premaxillae from (left to right) cod Gadus morhua; ling Molva molva; saithe Pollachius virens and pollack P. pollachius.

Plate 11. Ventral view of modern premaxillae from (left to right) cod Gadus morhua; ling Molva molva; saithe Pollachius virens and pollack P. pollachius.

The tooth row of the saithe, *Pollachius virens*, at the symphysis may consist of as many as 9-12 rows of small teeth which vary slightly in size. The tooth-sockets of the buccal row are the largest (in a specimen of 860 mm total length the maximum tooth-socket diameter are 0.6 mm).

The tooth row of the pollack, *Pollachius pollachius*, is very similar to that of the saithe. The only difference being the larger size of the buccal row of tooth-sockets. In a pollack of 790 mm total length the buccal teeth in the region of the symphysis measure 1.2 mm diameter.

The form of the condyle of the premaxilla is rather similar in cod, pollack and saithe, but haddock and ling can readily be distinguished. In haddock the height of the ascending process is much longer than the articulating process. In the ling the squat shape of the head of the premaxilla is also highly characteristic. More subtle, but still a consistent character is the cross-section of the premaxilla shaft next to the head. A shallow broad furrow running antera-posteriorly along the bone distinguishes pollack from saithe. This character is not always as clear in fishes of less than 600 mm total length.

Chapter 6

RESULTS

This chapter describes the fish remains recovered during excavations at Freswick Links in the seasons of 1980, 1981 and 1982. An introduction to the biology of the species is presented together with data on range of elements present and the sizes of the animals represented in the deposits.

6.1 THE CONDITION AND DISTRIBUTION OF FISH REMAINS AT FRESWICK LINKS

The fish bones recovered from Freswick Links were generally exceptionally well preserved. Otoliths, which occur only rarely on most archaeological sites, were particularly abundant and many thin flat fragile bones were recovered. However, the condition of bones was not uniform across the site, neither were bones from the same context in identical condition.

Marked differences in the surface colour and texture of fish bones were noted. While most of the material from Area 4 was well preserved showing little surface flaking and having a 'fresh' appearance, that from contemporaneous levels in Area 10 was clearly bleached, presumably by sunlight, and often very friable. By contrast, much of the bone recovered from Areas 2a, 2b, 7 and 8 was stained dark grey to black by the penetration of fine organic particles or iron salts. It was not always possible to assign causes to account for the differences in appearance, but local sediment type and colour, the presence of modern roots and exposure to influences of the weather are significant variables.

Many bones, and some otoliths, showed signs of having been burnt (see section 6.7.1) and a large number of otoliths and bones appear to have been eaten or chewed by scavengers or piscivores (see section 6.7.2).

Fish and other remains were not distributed evenly through the deposits at Freswick Links. Table 15 shows the approximate weights of mollusc shell and bones of fish, bird and mammals and the concentrations of shell, fish and mammal bone in the different excavated areas. (The weights are approximate weights as it was impractical to ensure that all bones were completely free of sediment when weighed.)

Table 15. Approximate concentrations of shell, fish, bird and mammal bone in g/kg raw sediment at Freswick Links.

Area	No. samples	Conc. shell	Conc. fish bone	Conc. mammal bone
1	2	2.39	0.00	0.54
2	5	1.09	0.10	0.14
2a	9	5.46	1.67	0.12
2b	14	1.27	0.39	1.38
3	68	2.90	0.01	0.38
3E	70	8.49	0.49	0.27
4	82	4.31	2.44	0.62
5	53	8.95	2.11	0.10
6	47	1.51	0.48	0.12
7	197	0.93	0.68	0.38
8	220	5.51	0.59	0.46
9	39	0.72	0.08	0.07
10	36	1.39	0.04	0.04
11	97	0.87	0.24	0.09
12	46	1.81	0.01	0.26
13	79	0.53	0.01	0.19
14	104	4.44	0.02	0.16
Column 3	13	0.00	0.00	0.00

It is clear that fish bones were particularly common in Areas 2a, 4 and 5 (more than 1 g fish bone per kg sediment processed). By contrast Areas 1, 2, 2b, 3, 6, 9-14 and Column 3 contained low concentrations of fish remains (less than 0.50 g/kg sediment). Areas 7 and 8 gave intermediate concentrations.

The concentrations of mammal bone were less than 1 g/kg processed sediment in all areas except Area 2b. Shell was present in concentrations ranging from over 8 g/kg processed sediment in Areas 5 and 3E to less than 1 g/kg processed sediment in Areas 7, 9 and 13, and Column 3. There was a positive correlation between the concentrations of mollusc shell and fish bone in Areas 2a, 4 and 5. However, Areas 3E and 8 produced high concentrations of mollusc shell and low concentrations of fish remains.

The data giving details of the weights of recovered remains were examined to consider differences in weights and concentration of shell and bone in different stratigraphic levels. Level numbers were assigned after considering the stratigraphic sequences compiled by the excavators at Durham (see Morris et al forthcoming for details).

The purpose of defining levels is to identify contemporaneous stratigraphic units in different excavated areas. At the outset of the project it was hoped that it would be possible to make links across very large areas of the site. However, the complexity of the stratigraphic sequence coupled with the limited amount of excavation have precluded making such links except in the region of the cliff-edge where the section was carefully recorded and used to correlate with sections from the excavated areas.

The levels assigned to Areas 4, 5, 6, and 10 (Level Nos.

21-35) are closely correlated as the cliff-edge section and Area sections showed very similar sequences of finely stratified deposits. The stratigraphy of Areas 11-14 and the cliff section also showed great similarities. However, the deposits were much more homogeneous in nature than those in the northern midden and consequently the levels must be regarded as less secure as contemporaneous stratigraphic units. That said, the evidence from radiocarbon and pottery thermoluminescence determinations (Morris, Batey and Rackham forthcoming) and the modest amount of data from artefacts, suggests that the levels of Areas 12-14 are broadly contemporaneous.

Table 16 shows that fish bones were concentrated in levels 22, 24, 25 and 27 in the northern midden Areas. All other levels, except 29, gave less than 0.5 g fish bone/kg processed sediment. None of levels 2-11 gave more than 0.4 g fish bone per kg processed sediment.

To summarize, fish bones were distributed in almost all the excavated deposits, but were concentrated in Late Norse levels in the northern midden part of the site. Pictish layers contained fish remains, but in much lower concentrations.

Table 16. Approximate concentrations of shell, fish, bird and mammal bone in g/kg raw sediment at Freswick Links by stratigraphic level.

Level	Conc. shell	Conc. fish bone	Conc. mammal bone	
Southern midden (Areas 11-14)				
2	3.86	0.39	0.19	Norse midden
3	3.04	0.04	0.17	Uncertain date
4	2.43	0.01	0.16	Uncertain date
5	0.63	0.10	0.40	Pictish
6	1.19	0.19	0.09	"
7	3.23	0.18	0.52	"
8	0.36	0.06	0.05	"
9	0.00	0.01	0.09	"
10	0.00	0.00	0.00	"
11	3.81	0.02	0.06	"
Northern midden (Areas 4,5,6 and 10)				
21	0.07	0.00	0.01	Late Norse/modern
22	2.31	1.91	0.30	Late Norse
23	0.05	0.00	0.05	?Late Norse
24	6.39	2.57	0.56	Norse
25	4.04	2.08	0.07	"
26	1.36	0.33	0.02	"
27	4.30	2.19	0.27	"
28	1.37	0.09	0.05	"
29	2.93	0.90	0.14	"
30	0.14	0.19	0.01	"
31	0.42	0.12	0.03	"
32	0.58	0.27	0.18	"
34	2.32	0.32	0.14	"
35	0.19	0.01	0.01	"
Unphased samples (Areas 1, 2, 3, 7, 8, and 9)				
-	3.15	0.39	0.37	

6.2 THE SPECIES PRESENT AT FRESWICK LINKS: THEIR REMAINS AND SIZE

In this section the taxa identified from the site are presented, together with an introduction to the biology of the species (based on Wheeler (1969) unless otherwise stated) and data on numbers and phasing where possible. At the end of the section Table 20 gives a full list of taxa and their percentage frequency in the deposits by context and sample.

Cartilaginous fishes, Elasombranchii

This taxon includes remains of cartilaginous fishes (sharks, dogfishes and rays) which were not sufficiently diagnostic to be assigned to family or species. The remains were 18 mineralized cores of vertebral centra which ranged in size from 4.1 - 6.9 mm maximum diameter of the centrum. The mineralized cores were consistent with those found in several species of ray (Rajidae) however, other kinds of cartilaginous fishes also produce mineralized vertebral cores. Thirteen of these remains were found in unphased deposits (10 from context MX), the remainder were found in Norse or Norse/Pictish deposits.

Dogfishes, Scyliorhinidae

Dogfishes are small sharks living on or near the bottom in shallow or deep waters. Three species, Galeus melastomus, Scyliorhinus stellaris and S. caniculus occur in the waters of Caithness, the latter being the most common. Only two dogfish mineralized cores of vertebral centra were recovered, one from unphased deposits in Area 3, the other from Pictish deposits in Area 11.

Thornback ray, Raja clavata L.

This is the most common ray in inshore waters, being found on most marine substrates at depths of 2-60 m. Only three remains, 2 teeth and one dermal denticle, were recovered. The dermal denticle was diagnostic of thornback ray, while the teeth (see Plate 12) were identical to those found on male thornbacks. However, it was not possible to check the teeth with all modern species of ray. The ray remains were restricted to an unphased deposit in Area 2b (DH); a Norse deposit in Area 13 and a Pictish deposit in Area 14.

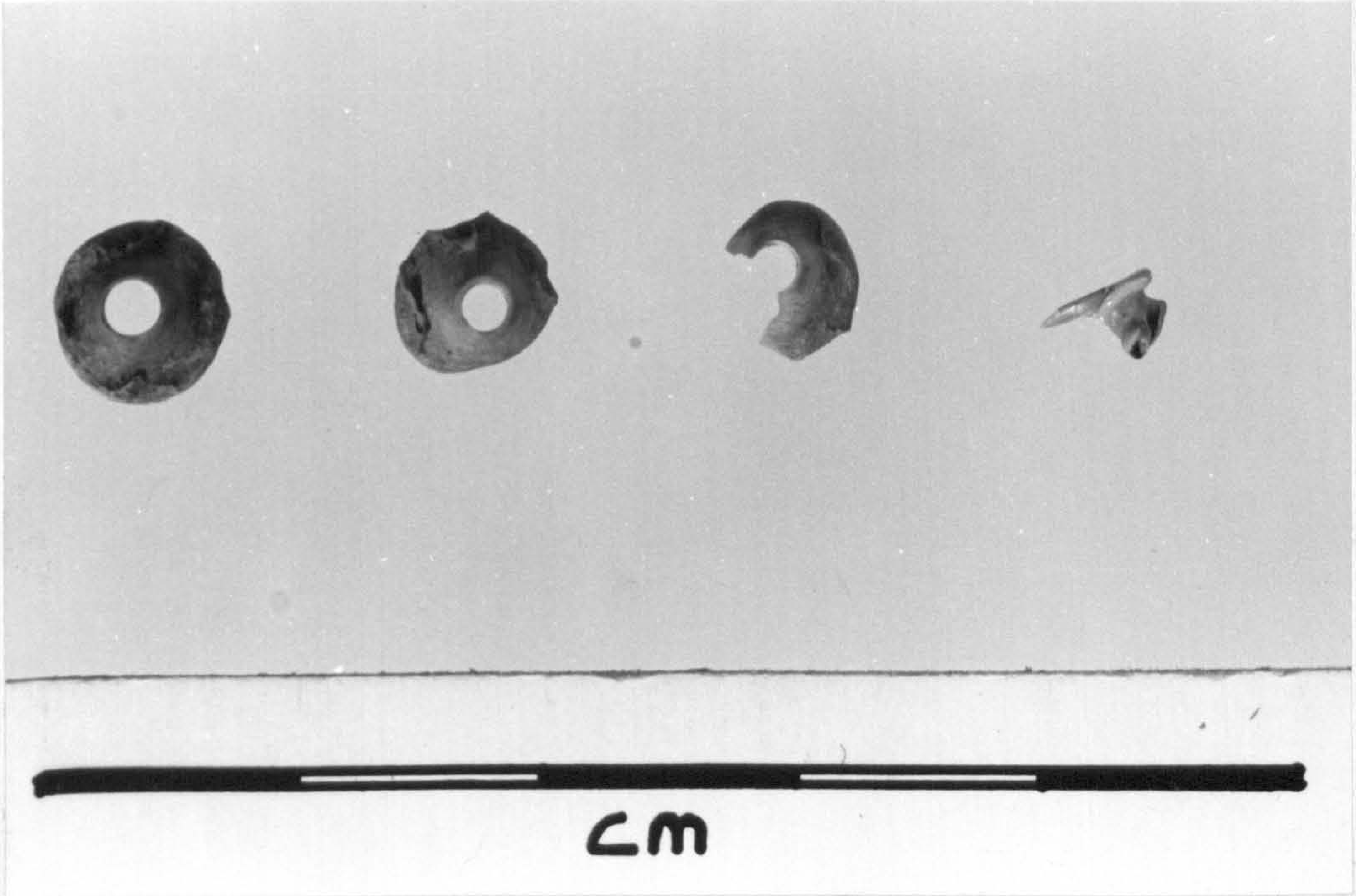


Plate 12. Elasmobranch mineralized vertebral core fragments and a tooth of a ray, probably thornback ray, ?Raja clavata.

Herring family, Clupeidae

This taxon includes bones from clupeids which were not sufficiently diagnostic to allow specific identification. The remains ascribed to this taxon were all small otic bullae consistent with those found in young herring or sprats. A group of 4 small otic bullae were recovered from Norse deposits in Area 5, while one small otic bulla was recovered from unphased deposits in Area 2a.

Herring, Clupea harengus L.

The herring is primarily a pelagic shoaling species found in offshore waters near the surface to depths of 200m. Some herring spawn close to shore in bays and young herring stay in shallow water. After two years (about 160-180mm total length) they migrate into deeper water. Herring undertake extensive migrations, and are usually caught in floating nets.

Table 17. Herring, Clupea harengus, bones from Freswick Links

opercular	1
otic bulla	1
subopercular	1
first vertebra	1
abdominal vertebra	44
caudal vertebra	18

The majority of herring bones (40 vertebrae) were recovered from an unphased deposit (AAX) in Area 8. All bones were from fishes ranging in length from 230-300 mm total length. No herring remains were recovered from Pictish deposits while 17 came from Norse or Norse/Pictish deposits. Six of the vertebrae (5 from Area 11 VH+VI, 1 from Area 2a DN) were crushed in a manner which suggested they had been chewed by a piscivorous mammal (see Plate 13).

Salmon family, Salmonidae

This family includes the salmon and trout, Salmo salar and S. trutta. Only five fish remains, all from unphased deposits, were assigned to this family. They comprise one abraded otolith (tentatively identified to the family) and four vertebral centra. All vertebrae were less than 2 mm across the articulating surface and thus from fishes of less than 200 mm total length.

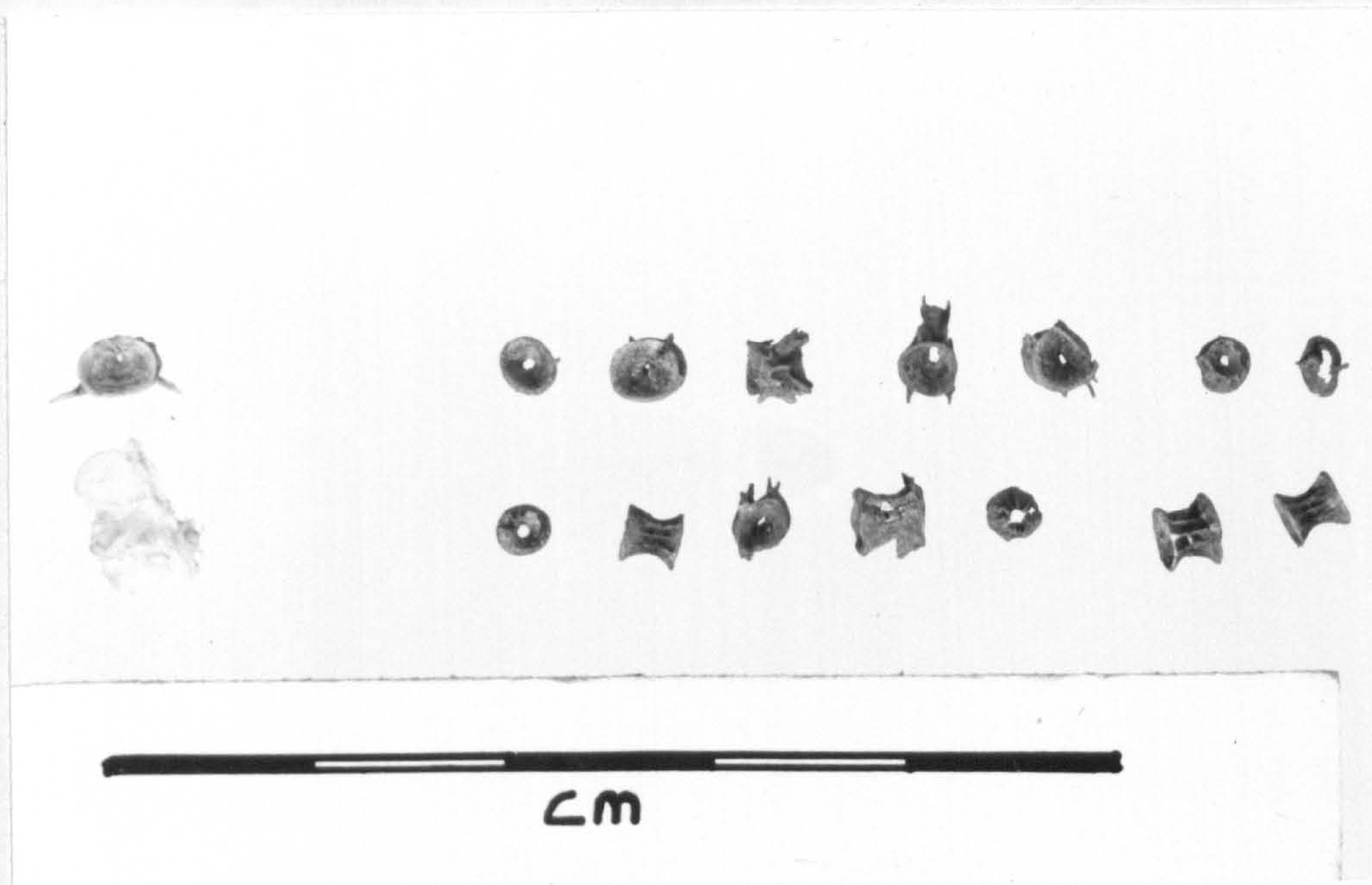


Plate 13. Herring, Clupea harengus, bones. Lower left fragment is an opercular fragment, the remainder are vertebrae. Note several are crushed.

Eel, Anguilla anguilla (L.)

The migrations of eel larvae, from the Sargasso Sea in the Atlantic Ocean to European coasts, are well documented. Eels are found throughout Europe, and in all parts of the British Isles. Most enter estuaries and ascend into freshwater, while some remain near the coast, particularly on rocky shores.

Eel was represented by two dentaries, one opercular and 12 vertebrae (see Plate 14). All were from small to medium sized animals (350-550 mm total length). One was recovered from a Pictish layer (VK, Area 11), five from Norse layers (JE, JF Area

4 and GU Area 5). The remainder was scattered throughout unphased layers. One vertebra was recovered from Column 3.

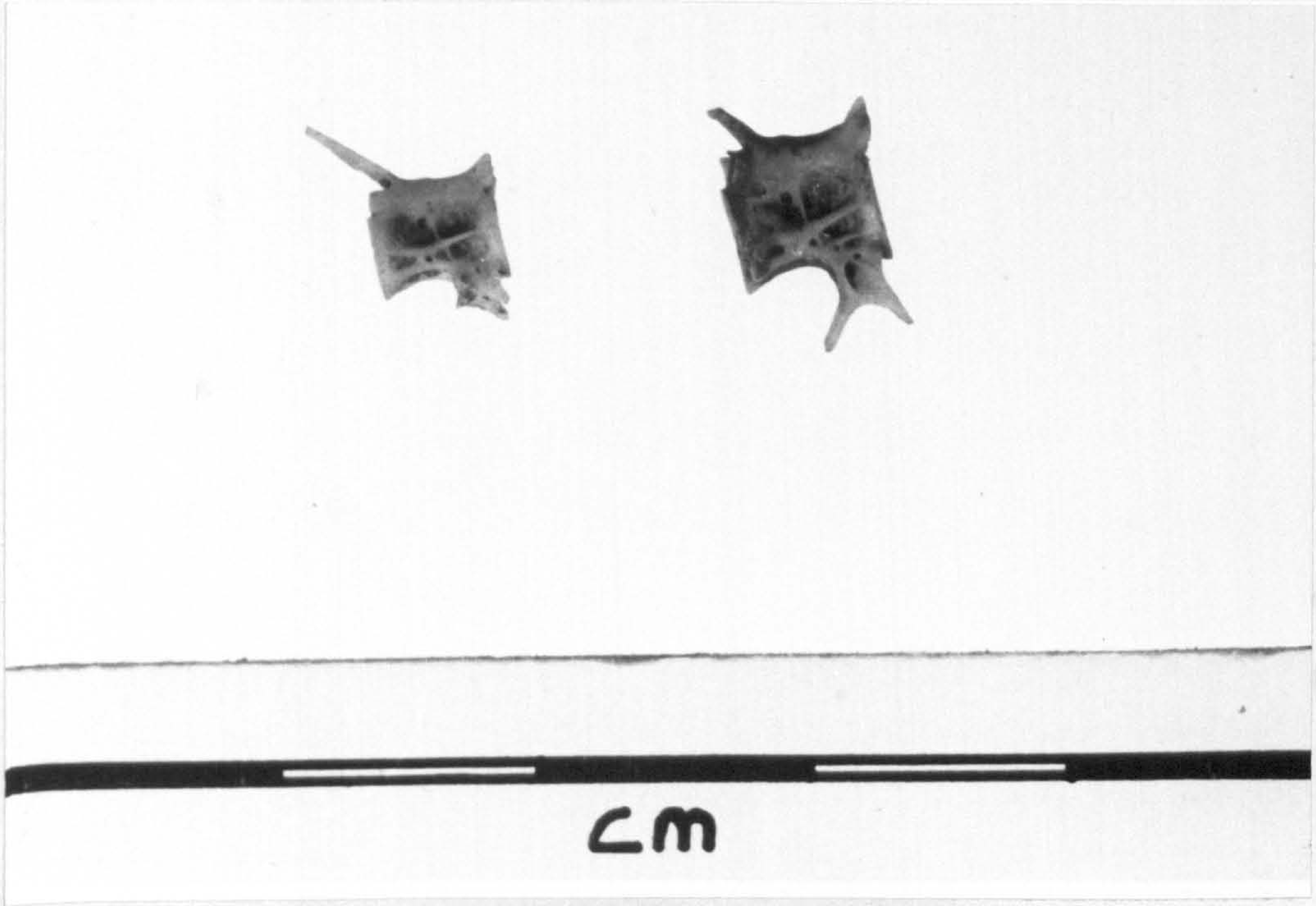


Plate 14. Eel, Anguilla anguilla, vertebrae.

Conger eel, Conger conger (L.)

The conger is a large marine eel that can reach 2.75 m and weigh 65 kg. It spawns in grounds in the tropical Atlantic and the larvae move northwards. Consequently, conger eels are most common in the south and west of Britain. Young congers are found close to the shore, in deep shore pools. Individuals up to 1.22 m are found inshore but are more common on rough ground.

In contrast with the remains of common eel, those of conger eel were abundant at Freswick.

Table 18. Conger eel, _Conger conger_, bones from Freswick Links

ceratohyal	1
dentary	3
maxilla	1
opercular	1
prevomer	1
abdominal centra	31
caudal centra	8
centrum	1

The size of the remains showed that while very large fish were represented (the largest centrum was 15.3 mm across the articulating surface of the centrum and was from an animal that measured roughly 2 m total length), the majority of the vertebrae were from small and medium sized animals (vertebral measurements 2-5 mm from animals ranging between 400 mm and 1 m total length). Most were recovered from Norse levels in Areas 4 and 5 and 6. Of particular interest is a group of vertebrae from a Norse deposit in Area 4 (JM) which yielded vertebrae which were clearly damaged (see Plate 6.04) suggesting they had survived passage through a piscivore's gut.

Garfish, _Belone belone_ (L.)

The garfish is primarily a fish of the upper waters of the open sea, although it regularly enters coastal waters. One vertebra, a dentary and a fragment of jaw bone (see Plate 16) were recovered from an unphased layer (MX) in Area 7. A group of five vertebrae was recovered from a Norse layer in Area 4. In addition five vertebrae from unphased deposits were tentatively assigned to garfish.

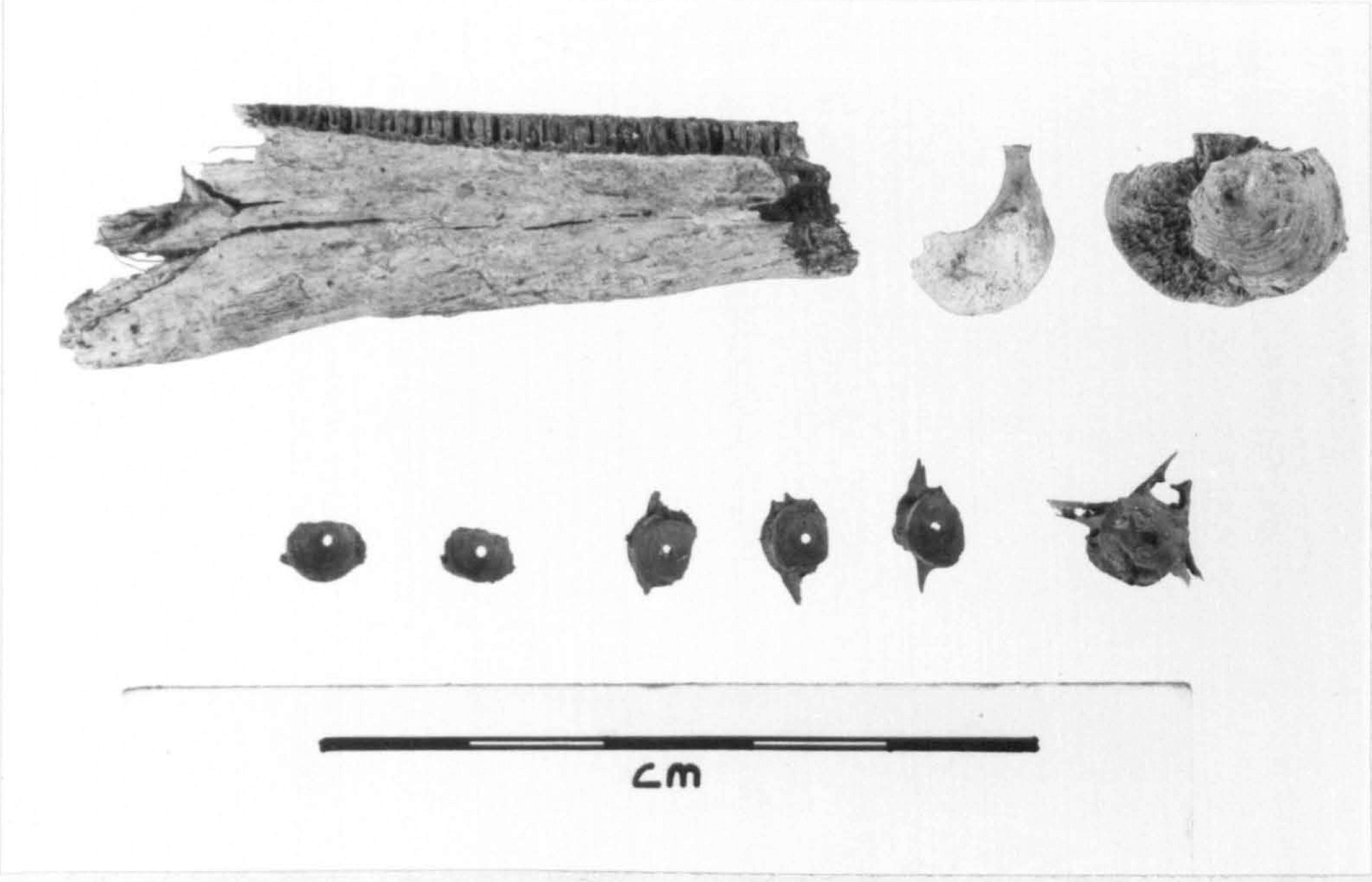


Plate 15. Conger eel, Conger conger, remains. Top row, left to right: large left dentary fragment; opercular and vertebra. Bottom row: vertebrae, all damaged, possibly by a piscivore.

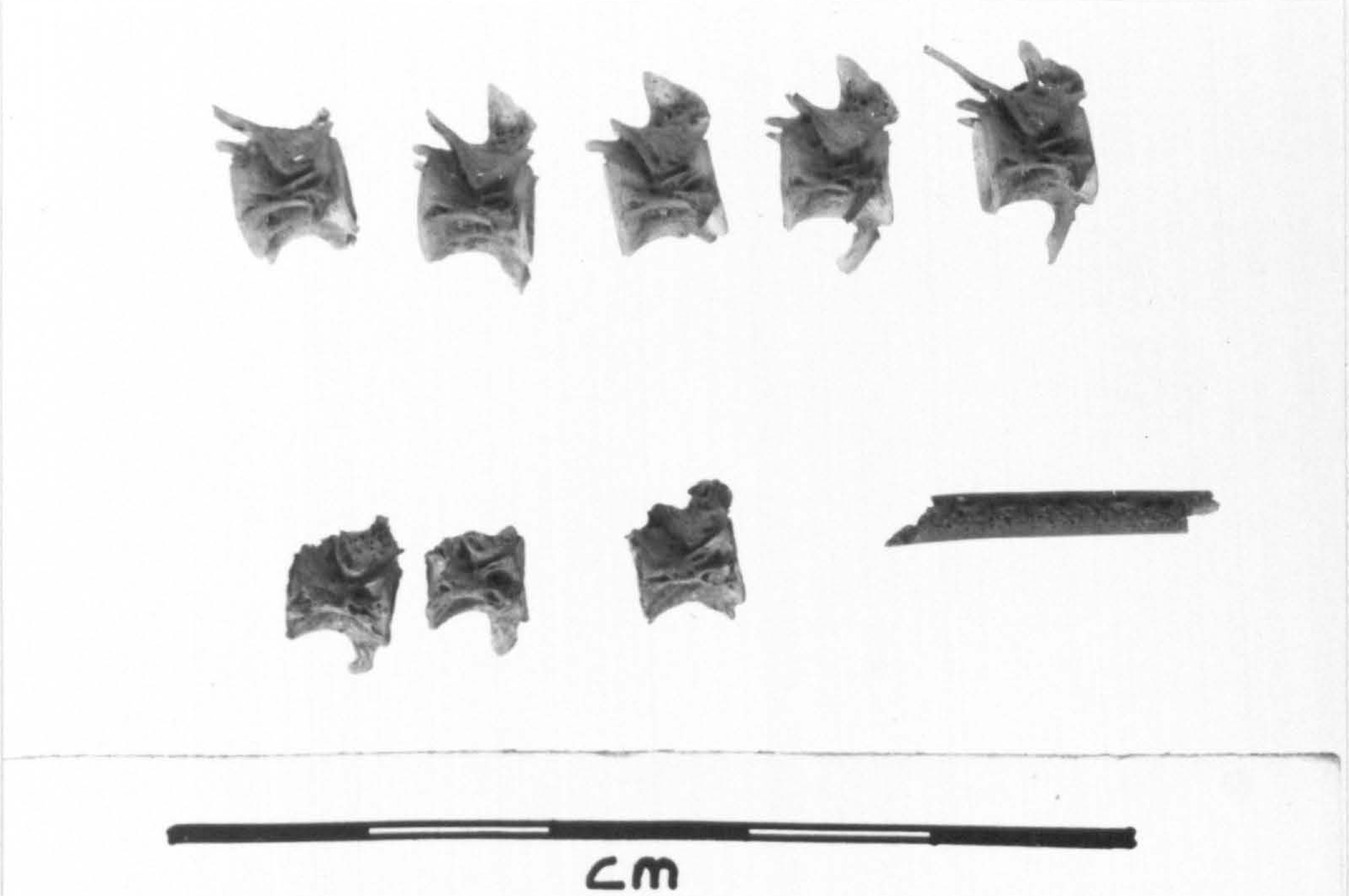


Plate 16. Garfish, Belone belone, remains. Bottom right: jaw bone fragment; remainder vertebrae.

Hake, Merluccius merluccius (L.)

The hake, the only member of the Merluccidae occurring in British waters, is found from Norway to the Mediterranean and is present around the British Isles with the exception of the south-east coast. It mainly inhabits depths of 165-550 m but enters shallower water during the summer. It was formerly more common in inshore waters and in the years following the Second World War (1939-15) was common in inshore waters off Ireland (Wheeler and Jones, 1989, 166). Hake spawn through the spring and summer, mainly in ground of the south and west of the British Isles. It is an important commercial species with a maximum size of 1.8 m but has long been affected by overfishing.

Hake was represented by two large otolith fragments in a Norse deposit (GY) in Area 5 and a premaxilla from Area 4 (JM). All were from large (>1m total length) fish. Unphased deposits gave a dentary fragment and a caudal vertebral centrum. Hand collected assemblages from Area 2a produced a group of 7 large hake vertebrae. A selection of hake remains is shown in Plate 17.

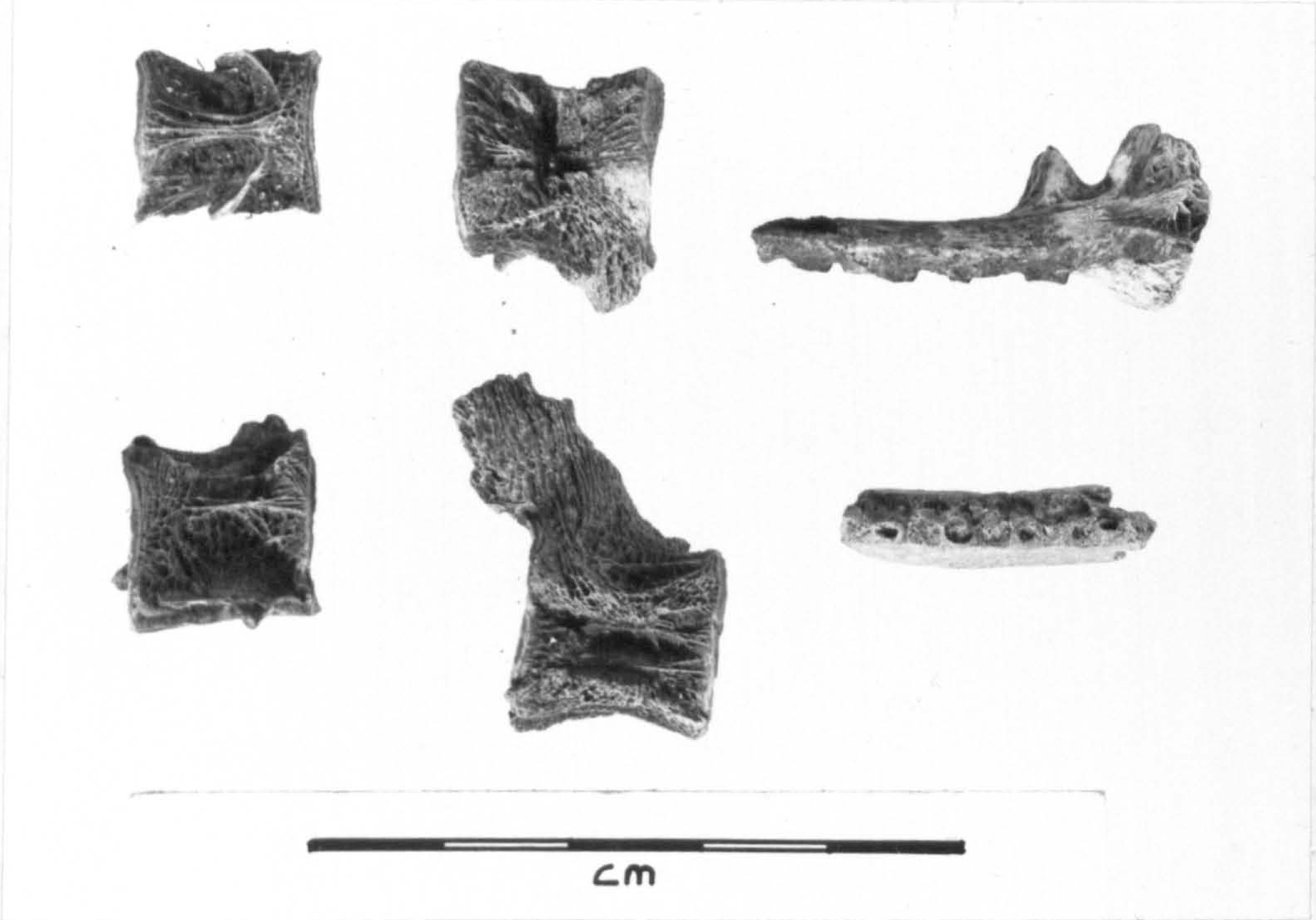


Plate 17. Four hake, Merluccius merluccius, vertebrae and 2 premaxillae fragments.

Cod family, Gadidae

The determination Gadidae was given to bones that were clearly from a member of the cod family, but which could not be determined to species or other taxon. The vast majority of fish remains from Freswick Links were from gadid (mainly large gadid) fishes. The following genera Merlangius, Pollachius, Trisopterus, Gadus, and Molva were represented by otoliths, while premaxillae and dentary bones showed that Brosme, Raniceps, Gaidropsarus and Ciliata were also represented. With such a great diversity of gadid fishes in the deposits many small vertebrae, other bones and bone fragments were assigned to this taxon.

Whiting, Merlangius merlangus (L.)

Whiting is extremely common in the North Sea in waters 30-100 m deep. It is rarely found below 200 m. Spawning takes place principally during April and May, but begins in the middle of

January in the south of its range and continues through to July in the north of its range. The growth rate varies with populations, but first year fish average 150 mm, second year fish up to 220 mm and third year up to fish 300 mm. Young fish live mainly inshore feeding on shrimps, young crabs, amphipods, gobies and sand eels. Whiting is an active predator feeding during daylight on sand eels, sprats, young gadoids and shrimps.

Whiting remains were restricted to four otoliths, two from Norse levels in Areas 4 and 6 and two from unphased levels in Areas 7 and 8. Three of the otoliths were clearly eroded or abraded, consistent with having been digested in a piscivore's gut. The absence of vertebrae and other whiting remains is noteworthy, as bones of this species are highly characteristic and often recovered from archaeological deposits.

Trisopterus spp. (including bib and poor cod)

A group of 28 otoliths were assigned to this genus and a further otolith determined as ?*Trisopterus*. One dentary was determined as ?*Trisopterus luscus* and a premaxillae as ?*T. minutus*; both were from Norse deposits. Most of the otoliths (see Plate 18 for an example) were from unphased deposits, 12 from deposits of Norse date and one from a Pictish layer. All the *Trisopterus* remains were from fishes of 250-300 mm total length.

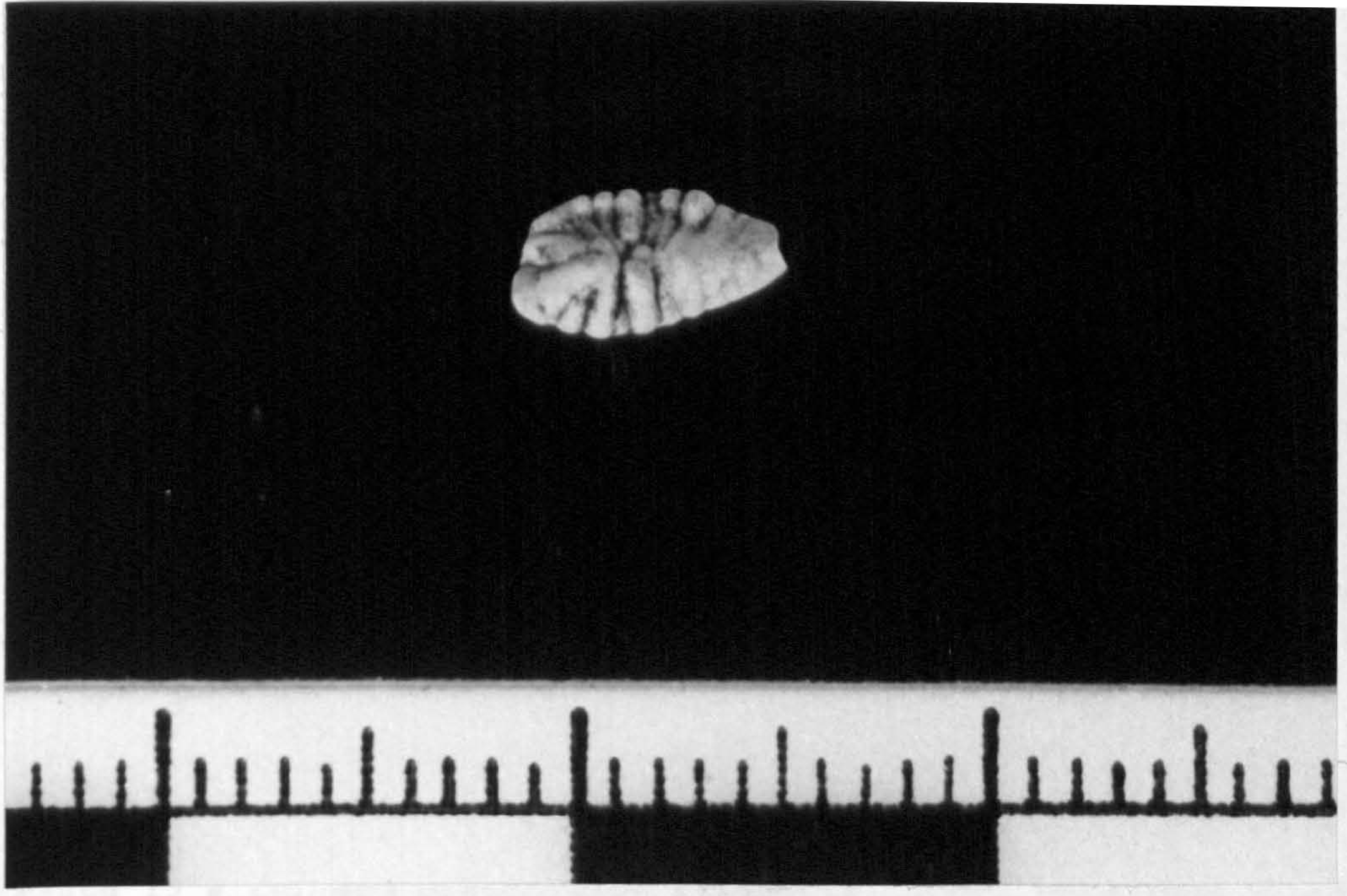


Plate 18. Trisopterus sp. otolith.

Pollack, Pollachius pollachius (L.)

This species has a similar distribution in the western Atlantic to saithe, from Iceland and north Norway to the west of Iberia and tends to be more common in southern waters. In British waters it is more common in the south and west than in the north. Spawning takes place between January and May, peaking in March in depths of 100 m and temperatures of 8-10 degrees C. The early life of pollack is very similar to saithe (Meek, 1916, 215) with the eggs and larvae drifting inshore arriving at the coast from April to May. Here they stay until autumn and grow rapidly reaching 150 mm by the end of the growing season. Their behaviour in the autumn and winter is less well known than that of saithe. However, they appear to move away from the shore (Kennedy, 1969, 308) and in the following spring are found around shallow reefs (up to 9 m). During the second winter they inhabit deep waters and are approximately 260-310 mm in length. In the following spring they return inshore. After their third year they are found in depths of 40-100 m.

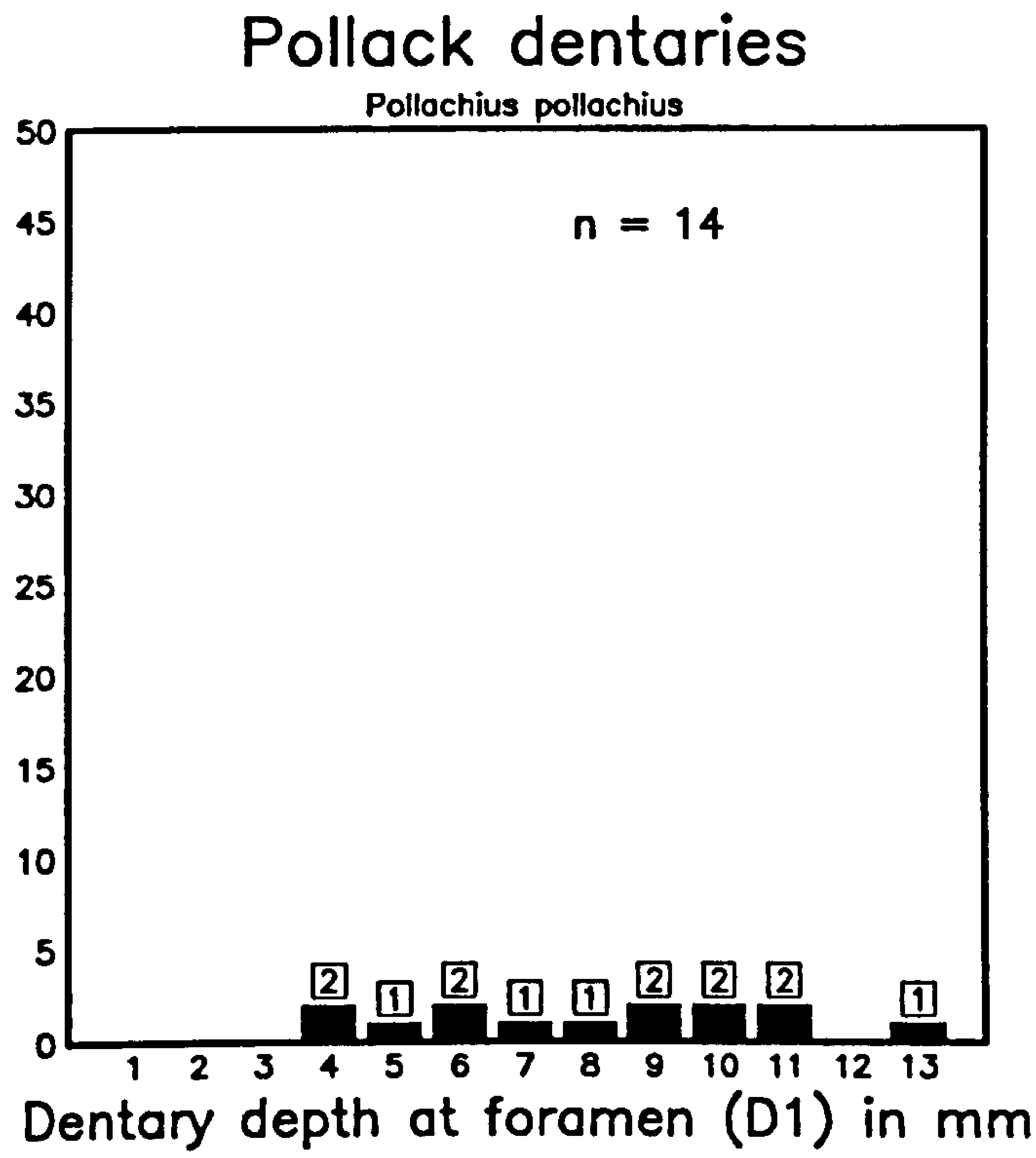
The adult pollack is an inshore fish found mainly within the 200 m line over rocks and rough ground. It is mainly solitary but may aggregate around reefs. Pollack may grow to 1.3 m (11 kg) but is more usually 500 mm and 4 kg. Large specimens are found further offshore although they may come near the shore in summer.

Remains identified definitely as pollack were dentary (see Plate 19 & 20) and premaxillae fragments. These were less common than those of saithe, although it is important to bear in mind that small numbers of jaw bones were also assigned to Pollachius sp. The bones definitely identified as pollack were from animals ranging in size from 350 mm to over 1 m total length (see Figures 65 & 66).

Plate 19. Lateral view of distal portion of (left) pollack, Pollachius pollachius, and (right) saithe, P. virens, right hand side dentaries. Note the differences in the shape of the bone at the symphysis and the striated surface of pollack and smooth, although irregular, surface of saithe.

Plate 20. As above, dorsal view.

Figure 65. Histograms of measurements taken on pollack dentaries.



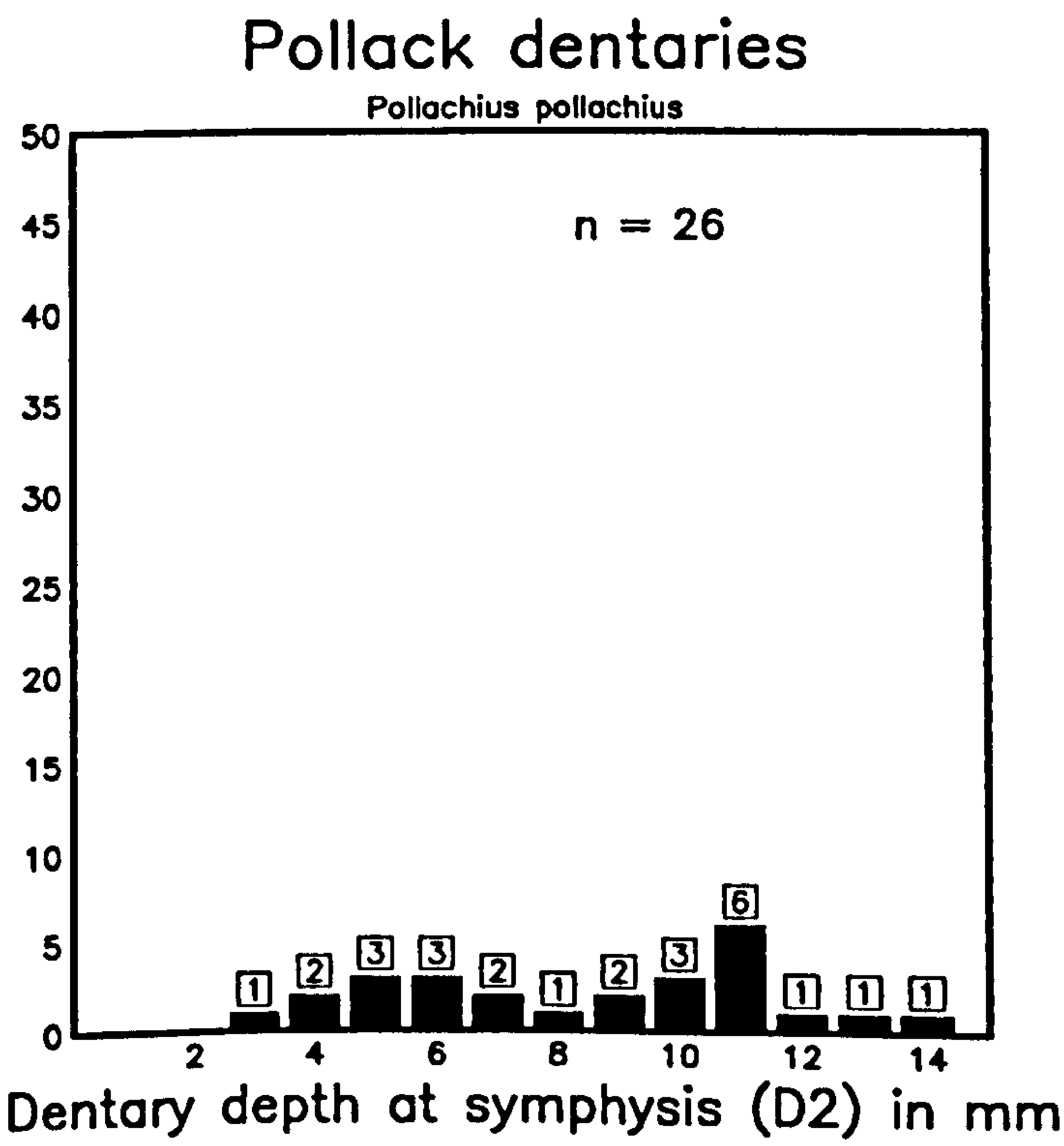
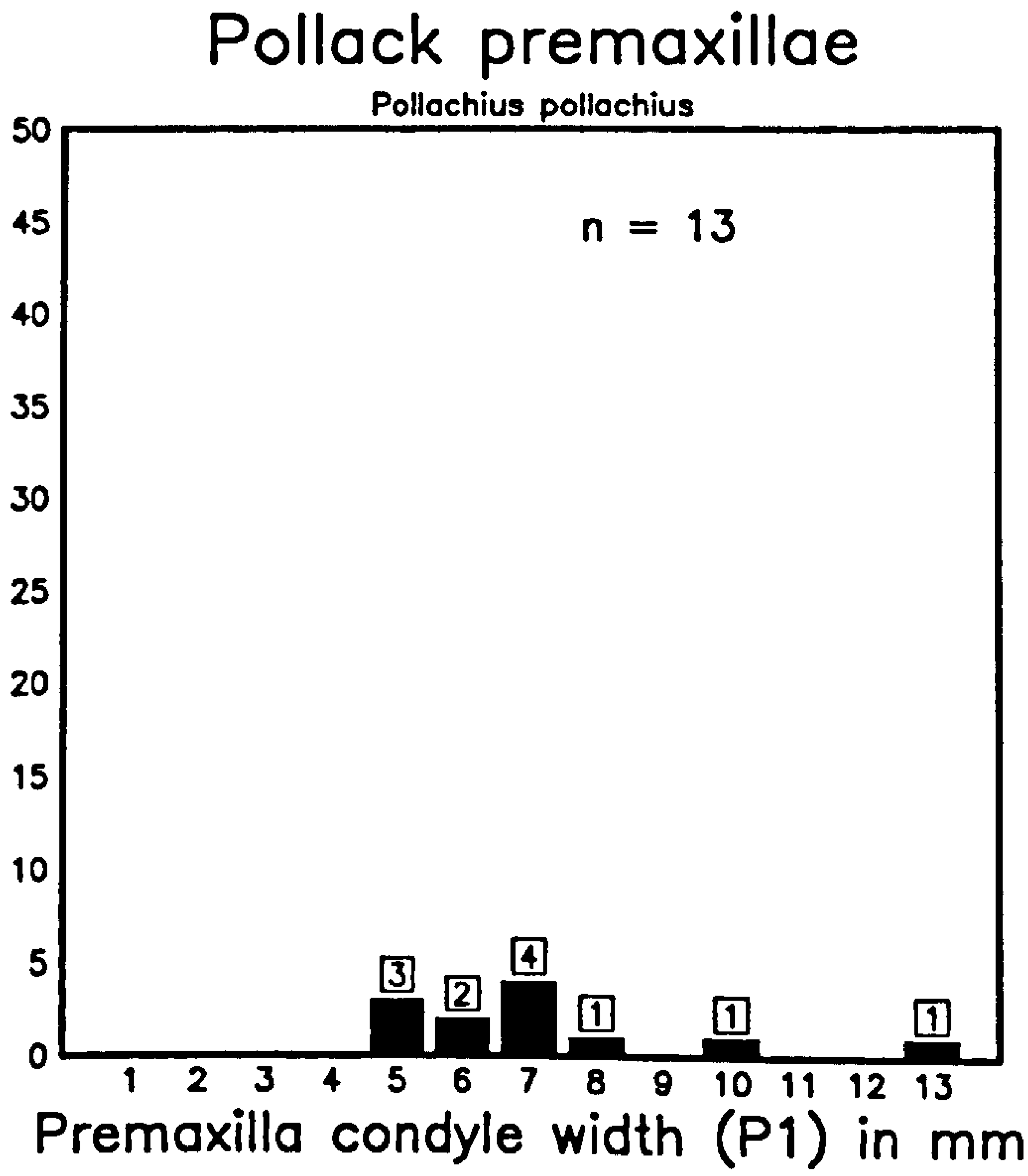
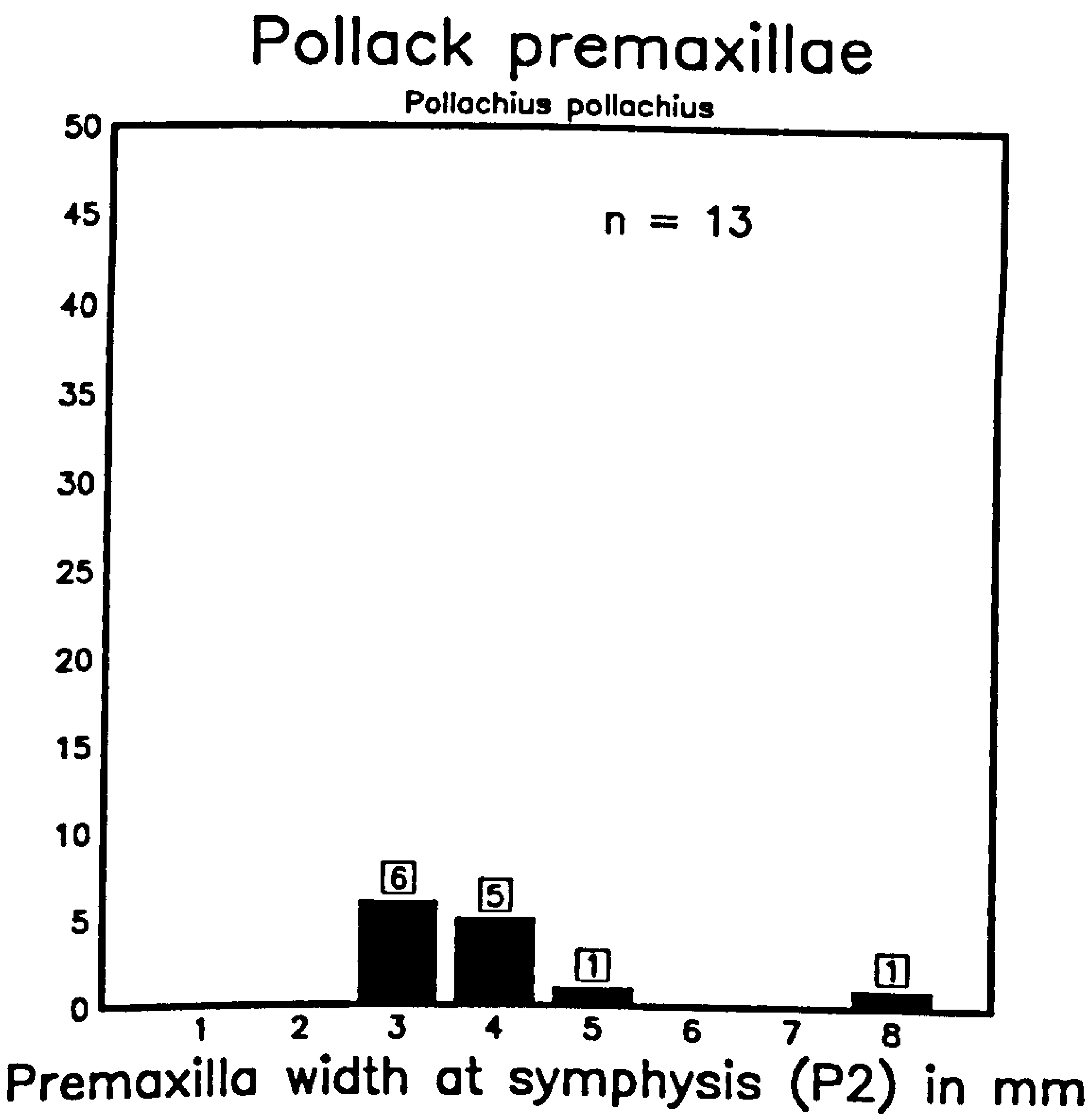


Figure 66. Histograms of measurements taken on pollack premaxillae.





Saithe, Pollachius virens (L.)

Saithe is a common fish, particularly in northern inshore waters, which forms small shoals. Saithe spawn between January and early May in offshore waters in 100-200 m. Within any one area the spawning period is restricted. For example, in the Faroes it starts during February and continues to May. Southern populations spawn earlier in the year. Saithe is fast growing species reaching a mean total length of approximately 150, 300 and 450 mm in the first 3 years in the North Sea. This rapid growth rate allows fisheries biologists to age individual fishes by examining length data, rather than sectioning otoliths. The growth of saithe in the Faroes was studied in considerable detail by Bertlesen (1942). He showed that fry leave their pelagic stage when 25-30 mm in length and move towards the shore. Here they grow at approximately 20 mm per month until they reach an average length of 140 mm. During the three coldest months the fish migrate into deeper water where growth continues but at a much reduced rate; the fish put on only 20 mm. This pattern of growth is repeated in the second and third years, the fish reaching 270 mm and 400 mm towards the end of the respective growing seasons. In more southerly waters growth is more rapid.

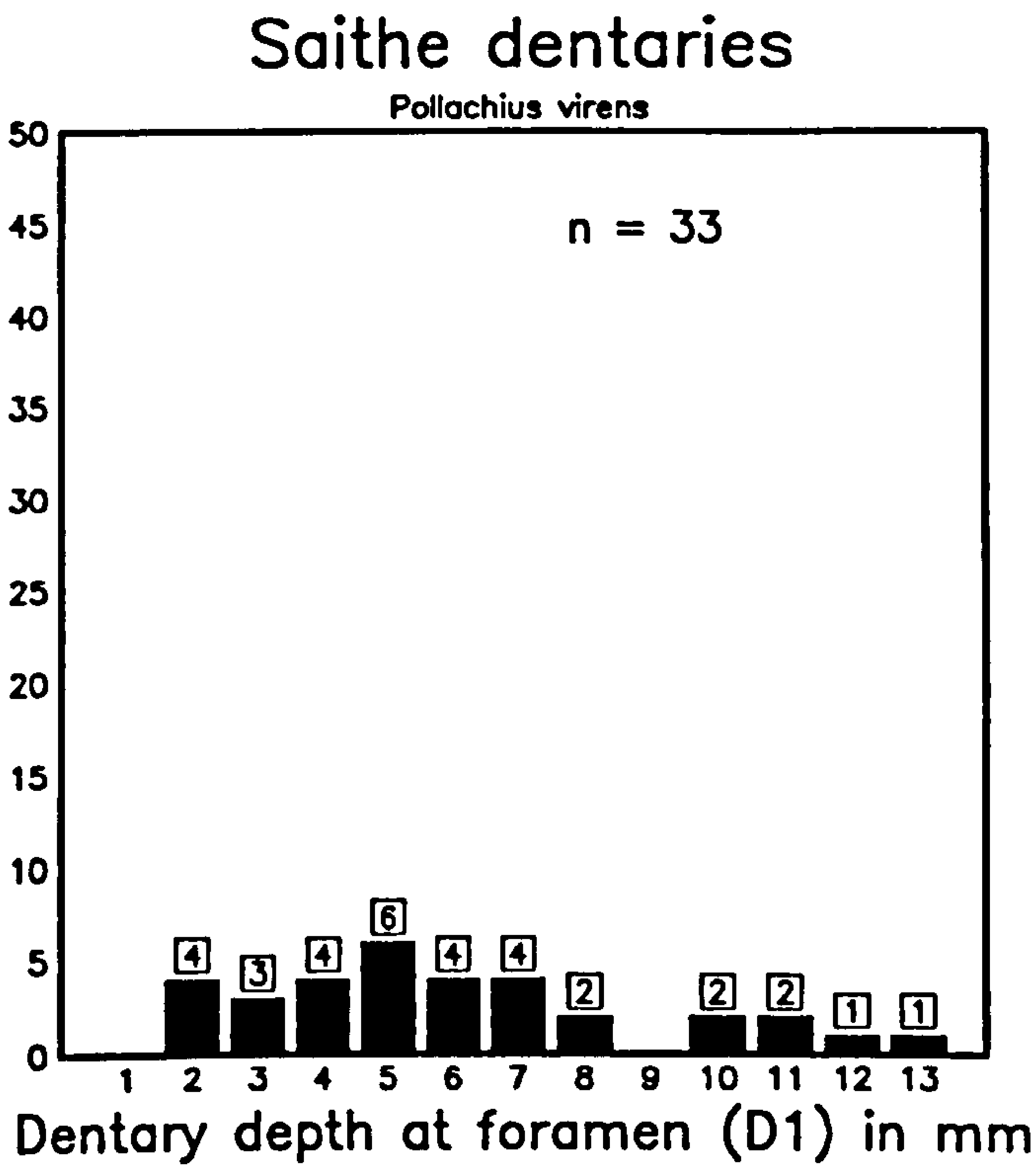
Thus there is a marked seasonal migration of young saithe from offshore waters to the coast in the late summer when the fish grow rapidly. During the winter the fish retreat to deeper waters where growth is slower.

From the third year saithe exhibit a less marked seasonal migration, being less conspicuous inshore, but are still sufficiently abundant to be caught in considerable numbers. Saithe reach approximately 1 m after eleven years.

Saithe was represented by substantial numbers of dentary (see Plate 19 & 20) and premaxillae bones in unphased, Norse and Pictish deposits. Other saithe bones were recognized in Areas 3 and 9 where an attempt was made to identify all fish remains. A large number of remains, including over 900 otoliths (see Plate 21) were assigned tentatively to saithe. There can be little doubt that the majority are from saithe, however, a small number may be from pollack, Pollachius pollachius and a few may be from haddock, Melanogrammus aeglefinus.

Plate 21. ?Saithe, ?Pollachius virens, otoliths.

Figure 67. Histograms of measurements taken in saithe dentaries.



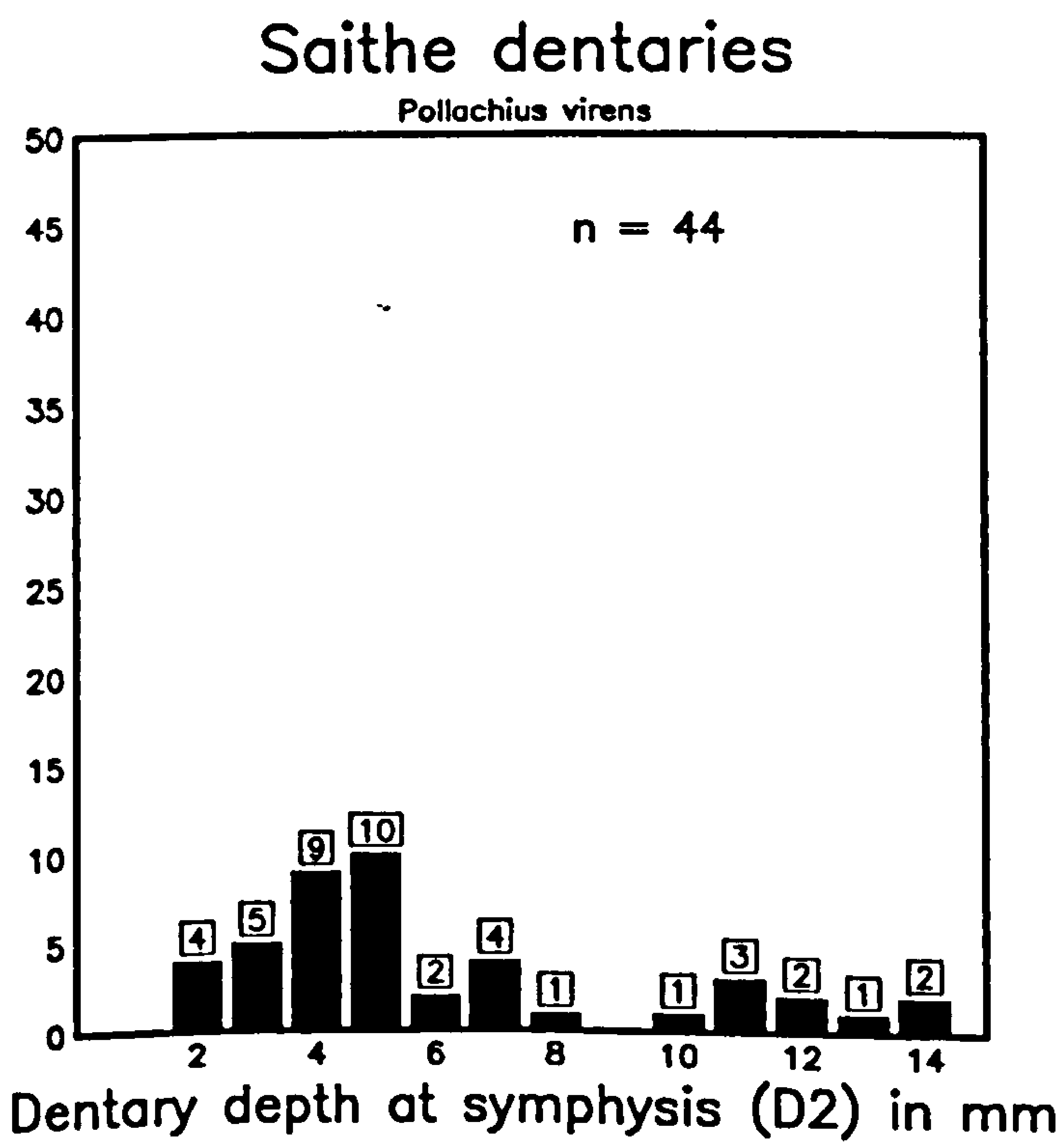
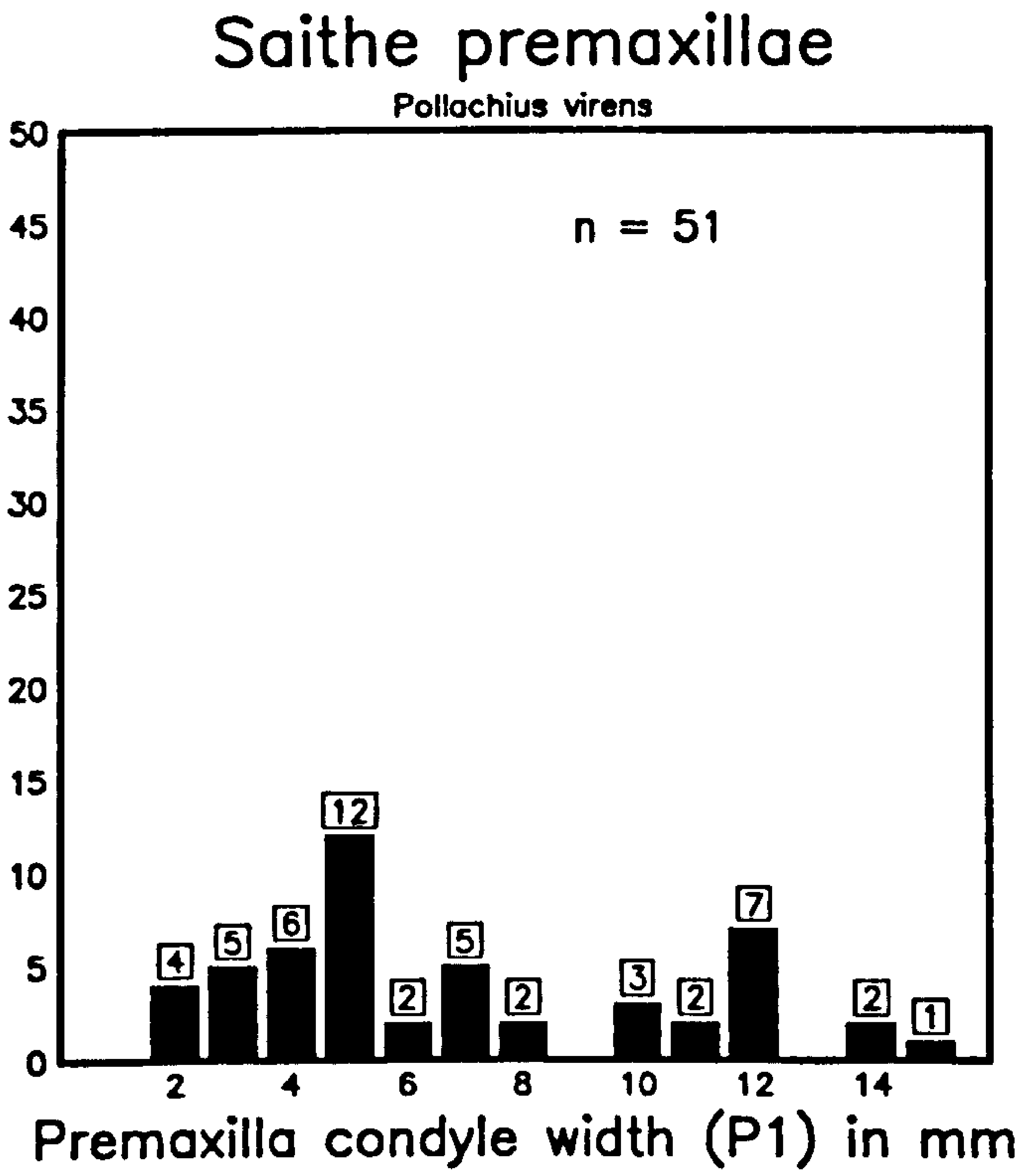


Figure 68. Histograms of measurements taken on saithe premaxillae.



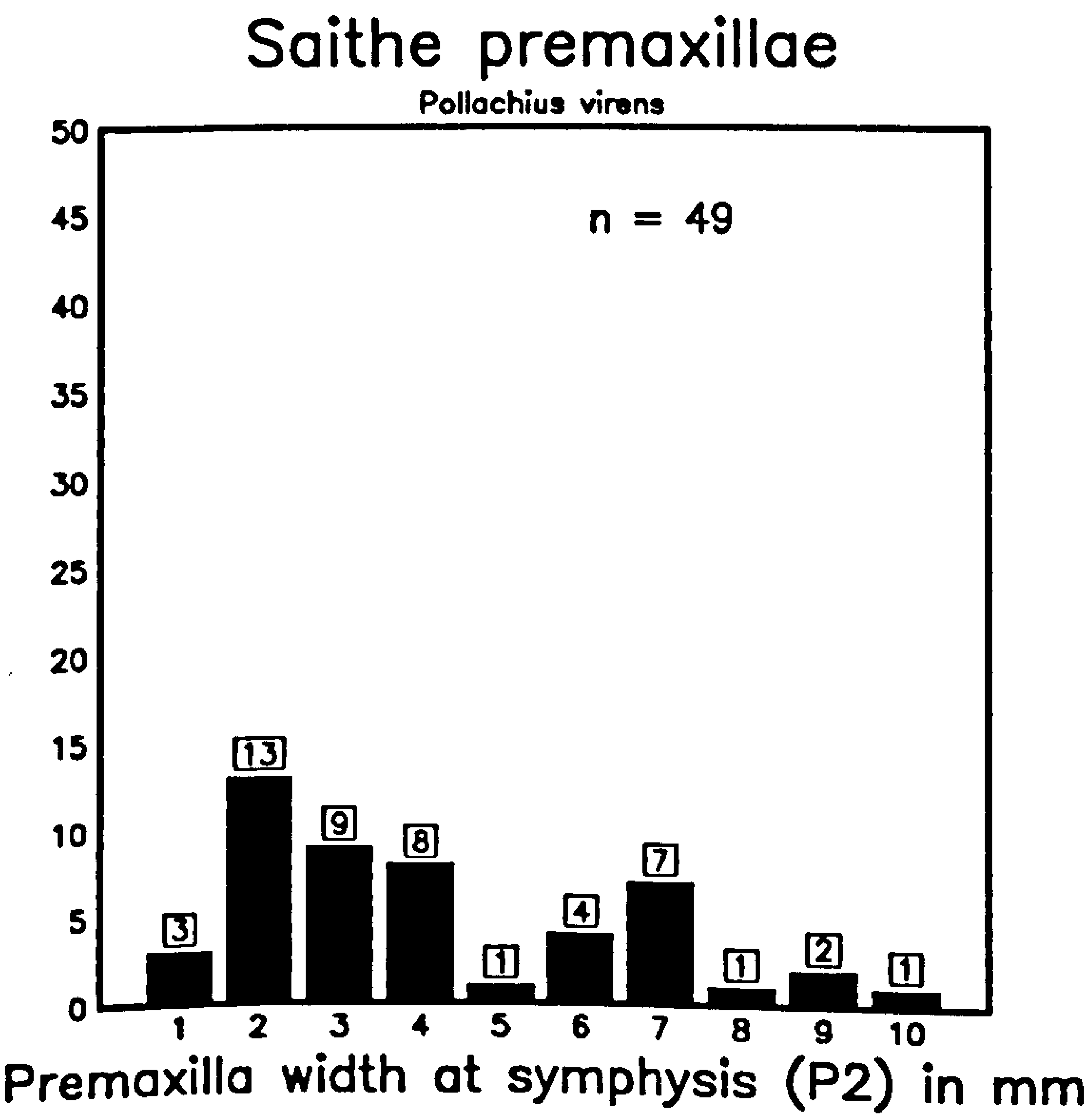
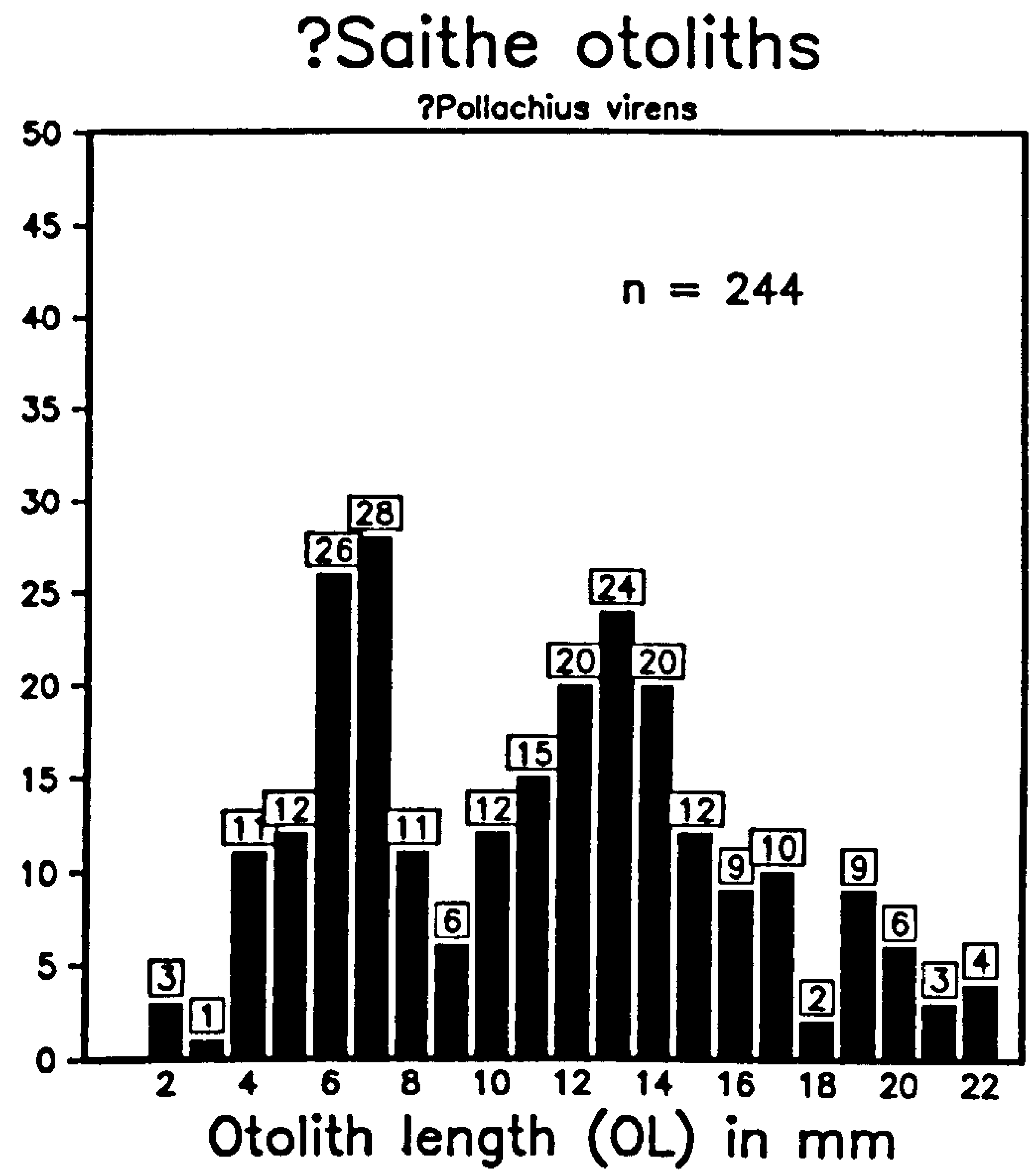
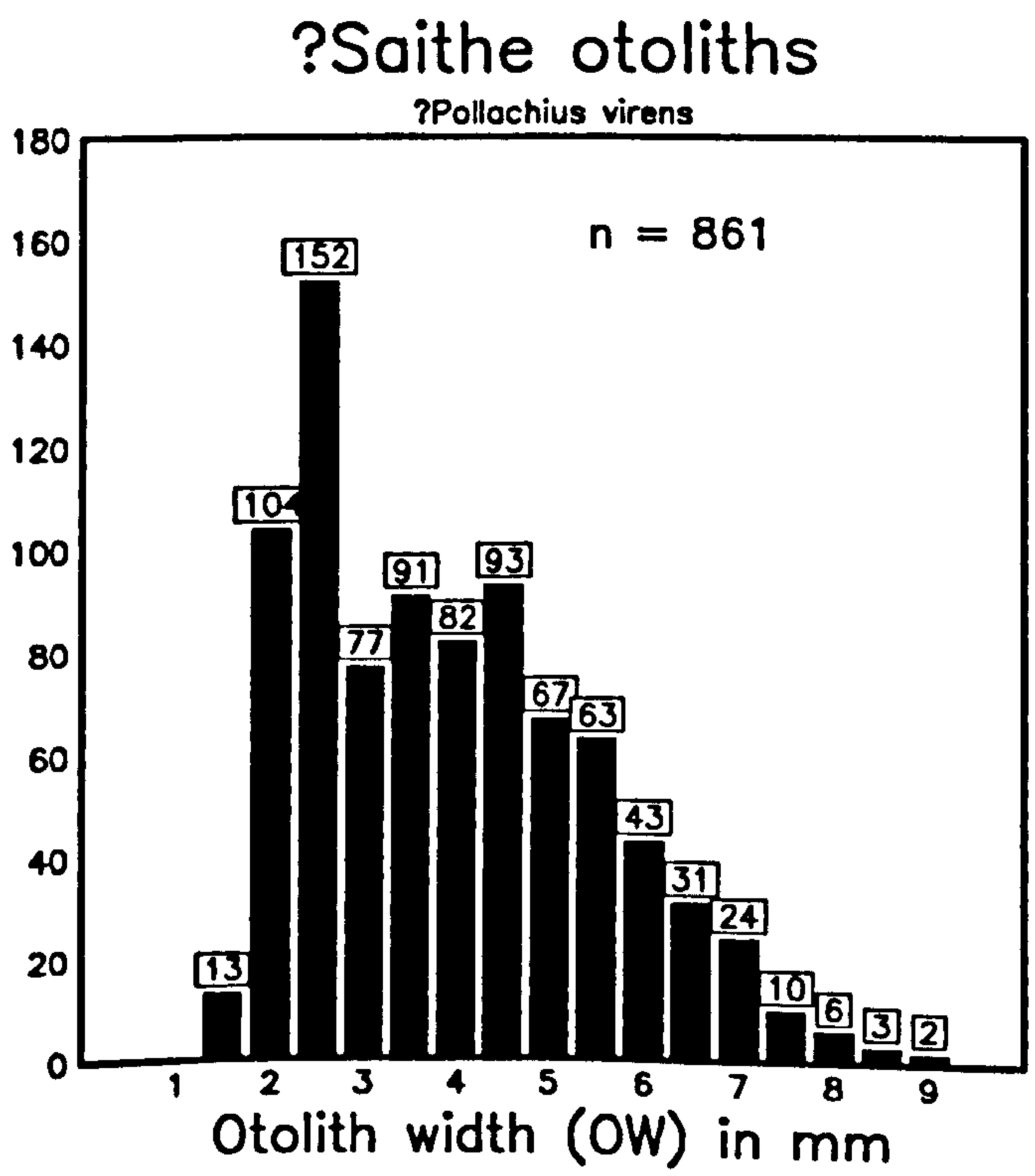


Figure 69. Histograms of measurements taken on ?saithe otoliths.





Saithe bones were recovered from fishes ranging in size from less than 200 mm in length to individuals longer than 1 m total length (see Figures 67-69).

The histogram of ?saithe otolith length measurements (Figure 69) show a polymodal distribution with peaks at 7 and 13 mm. These peaks correspond with the sizes of otoliths found in first and second year old fish. The saithe premaxillae measurements show a skewed distribution in favour of small and medium sized fishes (250-600 mm total length).

Several bones and 78 ?saithe otoliths were abraded in a manner consistent with them having survived passage through a vertebrate's gut. In addition tooth marks were noted on two saithe dentaries and a ?saithe cleithrum.

Cod, *Gadus morhua* L.

This is the most important marine food fish in the British fauna and has been exploited by human groups for many centuries. Its biology has been extensively studied and much is known about its growth, feeding habits and population dynamics.

The North Atlantic cod exists in several populations, races or subspecies. However, there is considerable intermixing between adjacent populations. The biology of each is dependent on local habitat conditions. The Arcto-Norwegian stock is based on the shallow northern European plateau and the North Sea population is self-contained.

Spawning occurs over much of the continental shelf inside the 200 m line from February to April. Eggs are distributed by currents and larvae become demersal and live near the sea bed.

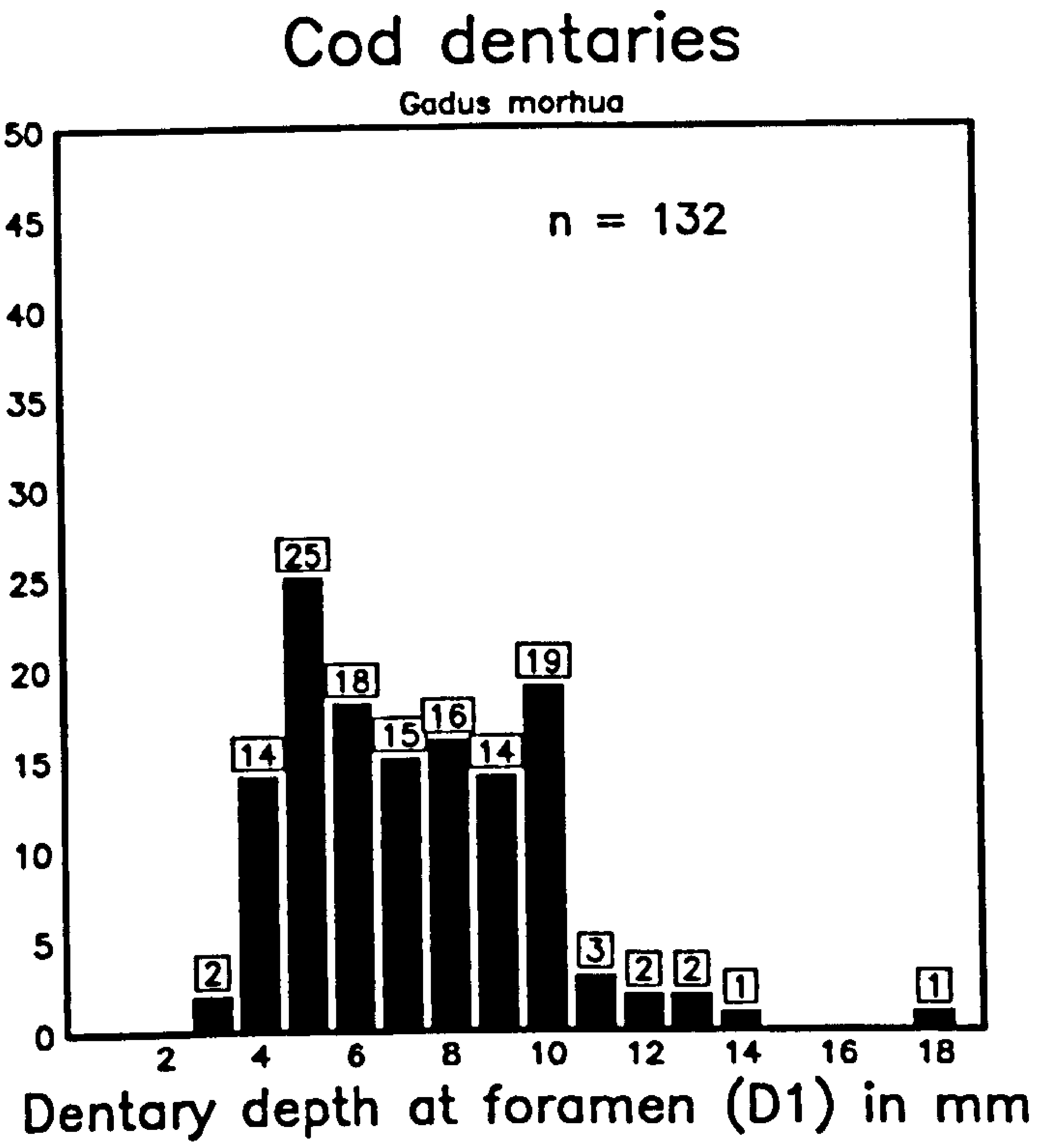
Cod are found from the shore line to 600 m forming dense shoals during daylight which disperse at night. The shoals are usually commonest at between 30 and 80 m off the bottom, although they feed on the bottom and near the surface. Fry and young fish eat a host of invertebrates but as they increase in size fishes (herring, sand eels, capelin, haddock and codling) become more important in their diet.

The growth rates vary with different populations. North Sea cod grow to an average length of 180 mm in their first year, 360 mm in their second year, 550 mm in their fourth and 680 mm in their fifth year. They can grow to 1500 mm and weigh 40 kg.

Remains of cod were the most common fish remains to be assigned to species from Freswick. While this is in part because cod otoliths (see Plate 22), dentaries and premaxillae are more readily identified to species than those of pollack and saithe, this reason is not alone sufficient to account for the large numbers of cod bones. The very large numbers of otoliths and bones must be seen as an indication that cod was the species most common in the deposits at Freswick Links.

Plate 22. Well preserved cod, Gadus morhua, otoliths.

Figure 70. Histograms of measurements taken on cod dentaries.



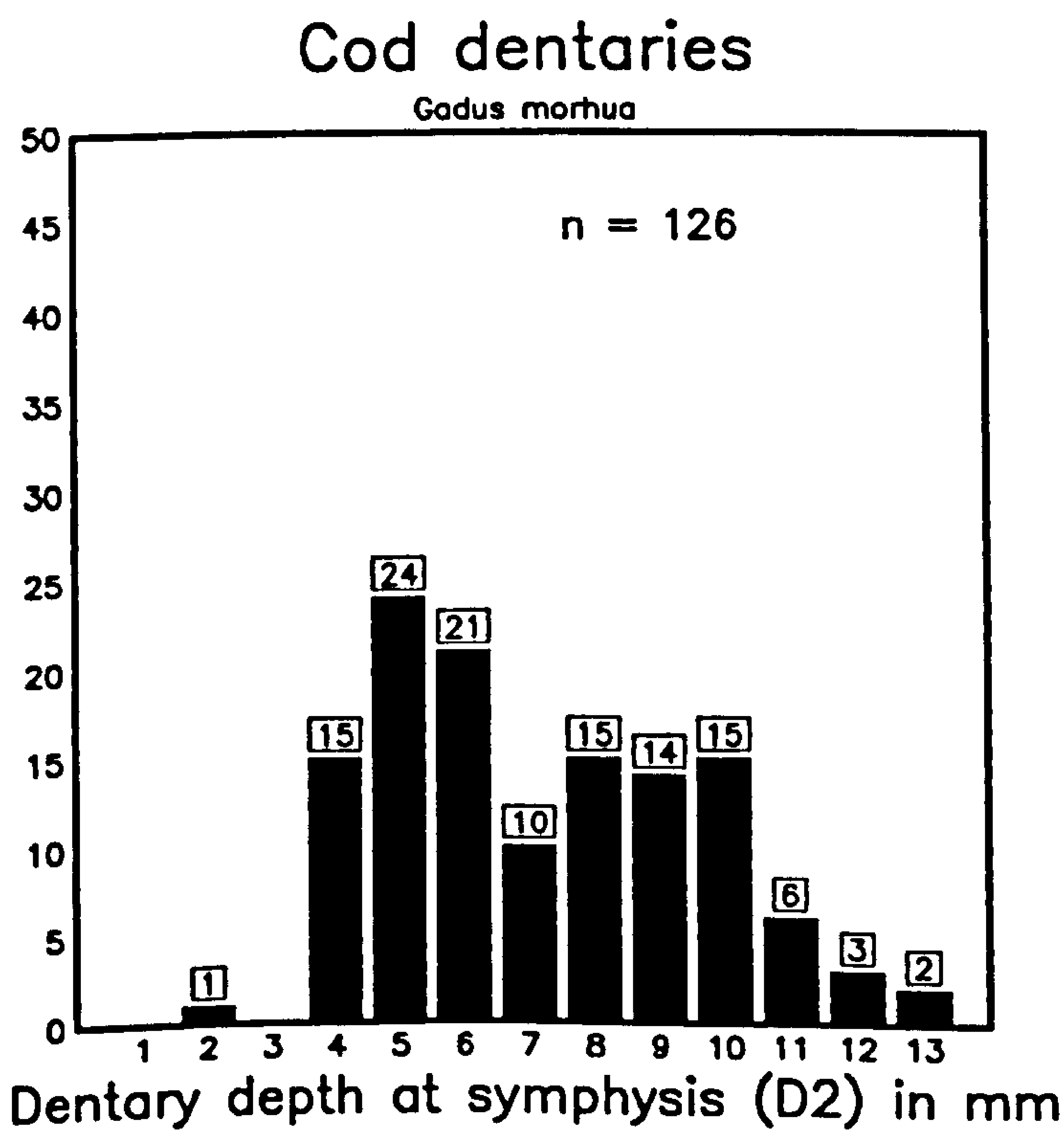
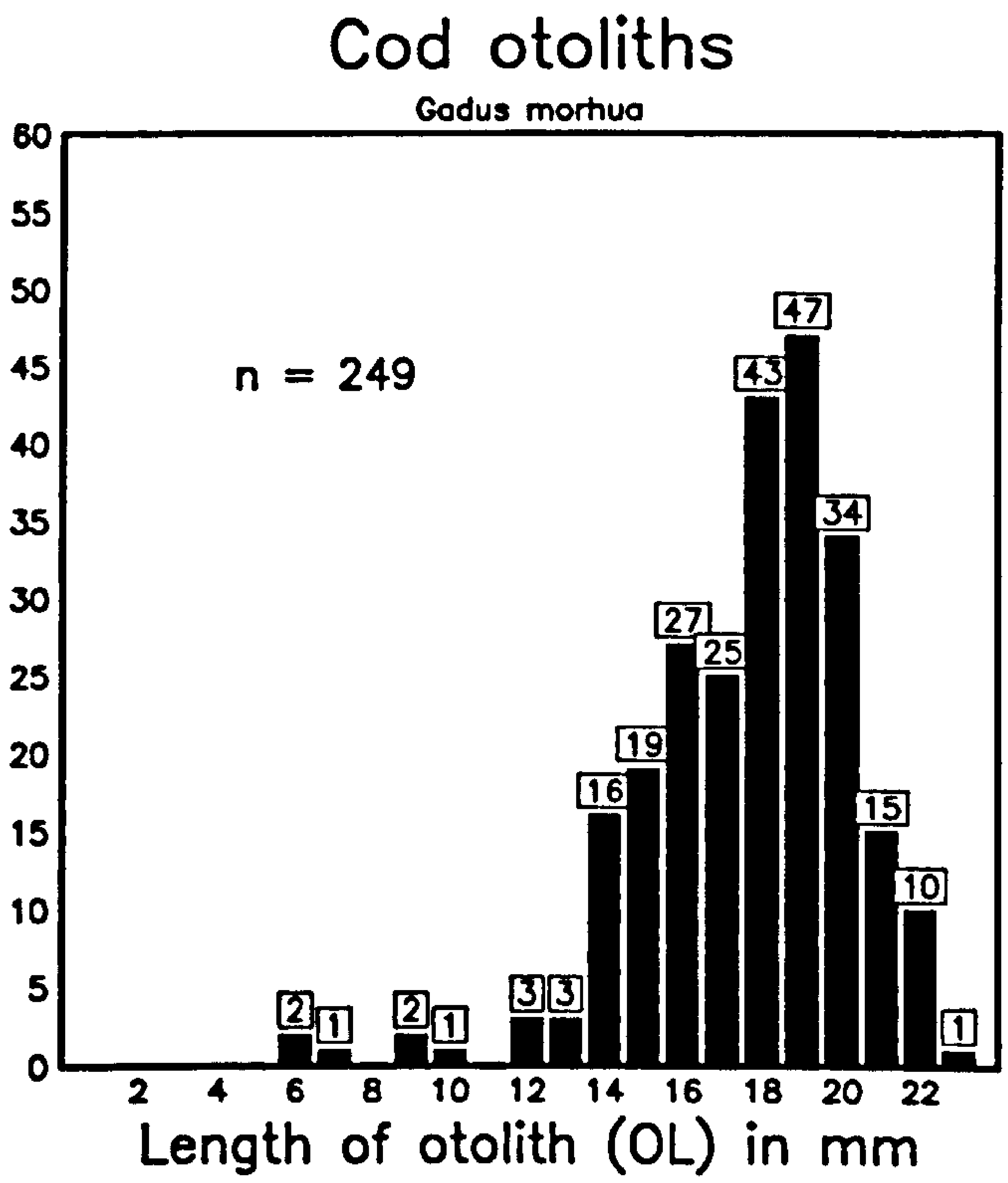


Figure 71. Histograms of measurements taken on cod otoliths.



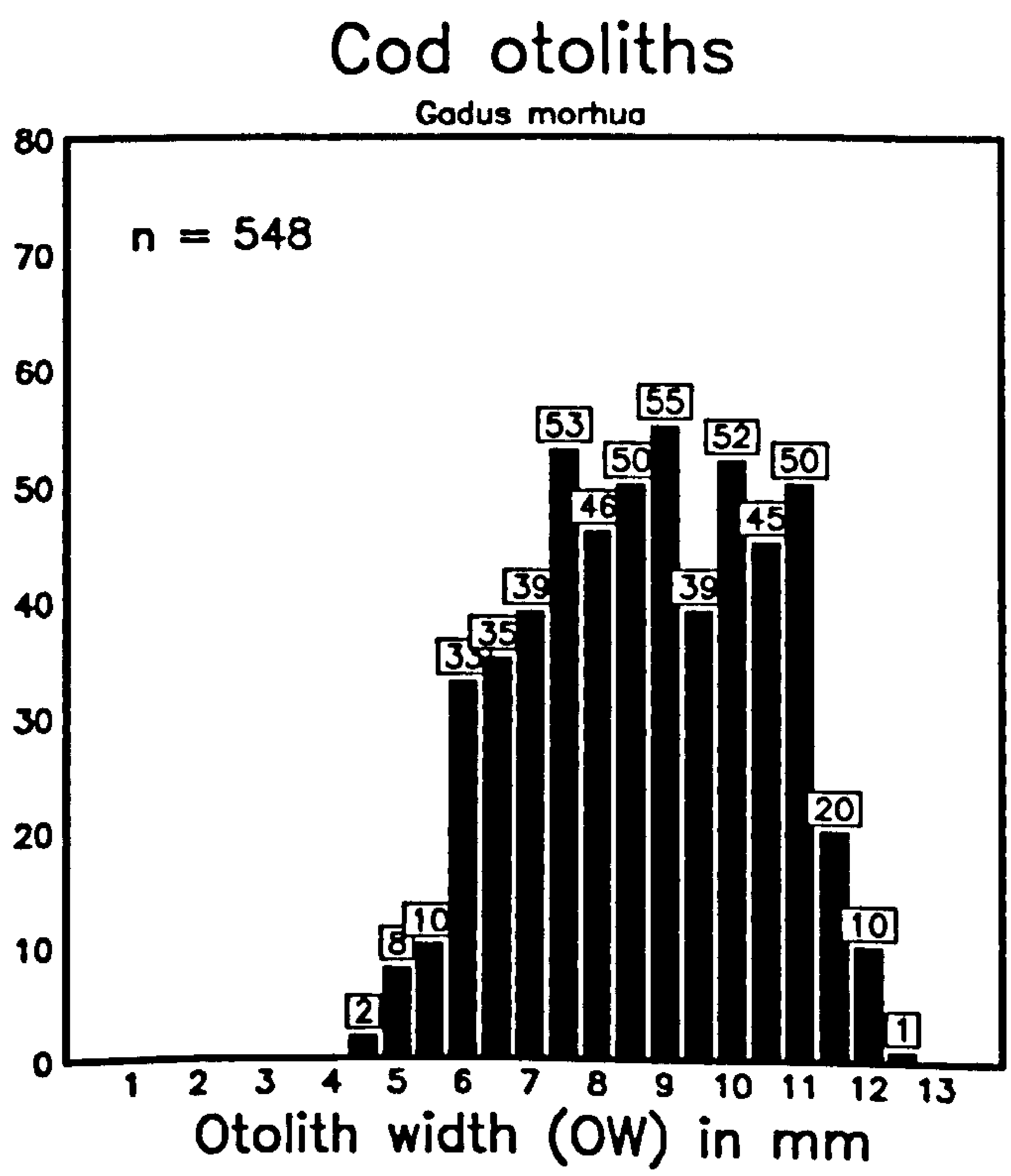
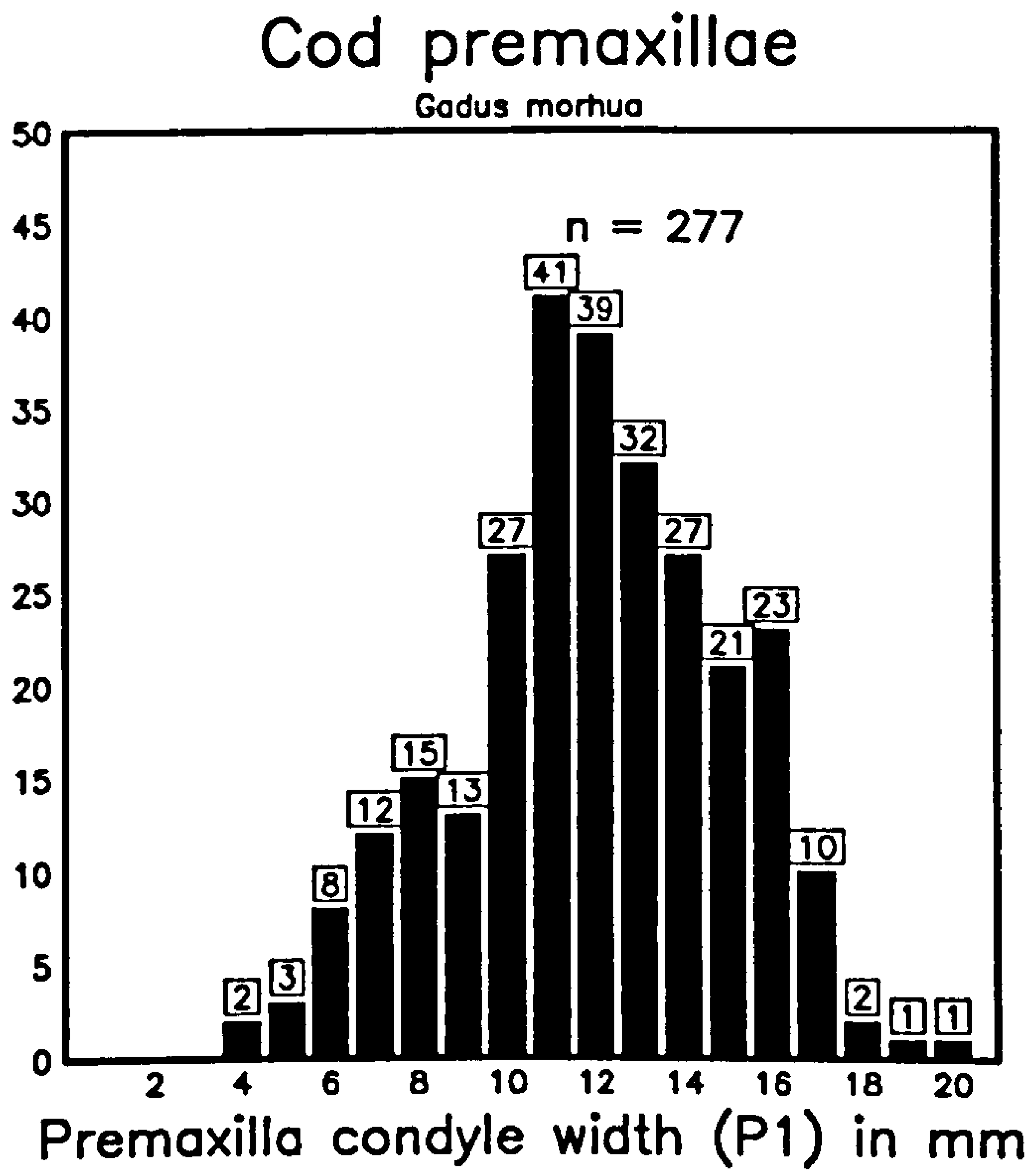
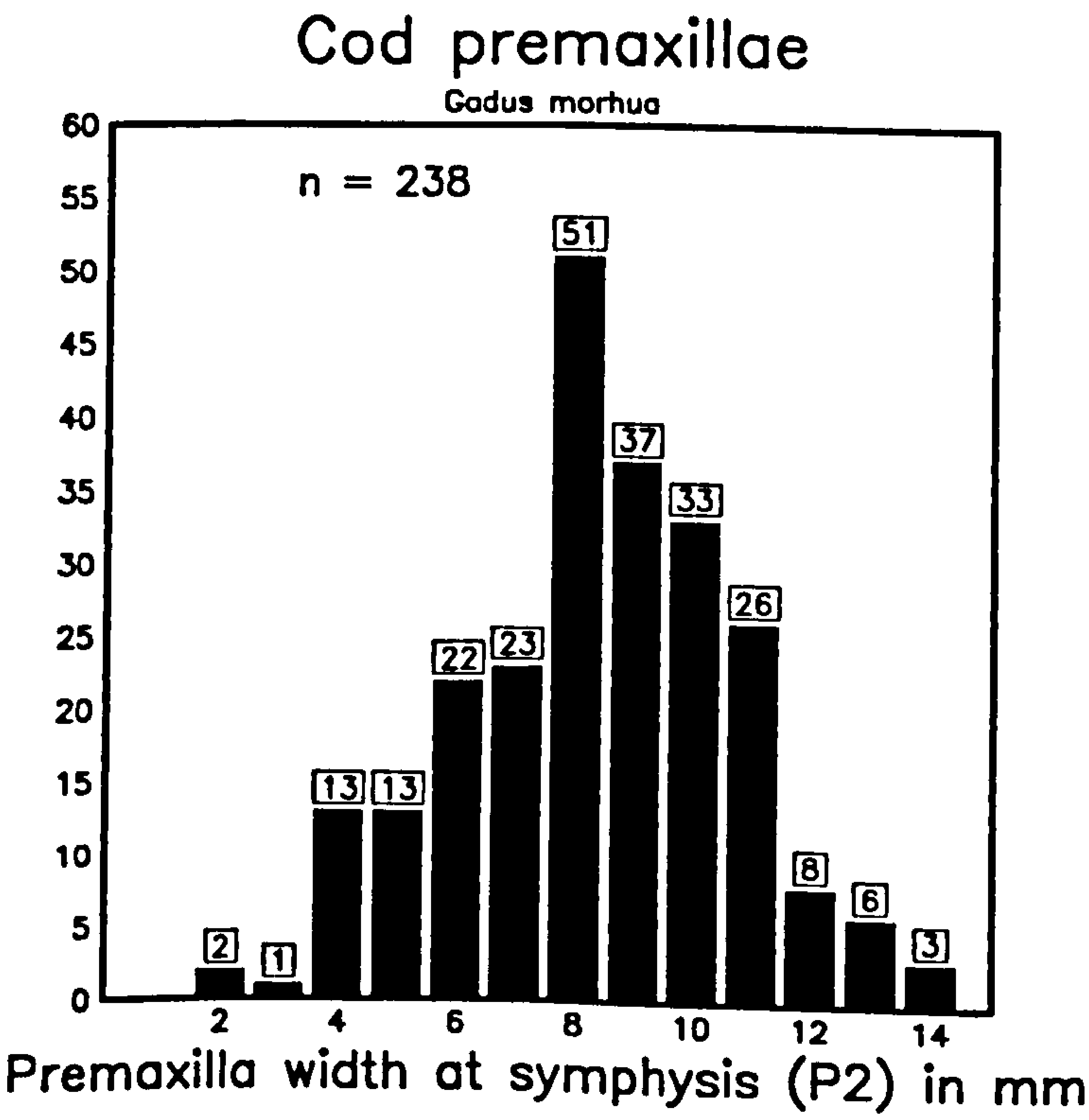


Figure 72. Histograms of measurements taken on cod premaxillae.





Eroded otoliths and tooth marks on bones show that cod were eaten or scavenged by animals other than man before the remains were buried in middens.

The small number of cod cleithra is to be noted. The significance of this observation is discussed in Chapter 7.

Figures 70-72 show that while cod of medium to large fishes were represented in the deposits, the majority were from animals between 800 and 1100 mm total length.

Haddock, Melanogrammus aeglefinus (L.)

The haddock occurs mainly close to the bottom in depths of 40-300 m. The main spawning grounds are in the northern North Sea and north to Trondheim, around the Faroes, Iceland and Ireland. It spawns between February and June, but mostly in March or April. The fish grow rapidly attaining 16-180 mm in the first year and about 300 mm in the second year. By the fourth year they are typically about 470 mm long and can reach 800 mm (2.7 kg) at ten years.

Haddock was best represented by cleithra (see Plate 23), a bone that is particularly robust and heavily mineralized in this species. Also present were modest numbers of premaxillae and dentary bones (Plate 24). Most haddock bones were recovered from Norse and unphased deposits, although a few were recovered from layers dated to Pictish occupation. The histogram of cleithra measurements (see Figure 73) shows a peak at 12-13 mm suggesting that these haddock were roughly 450 mm total length, although individuals as small as 250 mm total length were represented. The histograms of ?haddock otoliths and haddock premaxillae measurements (Figures 73 & 74) suggest that fishes ranging from just under 300 mm to over 500 mm were represented.

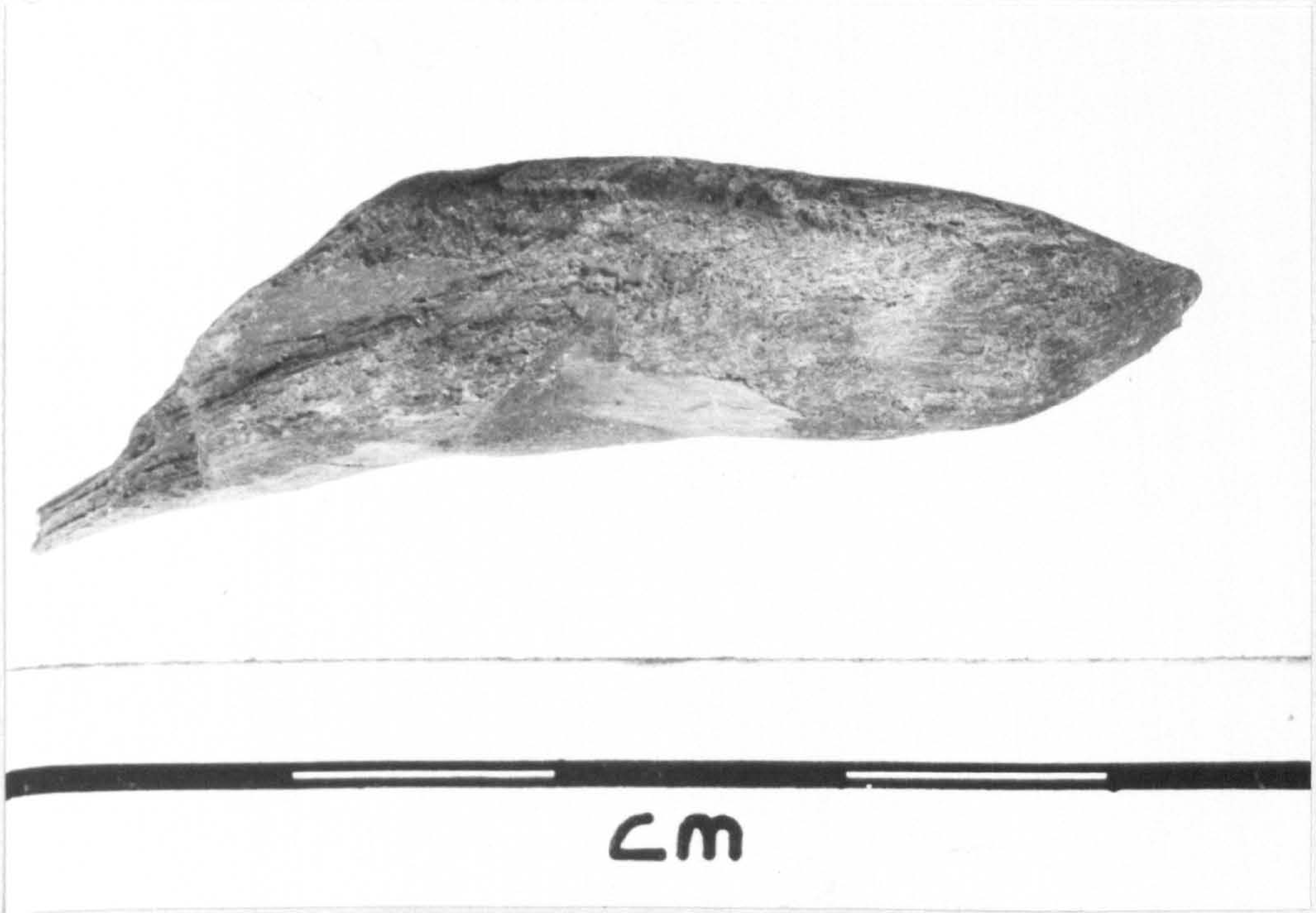


Plate 23. Haddock, Melanogrammus aeglefinus, right hand side cleithrum.

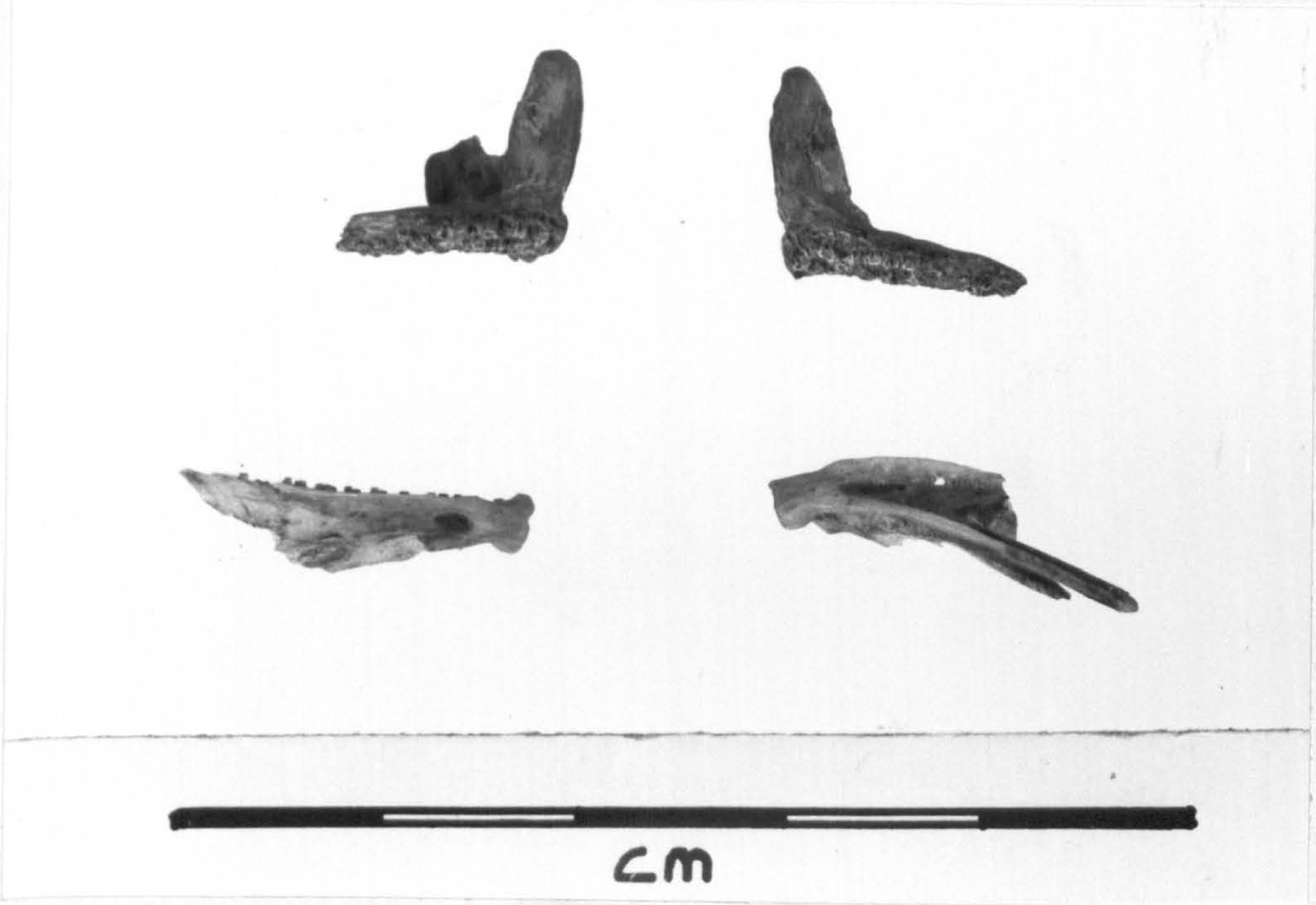


Plate 24. Haddock, Melanogrammus aeglefinus, premaxillae (top row) and dentaries (bottom row).

Figure 73. Histograms of measurements taken on haddock cleithra and premaxillae.

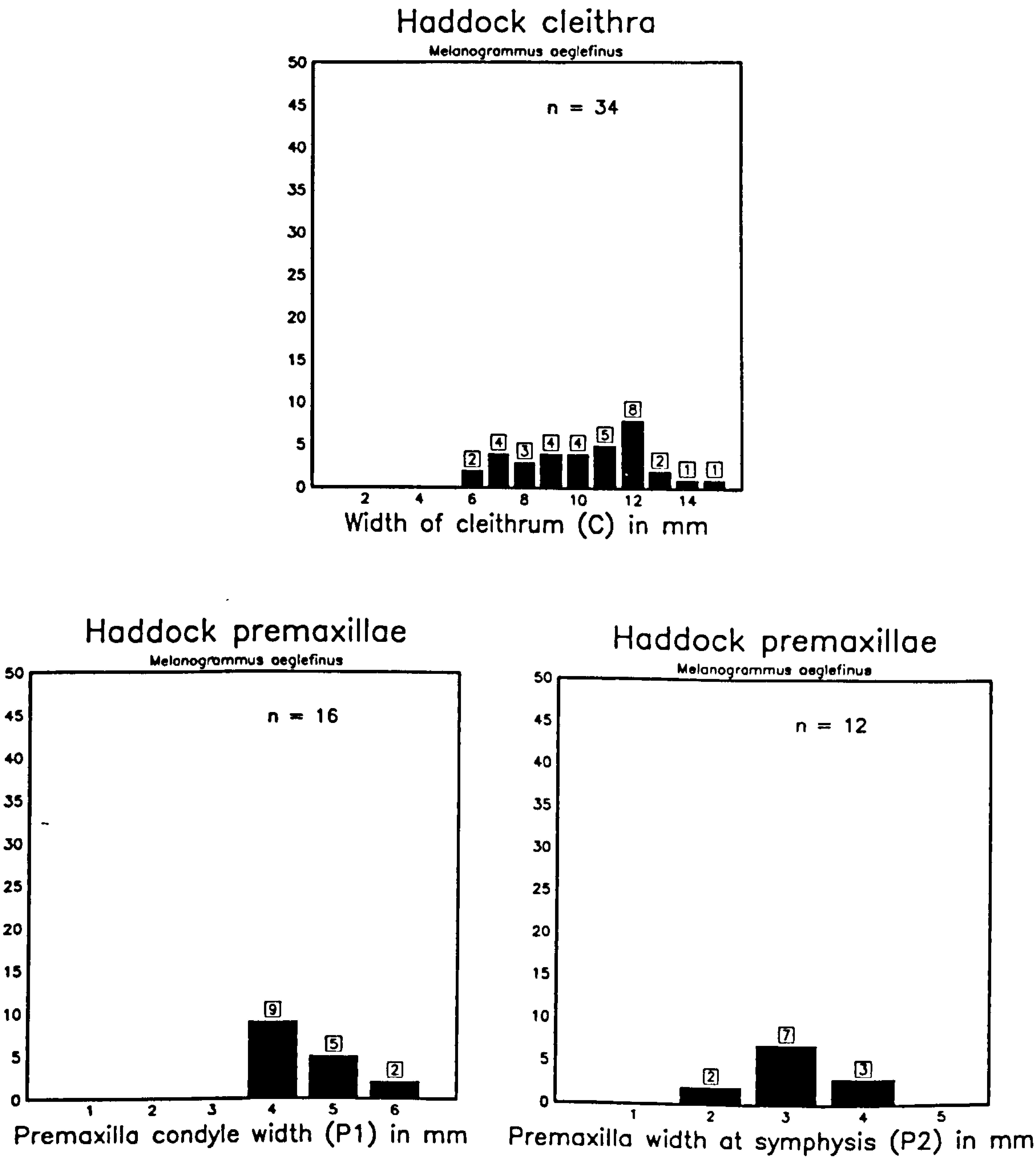
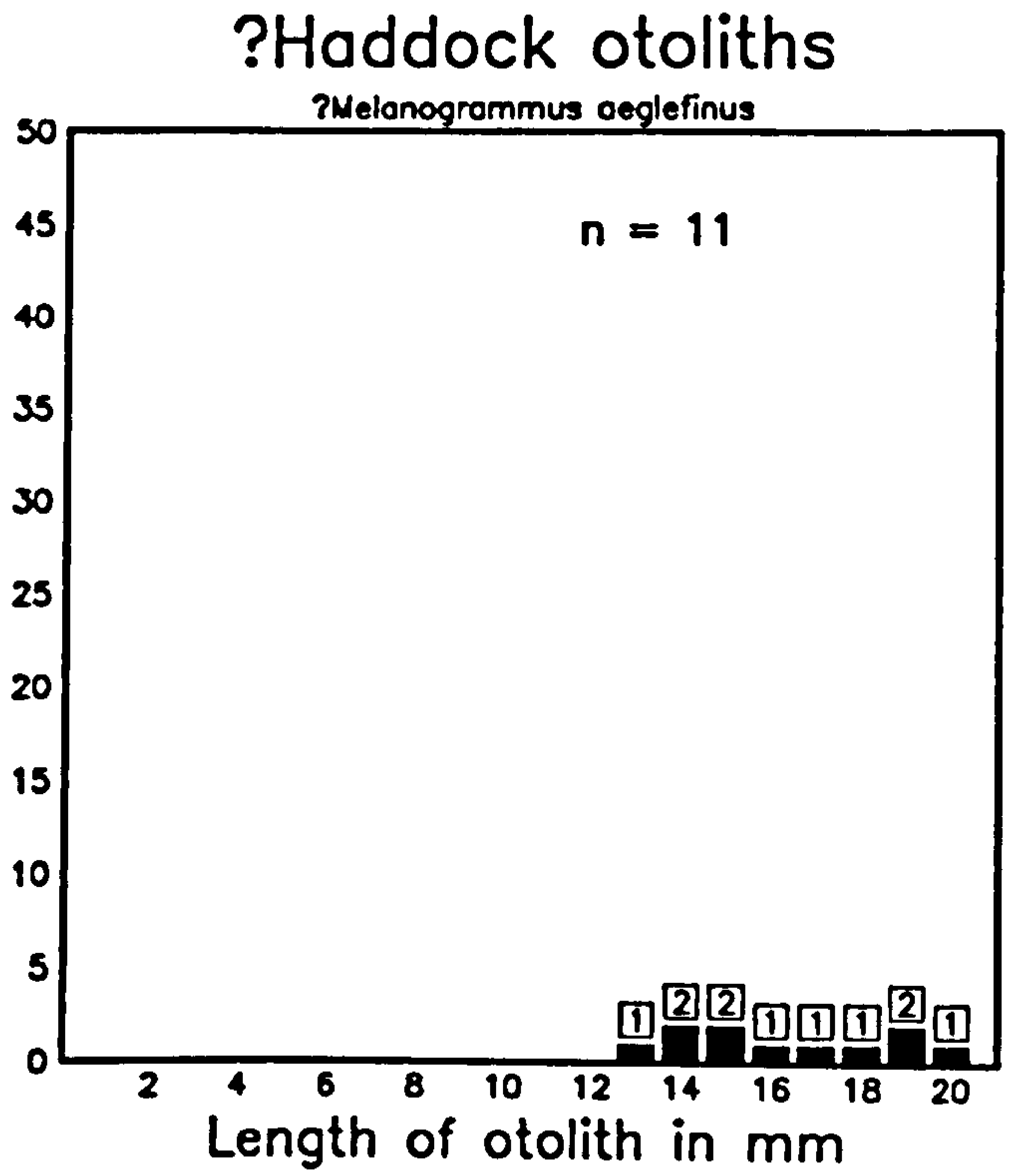
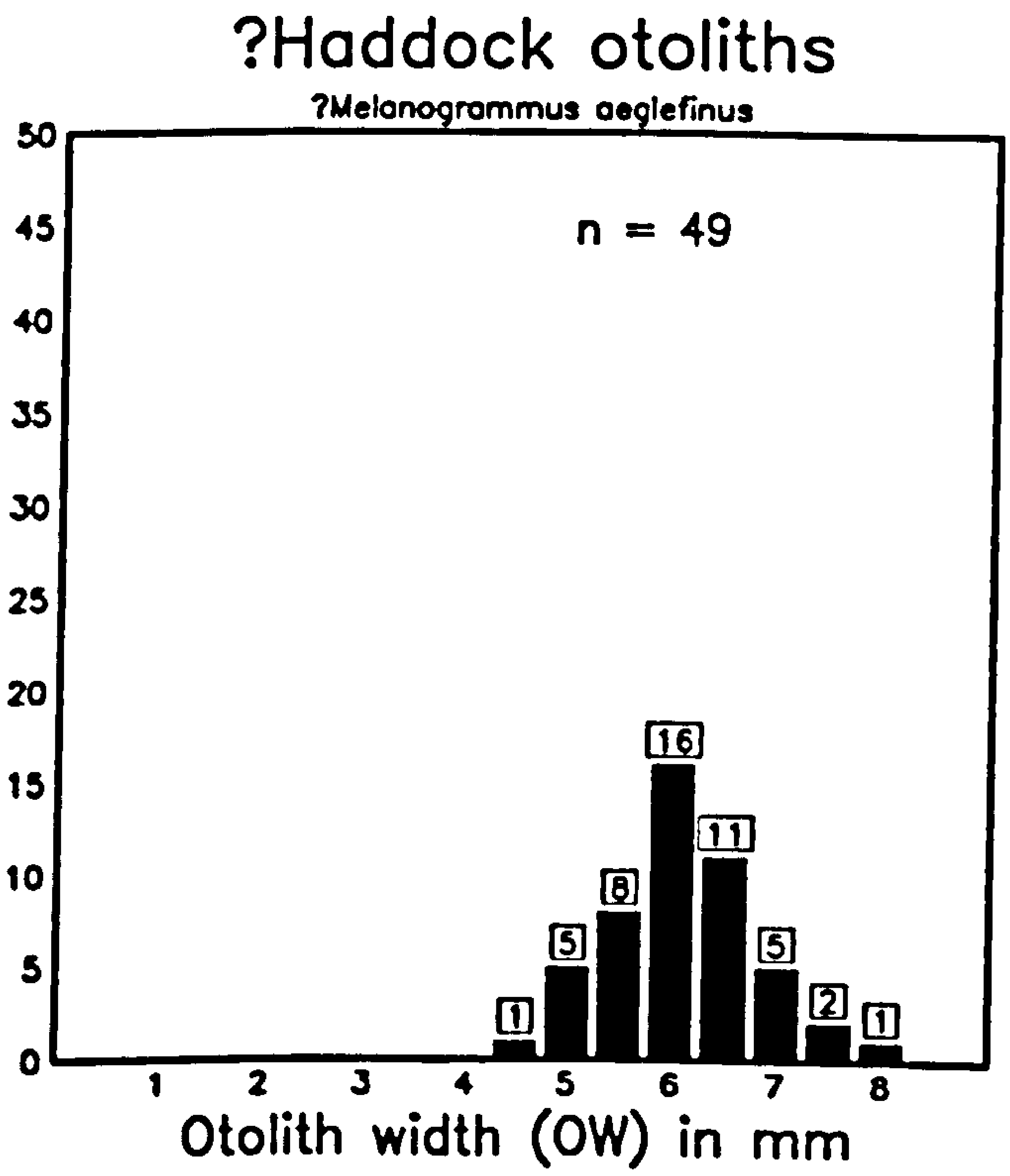


Figure 74. Histograms of measurements taken on ?haddock otoliths





Ling, *Molva* cf. *molva* (L.)

Molva molva is the most common of the species of ling in British waters, but different authors vary in the number of species which occur. Wheeler (1969 and 1978b) gives *M. dypterygia* and *M. macrophthalama* in addition to *M. molva*. Hureau and Monod (1979) recognize only *M. molva* and *M. dypterygia* (*M. dypterygia macrophthalma* is considered to be a separate subspecies). The material from Freswick produced bones which were consistent with *M. molva* (points of distinction between the species are given in Chapter 5). That said, the determination of ling bones to species is not as secure as that for cod and consequently they are ascribed to *Molva* cf. *molva*.

The ling is a common fish in the seas off northwest 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 characteristically a fish of deep water, 300-400 m although some are found in shallower water from March to July at 200 m mostly to the north of the British Isles. The young fishes are bottom-living fishes found in shallow depths (15-47 m) but from the third year, at lengths over 300 mm, move to deeper water. The maximum size is 2m sand 35 kg with fish up to 1-1.5 m occurring in inshore waters. The ling is one of the largest members of the cod family and is elongate with two dorsal fins and a single anal fin.

Ling was represented by large numbers of premaxillae and dentary bones, mainly in Norse and unphased deposits. Otoliths (Plate 25) were not well represented, but, in contrast to cod, ling cleithra (several bearing knife cuts) were relatively abundant, particularly in deposits from Area 4. A large number of ling dentaries represented by burnt fragments of the distal part of the bone. Most ling were from large animals (over 1 m total length) although a few small individuals were present. Figures 75-77 show the sizes of measurable ling bones and otoliths.

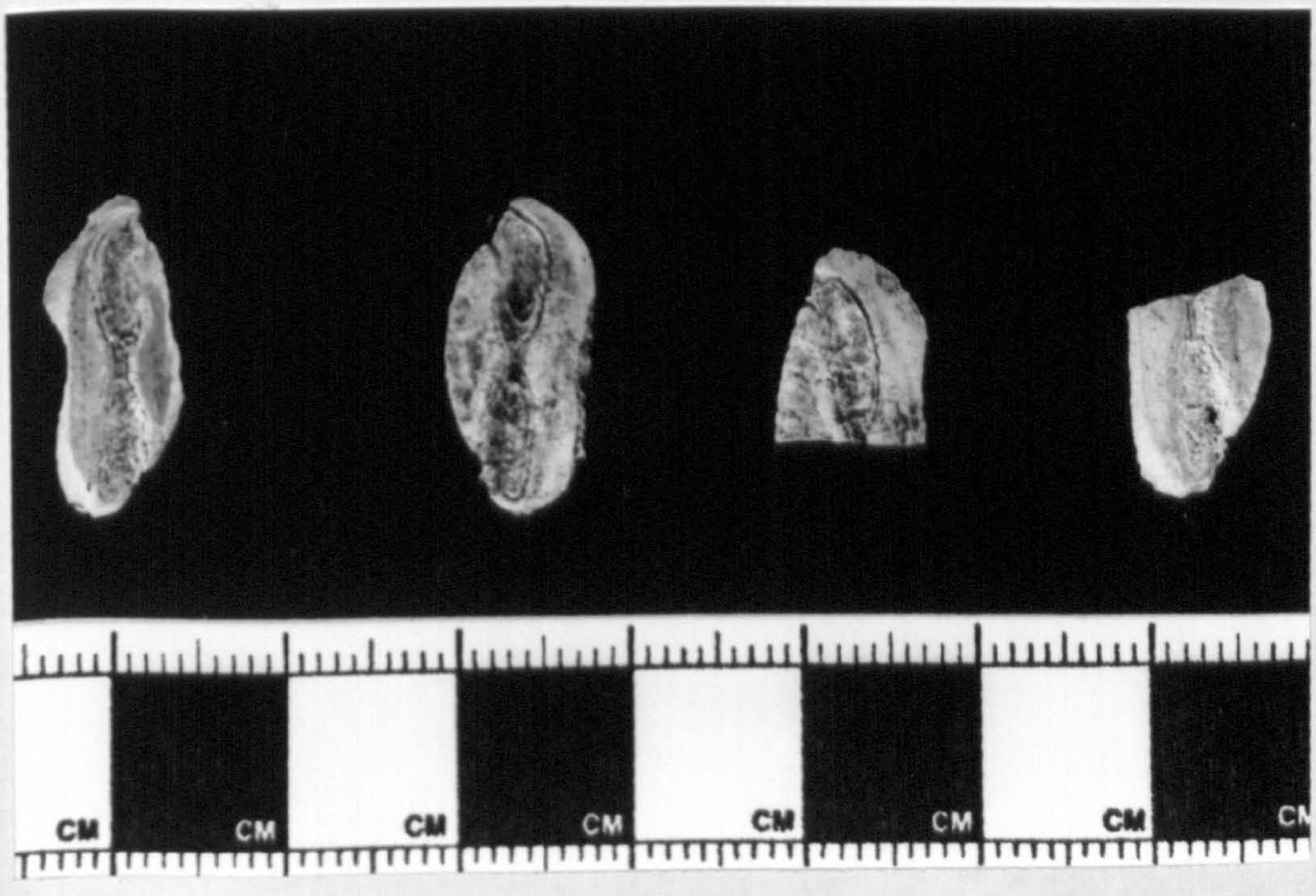


Plate 25. Ling, Molva cf. molva, otoliths.

Figure 75. Histograms of measurements taken on ling cleithra and dentaries.

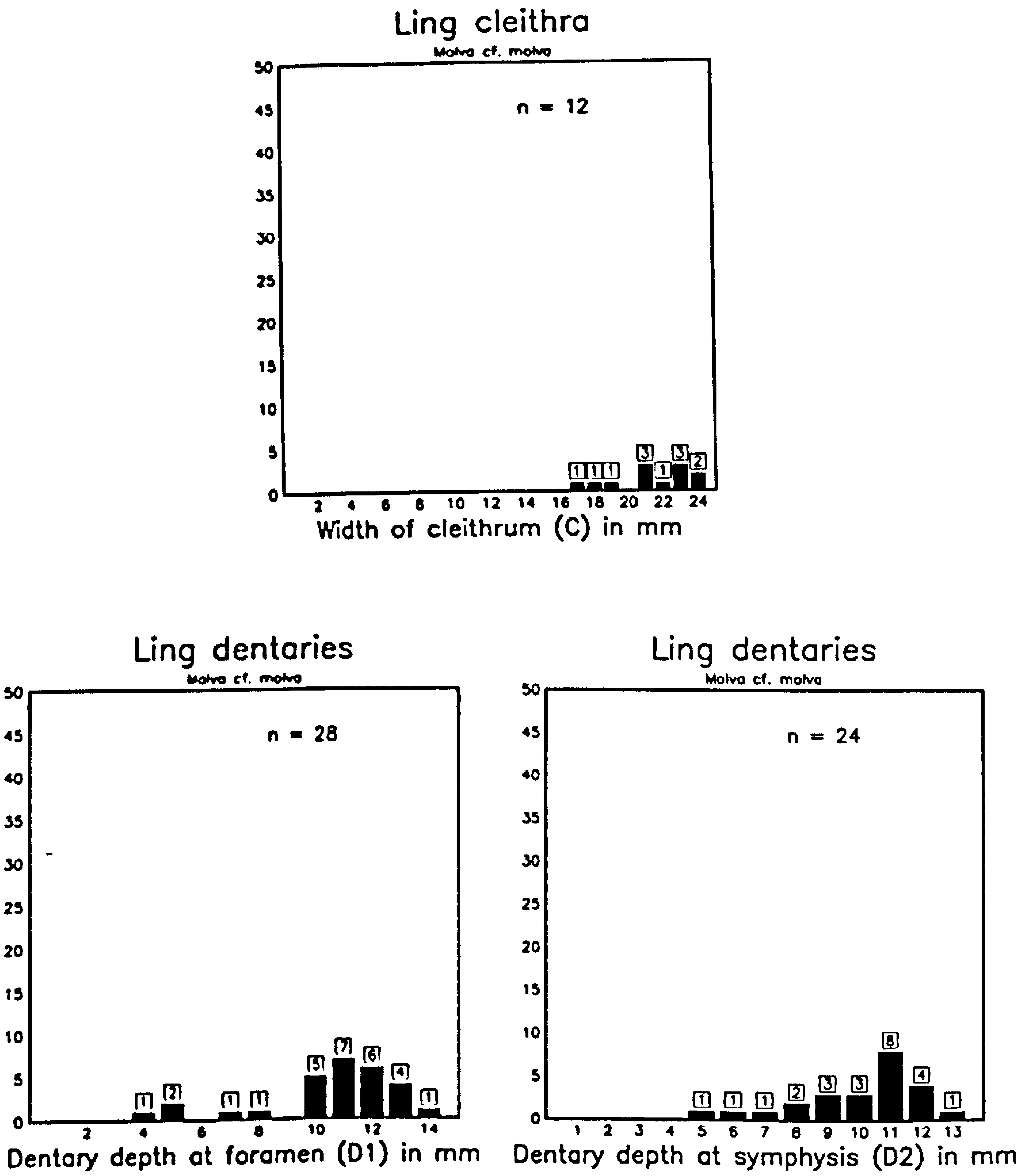
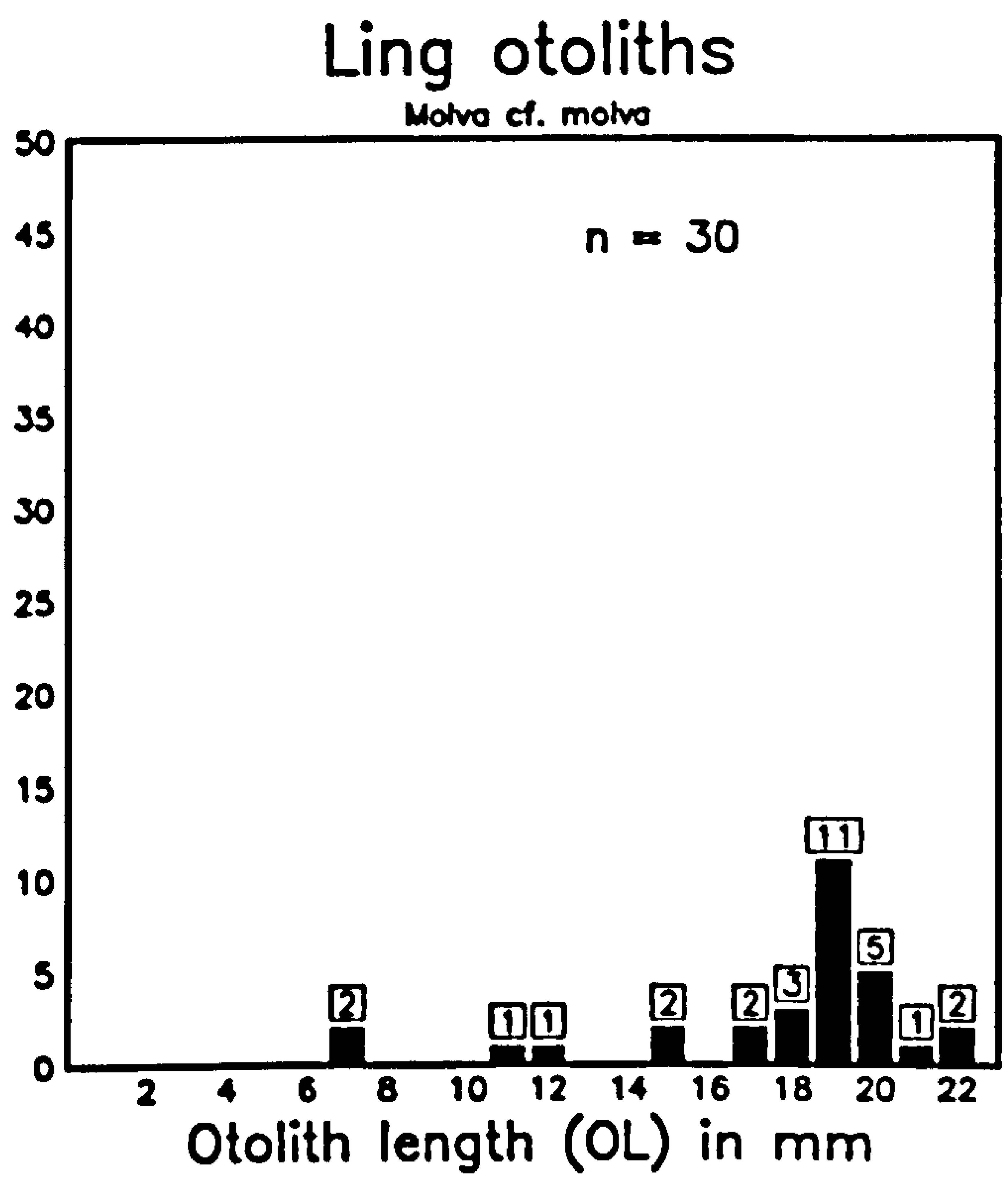


Figure 76. Histograms of measurements taken on ling otoliths.



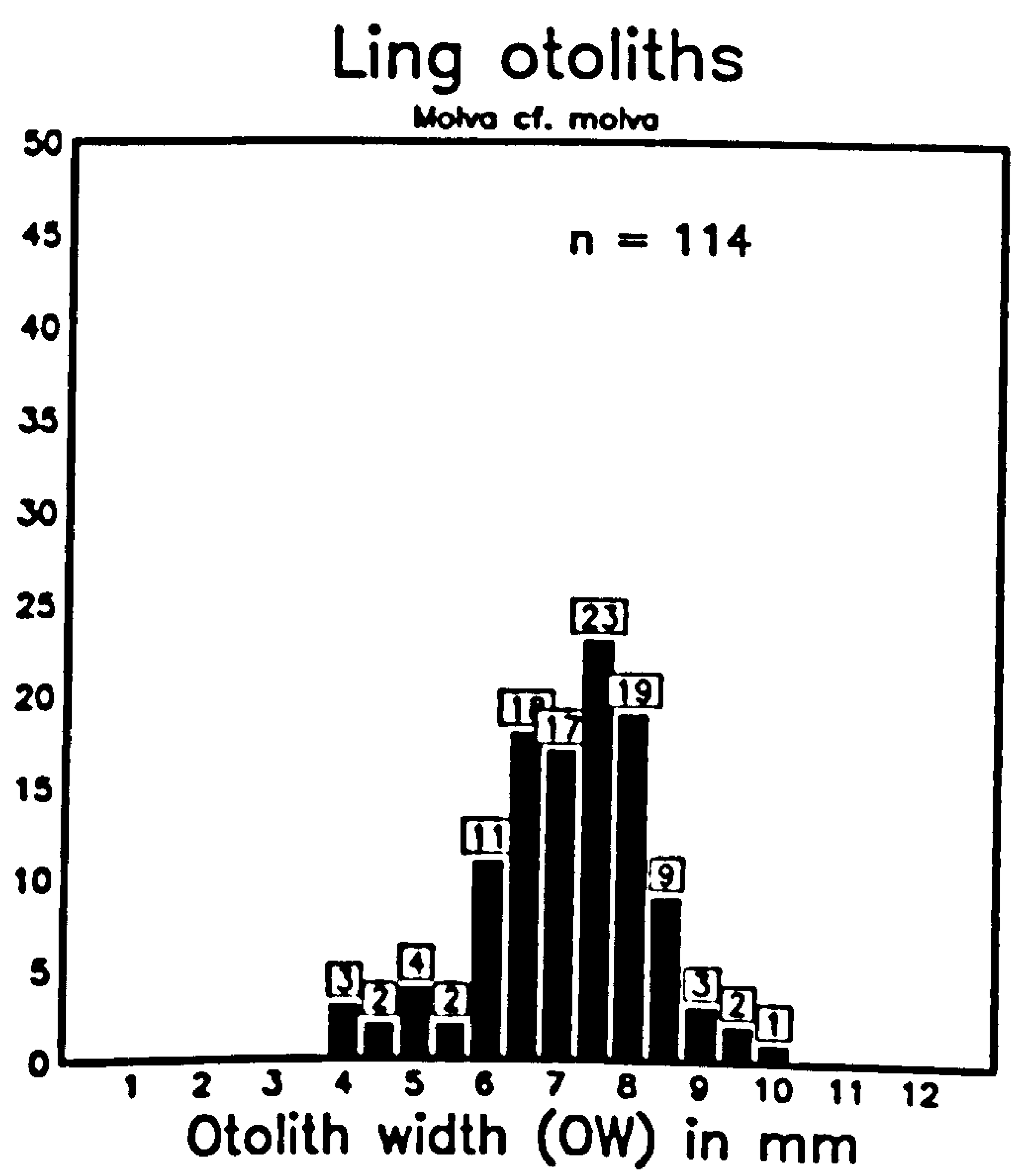
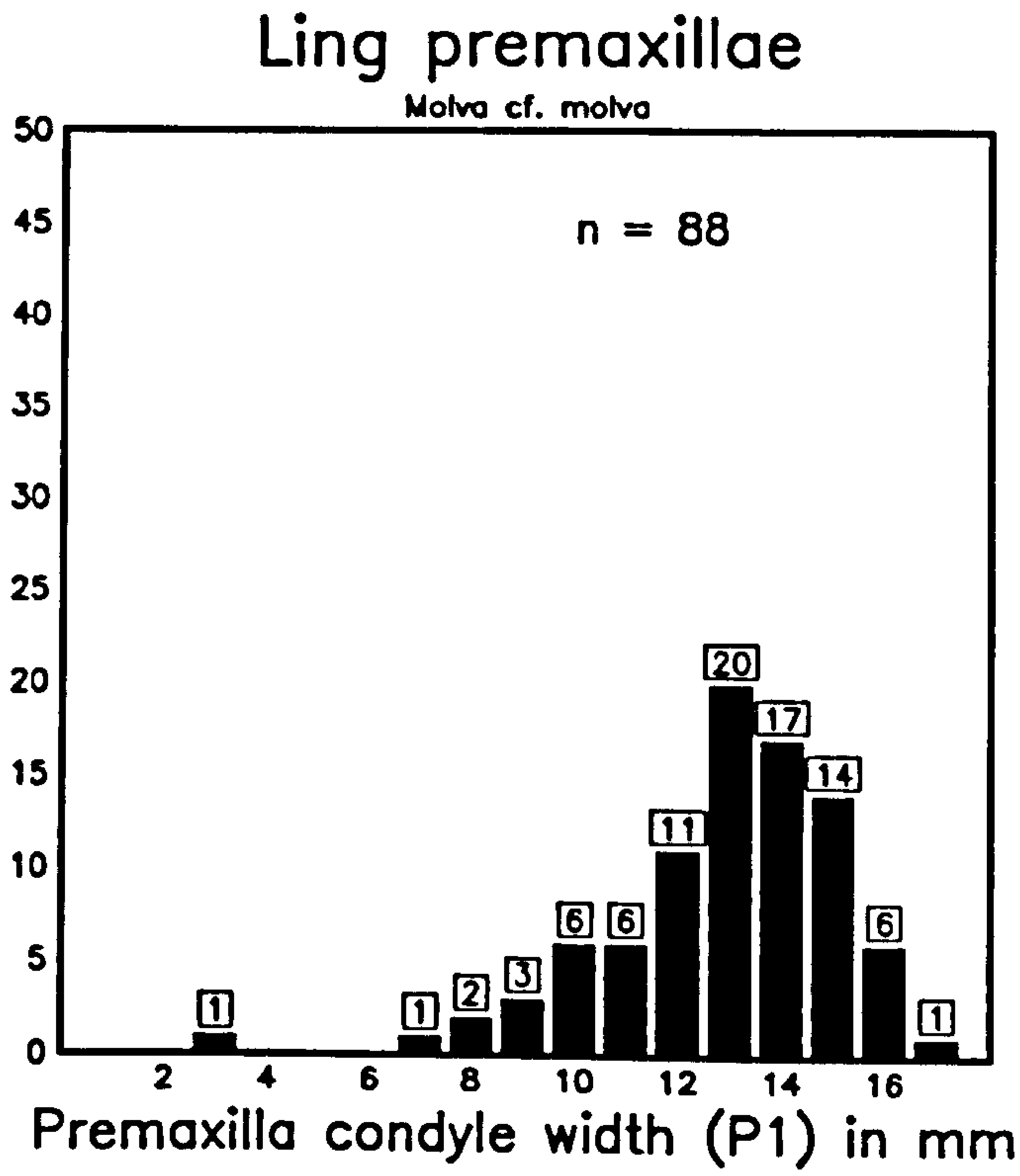
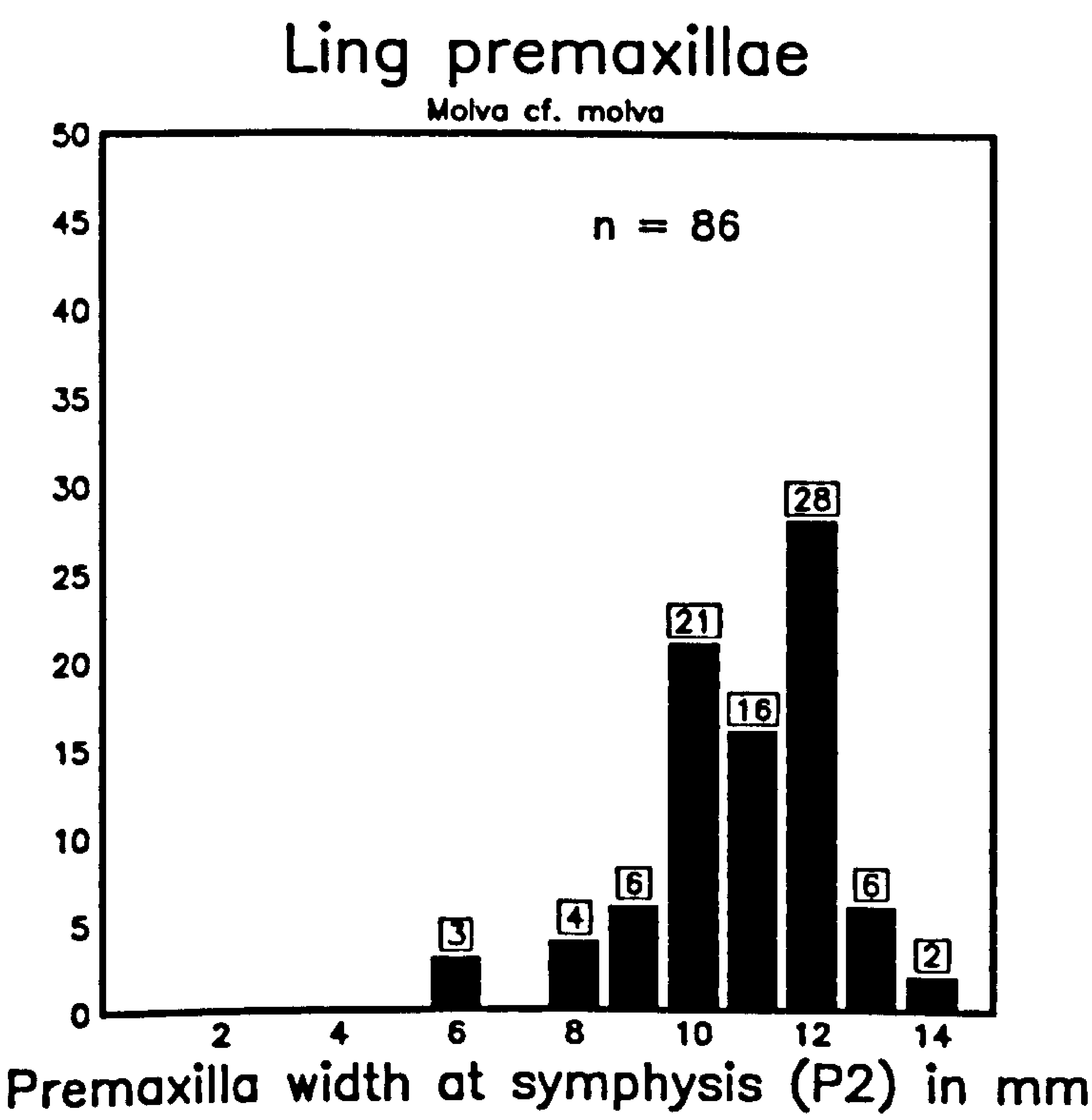


Figure 77. Histograms of measurements taken on ling premaxillae.





Torsk, Brosme brosme (Ascanius)

The torsk is a sedentary fish which does not form large shoals. It is usually found offshore in waters of 100-1000 m depth. Immature specimens are occasionally found in waters less than 50 m deep. It is typically a fish of the northern North Sea and northern Atlantic. Growth is slow, animals of 15 years reaching only 600-800 mm total length.

Torsk was represented by two similar sized premaxillae and a maxilla (possibly from the same individual) from a sample of context JK from Norse levels in Area 4 and by two abraded otoliths tentatively assigned to torsk from Area 5 (GU). All remains were from medium to small fish, less than 600 mm total length.

Tadpole fish, Raniceps raninus (L.)

The biology of this small (maximum length 300 mm) fish is not well known. It is probably a solitary but widespread species usually found in shallow water (10-20 m). It is frequently left stranded on the shore after storms. It spawns in the summer months (July to September) near the shore.

Remains of tadpole fish was represented by 4 premaxillae, one dentary (see Plate 26) and 2 otoliths mainly from Norse levels in Areas 4 (JK) and 5 (GY). The otoliths were both eroded and the bones from animals of approximately 300 mm total length.

Plate 26. Tadpole fish, Raniceps raniceps, premaxillae and dentary.

Rocklings, Gaidropsarus mediterraneus (L.), G. vulgaris (Cloquet), Rhinonemus cimbrius (L.), Ciliata septentrionalis (Collet), C. mustela (L.)

The rocklings are small elongate gadoid fishes typical of rock pools and the sublittoral zone. The various species of rockling are easily confused as whole fishes (G. mediterraneus has been confused with the young of G. vulgaris) and their bones are not readily identified to species.

Some of the rockling bones (see Plates 27-29) were assigned to the genus Ciliata, and other to Gaidropsarus. Others were not sufficiently diagnostic to allow generic identification and were determined as 'rockling'. Most rockling remains were recovered from Norse layers in Area 4.

Plate 27. Rockling jaw bones, Ciliata/Gaidropsarus sp./spp. Top row 2 premaxillae, bottom row 2 dentaries.

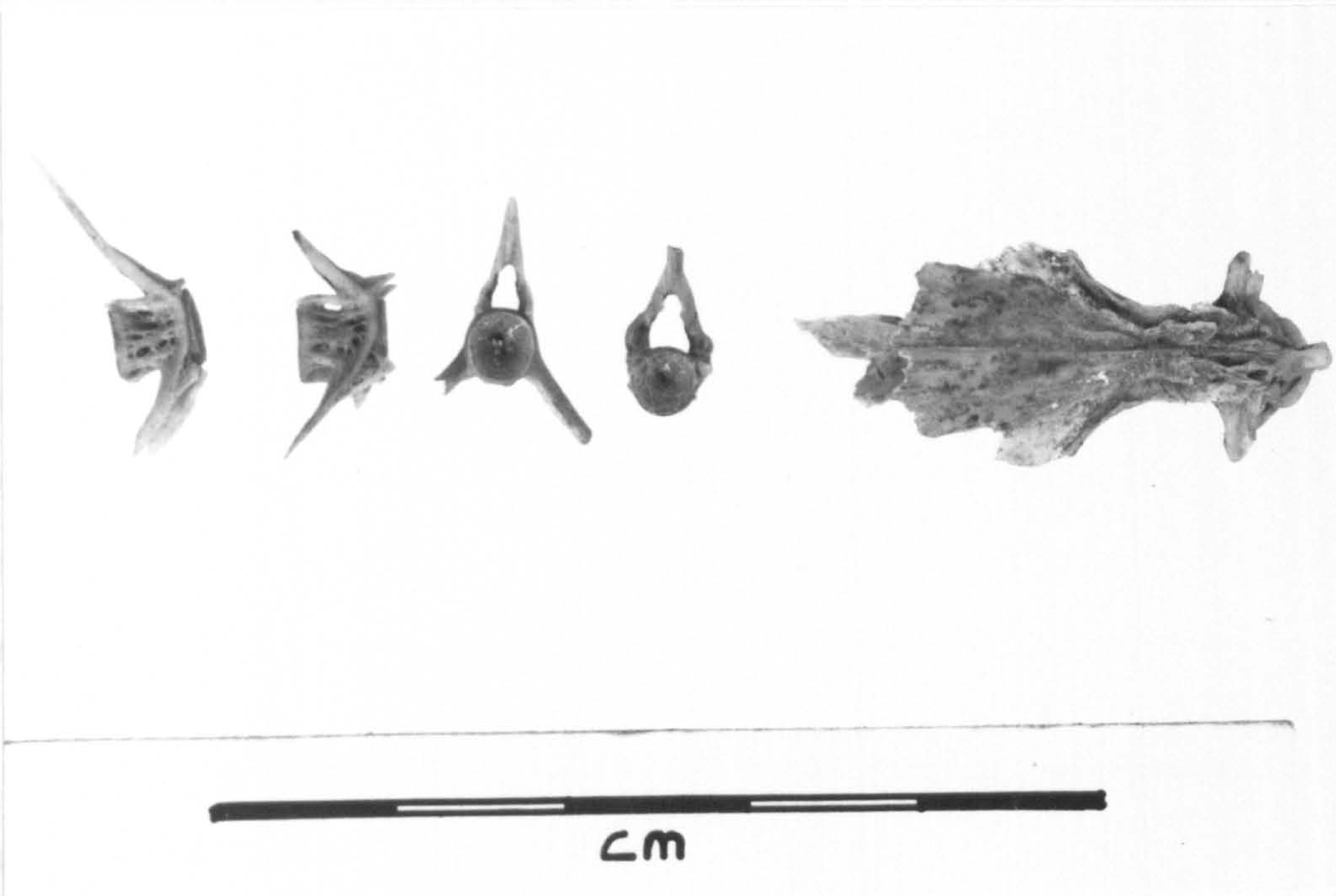


Plate 28. Rockling, <u>Ciliata/Gaidropsarus</u> sp./spp. vertebrae and neurocranium.

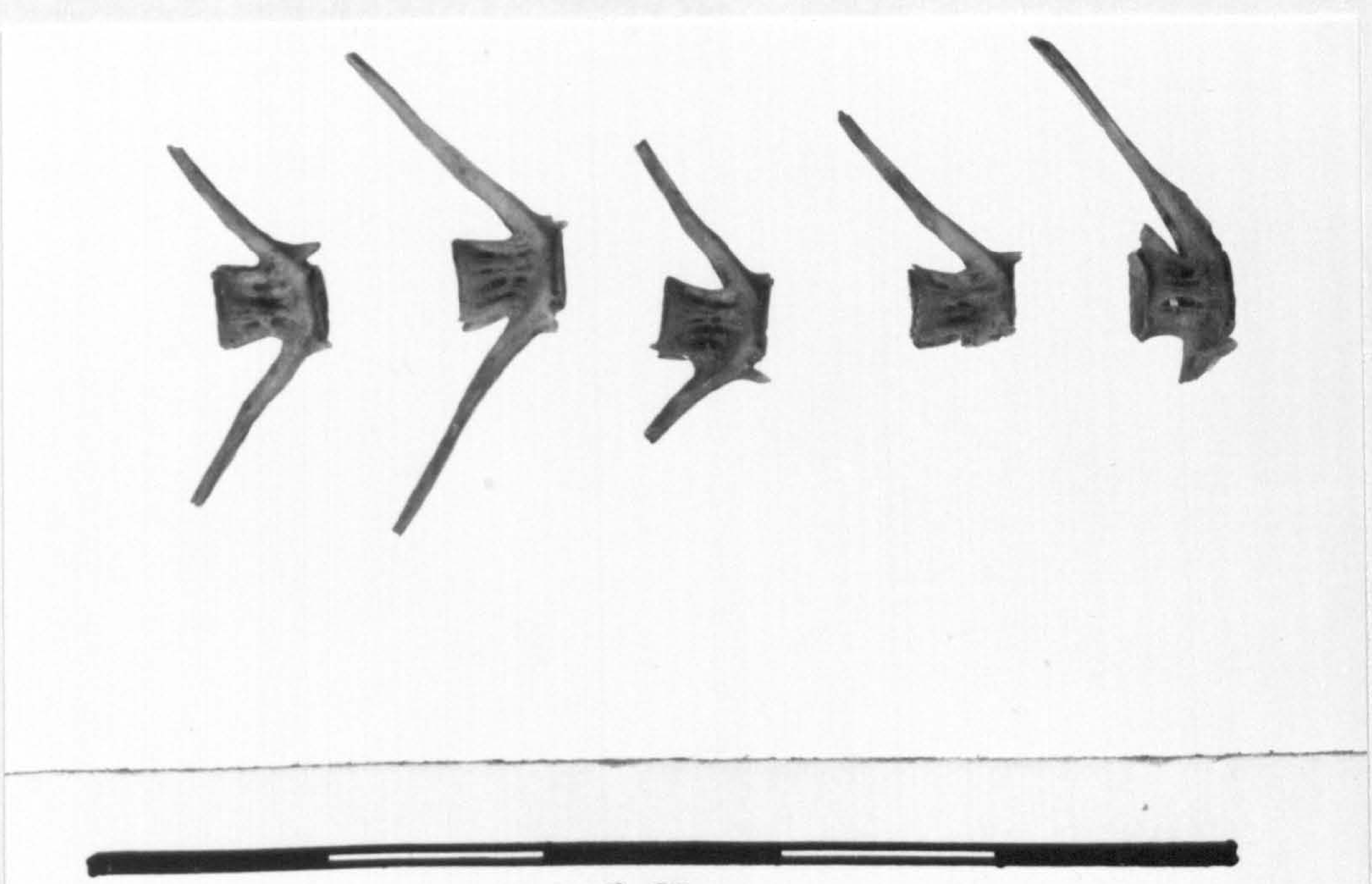


Plate 29. Rockling, <u>Ciliata/Gaidropsarus</u> sp./spp. vertebrae.

Bass, <u>Dicentrarchus</u> <u>labrax</u> (L.)

Bass are attracted to brackish water in the summer months and may be caught in estuaries and the lower reaches of rivers of southern Britain, but are rather rare in the northern North Sea. They appear to be attracted to inshore areas where the ground is a mixture of rocks and sand. An migration takes place to inshore waters in spring and offshore waters in winter months. Young bass feed on crustaceans and young fishes. Large animals take clupeoids and occasionally salmonids.

Only two bass bones, both vertebrae, were recovered (see Plate 30). Both were from animals at least 450 mm total length. One was from a Norse level in Area 4 (JK), the other from Area 7 (NQ).

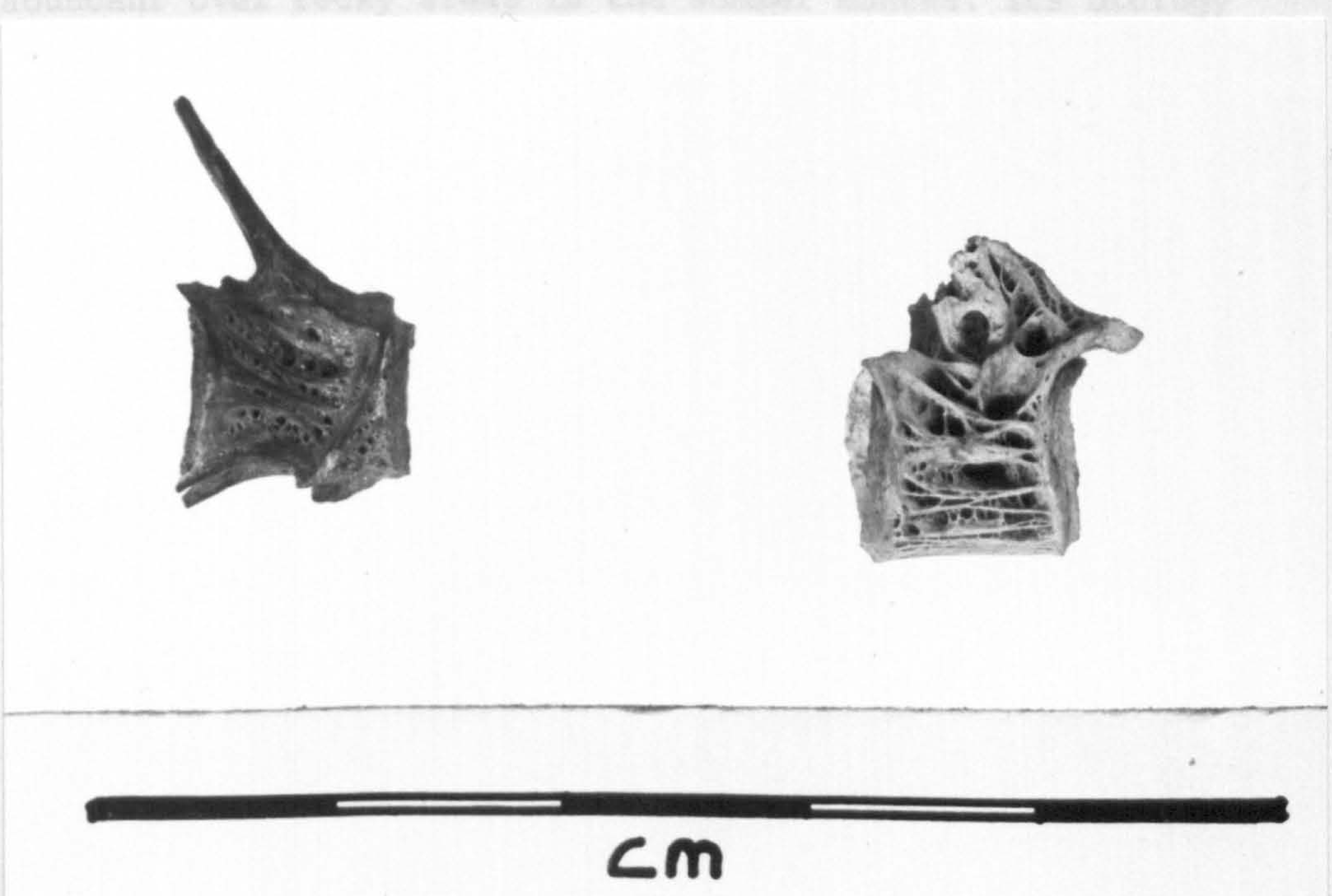


Plate 30. Bass, <u>Dicentrarchus</u> <u>labrax</u>, vertebrae.

Scad (Horse mackerel), *Trachurus trachurus* (L.)

This is a common European fish which forms large shoals. It can be taken near the coast in summer months and appears to retreat to deeper waters during the winter months.

Horse mackerel was represented by a single scute and 20 vertebrae (see Plate 31). Two of the vertebrae were eroded and one bore tooth marks. One was burnt. They were mainly recovered from unphased, Norse levels although one was recovered from Pictish deposits in Area 6 (KH+KG).

?Black Sea Bream, ?*Spondyliosoma cantharus* (L.)

The black sea bream is relatively common in the English Channel and western regions of the British Isles, but is rare in the northern North Sea and further north. It is locally abundant over rocky areas in the summer months. Its biology is not well known, but it appears to spawn in British waters in April or May. The adult fishes are thought to eat algae, animals which encrust rocks, small crustaceans and fishes.

The remains assigned to this taxon (Plate 32) consisted of a parasphenoid, and two precaudal and two caudal centra from sieved material from Norse deposits. In addition a caudal vertebra was recovered by hand from Area 5 (GU).

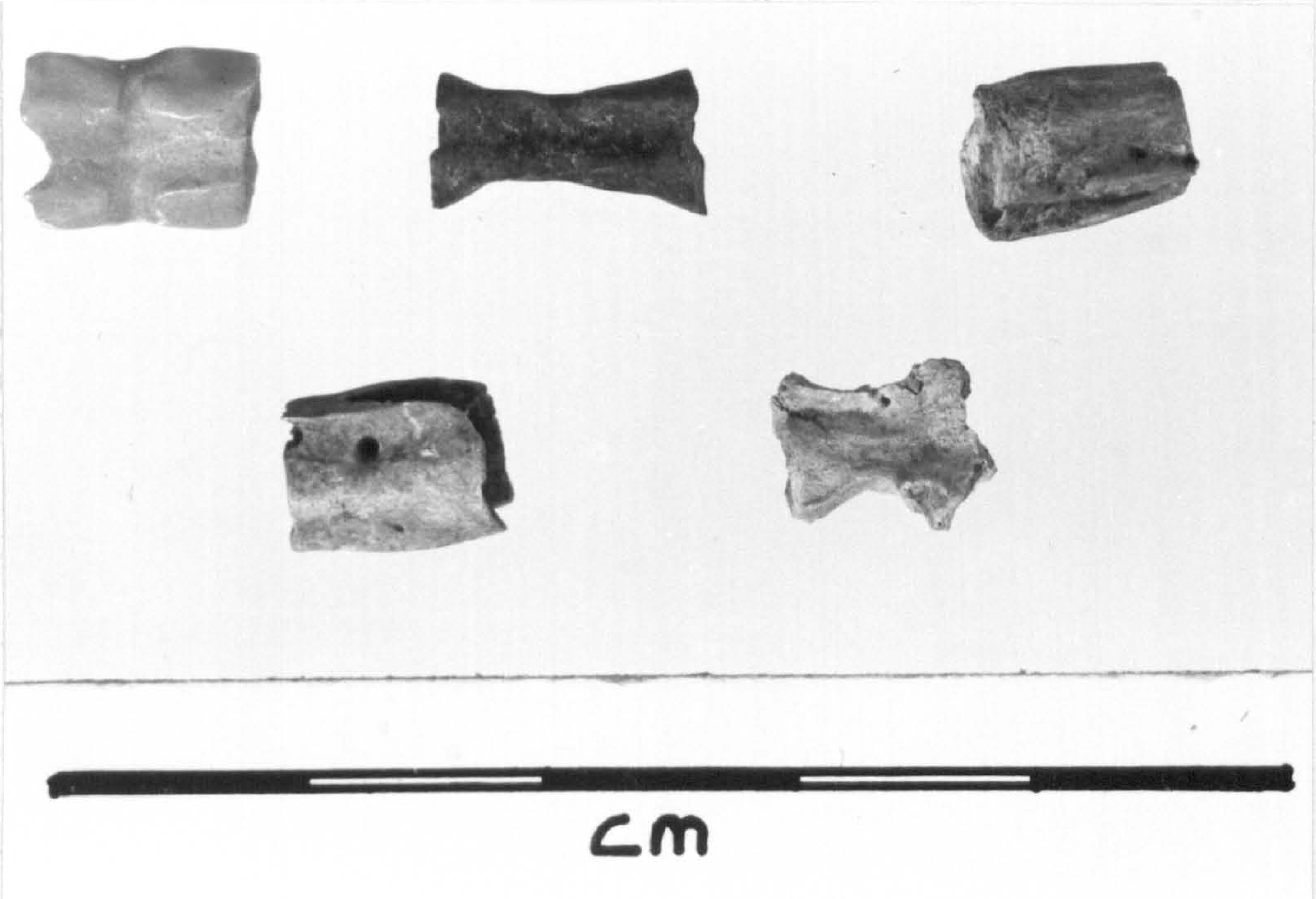


Plate 31. Vertebrae of horse mackerel, Trachurus trachurus. Note 2 left hand bones in upper row appear glossy and eroded, possibly acid eroded.

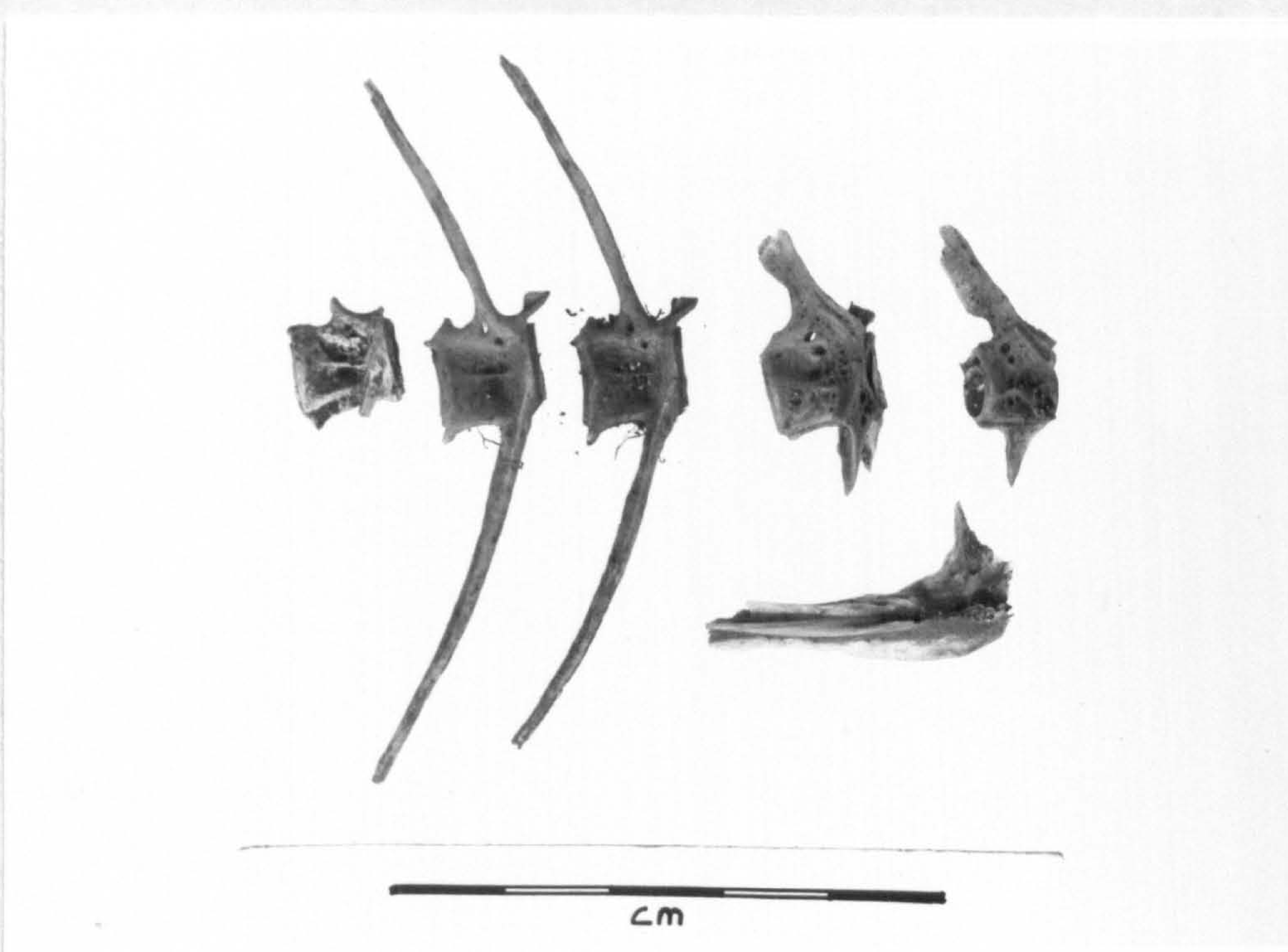


Plate 32. ?Black Sea Bream, ?Spondyliosoma cantharus, vertebrae and parasphenoid.

Wrasses, Labridae (Plate 33)

A small number of wrasse bones were present in the deposits and could not be assigned to species. In addition two species of wrasse were identified.

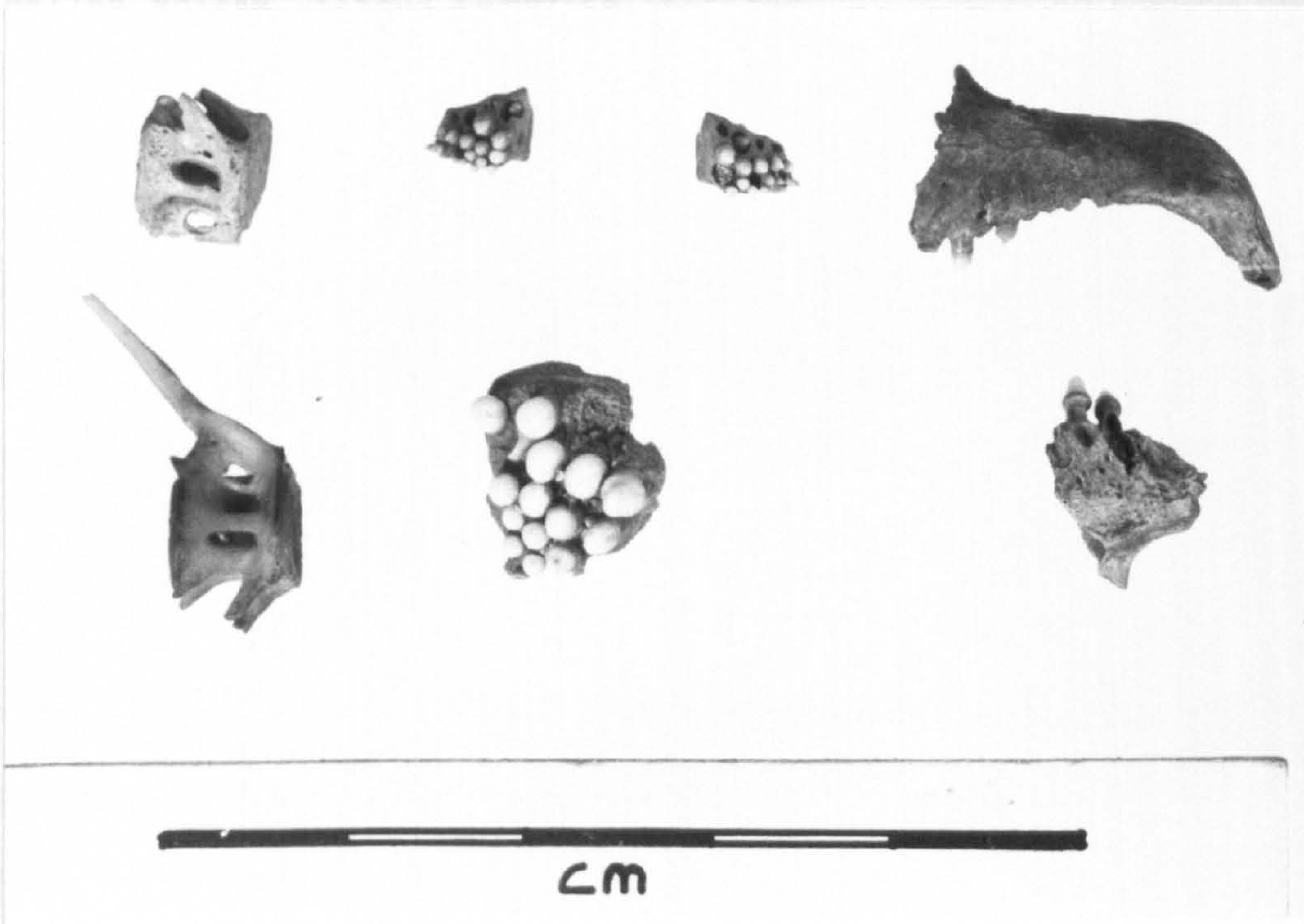


Plate 33. Selection of wrasse, Labridae, bones. Top row, left to right: caudal vertebra; 2 suprapharyngeals; premaxilla. Bottom row: caudal vertebra; suprapharyngeal; dentary.

Cuckoo Wrasse, Labrus bimaculatus L.

Despite being relatively widespread in European waters, surprisingly little is known of the biology of this species. It, like all wrasses, frequents rocks and rough ground, being seldom found in less than 10 m of water. It appears to feed mainly on crustaceans, molluscs and fishes. There is some evidence that it retreats to deeper waters during the winter months and moves inshore during the summer months.

This species was represented by a single suprapharyngeal bone from Norse levels Area 4 (JK).

Ballan Wrasse, *Labrus bergylta* Ascanius

The ballan wrasse is the largest and most common of the wrasses in British waters and is most common on southern and western coasts occurring mainly near algal covered rocks on offshore reefs down to a depth of about 9 m. It is an inshore fish largely confined to rocky ground and lays its eggs in 'nests' built in rock crevices in June-July. Young fish (up to 130 mm) are found in the littoral and sub-littoral zones while large animals inhabit deeper water. Ballan wrasse occur singly or in small shoals and there may be an offshore movement in winter as the fish is very susceptible to cold. It is usually caught in Orkney during the months of June and July (Colley, 1983b, 170).

Their food is mainly crustaceans and molluscs but barnacles and tube worms are also eaten. The fish are thought to be rather slow growing, reaching 40 cm in ten years.

Two right hand side premaxillae, one of which was bore clear tooth marks, and a suprapharyngeal bone were recovered from the sieved residues. In addition, a infrapharyngeal (Plate 34) was collected by hand from Area 5 (KD).

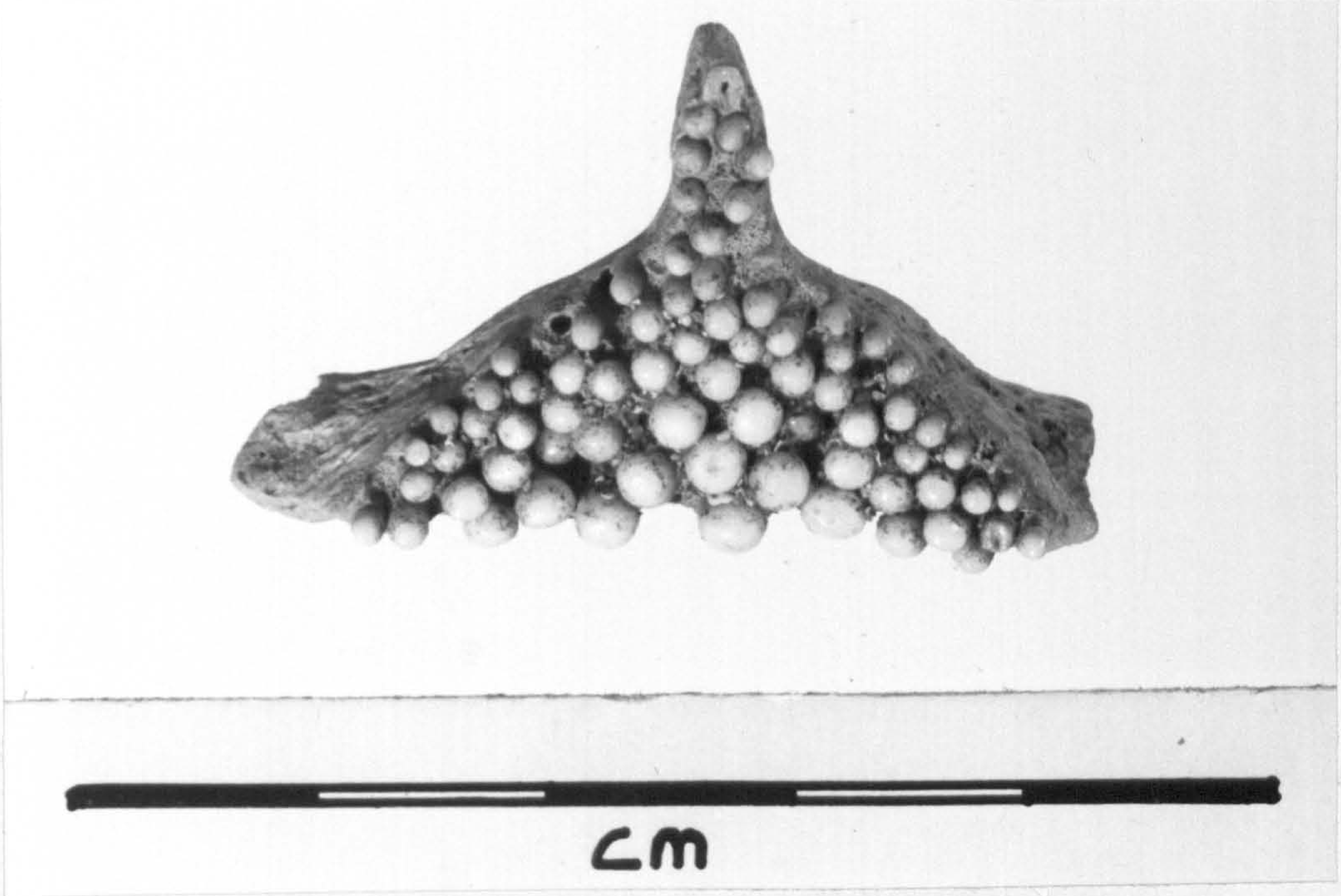


Plate 34. Infrapharyngeal plate of a Ballan wrasse, Labrus bergylta.

Sand eels, Ammodytidae

Sand eels are small eel-like fishes which are locally very abundant in European seas. They are of great importance as food for other species of fishes and many species of sea birds. All sand eels have elongate bodies, and are often found buried on sand in the littoral zone.

An eroded otolith was identified to this family. Two sand eel vertebrae, tentatively identified as Hyperoplus lanceolatus were recovered from an unphased deposit in Area 3. Sand eel vertebrae also were present amongst samples of very small vertebrae identified from Area 5.

Mackerel, Scomber scombrus L.

The mackerel is a shoaling fish which is particularly common off all British coasts except the southern North sea during the summer and autumn. It forms large spawning shoals in the spring and early summer. The fry grow rapidly and may reach 13 cm by the August of their first year. At one year they average 306 mm. Young fishes eat copepod eggs, larvae and adults, other small crustaceans and larval fishes. The adults eat large quantities of pelagic crustaceans, and young fishes. They are thought to retreat to deeper water in the winter months and survive in a state of virtual hibernation.

Mackerel bones were rare at Freswick. Three vertebrae (one crushed, one abraded) were assigned definitely to mackerel and a vertebral fragment identified tentatively. All were from fishes 250-350 mm total length. Two mackerel bones were from Norse levels and two from unphased levels.

Butterfish, *Pholis gunnellus* (L.)

This is a common seashore fish which occurs down to 40 m. It mainly inhabits the *Laminaria* zone under rocks and in crevices. Most individuals migrate into offshore waters in the winter. Remains of this fish were recognized in samples of small vertebrae identified to species from Area 5.

Catfish, ?*Anarhichas lupus* L.

The catfishes are moderate to large fishes typically found in deep-water although individual fishes can be found in crevices in shallow water. The two species, *A. minor* and *A. lupus* occur in the waters around Caithness but *A. lupus* is the most common. Catfish teeth (total 28) were the most abundant kind of remain ascribed to this taxon, although 3 vertebrae (see Plate 35) were also present. Most catfish teeth (21) were present in Norse layer JK (Area 4) in adjacent samples (61 and 57). Thirteen of these teeth were burnt.

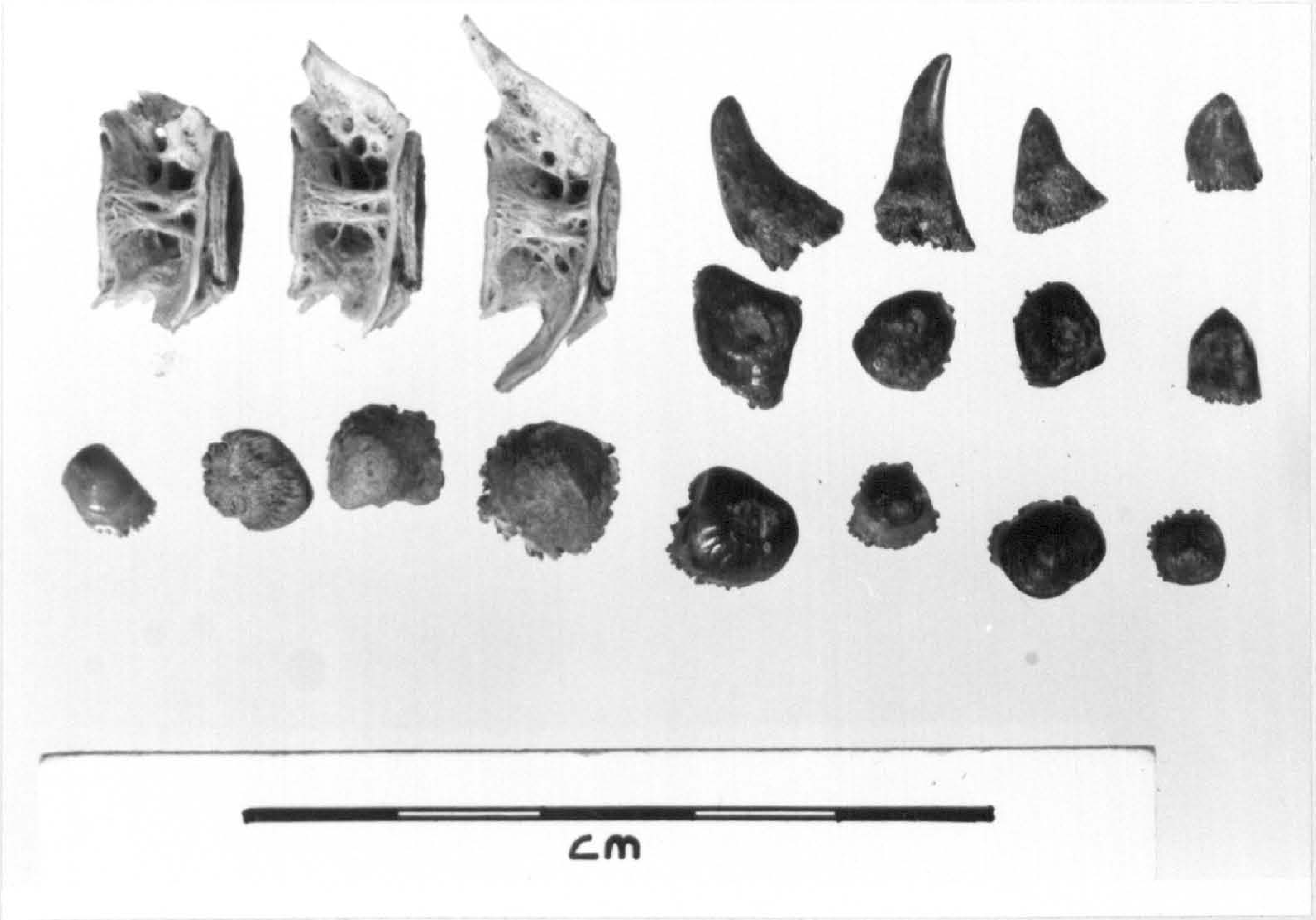


Plate 35. Catfish, ?Anarhicas lupus, remains. Top left: 3 vertebrae, the remainder are teeth.

Gurnards, Triglidae

Gurnards are common fishes in both inshore and deep waters around the British Isles. The most common gurnard is the grey gurnard, Eutrigla gurnardus (L.) which is found on all coasts from the shore line to depths of 140 m, although it is most common between 20 and 40 m. The only gurnard identified to species was the grey gurnard, Eutrigla gurnardus and all the bones assigned to the family Triglidae were consistent with this species.

Gurnard remains (see Plate 36) were relatively common in the deposits at Freswick, particularly in unphased deposits in Areas 7 and 8. Both Norse and Pictish layers in Area 11 produced gurnard remains.

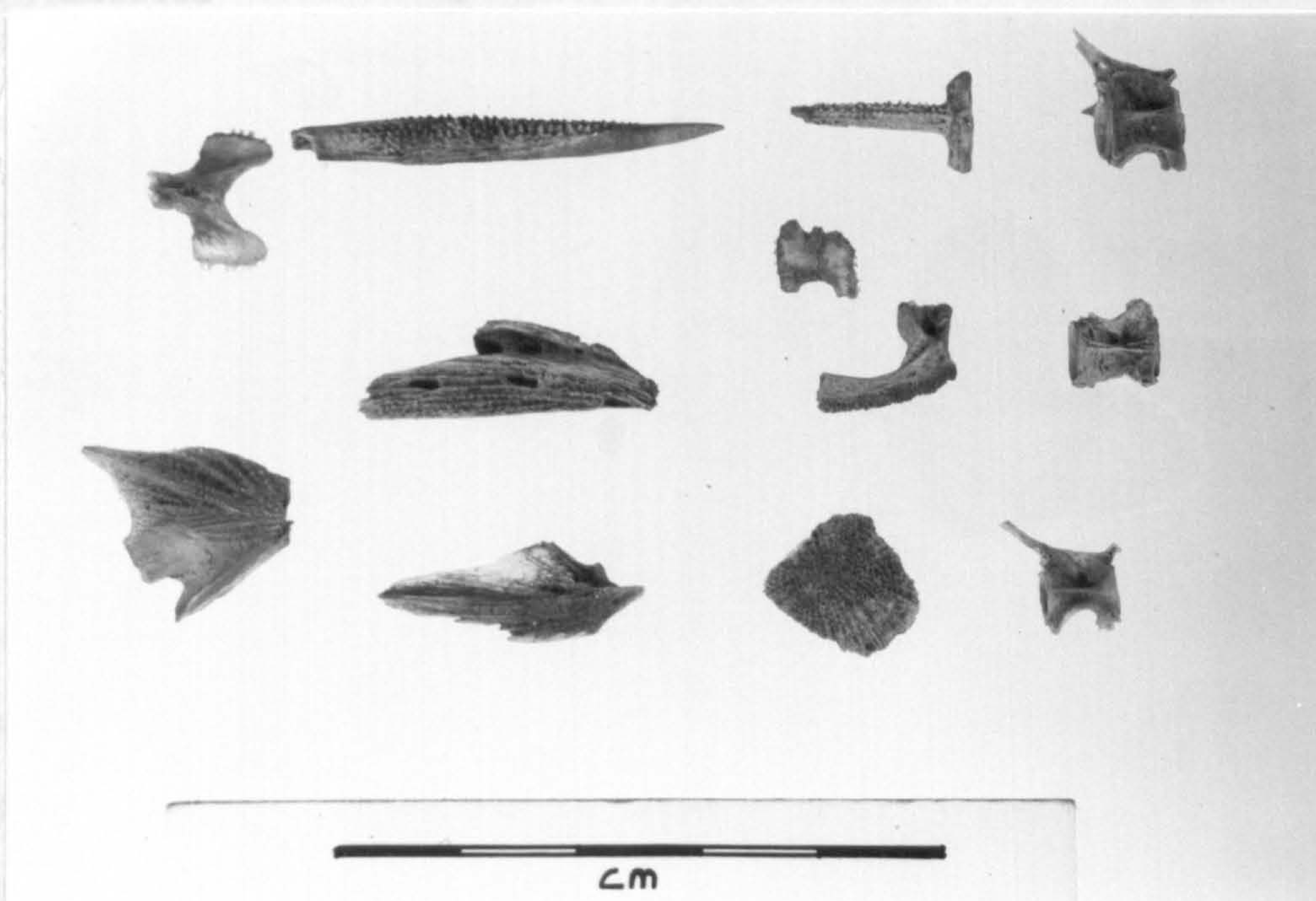


Plate 36. Gurnard, Triglidae, remains. Left to right, top row: scute; 2 spine fragments; vertebra. Middle row: dentary; scute fragment; premaxilla; vertebra. Bottom row: cleithrum fragment; articular; indeterminate fragment and vertebra. The dentary, premaxilla and articular were diagnostic of grey gurnard, Eutrigla gurnardus, the remainder were consistent with that species.

Table 19. Gurnard, Triglidae, remains from Freswick Links

	Eutrigla gurnardus	?*Eutrigla gurnardus*	Triglidae	?Triglidae
articular	1	-	-	-
basipterygium	1	-	-	-
ceratohyal	2	-	1	-
cleithrum	6	2	-	-
dentary	2	-	-	-
hyomandibular	1	-	-	-
lacrimal	4	-	-	-
maxilla	1	-	-	-
opercular	5	-	-	-
parasphenoid	1	2	1	-
premaxilla	6	-	-	-
preopercular	1	-	-	-
scute	5	4	54	-
spine	-	-	52	2
abdominal vertebrae	-	4	20	-
caudal vertebrae	-	2	129	-
vertebral fragments	-	-	11	2

?Bull rout, ?*Myoxocephalus scorpius* (L.)

This species is the largest British sea scorpion growing to a approximately 30 cm total length. It is common on all coasts occurring in depths of between 4 and 60 m. An otolith and a left premaxilla (see Plate 37) both from unphased deposits in Area 8 (MX) was tentatively assigned to this species.

Sea scorpion, *Taurulus bubalis* (Euphrasen)

This is an inshore and littoral fish, restricted to rocky terrain. It is common on all rocky shores and is found down to depths of 30 m. Distinctive preopercular bones (see Plate 37) and two dentaries were sufficiently diagnostic to allow this species to be identified. Sea scorpion remains were recovered from Norse levels in Area 4 (JF and JJ) and from unphased deposits in Area 2a (DH, DN, EA, FO) and Area 8 (ABN + OB).

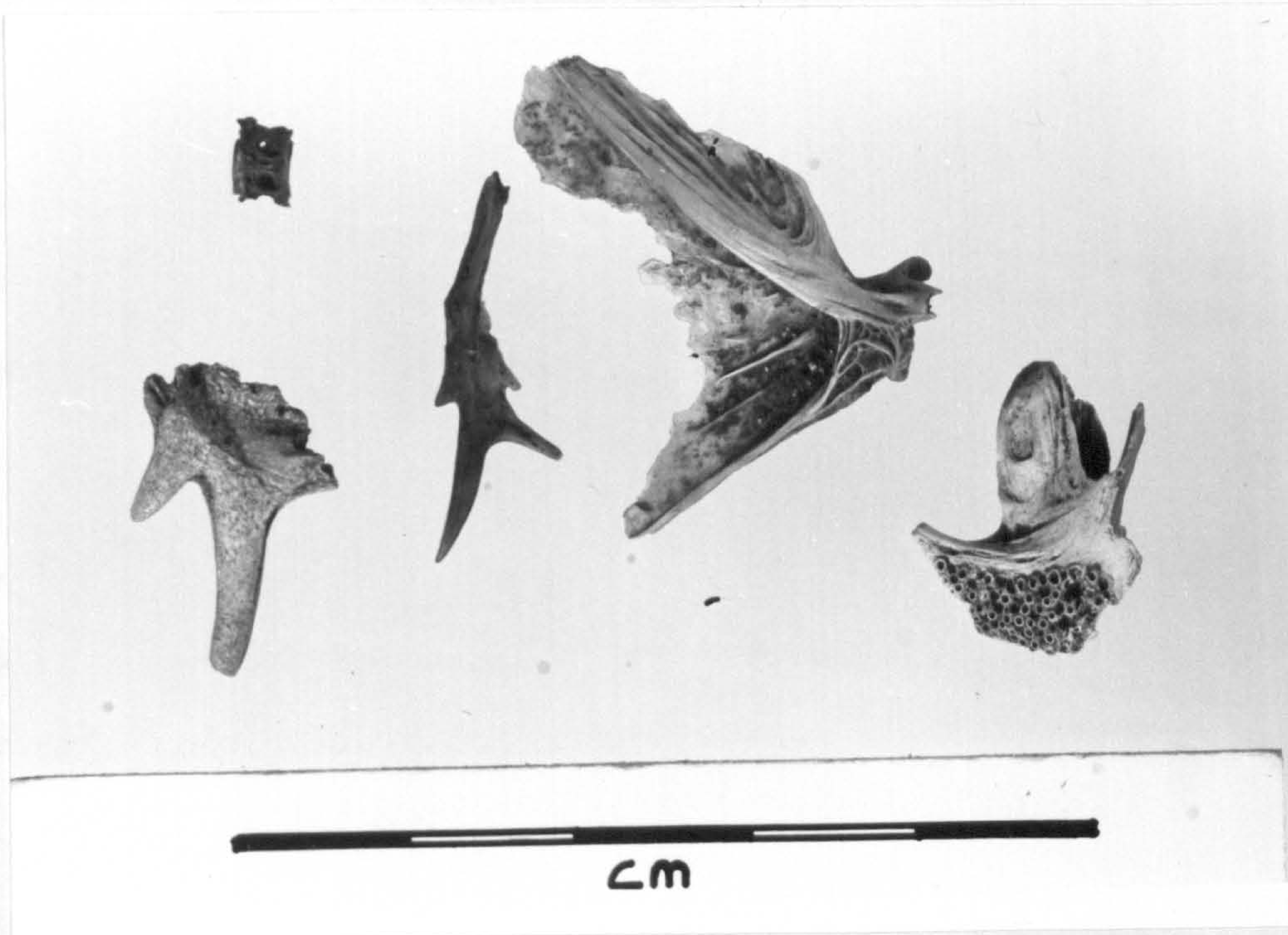


Plate 37. Cottid bones. Lower right: premaxilla fragment ?bull rout, ?Myoxocephalus scorpius. The remainder are from the sea scorpion, Taurulus bubalis.

Right-sided flatfish, Heterostomata

This taxon includes remains of flatfishes which were not of the Pleuronectidae, but which could not be more closely identified.

Topknot, Zeugopterus punctatus (Bloch)

This species of flatfish lives mainly on rocky grounds in shallow water and lower shore. It clings tightly to rocks. Young specimens are found chiefly amongst Laminaria holdfasts. Adult specimens are rarely longer than 24 cm total length.

The bones from Freswick Links are believed to be the first record of this species in British archaeological deposits. Only five topknot bones were recognized, 2 articulars (one left and one right), a dentary, an ectopterygoid and a quadrate (see

Plate 38). Four were found together in a sample from a Norse level in Area 4 (JK) and may be from the same adult fish. The other (the left articular) was found in an unphased layer from Area 8 (AAV).

Megrim, Lepidorhombus whiffiagonis (Walbaum)

The megrim is a deep water flatfish with a wide tolerance of depths. It can be caught in waters from 10-400 m deep, but is most common between 50 and 300 m. It is occasionally found close inshore.

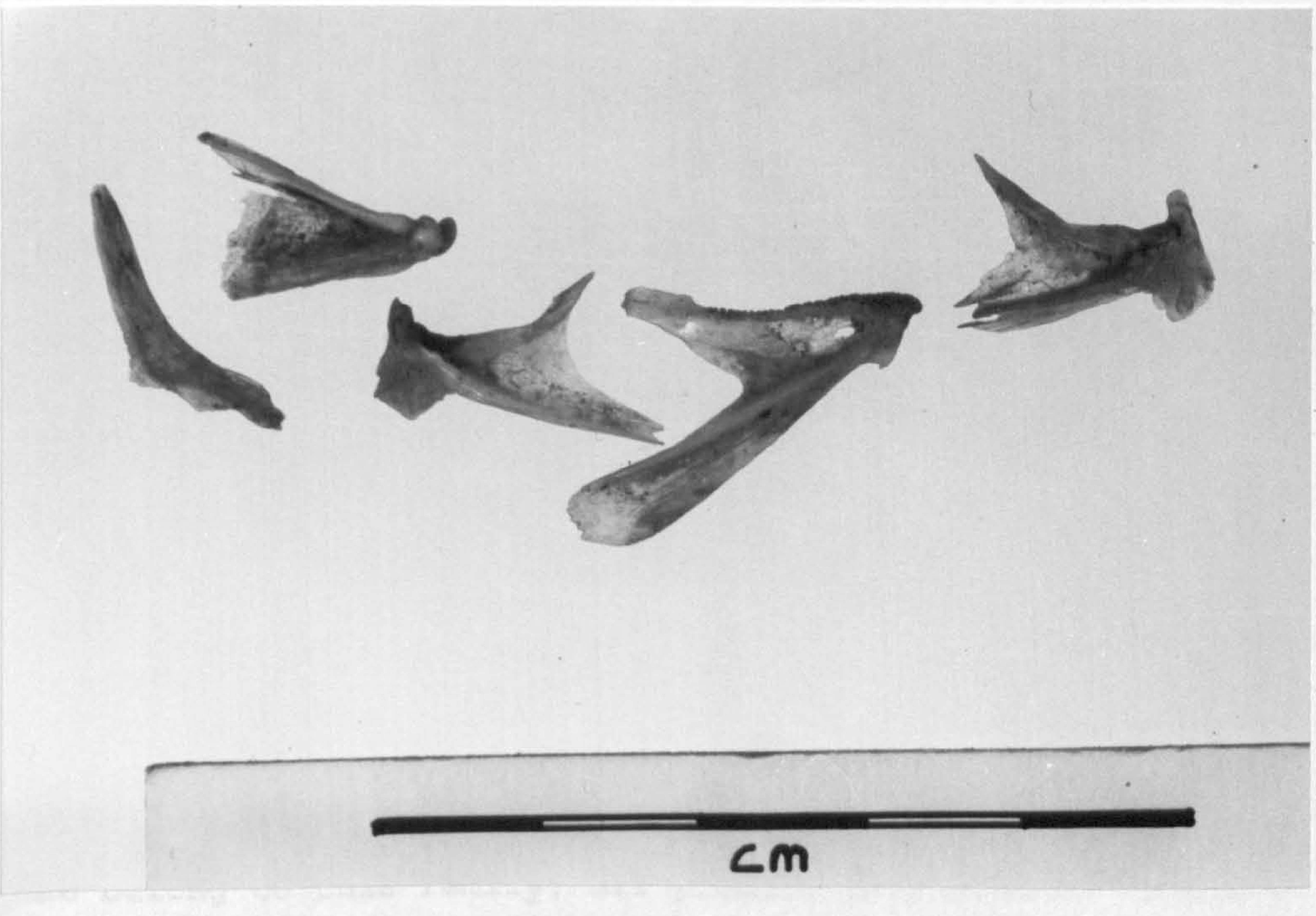


Plate 38. Topknot, Zeugopterus punctatus, remains. Left to right: ectopterygoid; quadrate; articular; dentary (all right side and found in the same sample) and a left side articular.

Plate 39. Megrim, Lepidorhombus whiffiagonis, bones. Left to right: cleithrum, 3 vertebrae.

Vertebrae, a cleithrum (see Plate 39) and a dentary were identified as megrim. All bones were from Norse levels, mainly in Area 4 (JE, JK, JL, & JM). The bones were from fish of approximately 450-500 mm total length.

The left-sided flatfishes, Pleuronectidae

Several species of flatfish, notably plaice, flounder, and dab belong to this family. All produce very similar vertebrae which cannot be assigned to species with confidence. Pleuronectid vertebrae (see Plates 40-41) were found scattered in small numbers throughout deposits at the site in Pictish, Norse and unphased layers. Most were from small to medium sized animals (200-450 mm total length).

Plate 40. Large flatfish remains. Left: caudal vertebra. Right: fragment of first anal pterygiophore. Both identified as Pleuronectidae.

Plate 41. Small pleuronectid bones. Left to right: cleithrum; dentary; vertebra.

Flounder, *Platichthys flesus* (L.)

The flounder is the only European flatfish that migrates into estuaries and freshwater, usually in the summer months. It is a common flatfish round most of the British Isles.

Flounder bones were rare, all were found in a Norse deposit in Area 6 (KF) and it is possible that all four bones including a highly distinctive ceratohyal were from the same fish which was approximately 450 mm total length.

Plaice, *Pleuronectes platessa* L.

Plaice is the most well-known European flatfish with its distinctive orange spots when fresh. It is common in the North Sea and around the entire British Coast. Four bones, a small dentary an ectopterygoid and two small premaxillae (see Plate 42) testified to the presence of fishes ranging in size from 250 to approximately 550 mm total length.

Halibut, *Hippoglossus hippoglossus* (L.)

The halibut is the largest of flatfishes and can grow to enormous size (up to 252 kg). Halibut are found in waters of 110 m depth and deeper. They move inshore in summer months to feed. Halibut was represented by three large (15.6-18.7 mm wide) caudal vertebrae centra definitely identified as halibut and 3 further large vertebrae and a urohyal tentatively identified as halibut (see Plate 43). Two of the halibut bones bore tooth marks indicating they had been chewed.

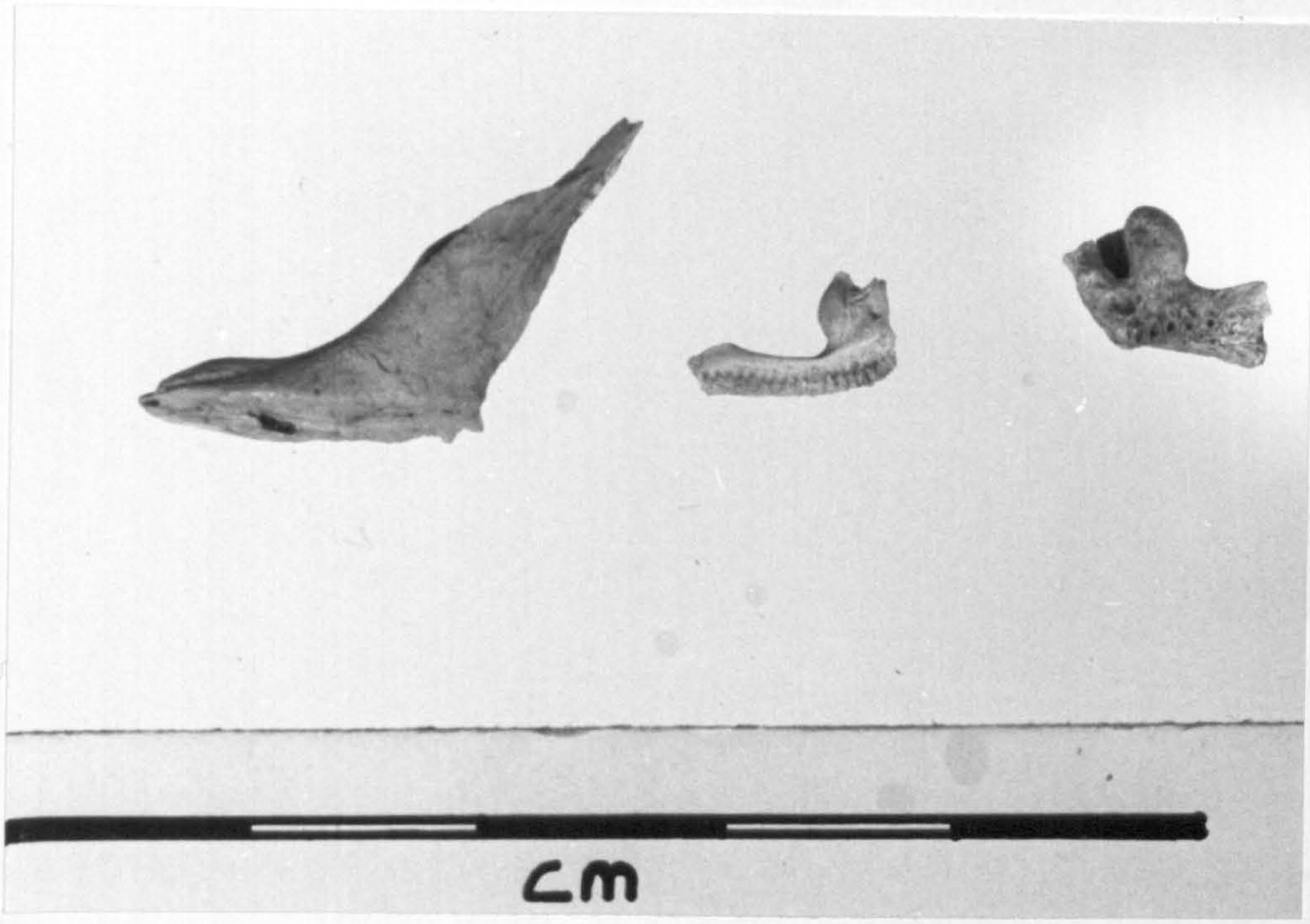


Plate 42. Plaice, Pleuronectes platessa, remains. Left to right: ectopterygoid, 2 premaxillae fragments.

Angler fish, ?Lophius piscatorius L.

Two species of angler occur in British waters, Lophius piscatorius and L. budegassa which have often been confused as fresh fish. L. budegassa is generally thought to have a more southerly distribution than L. piscatorius. The angler fish can live in intertidal waters to depths of 550 m. Five badly broken fragments of dentary (see Plate 44) and a tooth were found in the Norse deposit GW in Area 5 while Area 4 (JE) produced a single tooth. All remains were from fish at least 700 mm total length.

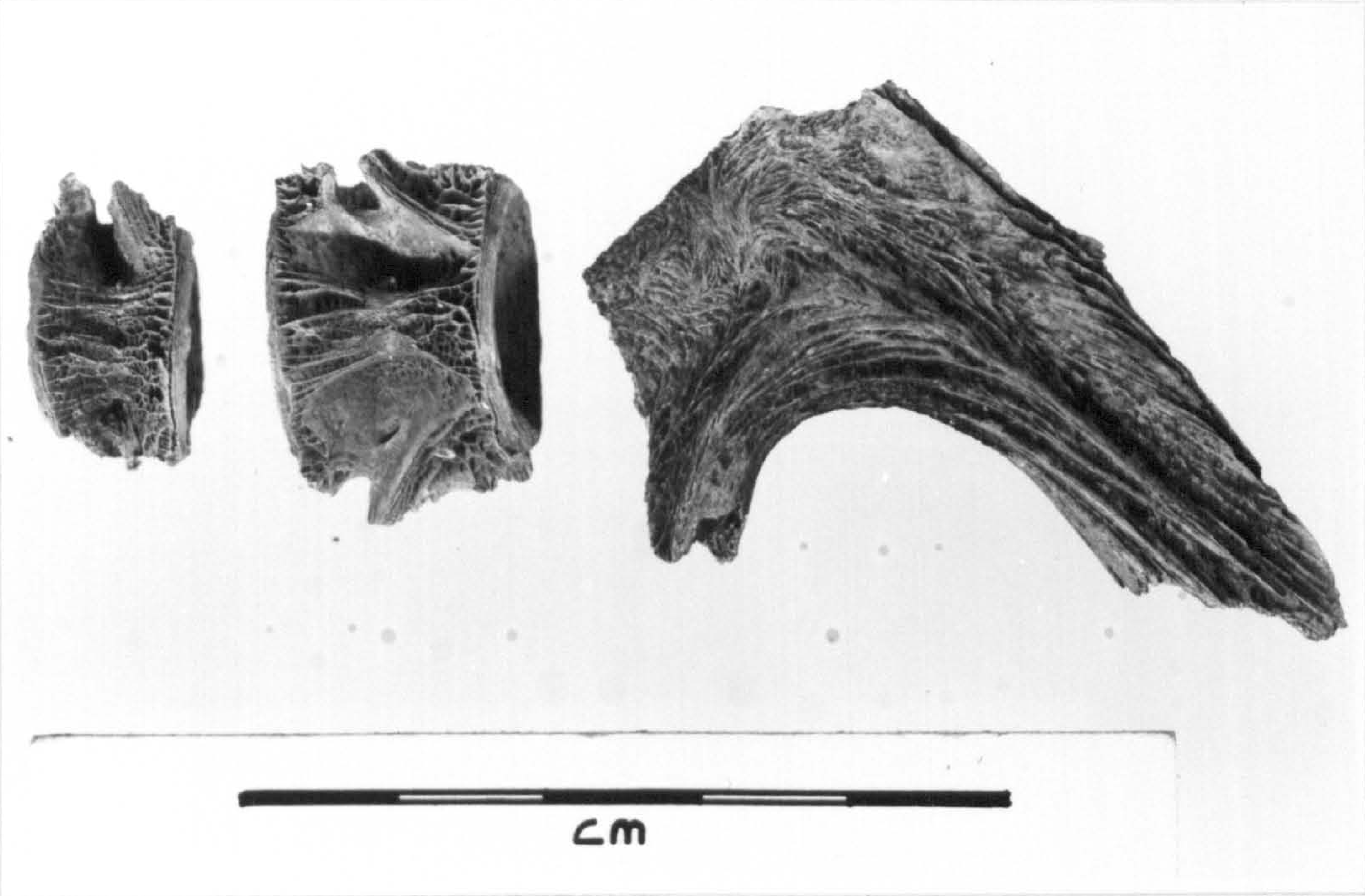


Plate 43. Halibut, Hippoglossus hippoglossus, vertebrae and ?halibut urohyal.

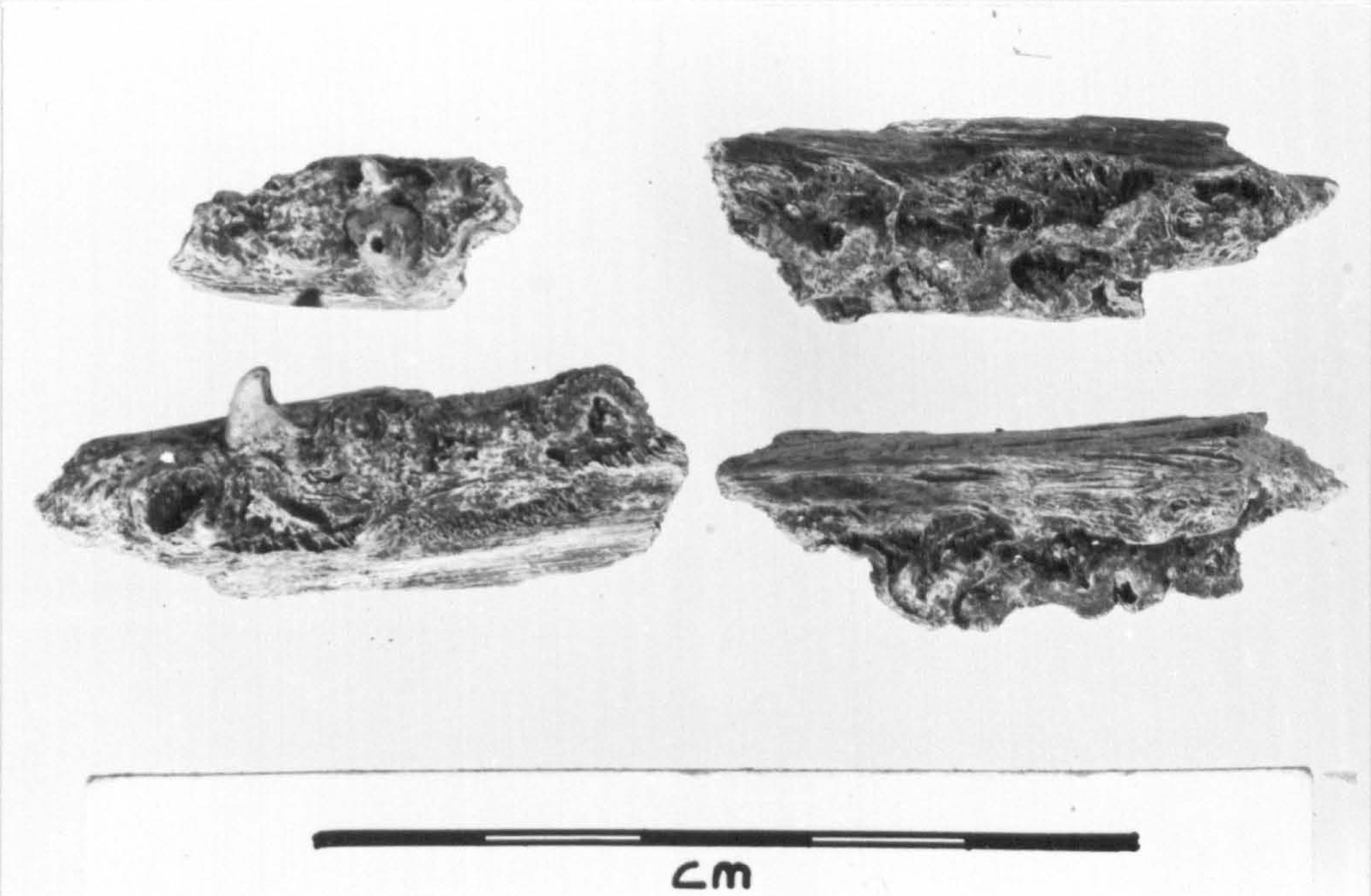


Plate 44. Fragments of angler fish ?Lophius piscatorius, dentary.

Table 20

Taxa identified and their relative percentage frequency in contexts and samples

Taxon	% frequency by context	% frequency by sample
Elasmobranchii	3.18	1.16
Scyliorhinidae	0.79	0.29
?Raja clavata L.	0.40	0.15
Raja clavata L.	0.79	0.30
Clupeidae	0.79	0.30
?Clupea harengus L.	0.40	0.15
Clupea harengus L.	5.16	2.17
?Salmonidae	0.40	0.15
Salmonidae	0.79	0.29
?Anguilla anguilla (L.)	0.40	0.15
Anguilla anguilla (L.)	3.97	1.59
Conger conger (L.)	7.14	3.62
?Belone belone (L.)	0.79	0.29
Belone belone (L.)	0.79	0.43
?Merluccius merluccius (L.)	0.40	0.15
Merluccius merluccius (L.)	3.57	0.58
?Gadidae	3.57	1.45
Gadidae	48.81	39.66
?Merlangius merlangus (L.)	1.19	0.43
Merlangius merlangus (L.)	0.40	0.15
?Trisopterus sp.	0.40	0.15
Trisopterus sp.	7.14	2.89
?Trisopterus luscus (L.)	0.40	0.15
?Trisopterus minutus (L.)	0.40	0.15
Pollachius/Gadus	11.11	6.22
Pollachius sp.	5.56	2.31
?Pollachius pollachius (L.)	2.38	1.01
Pollachius pollachius (L.)	6.75	4.48
?Pollachius virens (L.)	53.18	49.35
Pollachius virens (L.)	21.83	14.47
?Gadus morhua L.	19.44	11.72
Gadus morhua L.	60.32	54.99
?Melanogrammus aeglefinus (L.)	10.12	4.43
Melanogrammus aeglefinus (L.)	10.93	6.64

Table 20 (cont.)

Taxon	% frequency by context	% frequency by sample
?Brosme brosme (Ascanius)	0.79	0.43
Brosme brosme (Ascanius)	0.40	0.15
?Molva cf. molva (L.)	5.95	2.61
Molva cf. molva (L.)	31.14	25.61
Raniceps raninus (L.)	1.59	0.72
Gaidropsarus sp.	0.40	0.15
Ciliata/Gaidropsarus	1.59	0.72
Ciliata sp.	1.59	0.72
?Dicentrarchus labrax (L.)	0.40	0.15
Dicentrarchus labrax (L.)	0.40	0.15
?Trachurus trachurus (L.)	0.40	0.15
Trachurus trachurus (L.)	3.57	1.59
?Spondyliosoma cantharus (L.)	1.98	0.72
?Ammodytidae	0.40	0.15
?Hyperoplus lanceolatus (Le Sauvage)	0.40	0.15
?Labridae	0.79	0.29
Labridae	1.98	0.72
Labrus bimaculatus L.	0.40	0.15
?Labrus bergylta Ascanius	0.79	0.29
Labrus bergylta Ascanius	0.79	0.29
?Scomber scombrus L.	0.40	0.15
Scomber scombrus L.	1.19	0.43
?Anarhichas lupus L.	3.18	1.30
?Triglidae	1.19	0.43
?Eutrigla gurnardus (L.)	2.78	1.16
Eutrigla gurnardus (L.)	3.97	3.18
?Myoxocephalus scorpius (L.)	0.40	0.15
?Taurulus bubalis (Euphrasen)	0.80	0.29
Taurulus bubalis (Euphrasen)	3.18	1.16
?Heterostomata	0.80	0.29
Heterostomata	0.40	0.15
Zeugopterus punctatus (Bloch)	0.80	0.29
Lepidorhombus whiffiagonus (Walbaum)	1.98	0.72
?Pleuronectidae	0.80	0.29
Pleuronectidae	15.47	11.29
?Platichthys flesus (L.)	0.40	0.15
Platichthys flesus (L.)	0.40	0.15
Pleuronectes platessa L.	1.59	0.58
?Hippoglossus hippoglossus (L.)	0.80	0.29
Hippoglossus hippoglossus (L.)	1.19	0.29
?Lophius piscatorius L.	0.80	0.29

6.3 NUMBERS AND CONDITION OF CLEITHRA, DENTARIES, OTOLITHS AND PREMAXILLAE FRAGMENTS

To survey the kinds of fish remains present in the deposits at Freswick Links, the numbers and condition of the four paired elements identified from all samples are considered. Tables 21-

24 give the numbers and condition of fragments identified to each taxon and show the numbers of right and left (the number of fragments which were not assigned to side can be calculated by subtracting the sum of the numbers of left and right fragments from the total number of specimens. In addition, they give the numbers of fragments that fell into 5 condition classes as described in Chapter 2.

Table 21. Numbers and condition of cleithra from Freswick Links.

TAXON	L	R	?	1	2	3	4	5	Total
?Gadidae	1	0	0	0	0	1	0	0	1
Gadidae	29	33	36	0	3	7	4	84	98
Pollachius/Gadus	12	23	5	0	0	2	6	32	40
Pollachius sp.	1	0	0	0	0	0	0	1	1
?Pollachius virens (L.)	0	1	0	0	0	0	0	1	1
?Gadus morhua L.	5	8	0	0	1	2	2	8	13
Gadus morhua L.	4	5	1	0	1	3	3	3	10
Melanogrammus aeglefinus (L.)	29	22	1	0	17	30	3	2	52
?Molva cf. molva (L.)	2	2	1	0	0	0	2	3	5
Molva cf. molva (L.)	28	26	4	0	0	16	12	30	58
Ciliata/Gaidropsarus	1	0	0	0	1	0	0	0	1
?Eutrigla gurnardus (L.)	1	1	0	0	0	0	0	2	2
Eutrigla gurnardus (L.)	3	3	0	0	0	2	3	1	6
Heterostomata	1	0	0	0	1	0	0	0	1
Lepidorhombus whiffiagonus (Walbaum)	1	0	0	0	0	0	1	0	1
Pleuronectidae	0	1	0	0	1	0	0	0	1

L = left; R = right; ? = side unknown; 1 = <25% survives; 2 = 25-50% survives; 3 = 50-75% survives; 4 = 75-100% survives; 5 = complete

Table 22. Numbers and condition of dentaries from Freswick Links.

TAXON	L	R	?	1	2	3	4	5	Total
Anguilla anguilla (L.)	1	0	1	0	2	0	0	0	2
Conger conger (L.)	1	2	0	0	1	1	1	0	3
Belone belone (L.)	0	1	0	0	0	0	0	1	1
Merluccius merluccius (L.)	0	0	1	0	0	0	0	1	1
Gadidae	10	10	26	0	0	1	0	45	46
?Trisopterus luscus (L.)	1	0	0	0	1	0	0	0	1
Pollachius/Gadus	0	2	0	0	0	0	0	2	2
Pollachius sp.	1	1	0	0	0	0	0	2	2
Pollachius pollachius (L.)	8	19	2	1	2	2	6	18	29
?Pollachius virens (L.)	4	1	0	0	0	1	1	3	5
Pollachius virens (L.)	36	31	0	0	13	9	7	38	67
?Gadus morhua L.	10	8	3	0	0	1	0	20	21
Gadus morhua L.	124	121	21	0	23	38	45	160	266
Melanogrammus aeglefinus (L.)	3	2	0	0	2	2	0	1	5
?Molva cf. molva (L.)	2	1	0	0	0	0	0	3	3
Molva cf. molva (L.)	37	30	38	0	6	15	10	74	105
Raniceps raninus (L.)	0	1	0	0	0	1	0	0	1
Ciliata/Gaidropsarus	1	0	1	0	1	0	0	0	1
Ciliata sp.	0	2	0	0	1	0	0	1	2
Eutrigla gurnardus (L.)	1	1	0	0	0	2	0	0	2
Taurulus bubalis (Euphrasen)	2	1	1	0	0	0	0	2	2
Zeugopterus punctatus (Bloch)	0	1	0	0	1	0	0	0	1
Lepidorhombus whiffiagonus (Walbaum)	1	0	0	0	0	1	0	0	1
Pleuronectes platessa L.	0	1	0	0	1	0	0	0	1
?Lophius piscatorius L.	0	0	5	0	0	0	0	5	5

Table 23. Numbers and condition of otoliths from Freswick Links.

TAXON	L	R	?	1	2	3	4	5	Total
?Salmonidae	0	0	1	1	0	0	0	0	1
?Merluccius merluccius (L.)	1	1	0	0	2	0	0	0	2
?Gadidae	0	0	9	0	0	1	1	7	9
Gadidae	12	15	198	3	8	3	11	200	225
?Merlangius merlangus (L.)	1	2	0	0	3	0	0	0	3
Merlangius merlangus (L.)	0	1	0	0	1	0	0	0	1
?Trisopterus sp.	0	1	0	1	0	0	0	0	1
Trisopterus sp.	10	15	1	22	4	0	0	0	26
Pollachius/Gadus	2	1	0	0	1	2	0	0	3
?Pollachius pollachius (L.)	0	3	0	2	1	0	0	0	3
?Pollachius virens (L.)	444	425	38	225	353	155	100	74	907
?Gadus morhua L.	13	9	19	1	3	5	8	24	41
Gadus morhua L.	329	303	19	236	147	131	76	61	651
?Melanogrammus aeglefinus (L.)	33	29	0	13	32	12	4	1	62
?Brosme brosme (Ascanius)	2	1	0	0	1	2	0	0	3
?Molva cf. molva (L.)	0	1	3	1	0	3	0	0	4
Molva cf. molva (L.)	50	67	9	26	13	55	24	8	126
Raniceps raninus (L.)	0	0	2	2	0	0	0	0	2
?Ammodytidae	1	0	0	0	1	0	0	0	1
Triglidae	0	0	1	0	0	0	0	5	5
?Myoxocephalus scorpius (L.)	0	0	1	1	0	0	0	0	1
Pleuronectidae	0	0	1	1	0	0	0	0	1

L = left; R = right; ? = side unknown; 1 = <25% survives; 2 = 25-50% survives; 3 = 50-75% survives; 4 = 75-100% survives; 5 = complete

Table 24. Numbers and condition of premaxillae from Freswick Links.

TAXON	L	R	?	1	2	3	4	5	Total
Merluccius merluccius (L.)	0	1	0	0	0	1	0	0	1
Gadidae	16	25	21	0	3	3	6	50	62
?Trisopterus minutus (L.)	0	1	0	0	1	0	0	0	1
Pollachius/Gadus	3	0	0	0	0	1	0	2	3
Pollachius sp.	4	4	0	0	1	1	0	6	8
?Pollachius pollachius (L.)	2	3	0	0	2	0	2	1	5
Pollachius pollachius (L.)	6	7	0	0	5	2	1	5	13
?Pollachius virens (L.)	19	16	1	0	1	4	10	20	35
Pollachius virens (L.)	28	28	56	1	25	6	6	18	56
?Gadus morhua L.	10	9	0	0	2	0	1	18	21
Gadus morhua L.	197	180	13	1	109	88	63	129	390
Melanogrammus aeglefinus (L.)	9	11	0	0	9	4	2	5	20
Brosme brosme (Ascanius)	1	1	0	0	2	0	0	0	2
?Molva cf. molva (L.)	4	1	1	0	0	0	1	5	6
Molva cf. molva (L.)	44	66	1	0	34	32	17	28	111
Raniceps raninus (L.)	2	2	0	0	1	0	0	3	4
Gaidropsarus sp.	1	0	0	0	1	0	0	0	1
Ciliata/Gaidropsarus	0	1	0	0	1	0	0	0	1
Ciliata sp.	0	2	0	0	2	0	0	0	2
?Labrus bergylta Ascanius	0	1	0	0	1	0	0	0	1
Labrus bergylta Ascanius	0	1	0	0	0	0	0	1	1
Eutrigla gurnardus (L.)	4	2	0	0	1	3	1	1	6
Taurulus bubalis (Euphrasen)	1	0	0	0	0	0	0	1	1
?Heterostomata	1	0	0	0	1	0	0	0	1
Pleuronectidae	0	1	0	0	1	0	0	0	1
Pleuronectes platessa L.	1	1	0	0	0	1	0	1	2

L = left; R = right; ? = side unknown; 1 = <25% survives; 2 = 25-50% survives; 3 = 50-75% survives; 4 = 75-100% survives; 5 = complete

It is clear that the numbers of fragments of each kind of element varied considerably. The total numbers of elements were as follows: otoliths 2092, premaxillae 758, dentaries 577, cleithra 291. It is also clear that taxa were not represented equally by the elements. To illustrate this more clearly the six most abundant taxa were placed in rank order for each element.

Table 25. The six most abundant taxa represented by cleithra, dentaries, otoliths and premaxillae in rank order of number of identifiable fragments.

Rank	Cleithra	Dentaries	Premaxillae	Otoliths
1	Gadidae	Gadus	Gadus	?P. virens
2	Molva	Molva	Molva	Gadus
3	Melanogrammus	P. virens	Gadidae	Gadidae
4	Gadus/P. sp?p	Gadidae	P. virens	Molva
5	?Gadus	P. poll	?P. virens	Melanogrammus
6	Gadus	?Gadus	?Gadus	?Gadus

Abbreviations: ?P. virens = ?Pollachius virens; P. sp?p = Pollachius sp?p.; P. poll. = Pollachius pollachius

While it is clear from Tables 21-24 that remains of gadid (mainly Gadus, Molva and Pollachius virens) dominate in the deposits, the number of fragments of each elements do not indicate consistently which species or taxon was the most common. The numbers of dentaries and premaxillae give the most similar picture with Gadus and Molva dominating the assemblages. Otoliths suggest that ?Pollachius virens is the most abundant kind of fish, while cleithra indicate that Molva and Melanogrammus are more important than Gadus, Pollachius virens or P. pollachius.

Further insights into patterning in fish remains gathered from the site can be gained by considering the numbers of fragments and their completeness. Tables 23 & 24 give the numbers of otoliths, premaxillae, dentaries and cleithra according to their degree of completeness. Table 26 gives the same data as percentages for those taxa for which more than 100 fragments were recovered.

Table 26. Percentage of selected remains according condition.

	100%	100-75%	75-50%	50-25%	<25%
Otoliths					
?Pollachius virens	25	39	17	11	8
Gadus	36	23	20	12	9
Gadidae	1	4	1	5	91
Molva	21	10	44	20	15
Premaxillae					
Gadus	0	28	23	16	33
Molva	0	30	29	15	26
Dentaries					
Gadus	0	9	14	17	60
Molva	0	6	14	10	70

From Tables 21-24 it emerges that otoliths were the best preserved of the four elements. Premaxillae were better preserved than dentaries. Cleithra were generally present as fragments less than 25% of the original bone. Haddock cleithra were the best preserved while Molva cleithra were the most abundant.

It is particularly interesting to note that the overall condition of the otoliths and bones and their abundance appear to be closely related. Otoliths were the most abundant element and the best preserved, followed by premaxillae and dentaries with cleithra being the least abundant of the fish remains and also clearly the least well-preserved. This result is seen as extremely significant and provides clear evidence of differential preservation of fish remains.

6.4 THE DISTRIBUTION OF FISH TAXA AT FRESWICK LINKS

During the analysis of fish remains from Freswick it became clear the assemblages of fish remains were remarkably consistent in species composition in different parts of the site. However, since the deposits were laid down over a period of several hundred years, and in different archaeological contexts, it was decided to examine the fish bone records to determine if changes in species, sizes of species and the condition of bones could be seen in deposits of different periods and in different parts of the site.

6.4.1 Distribution of Fish Taxa in Different Stratigraphic Levels

A series of levels identified as Pictish (roughly A.D. 297-847) in date from Areas 11-14 were compared with the fish-rich levels 24 and 22, dated as Late Norse (roughly A.D. 1050-1266) in Area 4.

Table 27 shows the frequency of taxa in Pictish deposits compared with that found in deposits from Levels 24 and 22 of the period of Late Norse occupation. Tables 28-33 and Figures 78 & 79 show the condition and sizes of remains from Pictish and Levels 24 and 22 Norse deposits. It is clear that the assemblages in the Pictish and Norse periods are very similar in species composition.

Table 27. Numbers of Pictish contexts and samples containing each taxon compared with total numbers of contexts and samples containing each taxon

Taxon	Pictish contexts		Level 24 samples		Level 22 samples	
	No.C	No.S	No.C.	No.S	No.C	No.S
Elasmobranchii	1	1	-	-	-	-
Scyliorhinidae	1	1	-	-	-	-
?Raja clavata L.	1	1	-	-	-	-
Clupeidae	-	-	1	1	-	-
Clupea harengus L.	1	1	1	2	1	1
Anguilla anguilla (L.)	1	1	2	2	1	1
Conger conger (L.)	1	1	6	9	1	2
Merluccius merluccius (L.)	-	-	1	1	-	-
?Gadidae	-	-	3	4	1	1
Gadidae	9	19	17	61	1	6
?Merlangius merlangus (L.)	-	-	1	1	-	-
Trisopterus sp.	2	2	4	5	1	1
?Trisopterus luscus (L.)	1	1	-	-	-	-
Pollachius/Gadus	-	-	8	17	2	2
Pollachius sp.	-	-	4	6	-	-
?Pollachius pollachius (L.)	-	-	-	-	1	2
Pollachius pollachius (L.)	2	2	5	11	1	3
?Pollachius virens (L.)	10	36	24	78	4	13
Pollachius virens (L.)	5	9	9	26	2	5
?Gadus morhua L.	4	7	10	20	1	4
Gadus morhua L.	9	30	22	100	2	12
?Melanogrammus aeglefinus (L.)	1	1	5	7	1	3
Melanogrammus aeglefinus (L.)	1	1	7	14	2	3
Brosme brosme (Ascanius)	-	-	1	1	-	-
?Molva cf. molva (L.)	2	2	2	2	1	3
Molva cf. molva (L.)	3	10	23	72	2	11
Raniceps raninus (L.)	-	-	2	3	-	-
Gaidropsarus sp.	1	1	-	-	-	-
Ciliata/Gaidropsarus	-	-	3	4	-	-
Ciliata sp.	-	-	2	3	1	1
Dicentrarchus labrax (L.)	-	-	1	1	-	-
Trachurus trachurus (L.)	1	1	1	1	-	-
?Spondyliosoma cantharus (L.)	-	-	2	2	-	-
?Labridae	-	-	1	1	-	-
Labridae	1	1	1	1	-	-
Labrus bimaculatus L.	-	-	1	1	-	-
?Labrus bergylta Ascanius	-	-	1	1	-	-
?Scomber scombrus L.	-	-	-	-	-	-
Scomber scombrus L.	-	-	1	1	-	-
?Anarhichas lupus L.	3	4	2	2	-	-
Triglidae	2	6	1	1	1	2
?Eutrigla gurnardus (L.)	2	2	-	-	-	-
Eutrigla gurnardus (L.)	2	2	-	-	1	1
Taurulus bubalis (Euphrasen)	1	1	2	2	-	-
Zeugopterus punctatus (Bloch)	-	-	1	1	-	-
Lepidorhombus whiffiagonis (Walbaum)	-	-	3	3	1	1
?Pleuronectidae	-	-	-	-	1	1
Pleuronectidae	2	10	7	25	2	4
?Platichthys flesus (L.)	-	-	-	-	-	-
?Lophius piscatorius L.	-	-	1	1	1	1
Total number contexts	17		34		4	
Total number of samples		67		113		13

Table 28. Numbers of bones from Pictish levels in Areas 11-14.

Taxon	Element	Number of fragments
Elasmobranchii		
	mineralized core of vertebral centrum	1
Scyliorhinidae		
	mineralized core of vertebral centrum	1
Raja clavata L.		
	dermal denticle	1
Clupea harengus L.		
	vertebral centrum (abdominal)	5
	vertebral centrum (caudal)	4
Anguilla anguilla (L.)		
	dentary	1
Conger conger (L.)		
	vertebral centrum (abdominal)	1
Gadidae		
	cleithrum	2
	dentary	3
	otolith	18
	premaxilla	10
Trisopterus sp.		
	otolith	2
?Trisopterus luscus (L.)		
	dentary	1
Pollachius pollachius (L.)		
	dentary	2
?Pollachius virens (L.)		
	otolith	97
	premaxilla	5
Pollachius virens (L.)		
	dentary	4
	premaxilla	8
?Gadus morhua L.		
	otolith	3
	premaxilla	4
Gadus morhua L.		
	dentary	7
	otolith	50
	premaxilla	16
?Melanogrammus aeglefinus (L.)		
	otolith	1
Melanogrammus aeglefinus (L.)		
	premaxilla	1
?Molva cf. molva (L.)		
	dentary	1
	premaxilla	1
Molva cf. molva (L.)		
	dentary	1
	otolith	7
	premaxilla	7

Table 28 (cont.). Identified bones from Pictish levels in Areas 11-14

Gaidropsarus sp.		
	premaxilla	1
Trachurus trachurus (L.)		
	vertebral centrum (caudal)	1
Labridae		
	vertebral centrum (caudal)	1
?Anarhichas lupus		
	tooth	5
Triglidae		
	indeterminate fragment	1
	otolith	1
	scute	2
	vertebral centrum	1
	vertebral centrum (abdominal)	2
	vertebral centrum (caudal)	2
?Eutrigla gurnardus (L.)		
	scute	2
Eutrigla gurnardus (L.)		
	scute	2
Taurulus bubalis (Euphrasen)		
	vertebral centrum (abdominal)	1
Pleuronectidae		
	vertebral centrum (abdominal)	2

Table 29. Numbers and condition of bones and otoliths from Pictish levels in Areas 11-14.

	Condition 1	2	3	4	5	Tot
CLEITHRUM						
Gadidae	0	0	0	0	2	2
DENTARY						
Anguilla anguilla (L.)	0	1	0	0	0	1
Gadidae	0	0	0	0	3	3
?Trisopterus luscus (L.)	0	1	0	0	0	1
Pollachius pollachius (L.)	0	0	0	0	2	2
Pollachius virens (L.)	0	0	0	2	2	4
Gadus morhua L.	0	0	1	0	6	7
?Molva cf. molva (L.)	0	0	0	0	1	1
Molva cf. molva (L.)	0	0	1	0	0	1
OTOLITH						
Gadidae	0	0	1	1	16	18
Trisopterus sp.	2	0	0	0	0	2
?Pollachius virens (L.)	25	36	19	12	5	97
?Gadus morhua L.	0	0	0	0	3	3
Gadus morhua L.	11	11	13	12	3	50
?Melanogrammus aeglefinus (L.)	0	0	1	0	0	1
Molva cf. molva (L.)	1	0	6	0	0	7
Triglidae	0	0	0	0	1	1
PREMAXILLA						
Gadidae	0	0	0	1	9	10
?Pollachius virens (L.)	0	0	1	0	4	5
Pollachius virens (L.)	0	3	1	0	4	8
?Gadus morhua L.	0	0	0	1	3	4
Gadus morhua L.	0	1	1	1	13	16
Melanogrammus aeglefinus (L.)	0	0	0	0	1	1
?Molva cf. molva (L.)	0	0	0	0	1	1
Molva cf. molva (L.)	0	0	2	3	2	7
Gaidropsarus sp.	0	1	0	0	0	1

Table 30. Identified fish remains from deposits ascribed to level 24 (Norse).

Taxon of Fragments	Element	Number
Clupeidae		
	otic bulla	4
Clupea harengus L.		
	vertebral centrum (abdominal)	2
Anguilla anguilla (L.)		
	opercular	1
	vertebral centrum (caudal)	2
Conger conger (L.)		
	dentary	1
	opercular	1
	prevomer	1
	vertebral centrum	1
	vertebral centrum (abdominal)	17
	vertebral centrum (caudal)	7
Belone belone (L.)		
	vertebral centrum (abdominal)	5
Merluccius merluccius (L.)		
	premaxilla	1
?Gadidae		
	otolith	4
Gadidae		
	cleithrum	50
	dentary	9
	otolith	88
	premaxilla	13
?Merlangius merlangus (L.)		
	otolith	1
Trisopterus sp.		
	otolith	6
Pollachius or Gadus sp.		
	cleithrum	17
	otolith	3
	premaxilla	1
Pollachius/Melanogrammus		
	otolith	1
Pollachius sp.		
	articular	1
	premaxilla	4
Pollachius pollachius (L.)		
	dentary	14
	premaxilla	4
?Pollachius virens (L.)		
	dentary	1
	otolith	319
	premaxilla	4
Pollachius virens (L.)		
	dentary	22
	premaxilla	14

Table 30 (cont.). Identified fish remains from deposits ascribed to Level 24, Freswick Links

?Gadus morhua L.		
	cleithrum	7
	dentary	5
	otolith	8
	premaxilla	2
Gadus morhua L.		
	cleithrum	4
	dentary	82
	otolith	197
	premaxilla	110
?Melanogrammus aeglefinus (L.)		
	otolith	7
?Brosme brosme (Ascanius)		
	otolith	3
Melanogrammus aeglefinus (L.)		
	cleithrum	20
	dentary	3
	premaxilla	7
Brosme brosme (Ascanius)		
	maxilla	1
	premaxilla	2
?Molva cf. molva (L.)		
	otolith	1
	premaxilla	1
Molva cf. molva (L.)		
	cleithrum	48
	dentary	68
	otolith	77
	premaxilla	56
Raniceps raninus (L.)		
	dentary	1
	premaxilla	3
Ciliata/Gaidropsarus		
	cleithrum	1
	frontal	2
	parasphenoid	1
	prevomer	1
	vertebral centrum	14
	vertebral centrum (abdominal)	8
	vertebral centrum (caudal)	5
Ciliata sp.		
	dentary	1
	premaxilla	1
Dicentrarchus labrax (L.)		
	vertebral centrum (caudal)	1
Trachurus trachurus (L.)		
	scute	1
	vertebral centrum (caudal)	3

Table 30 (cont.). Identified fish remains from deposits ascribed to Level 24, Freswick Links

?Spondyliosoma cantharus (L.)		
	vertebral centrum (abdominal)	2
?Labridae		
	vertebral centrum (caudal)	1
Labridae		
	pharyngeal bone	1
Labrus bimaculatus L.		
	suprapharyngeal	1
?Labrus bergylta Ascanius		
	suprapharyngeal	1
Scomber scombrus L.		
	vertebral centrum (caudal)	1
?Anarhichas lupus		
	tooth	21
Triglidae		
	scute	1
Taurulus bubalis (Euphrasen)		
	preopercular	2
Zeugopterus punctatus (Bloch)		
	articular	1
	dentary	1
	ectopterygoid	1
	quadrate	1
Lepidorhombus whiffiagonis (Walbaum)		
	dentary	1
	vertebral centrum (caudal)	4
Pleuronectidae		
	cleithrum	1
	otolith	1
	premaxilla	1
	preopercular	1
	vertebral centrum (abdominal)	4
	vertebral centrum (caudal)	62
?Lophius piscatorius L.		
	dentary	5
	tooth	3

Table 31. Numbers and condition of cleithra, dentaries, otoliths and premaxillae from level 24 (Norse).

	Condition 1	2	3	4	5	Tot
CLEITHRUM						
Gadidae	0	2	6	4	38	50
Pollachius or Gadus sp.	0	0	1	4	12	17
?Gadus morhua L.	0	1	0	2	4	7
Gadus morhua L.	0	1	2	1	0	4
Melanogrammus aeglefinus (L.)	0	3	13	3	1	20
Molva cf. molva (L.)	0	0	15	8	25	48
Ciliata/Gaidropsarus	0	1	0	0	0	1
Pleuronectidae	0	1	0	0	0	1
DENTARY						
Conger conger (L.)	0	0	0	1	0	1
Gadidae	0	0	1	0	8	9
Pollachius pollachius (L.)	1	2	1	3	7	14
?Pollachius virens (L.)	0	0	0	1	0	1
Pollachius virens (L.)	0	8	1	2	11	22
?Gadus morhua L.	0	0	0	0	5	5
Gadus morhua L.	0	9	15	13	45	82
Melanogrammus aeglefinus (L.)	0	1	2	0	0	3
Molva cf. molva (L.)	0	4	12	7	45	68
Raniceps raninus (L.)	0	0	1	0	0	1
Ciliata sp.	0	1	0	0	0	1
Zeugopterus punctatus (Bloch)	0	1	0	0	0	1
Lepidorhombus whiffiagonis (Walbaum)	0	0	1	0	0	1
?Lophius piscatorius L.	0	0	0	0	5	5
OTOLITH						
?Gadidae	0	0	0	0	4	4
Gadidae	1	2	0	8	77	88
?Merlangius merlangus (L.)	0	1	0	0	0	1
Trisopterus sp.	6	0	0	0	0	6
Pollachius or Gadus sp.	0	1	2	0	0	3
Pollachius/Melanogrammus	0	1	0	0	0	1
?Pollachius virens (L.)	84	105	61	39	30	319
?Gadus morhua L.	0	0	1	1	6	8
Gadus morhua L.	66	46	44	24	17	197
?Melanogrammus aeglefinus (L.)	1	1	4	1	0	7
?Brosme brosme (Ascanius)	0	1	2	0	0	3
?Molva cf. molva (L.)	1	0	0	0	0	1
Molva cf. molva (L.)	13	12	34	16	2	77
Pleuronectidae	1	0	0	0	0	1

Table 31 (cont.). Numbers and condition of cleithra, dentaries, otoliths and premaxillae from Level 24 deposits Freswick Links

PREMAXILLA

Merluccius merluccius (L.)	0	0	1	0	0	1
Gadidae	0	1	0	1	11	13
Pollachius or Gadus sp.	0	0	0	0	1	1
Pollachius sp.	0	0	1	0	3	4
Pollachius pollachius (L.)	0	2	1	0	1	4
?Pollachius virens (L.)	0	1	1	1	1	4
Pollachius virens (L.)	0	7	3	2	2	14
?Gadus morhua L.	0	0	0	0	2	2
Gadus morhua L.	1	45	28	13	23	110
Melanogrammus aeglefinus (L.)	0	4	1	2	0	7
Brosme brosme (Ascanius)	0	2	0	0	0	2
?Molva cf. molva (L.)	0	0	0	0	1	1
Molva cf. molva (L.)	0	15	19	10	12	56
Raniceps raninus (L.)	0	1	0	0	2	3
Ciliata sp.	0	1	0	0	0	1
Pleuronectidae	0	1	0	0	0	1

Table 32. Identified fish remains ascribed to level 22 (late Norse).

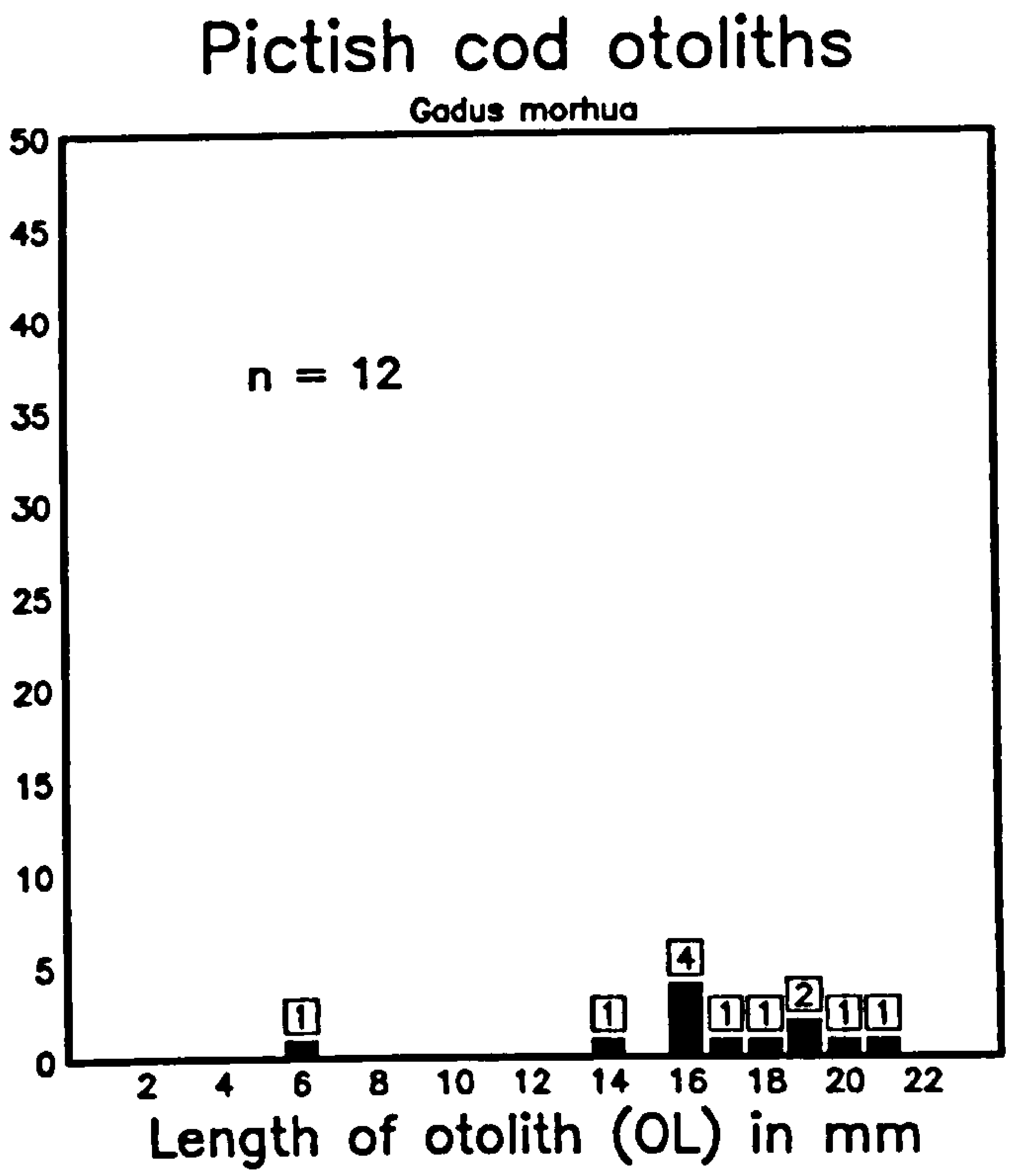
Taxon	Element	Number of fragments
Clupea harengus L.		
	vertebral centrum (abdominal)	2
Anguilla anguilla (L.)		
	vertebral centrum (caudal)	2
Conger conger (L.)		
	vertebral centrum (abdominal)	2
?Gadidae		
	otolith	1
Gadidae		
	cleithrum	5
	otolith	7
Trisopterus sp.		
	otolith	1
Pollachius or Gadus sp.		
	cleithrum	1
	premaxilla	1
?Pollachius pollachius (L.)		
	otolith	1
	premaxilla	1
Pollachius pollachius (L.)		
	dentary	3
?Pollachius virens (L.)		
	ceratohyal	3
	dentary	1
	otolith	60
	premaxilla	4
Pollachius virens (L.)		
	dentary	9
	premaxilla	2
?Gadus morhua L.		
	cleithrum	1
	otolith	2
Gadus morhua L.		
	dentary	11
	otolith	23
	premaxilla	22
?Melanogrammus aeglefinus (L.)		
	otolith	3
Melanogrammus aeglefinus (L.)		
	cleithrum	2
	dentary	1
?Molva cf. molva (L.)		
	cleithrum	1
	premaxilla	2

Table 32 (cont.). Identified fish remains from deposits ascribed to Level 22 (Late Norse) at Freswick Links

Molva cf. molva (L.)		
	cleithrum	2
	dentary	5
	otolith	9
	premaxilla	13
	vertebral centrum (caudal)	1
Ciliata sp.		
	premaxilla	1
Triglidae		
	indeterminate fragment	1
	vertebral centrum (caudal)	1
Eutrigla gurnardus (L.)		
	premaxilla	1
Lepidorhombus whiffiagonis (Walbaum)		
	cleithrum	1
?Pleuronectidae		
	ultimate vertebra	1
Pleuronectidae		
	vertebral centrum (abdominal)	2
	vertebral centrum (caudal)	4
?Lophius piscatorius L.		
	tooth	1

Table 33. Numbers and condition of cleithra, dentaries, otoliths and premaxillae from level 22 (Late Norse).

	Condition 1	2	3	4	5	Tot
CLEITHRUM						
Gadidae	0	0	0	0	5	5
Pollachius or Gadus sp.	0	0	0	0	1	1
?Gadus morhua L.	0	0	1	0	0	1
Melanogrammus aeglefinus (L.)	0	0	1	1	0	2
?Molva cf. molva (L.)	0	0	0	1	0	1
Molva cf. molva (L.)	0	0	1	1	0	2
Lepidorhombus whiffiagonis (Walbaum)	0	0	0	1	0	1
DENTARY						
Pollachius pollachius (L.)	0	0	0	1	2	3
?Pollachius virens (L.)	0	0	0	0	1	1
Pollachius virens (L.)	0	3	3	0	3	9
Gadus morhua L.	0	0	1	2	8	11
Melanogrammus aeglefinus (L.)	0	1	0	0	0	1
Molva cf. molva (L.)	0	1	0	1	3	5
OTOLITH						
?Gadidae	0	0	0	1	0	1
Gadidae	0	1	0	0	6	7
Trisopterus sp.	1	0	0	0	0	1
?Pollachius pollachius (L.)	1	0	0	0	0	1
?Pollachius virens (L.)	14	24	9	9	4	60
?Gadus morhua L.	1	0	1	0	0	2
Gadus morhua L.	7	1	7	3	5	23
?Melanogrammus aeglefinus (L.)	0	1	2	0	0	3
Molva cf. molva (L.)	3	0	3	1	2	9
PREMAXILLA						
Pollachius or Gadus sp.	0	0	1	0	0	1
?Pollachius pollachius (L.)	0	0	0	1	0	1
?Pollachius virens (L.)	0	0	1	1	2	4
Pollachius virens (L.)	1	1	0	0	0	2
Gadus morhua L.	0	6	4	4	8	22
?Molva cf. molva (L.)	0	0	0	0	2	2
Molva cf. molva (L.)	0	5	3	1	4	13
Ciliata sp.	0	1	0	0	0	1
Eutrigla gurnardus (L.)	0	1	0	0	0	1



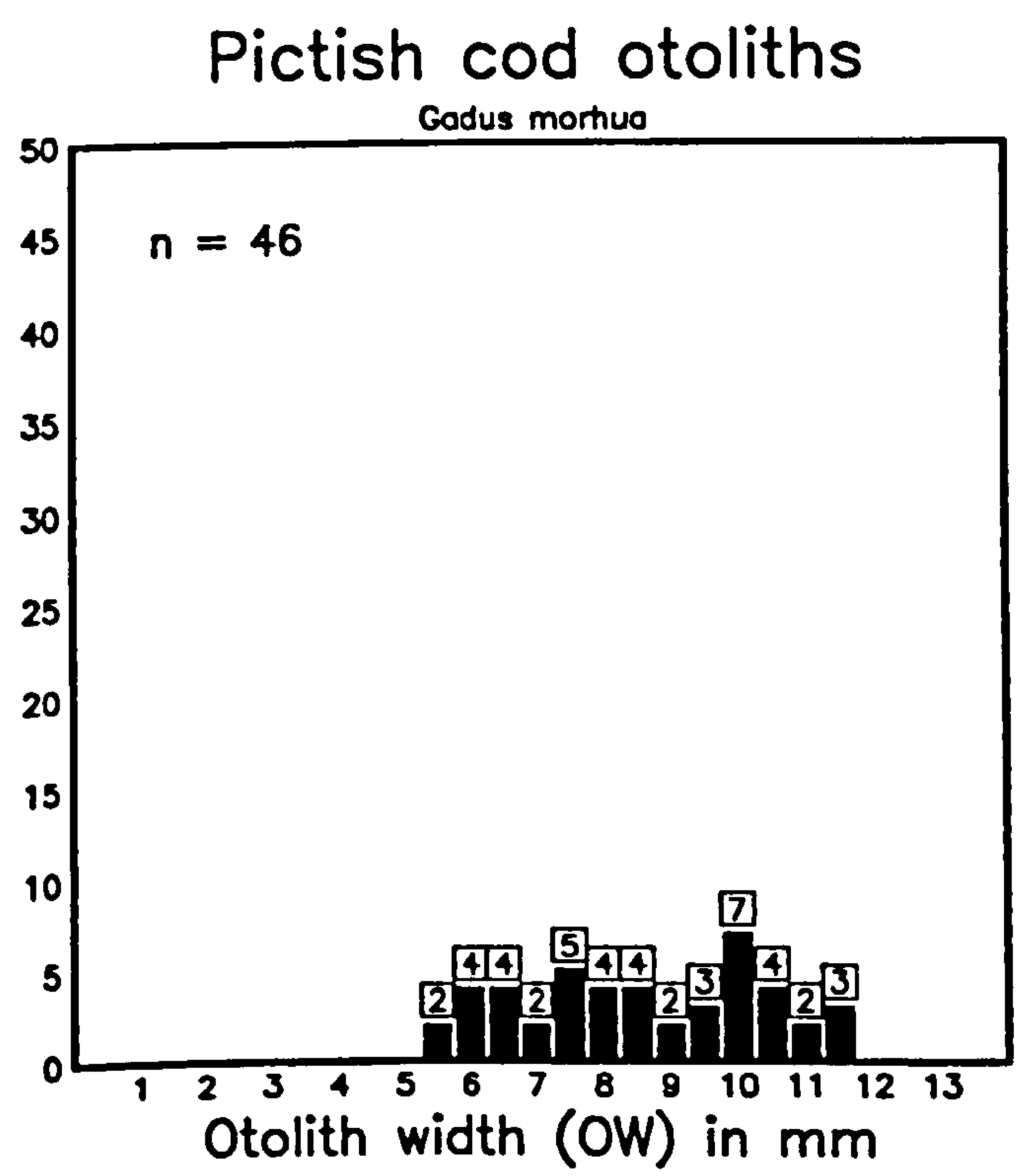
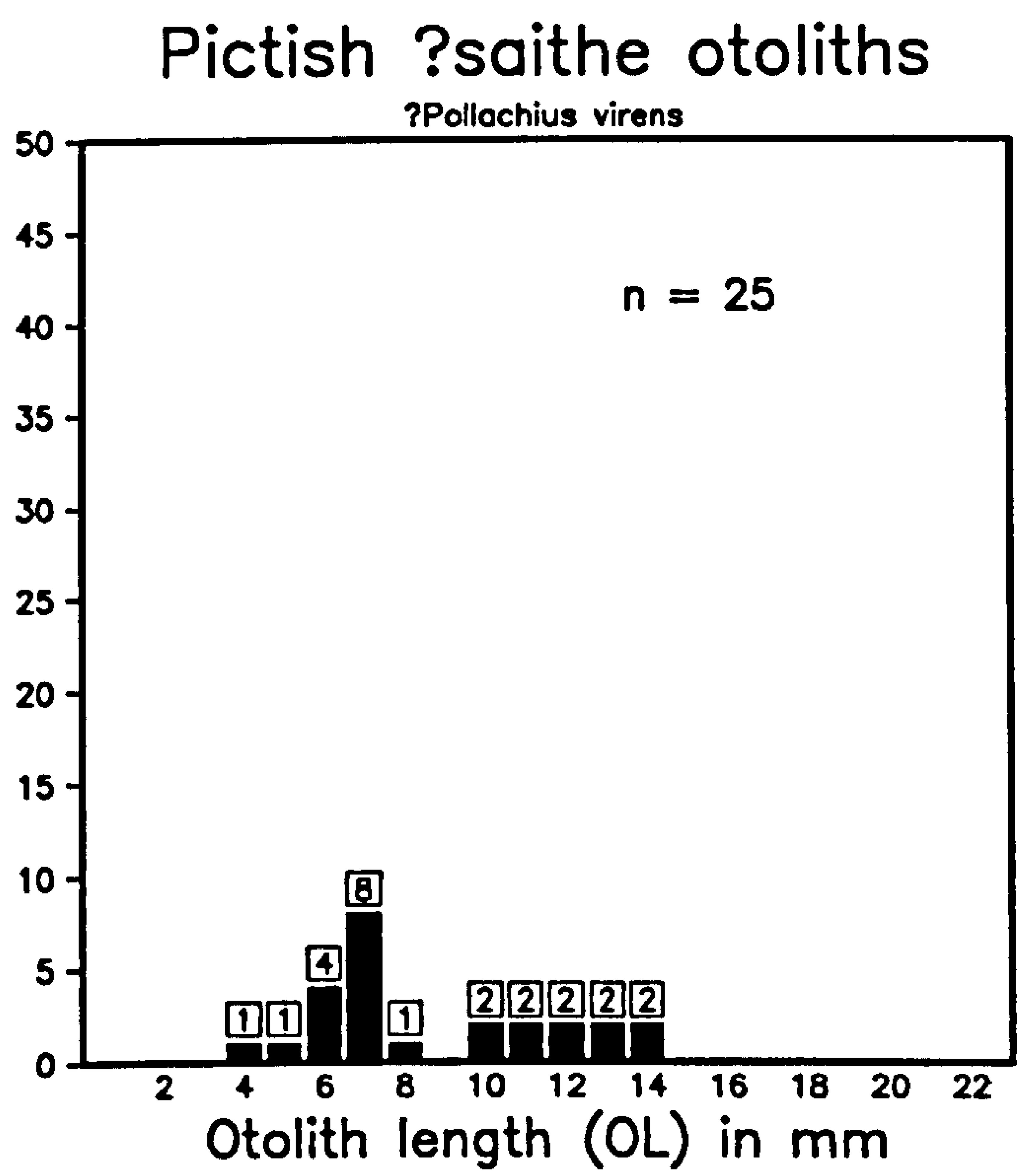


Figure 78. Histograms of measurements on cod otoliths from Pictish levels.



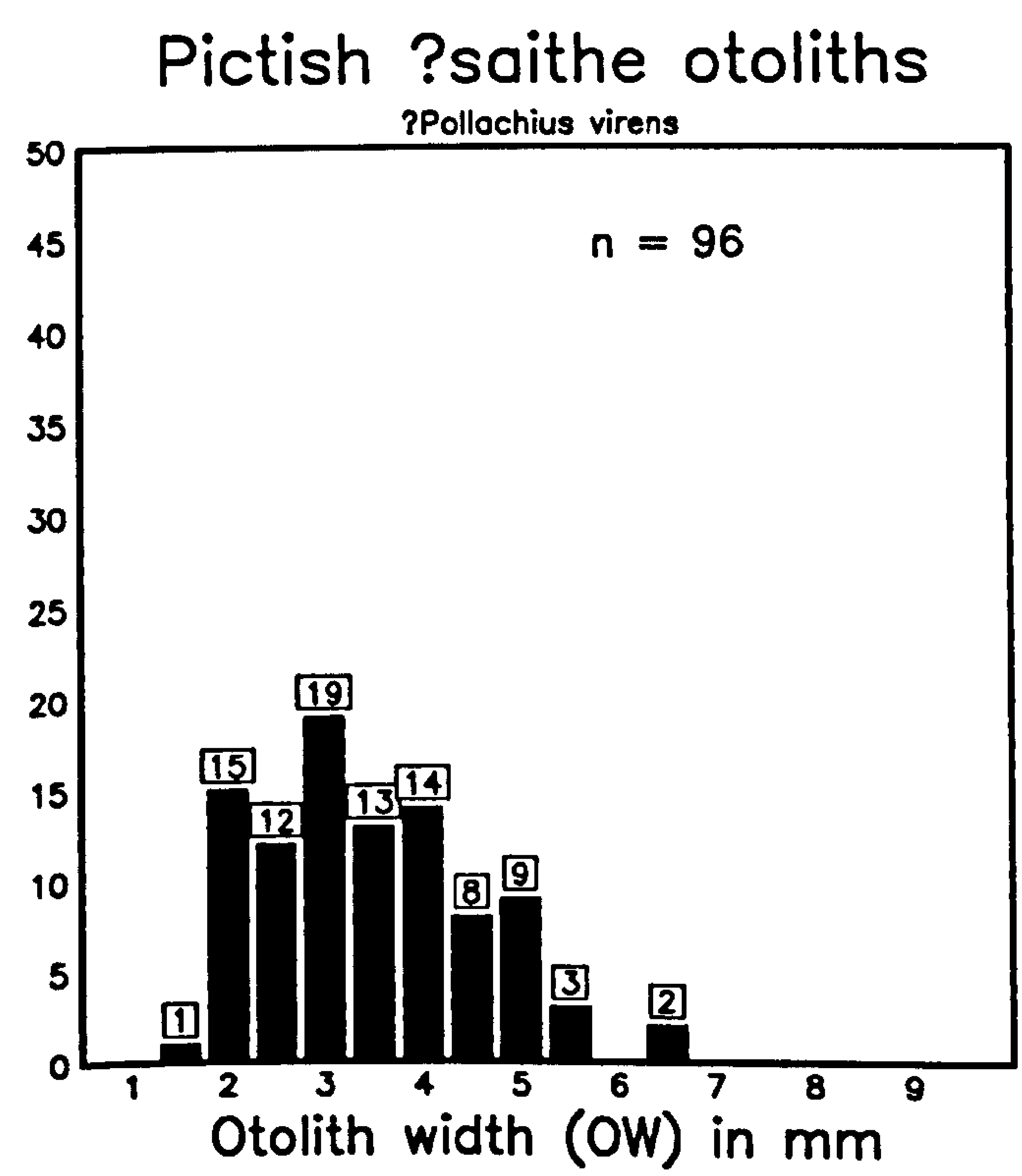


Figure 79. Histograms of measurements of ?saithe otoliths from Pictish levels.

6.4.2 The Kinds and Distribution of Fish Remains in Different Areas of Excavation

The fish remains recovered from levels dated to periods of Norse occupation in Areas 2a and 2b, 3, 4 and 9 were selected for close scrutiny. Details of the remains recovered from these areas are presented in Tables 34-41.

Table 34. Identified fish remains from Areas 2a and 2b Freswick Links

Taxon	Element	Number of fragments
?Raja clavata		
	tooth	1
Clupeidae		
	otic bulla	1
Clupea harengus L.		
	vertebral centrum (abdominal)	1
Anguilla anguilla (L.)		
	vertebral centrum (caudal)	1
Conger conger (L.)		
	dentary	1
?Belone belone (L.)		
	vertebral centrum (abdominal)	4
?Gadidae		
	otolith	1
Gadidae		
	cleithrum	7
	dentary	15
	otolith	16
	premaxilla	15
Pollachius or Gadus sp.		
	cleithrum	1
Pollachius pollachius (L.)		
	dentary	1
?Pollachius virens (L.)		
	dentary	1
	otolith	21
	premaxilla	9
Pollachius virens (L.)		
	dentary	3
	premaxilla	3
?Gadus morhua L.		
	cleithrum	3
	dentary	8
	premaxilla	4
Gadus morhua L.		
	cleithrum	2
	dentary	51
	otolith	91
	premaxilla	91
?Melanogrammus aeglefinus (L.)		
	otolith	1
?Molva cf. molva		
	premaxilla	1
Molva cf. molva		
	otolith	2
	premaxilla	2
Raniceps raninus (L.)		
	premaxilla	1

Table 34. (cont.). Identified fish remains from Areas 2a and 2b Freswick Links

Trachurus trachurus (L.)		
	vertebral centrum (abdominal)	2
?Scomber scombrus L.		
	vertebral centrum (caudal)	1
Triglidae		
	indeterminate fragment	22
	scute	17
	spine	7
	vertebral centrum (abdominal)	2
	vertebral centrum (caudal)	26
?Eutrigla gurnardus (L.)		
	cleithrum	1
Eutrigla gurnardus (L.)		
	basipterygium	1
	ceratohyal	1
	cleithrum	1
	dentary	1
	hyomandibular	1
	opercular	2
	parasphenoid	1
	premaxilla	2
?Taurulus bubalis (Euphrasen)		
	vertebral centrum (caudal)	1
Taurulus bubalis (Euphrasen)		
	dentary	2
	preopercular	1
?Pleuronectidae		
	vertebral centrum (caudal)	1
Pleuronectidae		
	vertebral centrum (caudal)	3
?Hippoglossus hippoglossus (L.)		
	vertebral centrum (abdominal)	1
	vertebral centrum (caudal)	1

Table 35. Condition of cleithra, dentaries, otoliths and premaxillae from Areas 2a and 2b, Freswick Links.

	Condition 1	2	3	4	5	Tot
CLEITHRUM						
Gadidae	0	0	0	0	7	7
Pollachius or Gadus sp.	0	0	0	0	1	1
?Gadus morhua L.	0	0	0	0	3	3
Gadus morhua L.	0	0	0	1	1	2
?Eutrigla gurnardus (L.)	0	0	0	0	1	1
Eutrigla gurnardus (L.)	0	0	1	0	0	1
DENTARY						
Conger conger (L.)	0	0	1	0	0	1
Gadidae	0	0	0	0	15	15
Pollachius pollachius (L.)	0	0	0	0	1	1
?Pollachius virens (L.)	0	0	1	0	0	1
Pollachius virens (L.)	0	0	0	0	3	3
?Gadus morhua L.	0	0	0	0	8	8
Gadus morhua L.	0	5	8	10	28	51
Eutrigla gurnardus (L.)	0	0	1	0	0	1
Taurulus bubalis (Euphrasen)	0	0	0	0	2	2
OTOLITH						
?Gadidae	0	0	1	0	0	1
Gadidae	0	0	0	0	16	16
?Pollachius virens (L.)	4	5	4	4	4	21
Gadus morhua L.	12	39	18	15	7	91
?Melanogrammus aeglefinus (L.)	0	1	0	0	0	1
Molva cf. molva (L.)	0	0	2	0	0	2
PREMAXILLA						
Gadidae	0	0	0	2	13	15
?Pollachius virens (L.)	0	0	0	4	5	9
Pollachius virens (L.)	0	1	1	0	1	3
?Gadus morhua L.	0	1	0	0	3	4
Gadus morhua L.	0	25	24	23	19	91
?Molva cf. molva (L.)	0	0	0	0	1	1
Molva cf. molva (L.)	0	0	0	1	1	2
Raniceps raninus (L.)	0	0	0	0	1	1
Eutrigla gurnardus (L.)	0	0	1	0	1	2

Table 36. Identified fish remains from Area 3 Freswick Links.

Taxon	Element	Number of fragments
Scyliorhinidae		
	mineralized core of vertebral centrum	1
?Clupea harengus L.		
	vertebral centrum	1
Clupea harengus L.		
	otic bulla	1
Salmonidae		
	vertebral centrum	3
Gadidae		
	articular	2
	ceratohyal	2
	cranial bone	400
	dentary	1
	ectopterygoid	1
	indeterminate fragment	190
	maxilla	2
	otolith	24
	palatine	1
	post temporal	2
	prevomer	1
	quadrate	4
	supracleithrum	1
	vertebral centrum	252
	vertebral centrum (abdominal)	14
	vertebral centrum (caudal)	13
Trisopterus sp.		
	otolith	3
Pollachius or Gadus sp.		
	infrapharyngeal	1
?Pollachius virens (L.)		
	ceratohyal	1
	maxilla	1
	otolith	41
	supracleithrum	1
	vertebral centrum	18
Pollachius virens (L.)		
	maxilla	1
?Gadus morhua L.		
	otolith	3
	post temporal	1

Table 36 (cont.). Identified fish remains from Area 3 Freswick Links

Gadus morhua L.		
	articular	20
	basioccipital	2
	ceratohyal	8
	cleithrum	1
	cranial bone	25
	dentary	16
	epihyal	1
	maxilla	27
	opercular	1
	otolith	67
	parasphenoid	6
	post temporal	7
	premaxilla	59
	prevomer	15
	quadrate	7
	supracleithrum	5
	vertebral centrum	141
	vertebral centrum (abdominal)	33
?Melanogrammus aeglefinus (L.)		
	otolith	1
Melanogrammus aeglefinus (L.)		
	cleithrum	1
	otolith	1
	vertebral centrum (abdominal)	1
?Molva cf. molva		
	otolith	1
Molva cf. molva		
	cleithrum	1
	otolith	1
Trachurus trachurus (L.)		
	vertebral centrum	5
	vertebral centrum (caudal)	4
Labridae		
	tooth	1
Scomber scombrus L.		
	vertebral centrum	1
Triglidae		
	vertebral centrum	1
?Taurulus bubalis (Euphrasen)		
	vertebral centrum	1
Pleuronectidae		
	maxilla	1
	vertebral centrum (caudal)	6

Table 37. Numbers and condition of bones and otoliths from Area 3, Freswick Links.

	Condition 1	2	3	4	5	Tot
ARTICULAR						
Gadidae	0	0	0	0	2	2
Gadus morhua L.	0	0	4	8	8	20
BASIOCCIPITAL						
Gadus morhua L.	0	0	0	1	1	2
CERATOHYAL						
Gadidae	0	0	0	0	2	2
?Pollachius virens (L.)	0	0	1	0	0	1
Gadus morhua L.	0	0	5	3	0	8
CLEITHRUM						
Gadus morhua L.	0	0	0	0	1	1
Melanogrammus aeglefinus (L.)	0	1	0	0	0	1
Molva cf. molva (L.)	0	0	0	0	1	1
DENTARY						
Gadidae	0	0	0	0	1	1
Gadus morhua L.	0	0	0	3	13	16
EPIHYAL						
Gadus morhua L.	0	0	0	1	0	1
ECTOPTERYGOID						
Gadidae	0	0	0	1	0	1
MAXILLA						
Gadidae	0	0	1	0	1	2
?Pollachius virens (L.)	0	0	0	1	0	1
Pollachius virens (L.)	0	0	1	0	0	1
Gadus morhua L.	0	0	8	15	4	27
Pleuronectidae	0	0	0	0	0	1
MINERALIZED CORE OF VERTEBRAL CENTRUM						
Scyliorhinidae	0	1	0	0	0	1
OPERCULAR						
Gadus morhua L.	0	0	0	0	1	1

Table 37 (cont.). Condition of bones and otoliths from Area 3

OTIC BULLA						
Clupea harengus L.	0	0	1	0	0	1
OTOLITH						
Gadidae	1	5	1	1	16	24
Trisopterus sp.	3	0	0	0	0	3
?Pollachius virens (L.)	5	23	4	2	7	41
?Gadus morhua L.	0	0	0	0	3	3
Gadus morhua L.	37	11	9	3	7	67
?Melanogrammus aeglefinus (L.)	0	0	0	1	1	2
?Molva cf. molva (L.)	0	0	1	0	0	1
Molva cf. molva (L.)	0	0	0	0	1	1
PALATINE						
Gadidae	0	0	0	0	1	1
PARASPHENOID						
Gadus morhua L.	0	0	0	3	3	6
POST TEMPORAL						
Gadidae	0	0	0	0	2	2
?Gadus morhua L.	0	0	0	1	0	1
Gadus morhua L.	0	0	1	2	4	7
PREVOMER						
Gadidae	0	0	0	0	0	1
Gadus morhua L.	0	0	2	5	8	15
PREMAXILLA						
Gadus morhua L.	0	5	16	10	28	59
QUADRATE						
Gadidae	0	0	0	0	4	4
Gadus morhua L.	0	0	0	3	4	7
SUPRACLEITHRUM						
Gadidae	0	0	0	1	0	1
?Pollachius virens (L.)	0	0	1	0	0	1
Gadus morhua L.	0	1	1	3	0	5

Table 37 (cont.). Condition of bones and otoliths from Area 3

TOOTH						
Labridae	0	1	0	0	0	1
VERTEBRAL CENTRUM (ABDOMINAL)						
Gadidae	0	7	5	0	2	14
Gadus morhua L.	0	31	2	0	0	33
Melanogrammus aeglefinus (L.)	0	1	0	0	0	1
VERTEBRAL CENTRUM (CAUDAL)						
Gadidae	0	8	2	3	0	13
Trachurus trachurus (L.)	0	4	0	0	0	4
Pleuronectidae	0	5	0	0	1	6
VERTEBRAL CENTRUM						
?Clupea harengus L.	0	2	0	0	0	1
Salmonidae	0	3	0	0	0	3
Gadidae	0	27	25	89	111	252
?Pollachius virens (L.)	0	9	8	1	0	18
Gadus morhua L.	0	31	30	64	16	141
Trachurus trachurus (L.)	0	5	0	0	0	5
Scomber scombrus L.	0	0	0	0	1	1
Triglidae	0	0	1	0	0	1
?Taurulus bubalis (Euphrasen)	0	1	0	0	0	1

Table 38. Identified fish remains from Area 4, Freswick Links.

Taxon	Element	Number of fragments
Clupea harengus L.		
	vertebral centrum (abdominal)	4
Anguilla anguilla (L.)		
	vertebral centrum (caudal)	4
Conger conger (L.)		
	dentary	1
	vertebral centrum	1
	vertebral centrum (abdominal)	19
	vertebral centrum (caudal)	6
Belone belone (L.)		
	vertebral centrum (abdominal)	5
Merluccius merluccius (L.)		
	premaxilla	1
?Gadidae		
	otolith	1
Gadidae		
	cleithrum	33
	dentary	3
	otolith	76
	premaxilla	11
?Merlangius merlangus (L.)		
	otolith	1
Trisopterus sp.		
	otolith	1
Pollachius or Gadus sp.		
	cleithrum	15
	premaxilla	2
Pollachius sp.		
	premaxilla	3
?Pollachius pollachius (L.)		
	otolith	1
	premaxilla	1
Pollachius pollachius (L.)		
	dentary	9
	premaxilla	4
?Pollachius virens (L.)		
	dentary	1
	otolith	221
	premaxilla	7
Pollachius virens (L.)		
	dentary	25
	premaxilla	13
?Gadus morhua L.		
	cleithrum	7
	dentary	1
	otolith	4
	premaxilla	2

Table 38 (cont.) Identified fish remains from Area 4 Freswick Links

Gadus morhua L.		
	cleithrum	5
	dentary	74
	otolith	118
	premaxilla	92
?Melanogrammus aeglefinus (L.)		
	otolith	1
Melanogrammus aeglefinus (L.)		
	cleithrum	16
	dentary	4
	otolith	7
	premaxilla	7
Brosme brosme (Ascanius)		
	maxilla	1
	premaxilla	2
?Molva cf. molva (L.)		
	cleithrum	1
	premaxilla	2
Molva cf. molva (L.)		
	cleithrum	48
	dentary	57
	otolith	52
	premaxilla	63
Raniceps raninus (L.)		
	dentary	1
	premaxilla	3
Ciliata/Gaidropsarus		
	cleithrum	1
Ciliata sp.		
	dentary	1
	premaxilla	2
Dicentrarchus labrax (L.)		
	vertebral centrum (caudal)	1
?Spondyliosoma cantharus (L.)		
	vertebral centrum (abdominal)	2
?Labridae		
	vertebral centrum (caudal)	1
Labridae		
	pharyngeal bone	1
Labrus bimaculatus L.		
	suprapharyngeal	1
?Labrus bergylta Ascanius		
	suprapharyngeal	1
Scomber scombrus L.		
	vertebral centrum (caudal)	1
?Anarhichas lupus		
	tooth	21

Table 38 (cont.) Identified fish remains from Area 4 Freswick Links

Triglidae		
	indeterminate fragment	1
	scute	1
	vertebral centrum (caudal)	1
Eutrigla gurnardus (L.)		
	premaxilla	1
Taurulus bubalis (Euphrasen)		
	preopercular	2
Zeugopterus punctatus (Bloch)		
	articular	1
	dentary	1
	ectopterygoid	1
	quadrate	1
Lepidorhombus whiffiagonis (Walbaum)		
	cleithrum	1
	dentary	1
	vertebral centrum (caudal)	4
?Pleuronectidae		
	ultimate vertebra	1
Pleuronectidae		
	otolith	1
	vertebral centrum (abdominal)	3
	vertebral centrum (caudal)	35
?Lophius piscatorius L.		
	tooth	1

Table 39. Number and condition of cleithra, dentaries, otoliths and premaxillae from Area 4, Freswick Links.

	Condition 1	2	3	4	5	Tot
CLEITHRA						
Gadidae	0	2	2	2	27	33
Pollachius or Gadus sp.	0	0	1	4	10	15
?Gadus morhua L.	0	1	1	1	4	7
Gadus morhua L.	0	0	3	2	0	5
Melanogrammus aeglefinus (L.)	0	2	9	5	0	16
?Molva cf. molva (L.)	0	0	0	1	0	1
Molva cf. molva (L.)	0	0	16	10	22	48
Ciliata/Gaidropsarus	0	1	0	0	0	1
Lepidorhombus whiffiagonis (Walbaum)	0	0	0	1	0	1
DENTARIES						
Conger conger (L.)	0	0	0	1	0	1
Gadidae	0	0	0	0	3	3
Pollachius pollachius (L.)	0	1	2	1	5	9
?Pollachius virens (L.)	0	0	0	0	1	1
Pollachius virens (L.)	0	9	4	1	11	25
?Gadus morhua L.	0	0	0	0	1	1
Gadus morhua L.	0	9	13	16	36	74
Melanogrammus aeglefinus (L.)	0	2	2	0	0	4
Molva cf. molva (L.)	0	5	11	4	37	57
Raniceps raninus (L.)	0	0	1	0	0	1
Ciliata sp.	0	1	0	0	0	1
Zeugopterus punctatus (Bloch)	0	1	0	0	0	1
Lepidorhombus whiffiagonis (Walbaum)	0	0	1	0	0	1
OTOLITHS						
?Gadidae	0	0	0	1	0	1
Gadidae	1	2	0	5	68	76
?Merlangius merlangus (L.)	0	1	0	0	0	1
Trisopterus sp.	1	0	0	0	0	1
?Pollachius pollachius (L.)	1	0	0	0	0	1
?Pollachius virens (L.)	57	81	42	27	14	221
?Gadus morhua L.	1	0	1	1	1	4
Gadus morhua L.	37	27	26	13	15	118
?Melanogrammus aeglefinus (L.)	0	2	5	1	0	8
Molva cf. molva (L.)	10	9	20	9	4	52
Pleuronectidae	1	0	0	0	0	1

Table 39 (cont.). The numbers of cleithra, dentaries, premaxillae and otoliths fragments Area 4 from Freswick Links and their degree of completeness.

PREMAXILLAE

Merluccius merluccius (L.)	0	0	1	0	0	1
Gadidae	0	1	0	1	9	11
Pollachius or Gadus sp.	0	0	1	0	1	2
Pollachius sp.	0	0	1	0	2	3
?Pollachius pollachius (L.)	0	0	0	1	0	1
Pollachius pollachius (L.)	0	1	1	0	2	4
?Pollachius virens (L.)	0	0	2	2	3	7
Pollachius virens (L.)	1	6	3	1	2	13
?Gadus morhua L.	0	0	0	0	2	2
Gadus morhua L.	0	37	25	13	17	92
Melanogrammus aeglefinus (L.)	0	4	1	2	0	7
Brosme brosme (Ascanius)	0	2	0	0	0	2
?Molva cf. molva (L.)	0	0	0	0	2	2
Molva cf. molva (L.)	0	20	19	10	14	63
Raniceps raninus (L.)	0	1	0	0	2	3
Ciliata sp.	0	2	0	0	0	2
Eutrigla gurnardus (L.)	0	1	0	0	0	1

Table 40. Identified fish remains from Area 9, Freswick Links.

Taxon	Element	Number of fragments
Salmonidae		
	vertebral centrum (caudal)	1
?Anguilla anguilla (L.)		
	vertebral centrum (caudal)	1
Gadidae		
	cleithrum	1
	hyomandibular	1
	infrapharyngeal	1
	otolith	2
	parasphenoid	1
	premaxilla	1
	quadrate	1
	vertebral centrum	50
	vertebral centrum (abdominal)	1
	vertebral centrum (caudal)	8
?Trisopterus sp.		
	otolith	1
Pollachius sp.		
	parasphenoid	1
?Pollachius virens (L.)		
	basioccipital	1
	otolith	3
	palatine	1
	vertebra (no 1)	2
	vertebral centrum (abdominal)	7
	vertebral centrum (caudal)	1
Pollachius virens (L.)		
-	articular	1
	maxilla	1
	quadrate	1
	vertebra (no 1)	1
	vertebral centrum	3
	vertebral centrum (abdominal)	6
	vertebral centrum (caudal)	2
?Gadus morhua L.		
	post temporal	1
Gadus morhua L.		
	ceratohyal	1
	dentary	3
	otolith	6
	parasphenoid	1
	premaxilla	3
	quadrate	1
	vertebral centrum	4
	vertebral centrum (abdominal)	7
	vertebral centrum (caudal)	2
?Melanogrammus aeglefinus (L.)		
	otolith	2

Table 40 (cont.) Identified fish remains from Area 9 Freswick Links

Melanogrammus aeglefinus (L.)		
	basioccipital	1
	cleithrum	1
	maxilla	2
	post temporal	1
	premaxilla	2
	supracleithrum	1
	vertebra (no 1)	1
	vertebral centrum (abdominal)	3
?Molva cf. molva (L.)		
	dentary	1
	epihyal	2
	premaxilla	1
Molva cf. molva (L.)		
	basioccipital	1
	ceratohyal	1
	dentary	5
	hyomandibular	1
	maxilla	2
	parasphenoid	1
	premaxilla	4
	preopercular	2
	prevomer	2
	vertebral centrum	1
	vertebral centrum (abdominal)	1
	vertebral centrum (caudal)	1
?Hyperoplus lanceolatus (Le Sauvage)		
	vertebral centrum	2
Pleuronectidae		
	vertebral centrum (caudal)	2

Table 41. Numbers and condition of bones and otoliths from Area 9, Freswick Links.

	Condition 1	2	3	4	5	Tot
ARTICULAR						
Pollachius virens (L.)	0	0	1	0	0	1
BASIOCCIPITAL						
?Pollachius virens (L.)	0	0	1	0	0	1
Melanogrammus aeglefinus (L.)	0	1	0	0	0	1
Molva cf. molva (L.)	0	1	0	0	0	1
CERATOHYAL						
Gadus morhua L.	0	0	0	0	1	1
Molva cf. molva (L.)	0	1	0	0	0	1
CLEITHRUM						
Gadidae	0	0	0	0	1	1
Melanogrammus aeglefinus (L.)	0	0	1	0	0	1
DENTARY						
Gadus morhua L.	0	1	0	0	2	3
?Molva cf. molva (L.)	0	0	0	0	1	1
Molva cf. molva (L.)	0	1	0	0	4	5
EPIHYAL						
?Molva cf. molva (L.)	0	1	1	0	0	2
HYOMANDIBULAR						
Gadidae	0	0	0	1	0	1
Molva cf. molva (L.)	0	1	0	0	0	1
INFRAPHARYNGEAL						
Gadidae	0	1	0	0	0	1
MAXILLA						
Pollachius virens (L.)	0	1	0	0	0	1
Melanogrammus aeglefinus (L.)	0	2	0	0	0	2
Molva cf. molva (L.)	0	0	1	0	1	2

Table 41 (cont.). Condition of bones and otoliths from Area 9

OTOLITH						
Gadidae	0	0	0	0	2	2
?Trisopterus sp.	1	0	0	0	0	1
?Pollachius virens (L.)	0	2	0	1	0	3
Gadus morhua L.	3	1	1	0	1	6
?Melanogrammus aeglefinus (L.)	1	1	0	0	0	2
PALATINE						
?Pollachius virens (L.)	0	1	0	0	0	1
PARASPHENOID						
Gadidae	0	0	1	0	0	1
Pollachius sp.	0	0	1	0	0	1
Gadus morhua L.	0	0	1	0	0	1
Molva cf. molva (L.)	0	0	1	0	0	1
PREOPERCULAR						
Molva cf. molva (L.)	0	2	0	0	0	2
POSTEMPORAL						
?Gadus morhua L.	0	0	0	0	1	1
Melanogrammus aeglefinus (L.)	0	1	0	0	0	1
PREVOMER						
Molva cf. molva (L.)	0	0	2	0	0	2
PREMAXILLA						
Gadidae	0	0	0	0	1	1
Gadus morhua L.	0	0	2	0	1	3
Melanogrammus aeglefinus (L.)	0	2	0	0	0	2
?Molva cf. molva (L.)	0	0	0	1	0	1
Molva cf. molva (L.)	0	1	2	0	1	4
QUADRATE						
Gadidae	0	0	0	0	1	1
Pollachius virens (L.)	0	1	0	0	0	1
Gadus morhua L.	0	0	0	1	0	1
SUPRACLEITHRUM						
Melanogrammus aeglefinus (L.)	0	1	0	0	0	1

Table 41 (cont.). Condition of bones and otoliths from Area 9

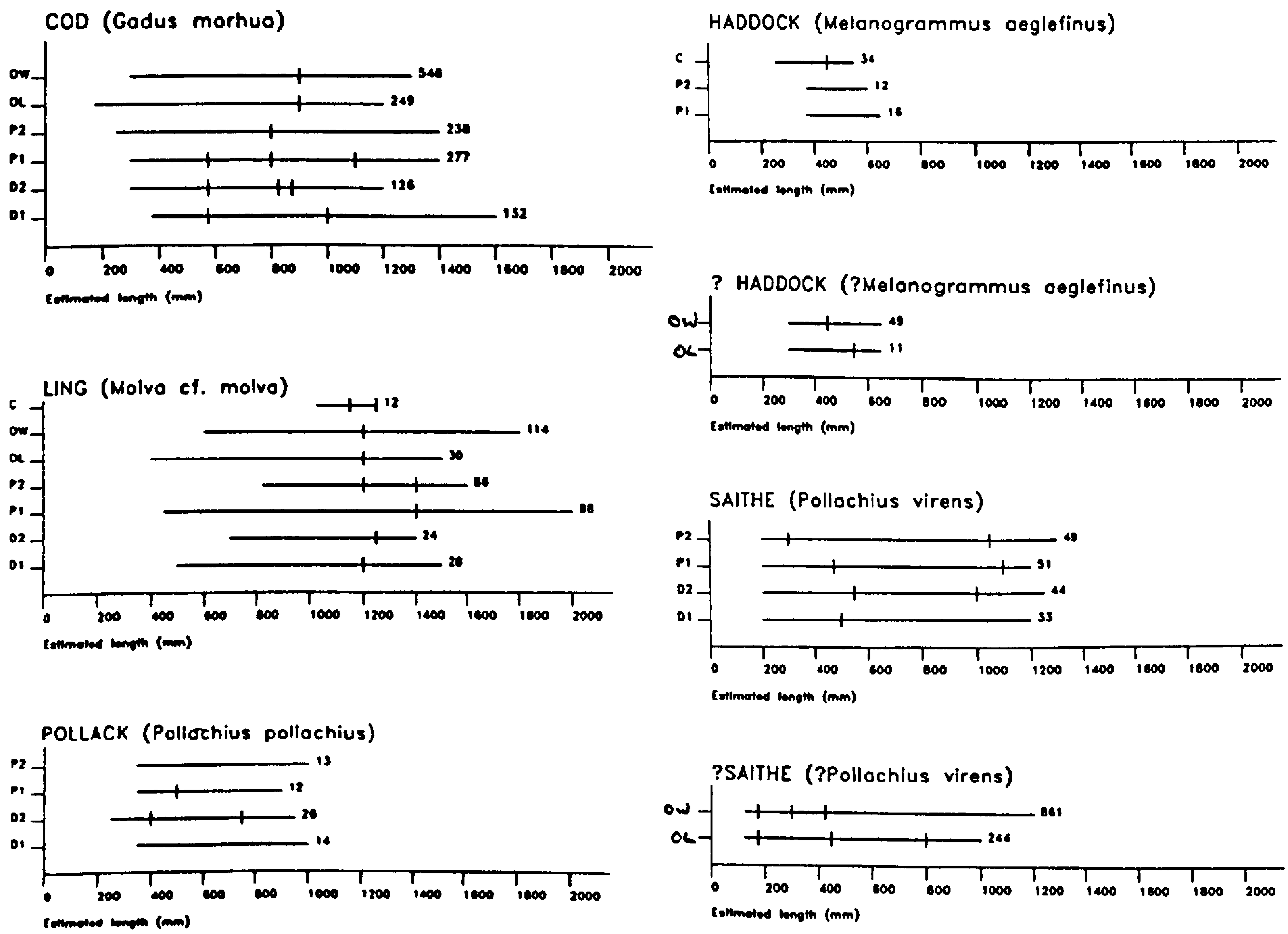
VERTEBRA (NO 1)						
?Pollachius virens (L.)	0	2	0	0	0	2
Pollachius virens (L.)	0	1	0	0	0	1
Melanogrammus aeglefinus (L.)	0	1	0	0	0	1
VERTEBRAL CENTRUM (ABDOMINAL)						
Gadidae	0	1	0	0	0	1
?Pollachius virens (L.)	0	6	1	0	0	7
Pollachius virens (L.)	0	5	0	1	0	6
Gadus morhua L.	0	7	0	0	0	7
Melanogrammus aeglefinus (L.)	0	3	0	0	0	3
Molva cf. molva (L.)	0	1	0	0	0	1
VERTEBRAL CENTRUM (CAUDAL)						
Salmonidae	0	1	0	0	0	1
?Anguilla anguilla (L.)	0	1	0	0	0	1
Gadidae	0	6	2	0	0	8
?Pollachius virens (L.)	0	0	1	0	0	1
Pollachius virens (L.)	0	0	1	1	0	2
Gadus morhua L.	0	2	0	0	0	2
Molva cf. molva (L.)	0	0	1	0	0	1
Pleuronectidae	0	2	0	0	0	2
VERTEBRAL CENTRUM						
Gadidae	0	9	0	0	41	50
Pollachius virens (L.)	0	3	0	0	0	3
Gadus morhua L.	0	4	0	0	0	4
Molva cf. molva (L.)	0	0	0	0	1	1
?Hyperoplus lanceolatus (Le Sauvage)	0	2	0	0	0	2

6.5 THE SIZES OF THE FISHES AS INDICATED BY MEASUREMENTS

Measurements of cleithra, dentaries, otoliths and premaxillae were recorded in order to investigate the size of the fishes present at Freswick Links. The illustrations presented in Chapter 4 were used to assess the size of the animals from their remains. In this section all the measurable bones recovered from the site are considered together. The estimates of fish size are based upon Figures 43-64 and are estimates of the fitted values.

The sizes of fish as determined from otolith and different bone measurements vary according to which measurement is considered. The most numerous cod element, the otolith, shows that fishes ranging from roughly 300-1300 mm total length were present. The distribution of otolith width measurements is unimodal and shows a roughly normal distribution. The distribution of otolith length measurements is strongly skewed in favour of large individuals with a peak for individuals approximately 900 mm total length. The dentary and premaxilla measurements give a slightly different picture of the sizes of the cod (see Figure 80).

Figure 80. Reconstruction of the total length of major gadid fishes based on measurements of cleithra, dentaries, otoliths and premaxillae. Each horizontal line shows the range of length of animals represented in deposits. The vertical bars mark peaks in measurement distribution. The numbers are the number of measured specimens.



6.6 AN INVESTIGATION ON COD AND SAITHE OTOLITHS TO DETERMINE AGE AND SEASON OF DEATH

The otoliths of teleosts are part of the paired labyrinth system enveloped in cranial bones and located near the brain and are connected with the perception of sound, vibrations and positional changes. Otoliths are composed mainly of needle-shaped crystals of calcium carbonate radiating in three dimensions from a nucleus and passing through a network of organic material (Williams and Bedford, 1974).

Otoliths of modern teleosts usually show clear banding when broken cleanly or sectioned. This feature of otoliths has been extensively studied by fisheries biologists and others and is now well understood. In the early life of a fish an opaque zone is laid down during the period of the year when the fish is growing rapidly. This usually wide zone appears white in reflected light and dark in transmitted light. During the period of slow growth a narrow hyaline band is formed. This appears dark in reflected light and pale in transmitted light. With successive years growth the opaque bands progressively become more narrow while the hyaline bands remains approximately the same width. In very old fish the opaque and hyaline bands become extremely narrow, regular and of about equal width.

Much effort has been spent by fisheries biologists determining the precise time of year when different species change from depositing opaque to hyaline material in their otoliths. For the cod it has been shown (Williams and Bedford, 1974) that different stocks vary in the time when each zone is deposited. Furthermore, as fish mature the time of year in which the change from opaque to hyaline material alters. In young North Sea cod the opaque band is laid down between February and September, the hyaline band being deposited during the period October to January. In 8 year old fish the opaque zone is deposited between June and early November.

Age determination and assessing the season of death of archaeological specimens would appear to be simply a matter of sectioning otoliths and counting the number of rings and determining the amount of marginal growth at the edge of the otolith. However, a number of difficulties make this less simple than at first it might appear. First, a small number of fish fail to grow normally. Otoliths from the same fish do not always have the same number of rings and between 1 and 5% of otoliths possess a crystalline structure without rings (Reinsch, 1976; Blacker, 1974). Perhaps more important is the occurrence of splits, checks and false rings within the opaque zone. Some hyaline false rings can be of such a width and so positioned within the opaque zone so that there appear to be two narrow rings instead of one wide one making the otolith seem to be from a fish older than its true age. In such cases the accuracy of age determination depends on the training and skill of the reader. This skill is not easily acquired, and Williams and Bedford (1974) maintain that it is necessary to train for 6 months in order to read competently the majority of straightforward otoliths (p.120). After 2 years experience, having read between 5,000 and 10,000 otoliths, otolith readers are considered to be proficient.

With these reservations in mind, one saithe and nine cod otoliths from Freswick Links were sectioned at the Ministry of Agriculture Food and Fisheries Laboratory in Lowestoft following the method of Bedford (1983). This involves embedding the otoliths in opaque resin and cutting thin sections though the otoliths. These sections were mounted on glass microscope slides and viewed with transmitted and reflected light. A selection of the clearest sections are presented in Plates 45-50.

The sections have been examined by several experienced otolith readers including Bernard Bedford, Gary Howlett (Lowestoft), Cathy Rowell (University of York) and the author. All are unanimous in their opinion that it is impossible reliably to age the otoliths or to estimate the time of year in which the fishes died. Although some areas of the sections show faintly the presence of rings, none could be identified as annual rings with confidence. However, Bedford (pers. comm.) did say that the overall appearance of the rings and their spacing across the otolith was consistent with the patterns seen in otoliths from modern North Sea cod.

A number of factors may account for the lack of clarity of growth related zonation in the ancient otoliths. First, it is possible that the calcium carbonate has partly recrystallized, obscuring any banding originally present. Second, the decay of otolin, the protein of otoliths may have allowed other salts to penetrate the otoliths and so disturb the banding.

This result, while disappointing, is consistent with that found by Wilkinson (pers. comm.) when he sectioned saithe otoliths from Oronsay. He too found that the clear banding visible on modern material was absent on excavated samples.

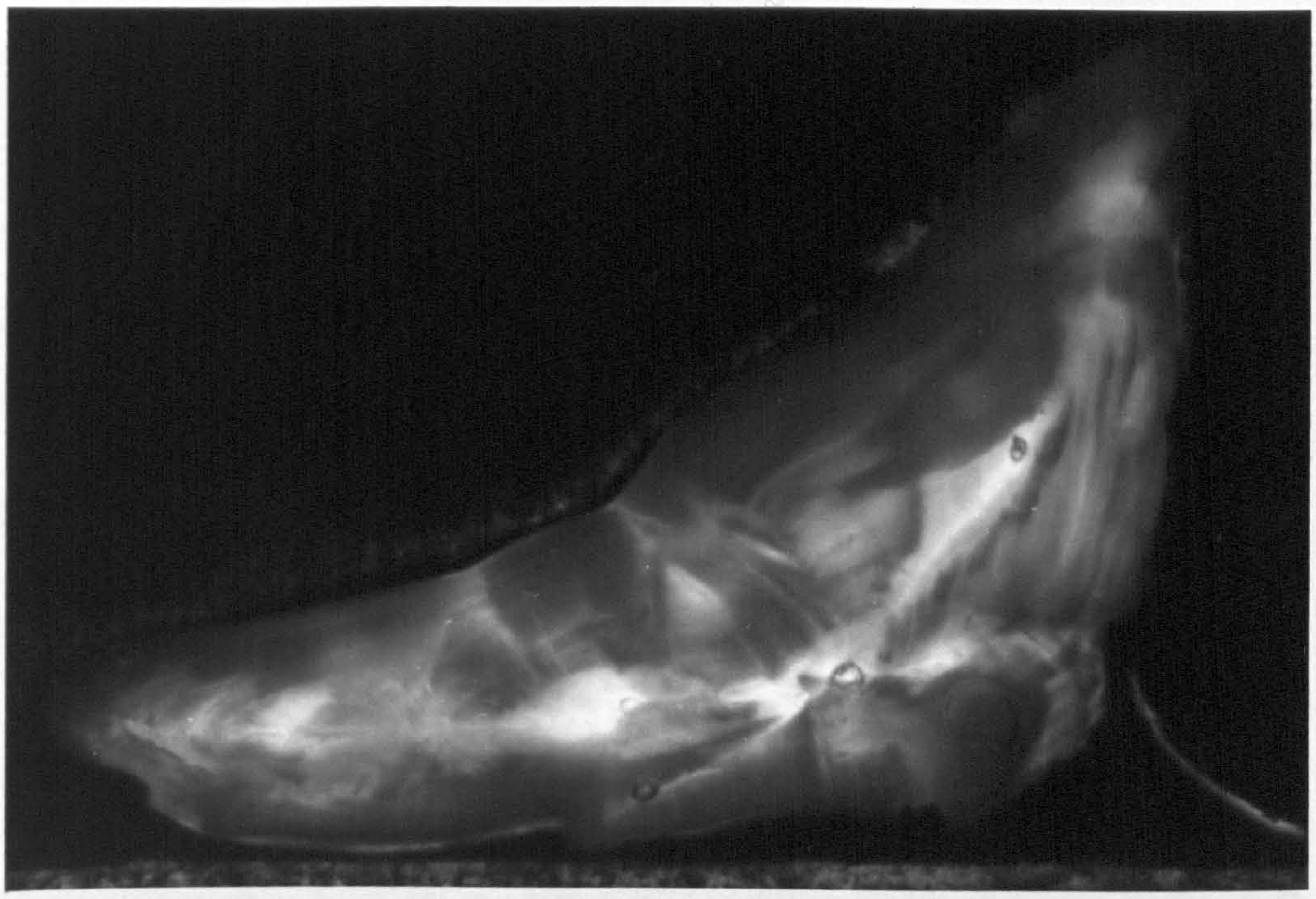


Plate 45. This section of a cod <u>Gadus</u> <u>morhua</u> otolith (width 9.8 mm) from Area 4 viewed in transmitted light.

Plate 46. The same section viewed in reflected light.

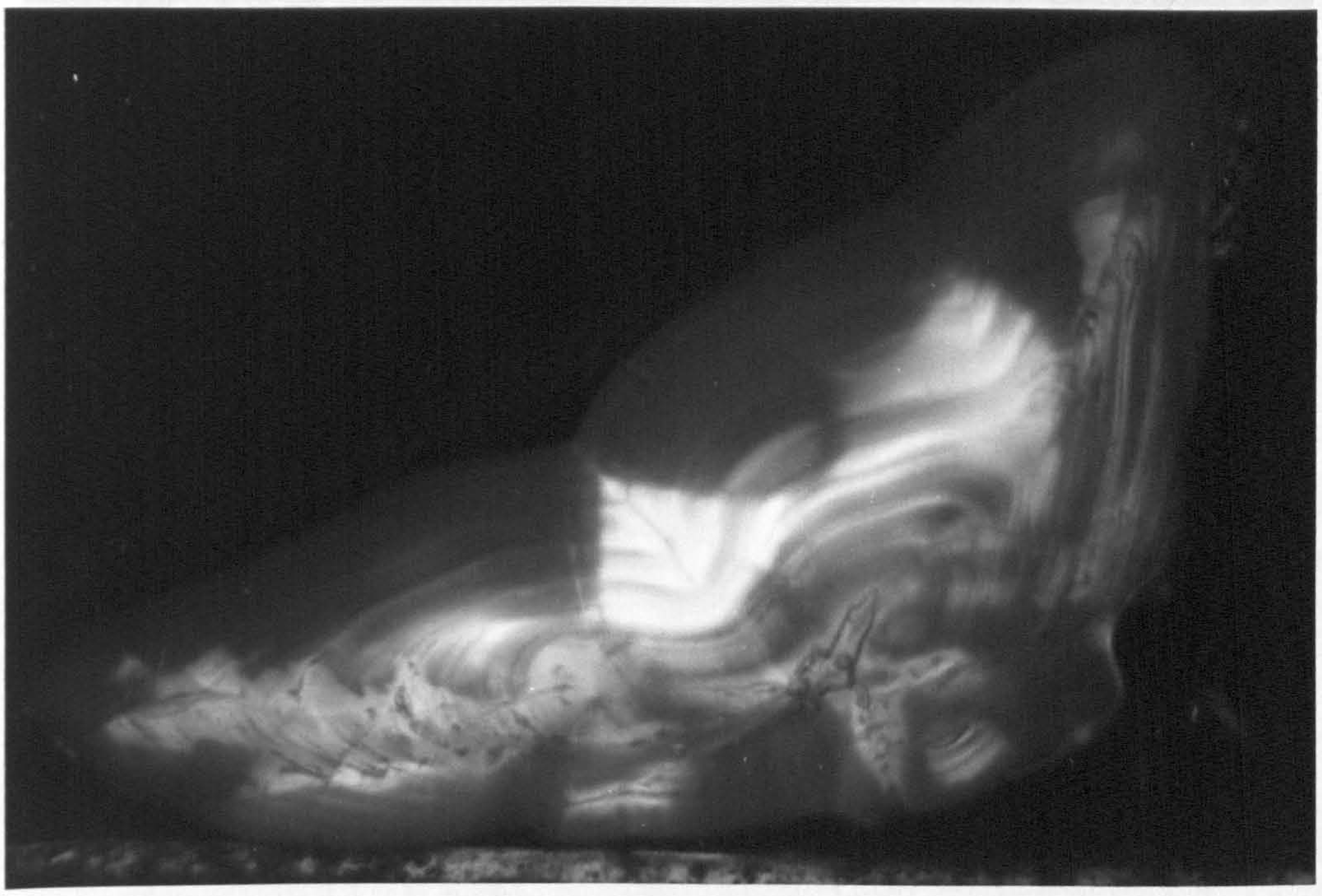


Plate 47. Thin section of cod Gadus morhua otolith (width 10.6 mm) from Area 4 viewed in transmitted light.

Plate 48. The same section viewed in reflected light.

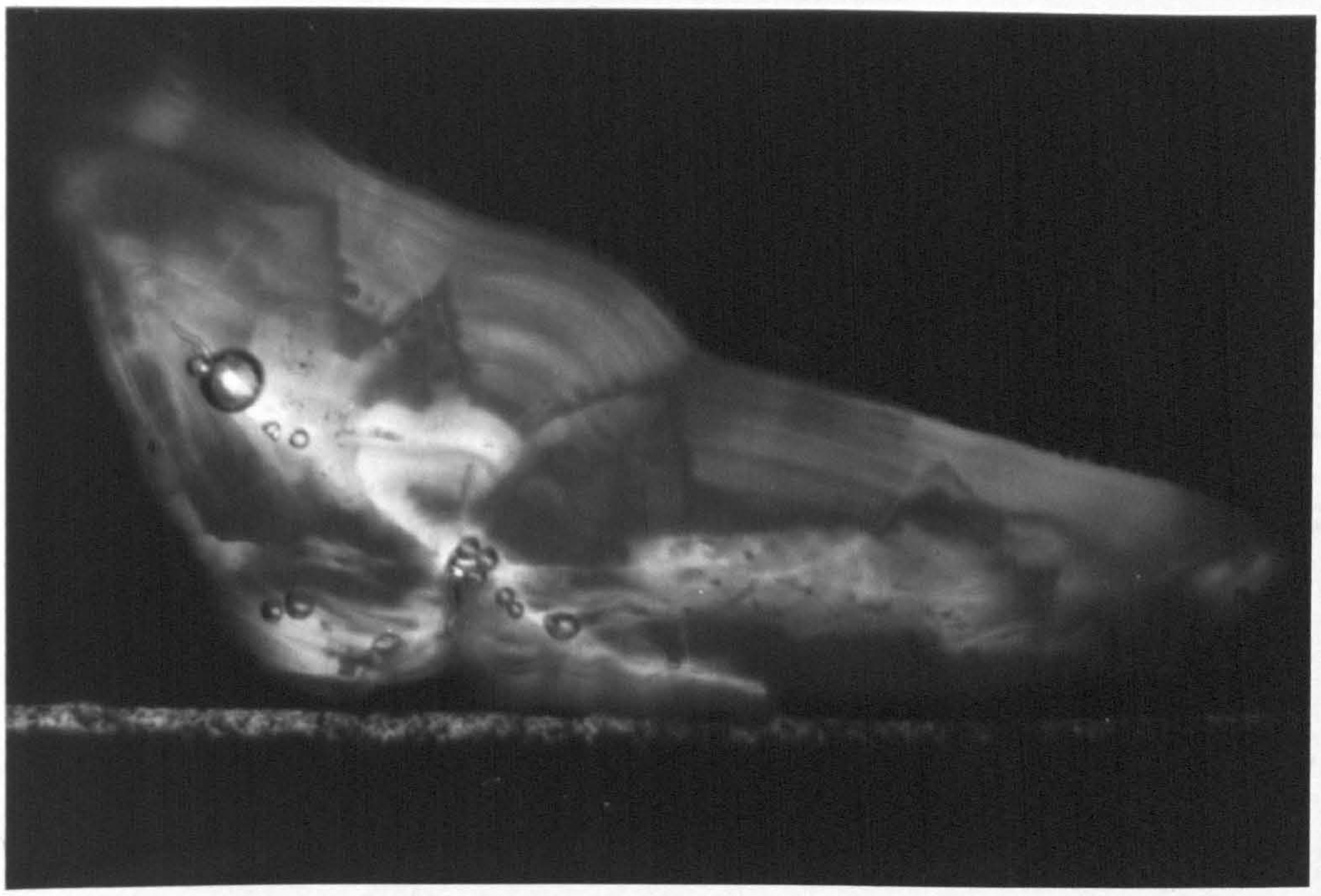


Plate 49. Thin section of cod, Gadus morhua otolith (width 10.2 mm) from Area 4 viewed in transmitted light.

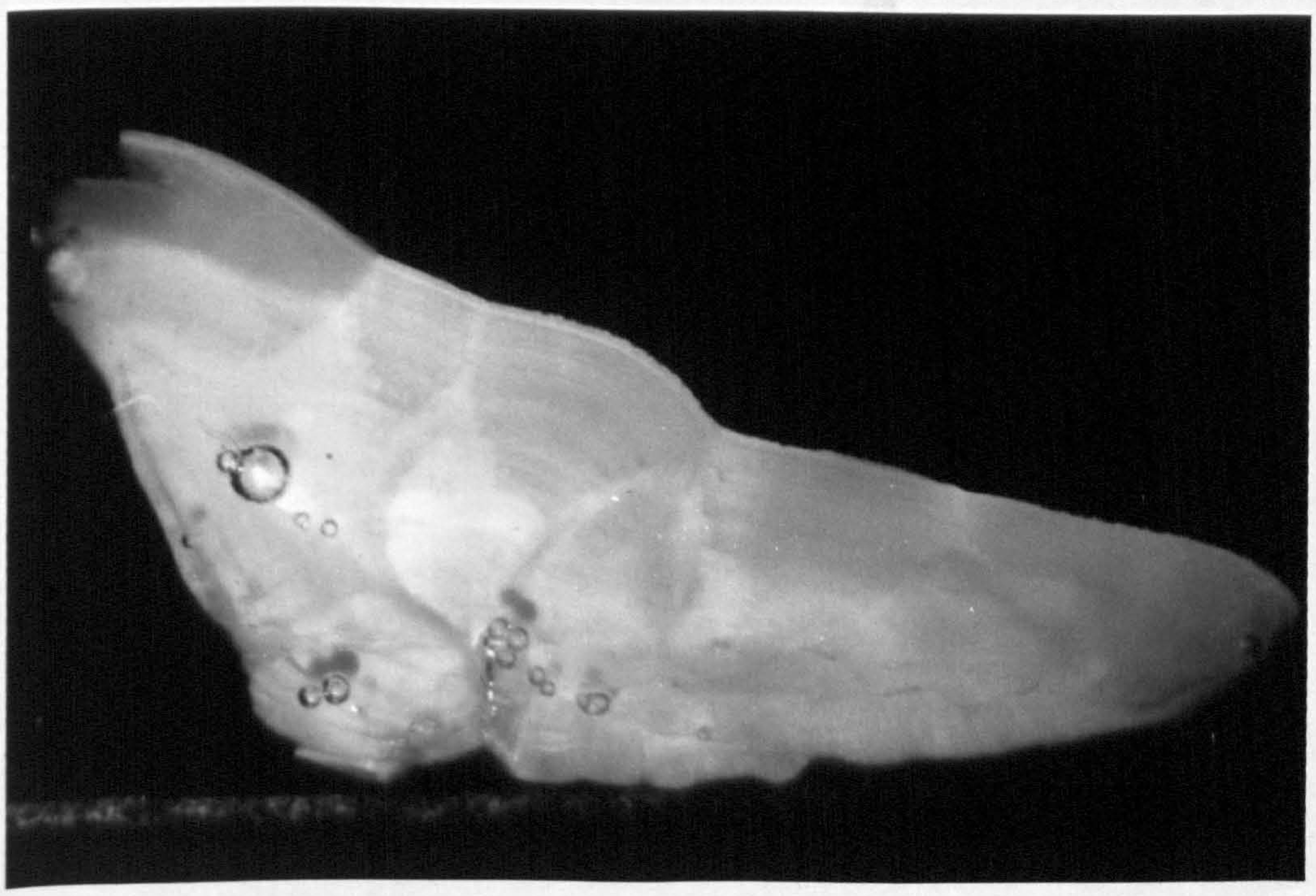


Plate 50. The same section viewed in reflected light.

6.7 TAPHONOMIC EVIDENCE

6.7.1 Articulated Bones

During the course of the excavation groups of articulated bones, usually vertebrae of large cod and ling, were recovered from the site (Plate 51) shows a collection of large ling, Molva cf. molva vertebrae found articulated during excavation. Although these are not listed in detail, the presence of such groups of bones can be used as an indication of the relatively undisturbed nature of at least parts of these deposits. Layers producing groups of articulated bones included DH, EA, GU, KC, KF, JK, JM, MB, MQ, NE, NP, NQ, NT

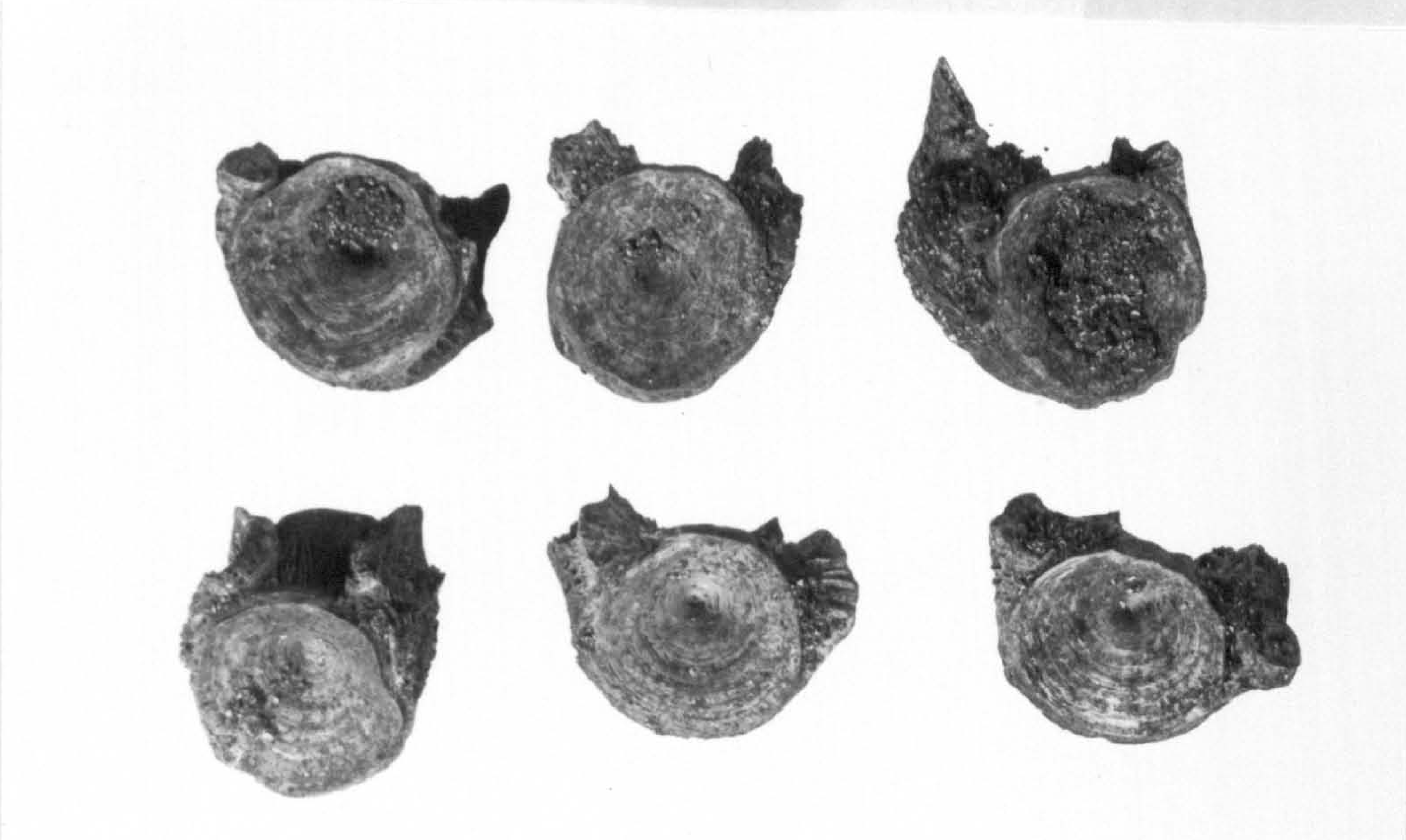


Plate 51. A group of ling Molva cf. molva vertebrae found articulated in Area 4.

6.7.2 Burnt Bones and Otoliths

Most layers produced small amounts of unidentifiable burnt fish bone. Otoliths and bones were found charred black, blue and white indicating they had been burnt. A few bones of all the main species were found to be burnt (see Plate 52). The distribution of burnt elements showed no clear patterning. However, a total of 35 distal dentary fragments of ling were recovered burnt, often charred black thoughout.

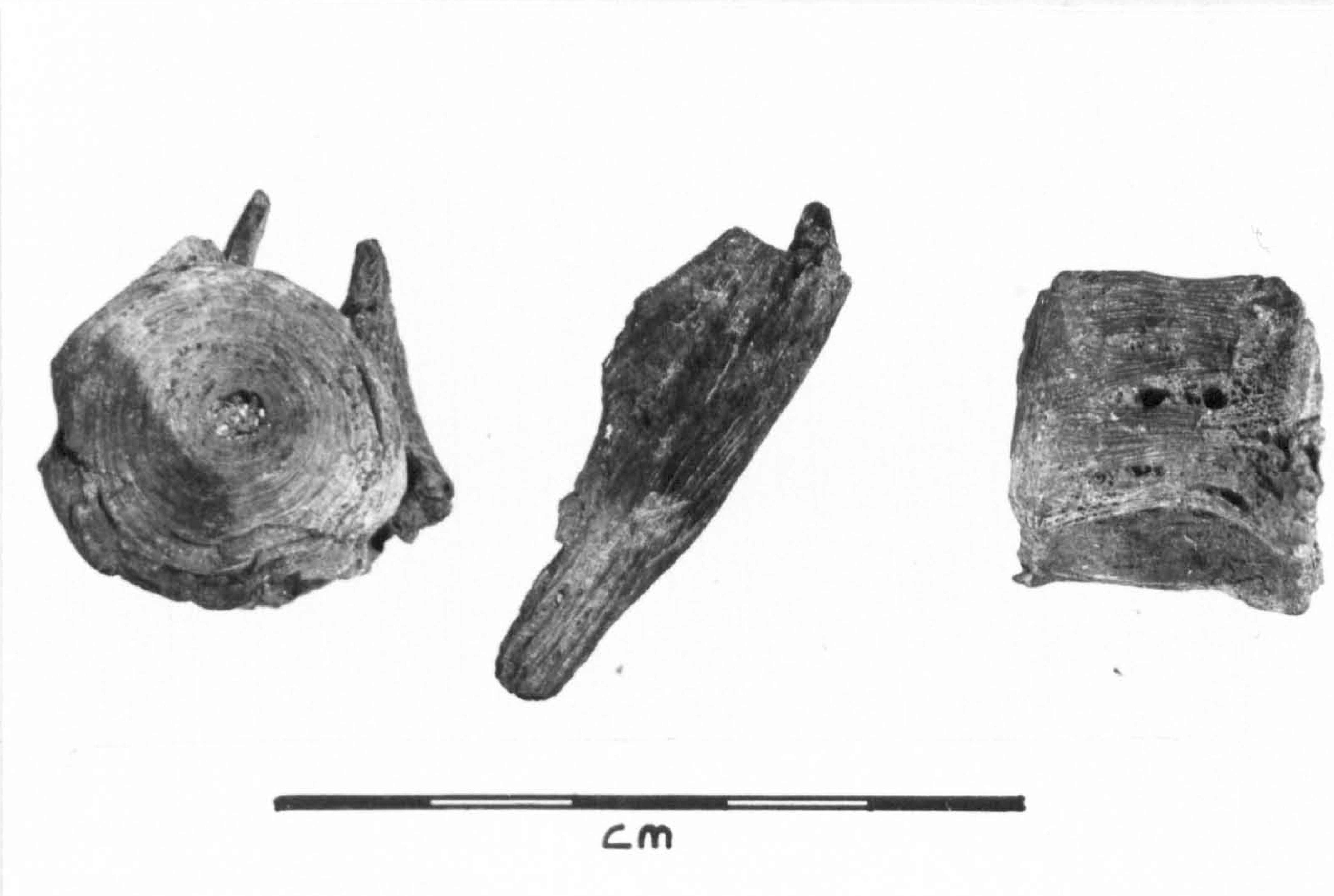


Plate 52. Ling Molva cf molva bones showing the effects of burning. Left to right, precaudal vertebral centrum (colour difference shows the bone was partly charred); cleithrum dorsal extremity (mostly charred) and precaudal vertebra uncharred.

6.7.3 Evidence of Gnawing and Digestion

Evidence of gnawing and digestion was noted on many of the bones. Table 43 provides details of these. Plates 53-60 illustrate bones and otoliths recovered in an eroded or acid digested state. It is important to bear in mind that when an otolith lacks surface sculpting, it is not always possible to be certain of the causes of that erosion. While most eroded otoliths share many features seen on otoliths recovered from

Table 42. Numbers of identifiable burnt bones fragments

Taxon	Element	Number of fragments
Conger conger		
	caudal vertebral centrum	1
Gadidae		
	cleithrum	2
	dentary	1
	otolith	2
	premaxilla	3
?Pollachius virens		
	otolith	3
Pollachius virens		
	dentary	5
?Gadus morhua		
	dentary	1
	otolith	3
	premaxilla	2
Gadus morhua		
	cleithrum	1
	dentary	5
	otolith	7
	premaxilla	9
?Melanogrammus aeglefinus		
	otolith	2
Melanogrammus aeglefinus		
	cleithrum	1
	premaxilla	2
?Molva cf. molva		
	cleithrum	1
	premaxilla	4
Molva cf. molva		
	dentary	35
	premaxilla	4
Trachurus trachurus		
	vertebrae	2
?Anarhicas lupus		
	tooth	13
Triglidae		
	spine	4
Pleuronectidae		
	vertebrae	3

piscivores faeces, e.g. a glossy surface, uneven margin, it is possible that some were eroded by other forces. The most likely are repeated rolling in sand by tide action and erosion by windblown sand particles. Otoliths rolled in silver sand for several hours have a rather similar appearance to those recovered from faeces (Nicholson, pers. comm). Bones bearing tooth marks are good evidence that bones have been chewed, but it is not possible to determine with certainty which species made the tooth marks.

While it is possible that some of the eroded bones may also have been reduced by being rolled in sand on the beach, there are two reasons for thinking that the majority were eroded as they passed through a vertebrate digestive system. First a few of the eroded bones bear tooth marks, and second, eroded bones were occasionally associated with coprolites or accumulations of chewed and crushed bones encrusted with coprolite material.

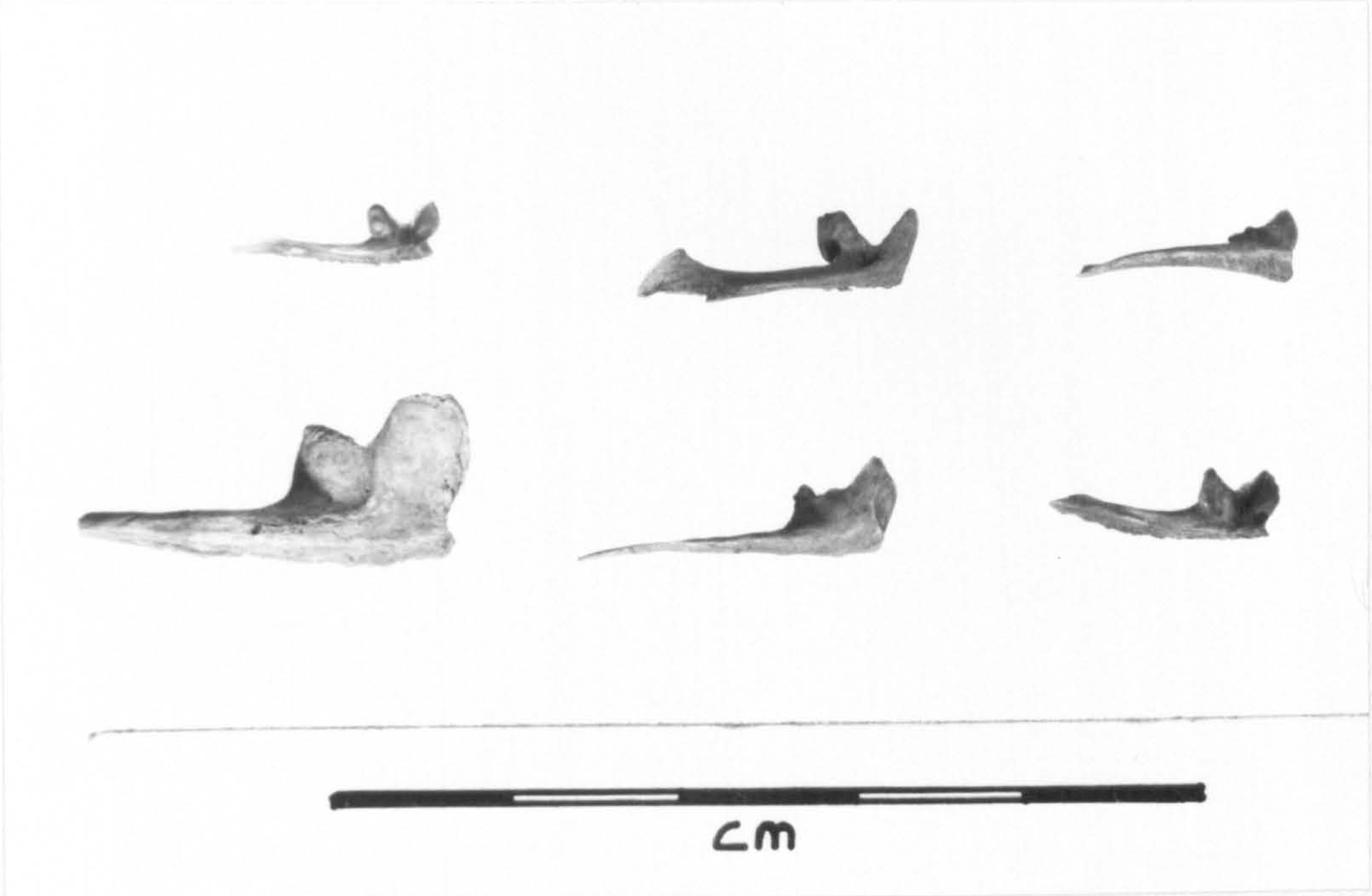


Plate 53. Eroded large cod Gadus morhua and gadid premaxillae (upper row) and gadid dentary (bottom left) and haddock Melanogrammus aeglefinus premaxilla (bottom right). Note reduced height of tooth sockets and polished surface, particularly of haddock premaxilla.

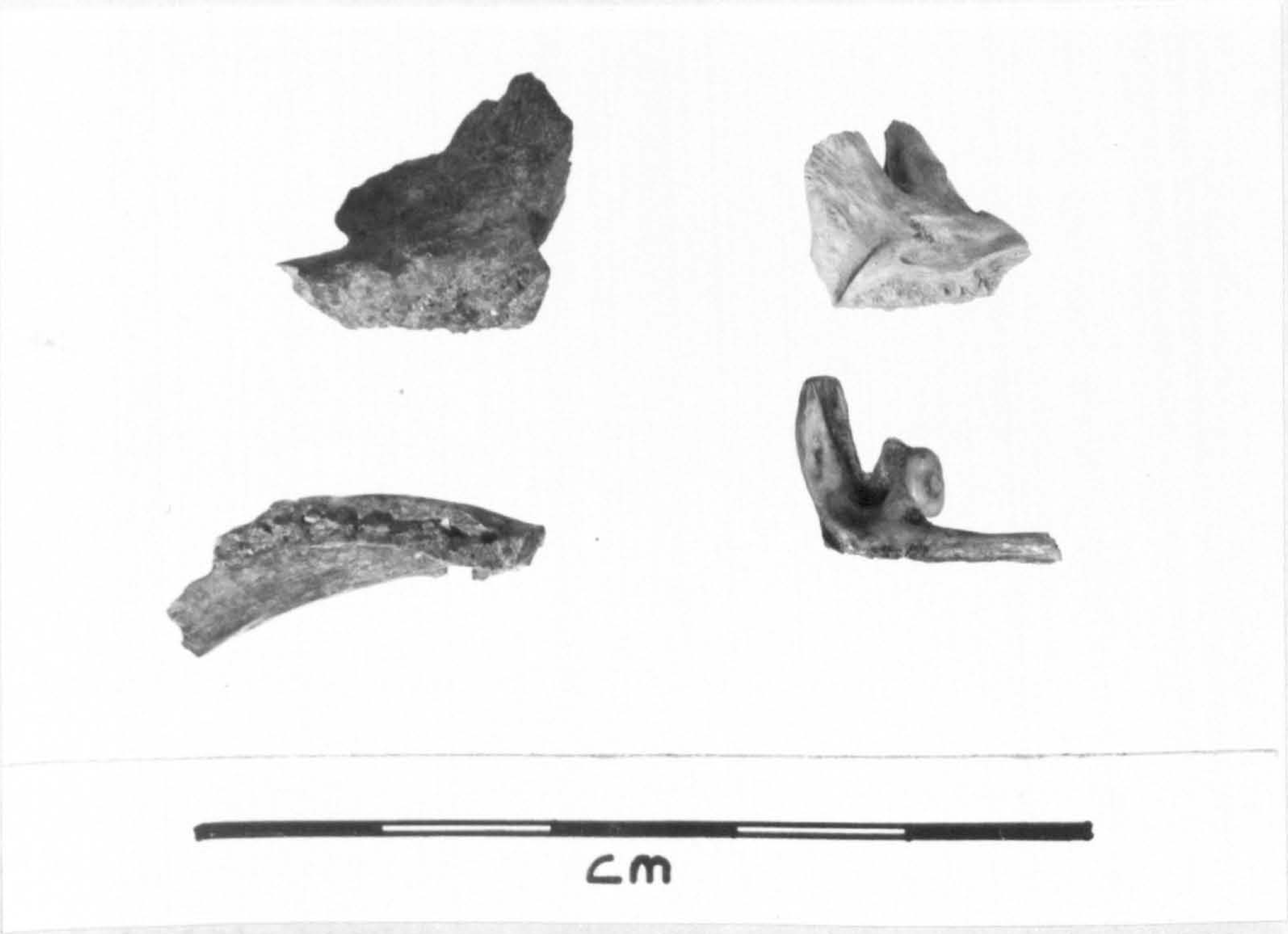


Plate 54. Group of eroded gadid premaxillae. Note lack of tooth sockets and other surface detail.

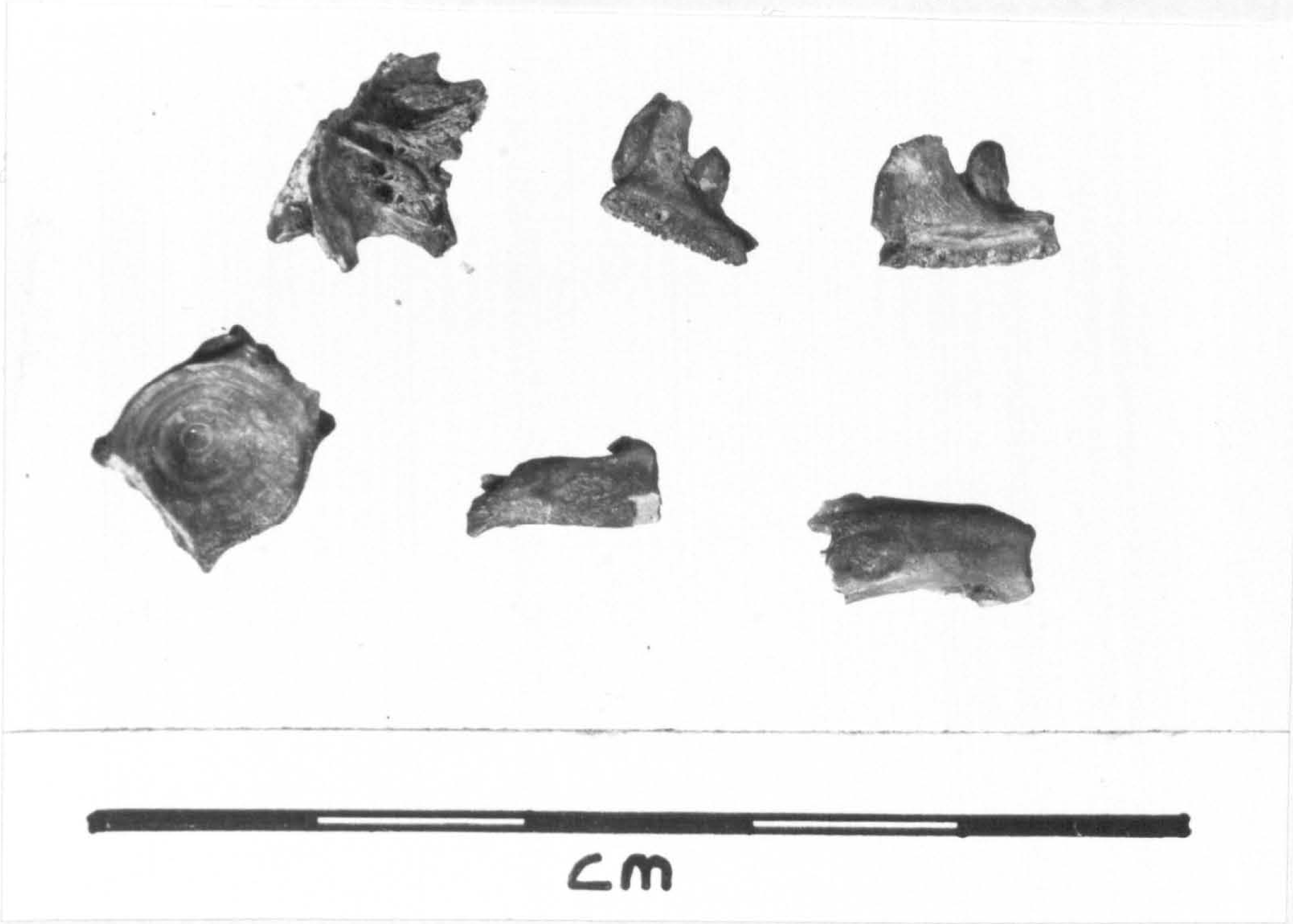


Plate 55. A collection of eroded gadid bones. Top row left to right: vertebra fragment; 2 premaxillae. Bottom row: vertebrae and 2 dentary fragments. Note glossy surface.

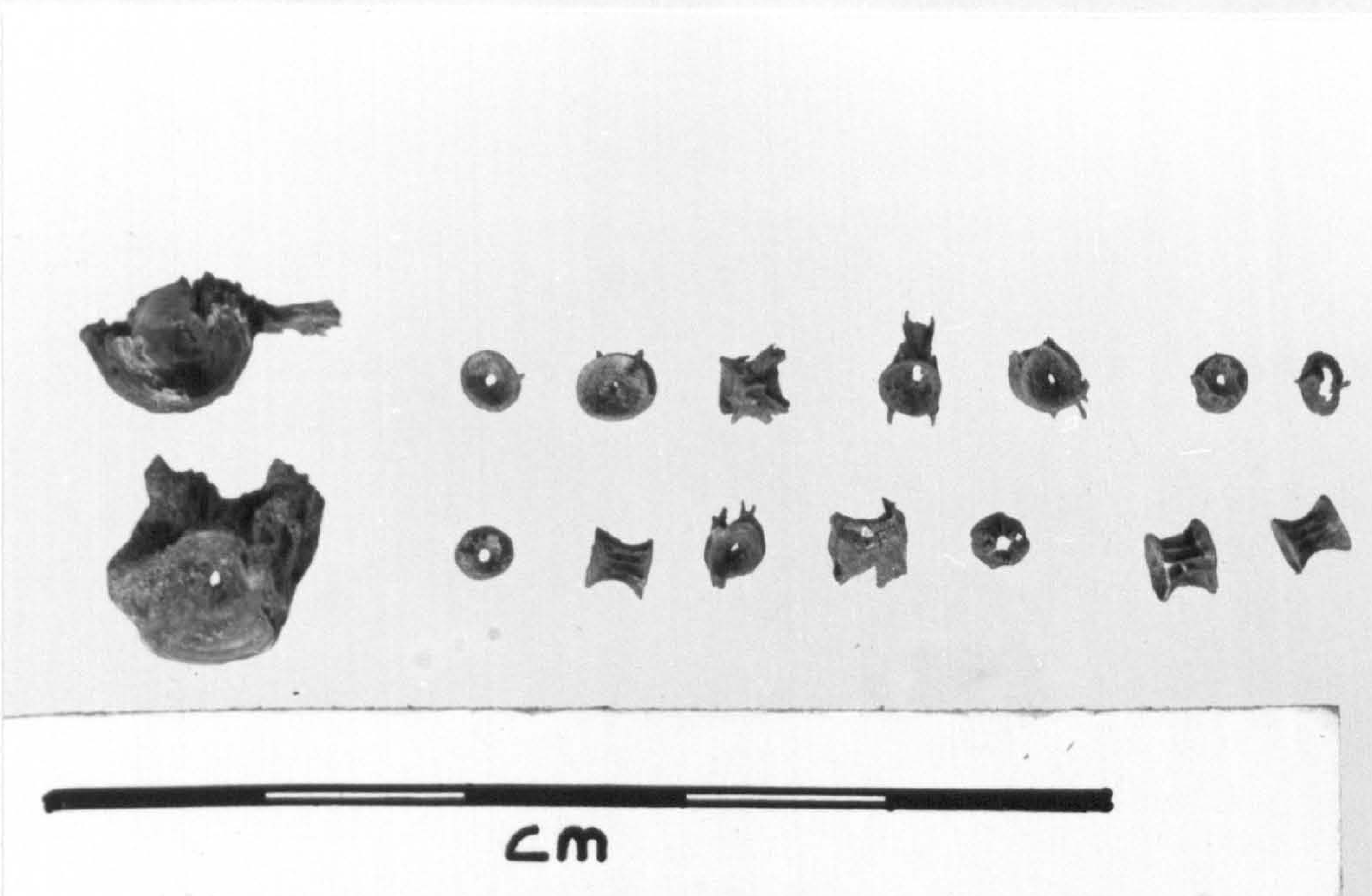


Plate 56. An assemblage of herring Clupea harengus vertebrae and 2 large gadid bones from Area 11 (VH/VI sample 632). Note several of the herring vertebrae are crushed and large gadid bones bear tooth marks.

Plate 57. Selection of severely eroded and chewed large gadid bones. Note glossy surface. Top left: premaxilla fragment. Top right: vertebrae fragment. Bottom left: dentary fragment. Bottom right: post temporal fragment.

Plate 58. Ventral view of an eroded ling Molva cf. molva premaxilla. Note reduced tooth sockets.

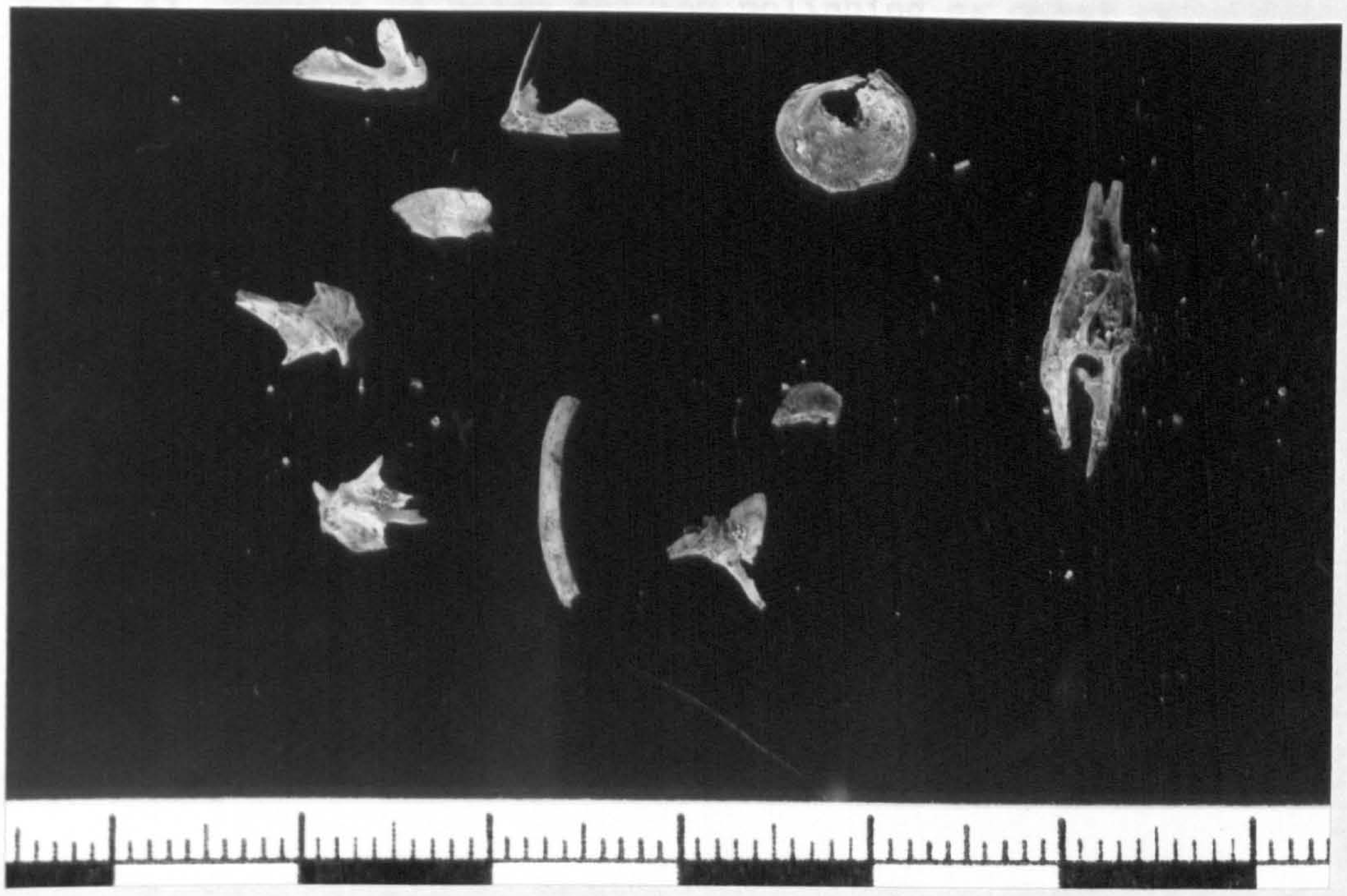


Plate 59. Collection of damaged bones from a coprolite. Note crushed and fragmentary nature of the bones.

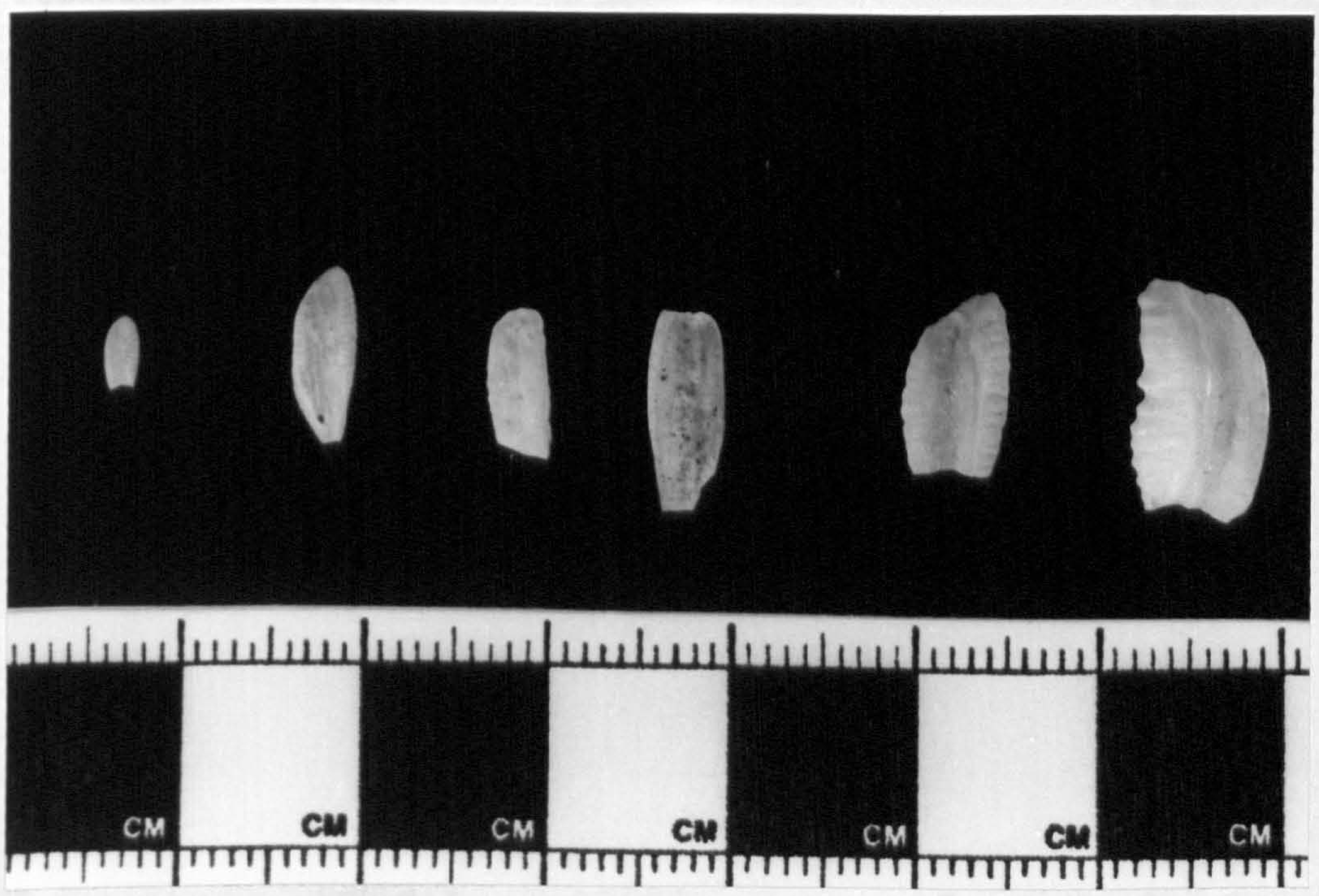


Plate 60. Eroded otoliths. Left to right: ?whiting ?Merlangius merlangus; ?saithe ?Pollachius virens; ?whiting and 2 cod Gadus morhua.

Table 43. Numbers of bones showing polishing or other reduction of surface features and tooth marks.

Taxon	Element	No. eroded	No. with tooth marks
?Salmonidae			
	otolith	1	-
Conger conger			
	vertebrae	7	1
?Merluccius merluccius			
	otolith	2	-
?Gadidae			
	otolith	2	-
Gadidae			
	cleithrum	-	1
	dentary	1	1
	otolith	19	-
	premaxilla	12	2
?Merlangius merlangus			
	otolith	1	-
Merlangius merlangus			
	otolith	1	-
?Trisopterus sp			
	otolith	1	-
?Trisopterus luscus			
	dentary	1	-
Trisopterus sp.			
	otolith	13	-
Pollachius or Gadus			
	dentary	1	-
	otolith	3	-
	premaxilla	2	-
Pollachius/Melanogrammus			
	otolith	1	-
Pollachius sp.			
	premaxilla	2	-
?Pollachius pollachius			
	otolith	1	-
Pollachius pollachius			
	premaxilla	1	-
?Pollachius virens			
	cleithrum	-	1
	dentary	1	-
	otolith	78	-
	premaxilla	1	-
Pollachius virens			
	dentary	1	2
	premaxilla	2	-
?Gadus morhua			
	dentary	-	1
	otolith	5	-
	premaxilla	2	-

Table 43 (cont.)

Taxon	Element	No. eroded	No. with tooth marks
Gadus morhua			
	dentary	7	6
	otolith	22	-
	premaxilla	9	16
?Melanogrammus aeglefinus			
	otolith	4	-
Melanogrammus aeglefinus			
	cleithrum	-	1
	premaxilla	1	1
?Brosme brosme			
	otolith	3	-
?Molva cf molva			
	otolith	2	-
Molva cf molva			
	cleithrum	-	1
	dentary	2	-
	otolith	1	-
	premaxilla	2	8
Raniceps raninus			
	otoliths	2	-
Trachurus trachurus			
	vertebrae	2	1
?Ammodytidae			
	otolith	1	-
Scomber scombrus			
	vertebra	1	1
?Labrus bergylta			
	premaxilla	-	1
Triglidae			
	vertebrae	-	3
?Heterostomata			
	premaxilla	1	-
?Hippoglossus hippoglossus			
	vertebra	1	1
Pleuronectidae			
	otolith	1	-
	premaxilla	1	-
	vertebra	-	1

6.7.4 Coprolites

Coprolites were recovered from a number of deposits. Plate 61 shows two typical examples. The shape of the coprolites and the large quantities of small fragments of mammal and fish bones present in the coprolites are consistent with, but not diagnostic of, dog droppings.

6.7.5 Evidence of Butchery and Fish Processing

A small number of bones (for examples see Plates 62-69) showed clear knife and other blade marks. Knife marks on cleithra are identical to those made by contemporary fishmongers and fish filleters when filleting large round fish.

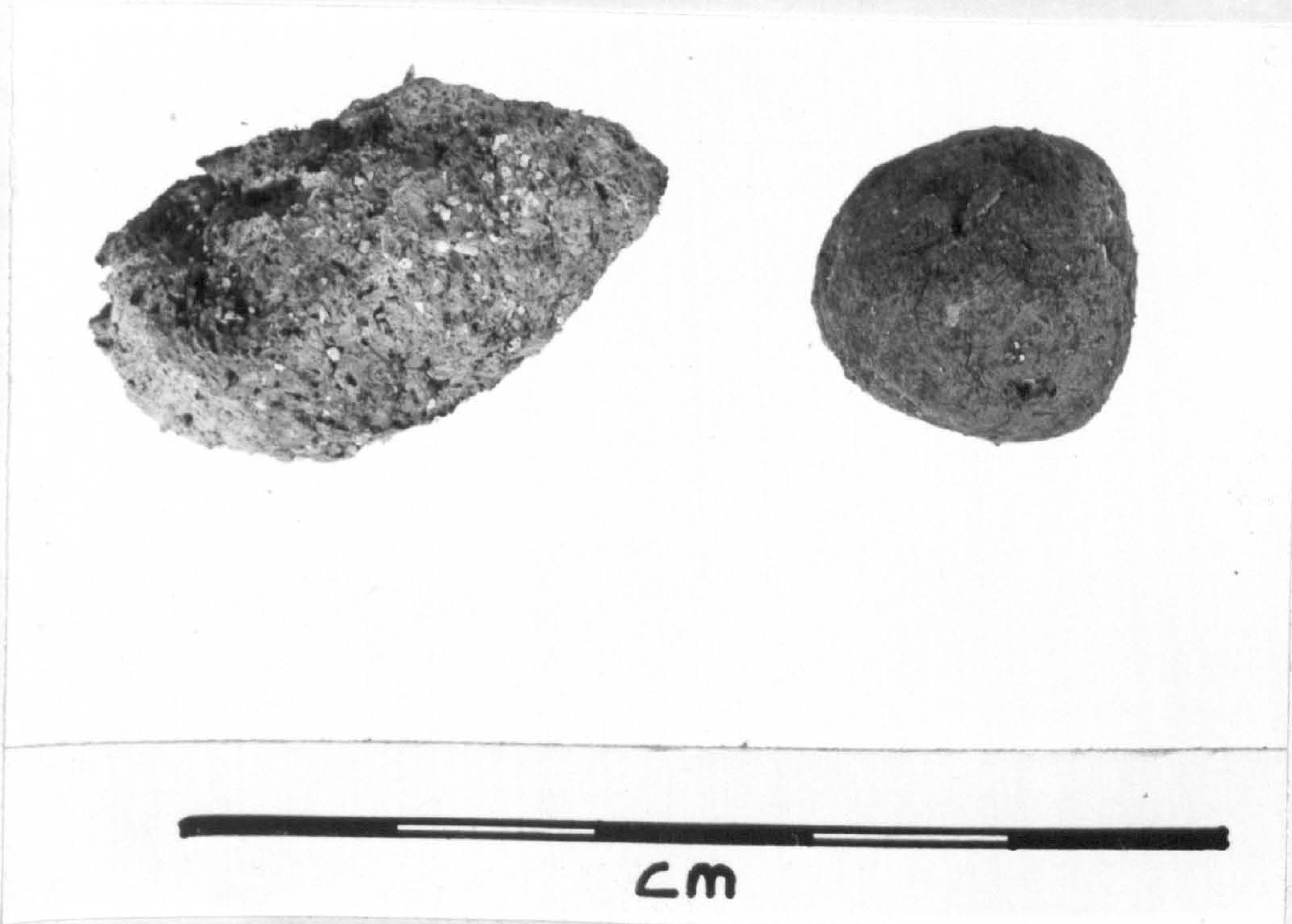


Plate 61. Coprolites, considered to be of canine origin.

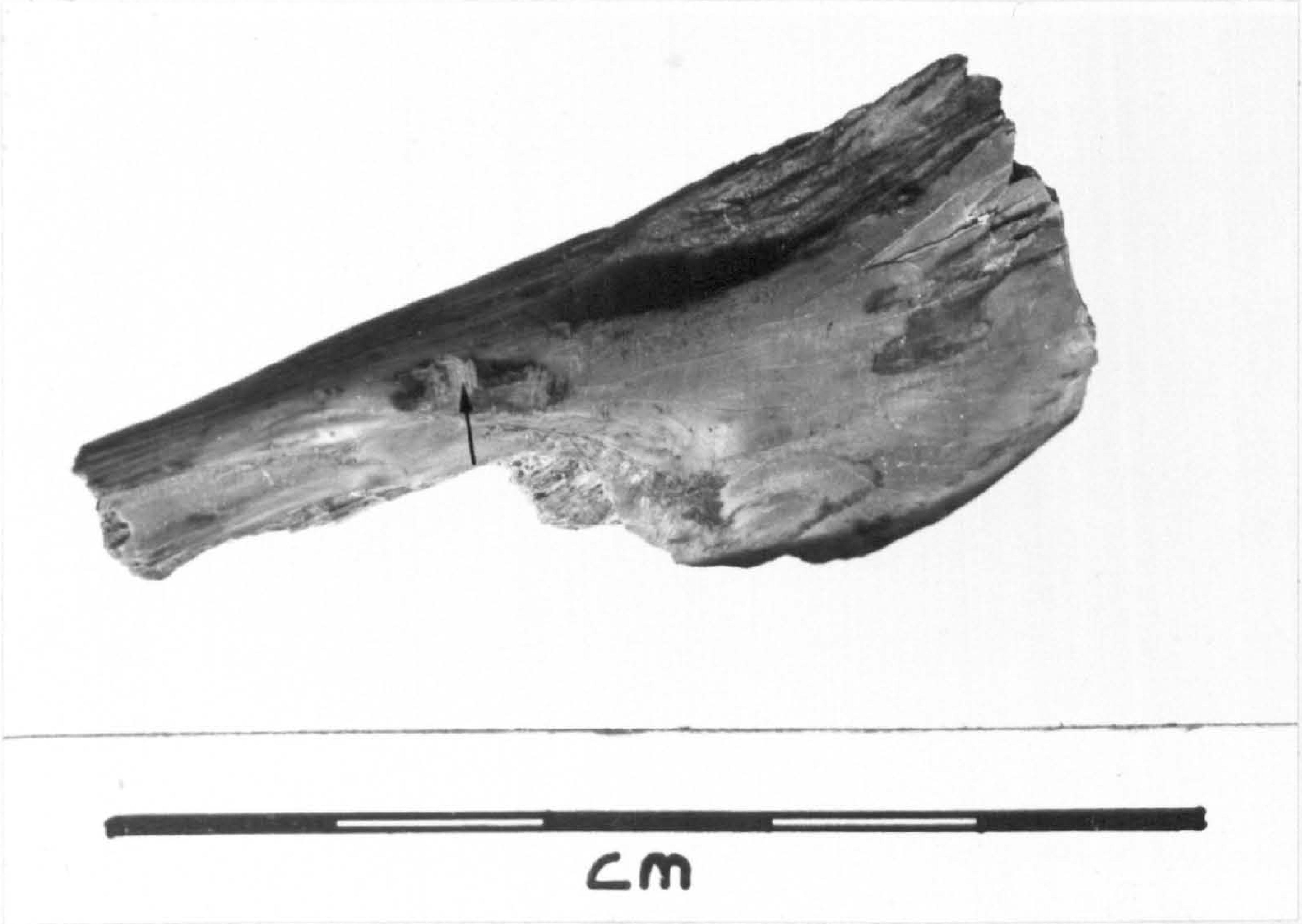


Plate 62. Fragment of ling Molva cf molva cleithrum with small knife marks probably made during filleting.

Plate 63. Fragment of cod Gadus morhua cleithrum with knife marks made during filleting.

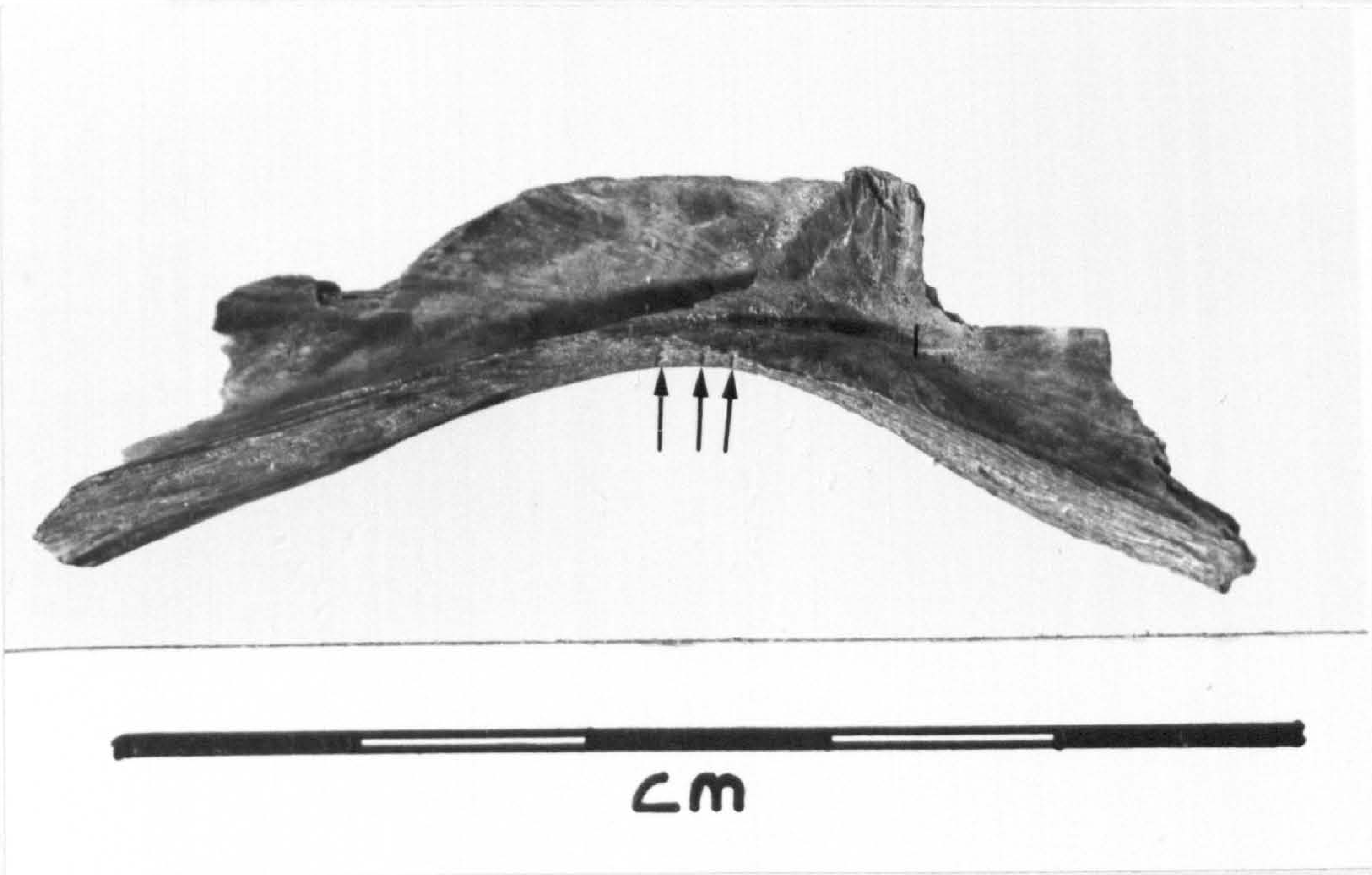


Plate 64. Fragment of cod Gadus morhua cleithrum with knife marks probably made during filleting.

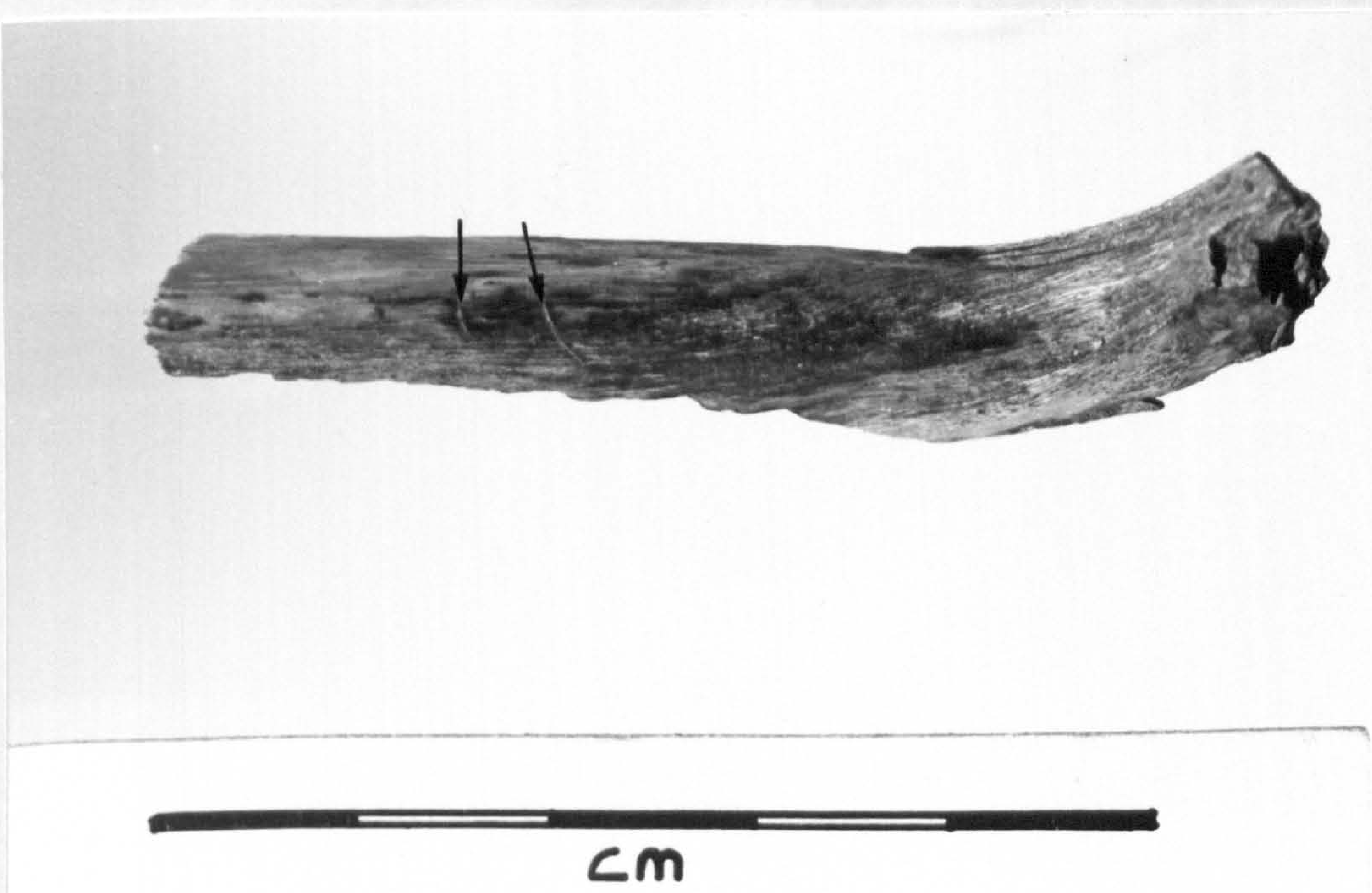


Plate 65. Fragment of ling Molva cf. molva cleithrum with knife marks made during filleting.

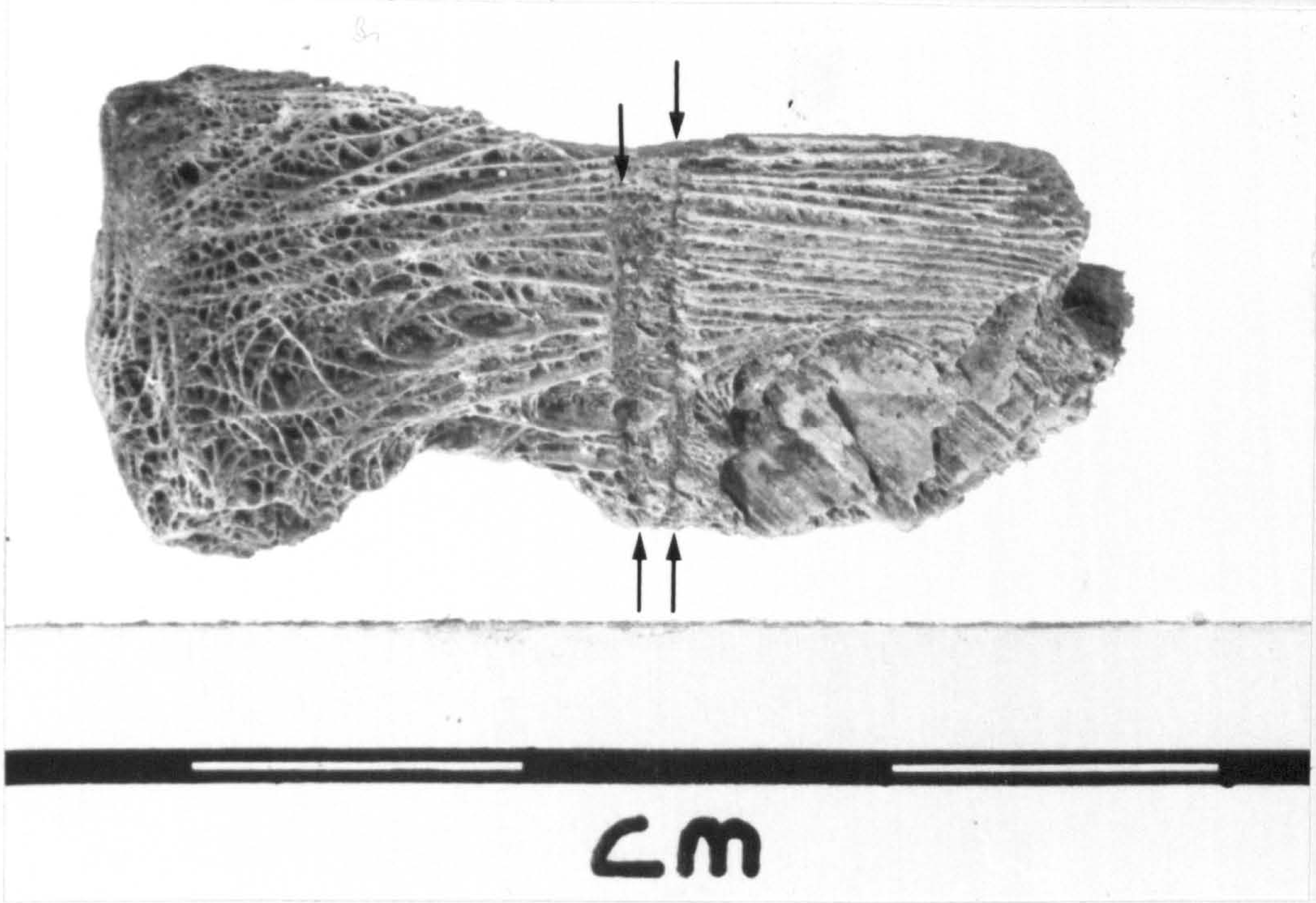


Plate 66. Large gadid basioccipital (ventral view) with two knife or chopper marks, presumably made during decapitation.

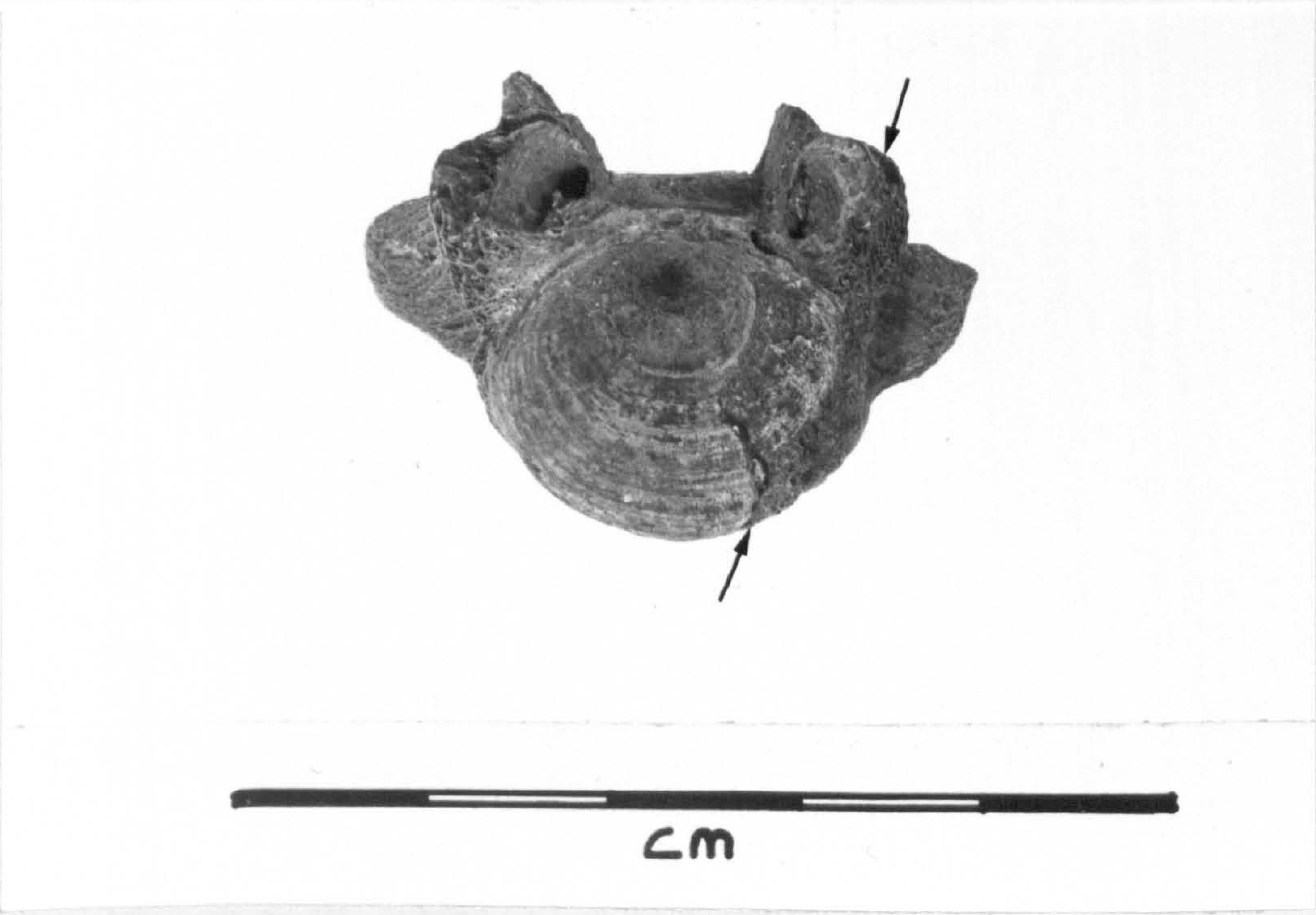


Plate 67. Anterior view of ling Molva cf. molva second vertebra with chop mark, possibly caused during decapitation.

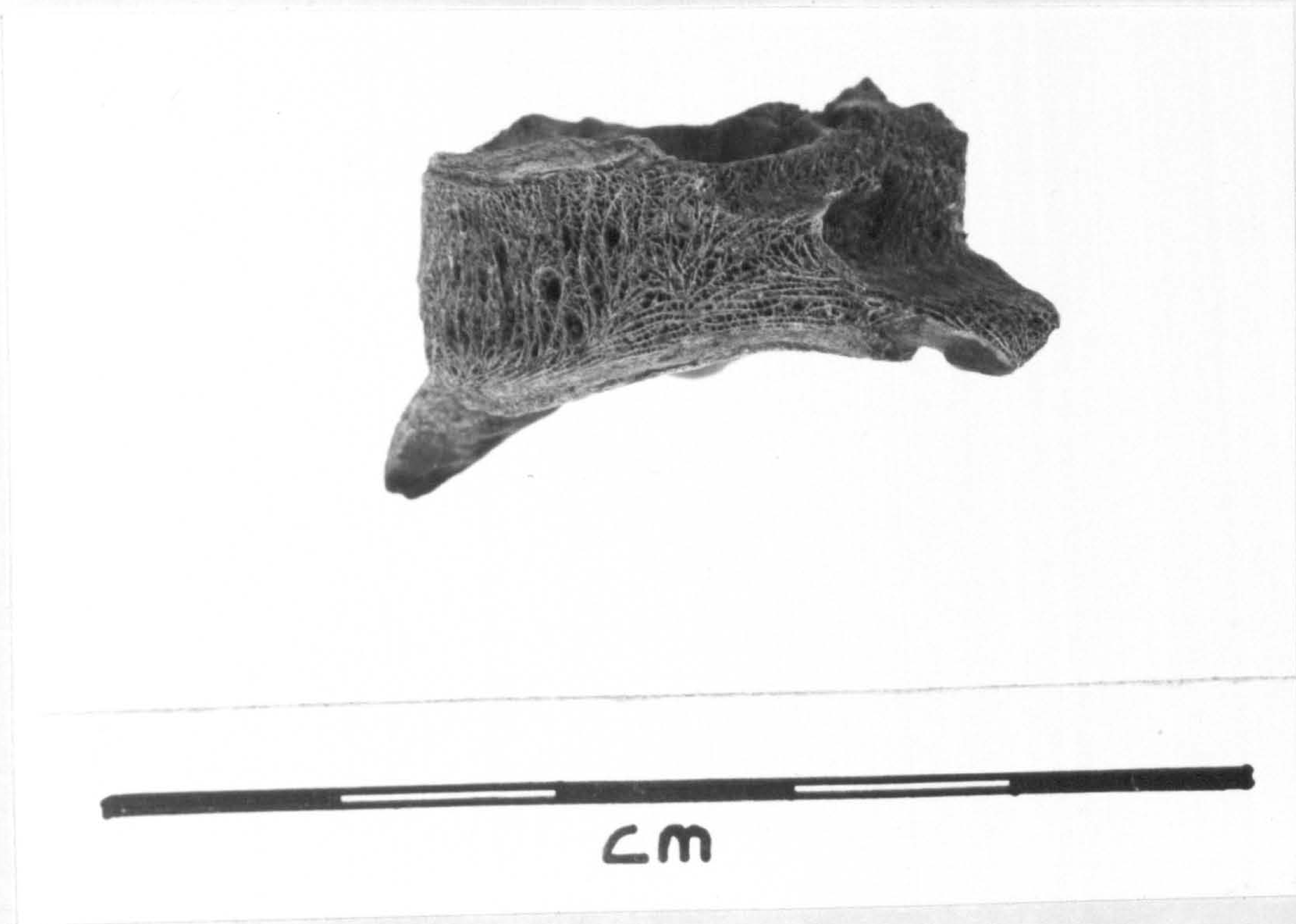


Plate 68. As plate 67 (ventral view).

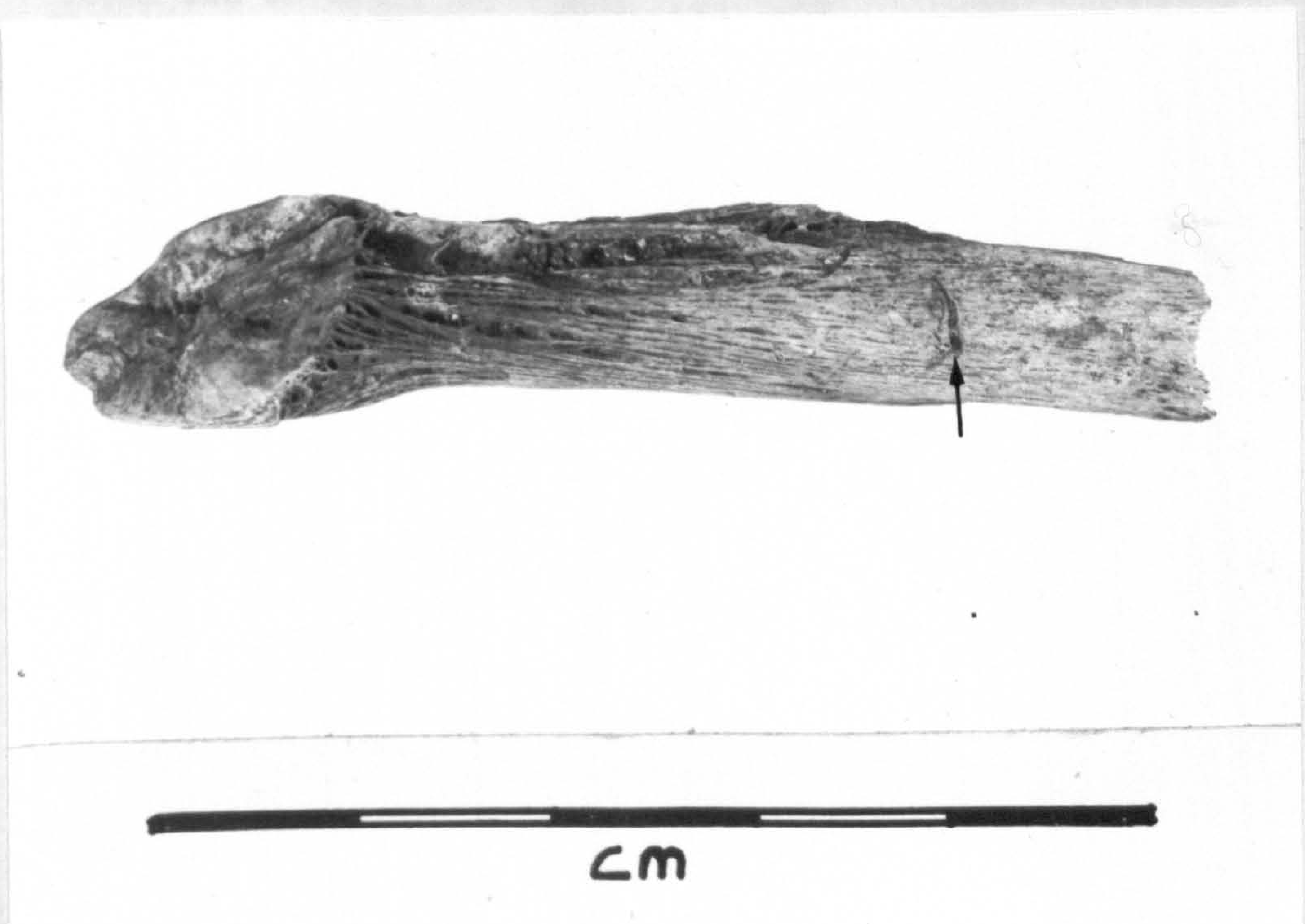


Plate 69. Cod, Gadus morhua supracleithrum with knife mark.

Table 44. Numbers of bones with knife and other blade marks.

Gadidae		
	cleithrum	7
	post temporal	1
Pollachius or Gadus		
	cleithrum	2
?Gadus morhua		
	cleithrum	1
	symplectic	1
Gadus morhua		
	basioccipital	2
	cleithrum	6
	post cleithrum	2
	supracleithrum	8
Molva cf. molva		
	basioccipital	1
	cleithrum	6
	first vertebra	3
	caudal centrum	1

Blade marks at or near the junction of the head and the trunk were noted on a few bones from Area 4. Most basioccipital bones and anterior vertebrae showed no signs of blade injury, however it was noticed that a large number of first vertebrae were asymmetrically damaged. The tube like anterior part of the bone was broken on one side. It is possible that this damage was inflicted when heads were twisted to separate the head from the vertebral column.

6.8 ABERRANT BONES

Aberrant fish remains are usually rare in archaeological deposits and the assemblages from Freswick Links are unexceptional in this respect. A small number of otoliths composed partly of crystalline deposits were recovered. Other aberrant bones included coalesced large gadid vertebrae

(Plate 70).

Table 45. List of aberrant bones.

Taxon	Element	Number of fragments
Gadidae		
	vertebral centra (coalesced)	2
?Pollachius virens		
	otolith (part crystalline)	5
Gadus morhua		
	otolith (part crystalline)	5
Molva cf. molva		
	otolith (part crystalline)	2

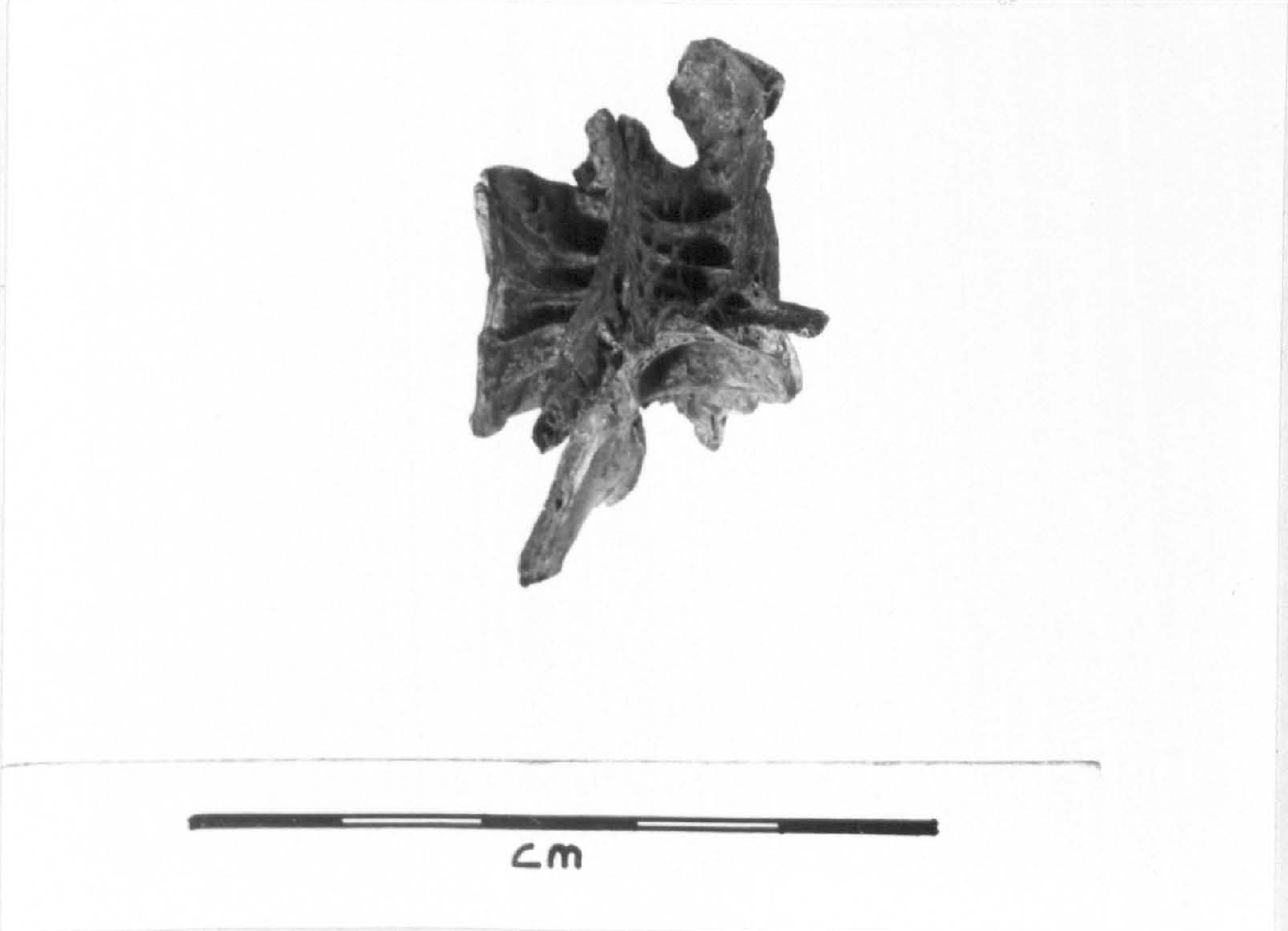


Plate 70. Two coalesced large gadid vertebrae from Freswick Links.

Chapter 7

DISCUSSION

The kinds of fishes represented in archaeological sites are of primary importance to the interpretation of past fishing activity, but an interpretation based solely on biological data - fish migrations, shoaling habits and ecology - is likely to be flawed. The distribution of fishes, particularly in coastal waters, has not remained static. Indeed, there is evidence, much anecdotal, that the concentration of important food fishes in the inshore waters of Caithness has substantially reduced over the last 50 years. Other sources of information can shed light on the methods of fishing and fish processing in Caithness. This chapter summarizes these disparate sources and assesses the evidence from Freswick Links.

7.1 THE INTERPRETATION OF FISHING ACTIVITY

Early written accounts, descriptions by early travellers, and government statistics, provide valuable insights into past fishing activities. Data collected by ethnographers and verbal evidence provided by the people of Caithness are also considered in section 7.1.1. Archaeological discoveries in the northern Scotland area are also reviewed in section 7.1.2. These topics have been covered in great detail by Goodlad (1971), Fenton (1978), Baldwin (1982) and Colley (1983b) for Orkney and Shetland. The present discussion draws heavily on these sources and is directed primarily at data for Caithness.

7.1.1 Documentary Sources

The earliest surviving documents providing evidence of fishing in the region are found in the Norse sagas. However, evidence for fishing, like many other aspects of everyday life, is not of primary concern in these accounts and so references to fish and fishing are scanty and no specific mention of fishing in Caithness is made. That said, line fishing appears to have been the dominant fishing technique in Norse and late Norse times. In Laxdaela Saga in Breidafjiord, Iceland, there is a mention of fish biting well for three men fishing from a boat. There are also hints that fishing and farming were carried out by the same individuals. We are told in the Orkneyinga Saga, that Earl Rognvald and a farmer fished from a rowing boat (Baldwin, 1982, 162).

There is also some evidence of net fishing. Egil's Saga tells of Grimm and his housecarls often going to the winter and spring herring fisheries along the Norwegian coast (Baldwin, 1982, 162). In Havamál Loki burned a net he had made and changed into a fish to escape the gods; but he was caught when they found the marks of the meshes in the ash and the gods made a new net to trap him (Goodlad, 1971, 59).

A far richer source of information on traditional fishing methods in Caithness is The Statistical Account of Scotland (S.A.S) which was compiled after the settlement at Freswick Links was abandoned (Sinclair, 1791-9). The S.A.S. contains a wealth of information on the fishing methods of the region treated parish by parish. The account for the parish of Canisbay provides a clear picture of a largely self-sufficient crofting community exploiting both terrestrial and marine resources. It states that not one man lives entirely by fishing but that every farmer in the parish, (the inland estate of Brabster excepted,) is a fisherman and every fisherman a farmer. Boats were jointly owned by 6 or 7 individuals, and fishing was not generally carried out as a commercial activity but in order to support the owners families (Morrison, 1793, 17).

There were few instances of one parishioner selling a fish to another, although fish-mongers had begun to engage some boats to fish cod and ling at a predetermined price. However, this branch of industry was in its infancy at the end of the 18th century (Morrison, 1793, 17).

There is evidence that humans scavenged the shore for fishes, particularly on the north coast. Morrison states that: 'the rapidity of the tides in the Pentland Firth is altogether unfavourable to fishing. In very stormy weather, cod and ling are, by the force of the billows, frequently thrown in alive upon the shore, and taken up by the people, who on these occasions go in quest for them' (Morrison, 1793, 18).

By contrast, Morrison considered that the east coast of the parish (including Freswick Bay) had great potential for fishing 'if proper exertions were made, and boats accustomed to make a greater stretch from land, before they dropt their lines. Gray fish, as they are called, of all kinds, abound every where around the coast, and constitute a great part of the sustenance of the inhabitants. The shoals of young fish that pour into every creek and bay, about the beginning of September, are such, that a boll of them may be caught in a few hawls, in the course of one evening. They seem to be the intermingling of various genera, and are called by the inhabitants Sellacs. They are tender and delicious in the highest degree, and, in general, between 3 and 4 inches long' (Morrison, 1793, 18). This reference notes two kinds of fishery: line fishing for cod and ling; and net fishing for sellags, a mixture of species but mainly young saithe. Furthermore, there are indications that large fishes occurred close to the shore.

Accounts for the neighbouring Caithness parishes provide equally clear and detailed pictures of traditional fishing methods. In the parish of Dunnet (immediately to the west of Canisbay) Jolly (1794,15) states: 'The cod and ling are found principally in deep water, in the tide way, and taken with a line of 50 or 60 fathoms, to which a single hook is fixed, and a lead weight or sinker. There are various other kinds of fish occasionally taken, as turbot , skate, whitings etc. In harvest, too, amazing shoals of small fish, called sellacks (which are no other than the young of saiths, and some species of cod), frequent the shores, and are often taken in a small sweep net to the quantity of several bushels at once'.

Elsewhere the Statistical Accounts for Scotland mention the scale of fishing. A particularly informative record for the parish of Kirkwall states: 'The little farmers on the shores of the Pentland Firth, in the times they could spare from their labour on land, have been known to catch 40,000 fine cod in the space of only one season' (Barry, 1793, 38). The abundance of small fishes caught from the rocks is apparent in the following mention in the account for Wick parish: 'Sillocks, a small fish caught with a rod from rocks in such quantities, as to be sold for a penny an hundred' (Sutherland, 1794, 12).

These references demonstrate that fishing was an effective food procurement activity which was carried out sporadically. They also demonstrate that boat fishing for large cod and ling (with incidental catches of other species) using hand lines was important and that the seasonal migrations of young saithe and other species (sellags) was well known. It is significant that the herring fishery, which was to become an important activity in the 19th century, is not mentioned. This type of fishing activity is typical of the Orkneys and Sheltands where Fenton exhaustively researched most aspects of traditional life (Fenton 1978). Many indicators including the traditional names of fishes and fishing gear show that Caithness has close cultural links with Orkney. As this group of islands has benefited from far more ethnographic scholarship than Caithness, information from Orkney and Shetland may reasonably be used to explore fishing techniques in Caithness. Furthermore, conversations with Caithness people have confirmed that methods of fishing were in essence identical in Caithness and Orkney.

The most important type of shore fishing was carried out from rocky sites, often from particular locations known as craig seats. These locations were closely guarded in the 19th century (Fenton, 1978, 528). From these locations a number of fishing methods were employed. A rod and line (wand) and the circular 'poke' net were used to take sellag or piltock, (first and second year saithe, Pollachius virens), and occasionally pollack and mackerel. These fishes were taken by attracting them to the shore with mashed limpets. This was a particularly common activity on calm late summer evenings and continued, when the conditions were appropriate, into the winter months. The limpets were gathered from the rocks, steeped in hot water (but not boiled) to loosen them from the shells and chewed and spat into the water. Limpets could also be kicked off rocks on route to a fishing spot, and mashed into 'soe' in small hollows cut into the rocks near the craig seat.

Rock cod, piltocks and small cod may also have been taken from the shore using a 'trailing fishing line' which consisted of a length of heavy cord several fathoms long to which a cork float was attached. From the main line hung a 6 foot (2 m) length of line bearing a hook, usually baited with a limpet. The line was anchored at the craig seat with a large stone and thrown out as far as possible (Fenton, 1978, 538). Fenton considers it likely that this method of fishing was used in the Norse period or earlier.

The poke net, made of an iron hoop approximately 1.5 m diameter and provided with fine mesh netting and suspended from a pole, is considered to be uncommon before the 19th century (Fenton, 1978, 539). Furthermore, Goodlad (1971, 47) rejected the likelihood of nets being used in the prehistoric or Norse periods in Shetland because twine and rope were scarce, and the labour to produce a net much more costly than that required to produce line. In addition, he doubted if nets would have provided any advantage over lines for catching fishes. However, given the technological achievements of Norse peoples it is most likely that such a simple device was available.

Although craig seats were prime locations, other places around the coast could also be good places for taking sellags and piltocks and to this day young saithe can readily be taken from the shore in calm waters in the late summer and autumn.

Sellag and piltock fishing often produced a vast surplus, which was in the 19th century sold as manure for the fields. This practice continued into the present century on the Caithness island of Stroma (Baldwin, 1982, 192). However, the majority of this fishing activity was organized at a domestic level. Some of the fishes were eaten fresh, but most would be dried and stored either for later consumption or to sell or pay rent. Drying was carried out by hanging the fishes over the fire or across the ceiling within domestic houses. They might also be placed in dry-stone wall huts known as skeos and used to dry and store fishes. Oil extracted by boiling livers in a pot half full of water was also a valuable commodity, being used for lamps or sold. The oil was skimmed off and put into stone (presumably stoneware) jars for future use (Fenton, 1978, 527).

Sellags and cuddins provided a welcome and often much-needed addition to a family's diet, eking out meagre crops of grain. And the water in which they were boiled could provide a pleasant hot drink (Baldwin, 1982, 192).

Rod fishing, especially for coalfish, was carried out extensively from small boats inshore. Either the boat was anchored in smooth water between the shore and the tidal current, or it was rowed rapidly against the wind and tide by one or two of its occupants to hold it in position while others fished. Traditionally this was done in April and May (Fenton, 1978, 528).

Larger fishes, cod, saithe and ling, were traditionally caught using the hand-line locally known as the 'ripper'. This consisted of a line long enough to reach the bottom, usually about 60 fathoms, with a lead weight (formerly soapstone) fitted with polished hooks or gorges. A common fishing method was to jerk the line up and down in imitation of the movements of a small fish. Ling and cod caught by hand-line in the spring were salted and stored for the following winter. Other species were caught while hand-lining. Some of these were highly regarded, others like plaice and lemon-sole were considered to be dirty fish, fit only for use as bait.

Such fishery, with hook and line for large saithe, cod and ling are still pursued in these northern waters for domestic use. But there is also considerable ethnographic and linguistic evidence to suggest a long tradition of exploiting the plentiful, tasty and nourishing tiny young of the saithe. This evidence covers not only Caithness, Orkney and Shetland, but the Western Isles. Whilst Norse period sites confirm the presence of large white and grey fish, evidence is notably absent for small inshore fish - particularly the young saithe (Baldwin, 1982, 162).

By the late 18th century small lines were used. These were mounted with about 100 baited hooks and were probably first used in post-Norse years. For best results a line had to be shot in the dark in the morning so as to be in position when the fish were inclined to feed at the first of the day. So men had to launch their boats in the middle of the night, row and sail their way to the grounds, shoot their lines, make their way back to shore, land their catch and then return to and bait the line again ready for the next morning.

A more detailed discussion of ancient fishing equipment is beyond the scope of this study; however to omit mention of the large numbers of stone sinkers from Norse sites in Orkney and Shetland is to ignore an important kind of evidence for fishing. It is important to point out that the attribution of 'line sinker' is not necessarily accurate. Many could have been used for a variety of purposes. However, the shape of at least some suggest a line towed behind a boat in tideways while others appear to have been directly dropped to the sea-bed from a stationary boat (Goodlad, 1971, 58-9).

7.1.2 Comparable Archaeological Material

The only substantial deposits of Pictish and Norse remains from the north of Scotland examined to date by comparable methods to those used at Freswick are the assemblages from Buckquoy (Wheeler, 1977a), various sites in Orkney examined by Colley (1983b; 1989) and an unpublished assemblage from Skaill, Deerness, examined by Rebecca Nicholson (n.d.).

The Buckquoy assemblage containing bones from Pictish and Norse contexts, was collected by hand and is dominated by cod which ranged in size from fishes about 400 mm to 860 mm TL. Saithe or pollack were present as small fishes and large individuals (about 900 mm TL), while ling were mainly large (over 1 m TL).

The Buckquoy assemblage showed greater species diversity in Norse layers than Pictish deposits and Wheeler suggested a greater reliance on fish during the Norse period, and improved fishing techniques.

Deposits at Quoygrew, Westray, Orkney, where Colley (1983b, 247-250, figures 7.3-7.5) sieved samples of midden of Norse date on 1.5 mm aperture meshes produced small samples of bones showing great similarities to those found at Freswick. Colley recorded the P1 measurement on 12 saithe premaxillae. Most were from small and medium sized fishes (P1 3-5.5 mm; n = 11) with some larger animals (up to 10 mm P1; n = 11). Dentary measurements (n = 29) gave similar picture of mainly small to medium sized animals (D1 2.5-6 mm and a few large specimens D1 11-13 mm).

Cod bones from this site were of a wide size range (P1 5-17 mm with indistinct peaks at 9 and 15; n = 61). The dentaries (n = 27) showed two groups: a group of small fish (D1 4-6 mm) and a second group of large fish (D1 8-12mm with a clear peak at 8.5 mm). Ling bones were uncommon and were generally from large fish (P1 8.5-16 mm; n = 10).

Only two of the Quoygrew bones had teeth marks. Few bones bore knife or other blade marks which Colley interpreted as associated with the removal of heads (p 215). However, the illustrations, (Figure 7.6 p 250) show that most marks on the post temporal and cleithrum are consistent with filleting.

At the site of Cleat, Westray, Colley (1983b, 217-22; figures 7.8-9) also wet sieved archaeological deposits on 1.5 mm aperture mesh. She was able to measure the 45 cod premaxillae (P1 ranging 3.8-16.6 mm indistinct peaks at 7-9 mm and 11-14 mm). The group of 37 cod dentaries ranged from D1 3.1-10.5mm. Small numbers of saithe and ling were recovered but these were not described in detail.

At Evertaft, Aikerness, Westray, Colley (1983b, 222-228; figures 7.12-13) found saithe to be the dominant species followed by cod. A total of 58 saithe otoliths, measured between 5.0-14.2 mm corresponding with first, second and third year fishes. Cod otoliths ranged from 10- 20 mm OL (n = 20) while cod premaxillae ranged from 4.2-14.2 mm (n = 10) and cod dentaries (D1) measured between 2.2-5.2 mm (n = 10). Few ling bones were recovered.

At the site of Tuquoy, Westray, samples were sieved on 1 mm aperture mesh and yielded large numbers of saithe otoliths, bones and cod bones (Colley, 1983b, 231; figures 7.14-16). Saithe otoliths (n = 52) measured between 5.1 and 14.1 mm OL with most being less than 10 mm OL. Premaxillae (P1) and dentary (D1) measurements (n = 22 and n = 17 respectively) also indicated that most saithe were young fishes. Cod premaxillae (n = 16) and dentaries (n = 15) showed fishes of a large ranges of sizes were present. The Tuquoy assemblage produced only three gnawed bones.

The site of Isbister neolithic Chambered Cairn (Colley, 1983b, 234-236) produced a large assemblage of bones sieved on 5 mm aperture mesh. The assemblage of fish remains was dominated by bones of wrasses and cottids and contrasts strongly with those from Westray. Colley considered the material to have been largely deposited by otters or another piscivore. A second deposit of fish remains thought to be otter dropping was recovered during excavation at Bu Broch, near Stromness, Orkney Mainland, a Pictish site (Colley, 1983b, 239-241).

At Saevar Howe (Colley, 1983b, 236; figure 7.18) bones of young and large saithe, medium and large cod and large ling were present in pre-Norse and later deposits. No measurements were recorded for this site.

Pre-Norse and Norse deposits were recovered from a series of sites around the Bay of Birsay, excavated between 1976-1980 (Colley, 1983b, 241-244 figures 7.21-22). A total of 43 cod premaxillae were measured (range 5-17 mm with most measuring 12-15 mm). Dentaries (n = 20) were mainly from large fishes (D1 7-11 mm). Small numbers of saithe were recovered. Most were from young fishes, with a few bones from large individuals.

Fish remains from the site of Skaill, Deerness, were examined by Nicholson (n.d.). This site contained mostly deposits dated to periods of Norse occupation with small amounts of Pictish occupation. The assemblage was dominated by bones of cod, with saithe, pollack and ling remains also being common. Fifteen other species were recorded including gurnard, conger eel, plaice, sea scorpion, mackerel, megrim, thick-lipped grey mullet and tope. As the material was collected by hand Nicholson considered it unwise to present details of the size of the fishes.

The material from Freswick is very similar to all the above assemblages in the species identified, with the notable exceptions of Isbister Chambered Cairn and Bu Broch, both which are thought to be formed by animals other than man. The evidence suggests that fishing for both large cod and ling and shore fishing, mainly for saithe, predates the Norse colonization of the region. Much of the variation that Colley identified is likely to be a result of small sample size rather than to reflect changes in fishing methods or the exploitation of different fish populations at the various sites considered. It is unwise to base the interpretation of fishing activity on a samples of only 50 measured bones.

Baldwin stated that for the Scandinavian (Norse) period in the Scottish north, evidence from sites such as Jarlshof and Underhoull in Shetland (Hamilton, 1956, 143, 215; Small, 1966) suggest the considerably greater importance of cod and ling fishing around the mid 12th century than during the earliest period of Norse settlement (Baldwin, 1982, 161). This statement is based on observations on the abundance of fish remains in archaeological deposits of different dates. Such deductions are of dubious validity given the methods of recovery used in the excavations of Jarlshof and Underhoull and the difficulties of finding comparable assemblages.

Furthermore, there is no evidence for technological developments in fishing methods. There are indications that more fish remains were present in Norse deposits than Pictish deposits at several sites in the region including Freswick and

Skaill; however this should not be seen as evidence for technological change. It is more likely to reflect better survival of fish remains in archaeological deposits or large amounts of fish waste being discarded, possibly related to increases in intensity and duration of human settlement.

To summarize, the traditional fishing activities in the Caithness region, prior to the development of the herring fishery in the 19th century, consisted of shore and shallow water boat fishing for sellags (mainly young saithe) and line fishing for cod, ling, saithe and pollack. This activity also produced small numbers of other species. The assemblages of fish remains show that the exploitation of common gadid fishes, mainly saithe, cod and ling, began well before the period of Norse occupation.

7.2 THE RELATIVE IMPORTANCE OF SPECIES REPRESENTED AT FRESWICK LINKS

It is clear from the numbers of identified bones of the various taxa, the large number of chewed and eroded bones and the unidentifiable fragments recovered from the site that much of the fish material deposited at Freswick has decayed to irretrievable or unrecognizable fragments. Thus, any appraisal of the importance of the different fishes recovered from archaeological sites is likely to be flawed; however, it is possible to use the numbers of identifiable remains and their occurrence in the deposits as indicators of the relative importance of the various species.

Archaeozoologists have devised a large number of methods for counting bones in order to demonstrate the relative importance of the species present in deposits. Most methods of quantification rely on the number of identified specimens (NISP) as the basis for later calculations. This measure is of most use when considering assemblages of large terrestrial mammals, which possess a very similar basic skeleton composed of relatively robust bone. Fishes are very diverse in their skeletal composition and the robustness of fish bone is extremely heterogeneous. Consequently NISP is a less useful measure of abundance in fishes than it is in mammals.

Furthermore, the number of identified specimens of each taxon must be used cautiously in the present study because of the recording procedures. The decision to record systematically all bones of non-gadid taxa and only cleithra, dentaries, otoliths and premaxillae of gadids means that the NISPs for gadids and non-gadids are not comparable. However, the numbers of cleithra, dentaries, otoliths and premaxilla (Tables 21-24) can be used to assess the relative abundance of the taxa present.

The frequency (number of occurrences of a taxon in a group of samples or contexts) and relative frequency (the percentage of samples or contexts yielding a taxon) have been calculated in order to assess the relative abundance of taxa. Several authors have discussed the benefits of frequency data in archaeology and zoology (Erlinge, 1968; O'Connor 1985; Bigg and Perez, 1985; and Wheeler and Jones, 1989). An advantage of using frequency data to assess the abundance of taxa is that this measure is determined by the number of contexts (or samples) in which a taxon was recorded. It does not take into account the number of elements of each taxon in each context (or sample). Thus, as a measure of abundance, frequency overcomes many of the objections levelled at NISP.

Whether the frequency data (Table 27) or the numbers of cleithra, dentaries, otoliths and premaxillae (Tables 21-26) are considered there can be little doubt that the remains of gadid fishes, primarily large cod and ling, dominate the assemblages from Freswick. Substantial numbers of remains of saithe and smaller numbers of haddock and pollack remains were also present. Of non-gadid fishes pleuronectid flatfishes and gurnards were the most common. In addition, small numbers of remains from a large variety of other species were recovered.

7.2.1 Fishing Methods and Locations

It is likely that most of these fishes were caught using a baited hook or gorge suspended on a line. It was hoped that the assemblage of fish remains might provide some clues concerning likely fishing locations. While several of the less common non-gadid fishes do have a restricted depth range (e.g. tadpole fish, Raniceps raninus, and topknot, Zeugopterus punctatus) which might suggest fishing close to the shore, possibly within Freswick Bay, two factors preclude using these data for determining past fishing locations. First, the number of bones of tadpole fish and topknot in the deposits was very small, and it is quite possible that they were brought onto the site by scavengers feeding on animals cast onto the shore during storms. If the tadpole fish and topknot were caught by humans, it is most unlikely that all fishing activity was restricted to the shore and Freswick Bay.

Although precise estimations of the importance of different fishes are impossible, the excavated material is considered to be at least approximately representative of the fishes brought onto the site in the light of evidence on traditional fishing activities and the abundance and distribution of fishes in Caithness waters. It appears that the fisherfolk of Freswick were targeting their fishing activities on a small number of species. While most of the edible fish landed appears to be from large gadid fishes, presumably caught with hook and line, it is unlikely that the large number of small ?saithe (represented mainly by otoliths) were caught using the same fishing gear used for large cod and ling.

7.2.2 Fish Remains Introduced by Other Piscivores

While it is likely that most of the fish present at Freswick were caught during fishing expeditions for large cod and ling, some may have been introduced by agents other than man. Many conger eel and herring bones showed clear signs of having been ingested or at least chewed by a piscivore. The damage caused is not characteristic of any one species, although birds and otters may be excluded. The tooth marks on many of the bones are identical to those seen on bones recovered from dog, common seal and grey seal faeces.

While tooth-marked bones may have been deposited by dogs scavenging fish from a domestic midden, it is equally possible that scavengers collected fish cast up on the beach during storms and deposited digested bones on the site. It is also possible that some of the damaged bones were deposited on the beach in seal faeces and that subsequent storms and wind transported them into the site.

Furthermore, it is likely that some fish bones may have been present in the guts of animals (including fishes) brought to the site by humans or non-human scavengers.

7.2.3 Comparison of Species from Pictish and Norse Deposits

Evidence from radiocarbon and pottery thermoluminescence determinations shows that some of the deposits were laid down during the Pictish period. Most of the material, including the unphased deposits, are of Norse and Late Norse date. It was decided to compare the frequency of species in Pictish and Norse deposits (Table 27). While the concentration of fish remains in these deposits was lower than that in the richest of Norse and Late Norse deposits (see Tables 28-33) the range of species present was similar. This suggests that the fishermen of the Pictish periods were exploiting the same species as those exploited by Norse and Late Norse fishers.

Although the general condition of bones in Pictish layers was less well-preserved than those of later periods, there does not appear to be any major change in the kinds of fishes present in Pictish layers when compared to those found in later deposits.

This is an interesting result as it shows that the kinds of fishes exploited by the site's inhabitants in the period A.D.

330-680 were the same as those in Norse and Late Norse periods. Wheeler (1977a) suggested a technological improvement during this time to improve fish catching. While changes in fishing method may have occurred at Freswick during this period, it is not possible to detect any change in kinds of fishes, given that smaller assemblages were recovered and that the bones are generally poorly preserved. The implication is that more Pictish bones have decayed, or are in a worse state of preservation, than Norse material.

The passage of time and the attendant decay processes may also account for the lower concentrations and state of bones from Pictish layers. It is important to bear in mind that most Pictish layers appear to have been plough soils judging from the regular banding of these deposits when viewed in plan and the characteristically contorted appearance in vertical section. The mechanical abrasion caused by repeated ploughing may be sufficient to account for the state of Pictish bones.

7.2.4 Material from Domestic Buildings

The site of Freswick contains several distinctly different kinds of deposits rich in fish bones. Thick, presumably rapidly accumulating, midden deposits close to the shore contrast with the material around the Norse and Late Norse domestic building excavated by Curle (Areas 2a and 2b). Assemblages of fish remains associated with the domestic house excavated by Curle, appear to be dominated by large cod remains (Tables 34). It is tempting to suggest that this is good evidence for selection of cod for domestic consumption. However, if the condition of the otoliths and bones (Table 35) is considered it is clear that few remains are well preserved in this part of the site. Thus caution must be exercised before accepting this result to reflect food preferences.

The increased human and other activity at and around a domestic dwelling, including trampling and scavenging, may have favoured the survival of large robust bones and otoliths of cod as opposed to other species.

The condition of bones and otoliths in Area 4 contrasts strongly with that seen in Areas 2a and 2b. At Area 4 the nature of the deposits and the state of preservation of fish remains all suggest that deposits built up more rapidly than in Areas 2a and 2b. Area 4 produced larger numbers of articulated bones and a more complete range of bones (including cleithra).

To summarize, the relative importance of the species recovered from archaeological sites cannot be assessed accurately because the recovered remains have been subjected to differential decay processes. Nevertheless, it is clear that large cod and ling with saithe of all sizes were the most important food fishes at the site in Pictish, Norse and Late Norse deposits.

7.3 PROBLEMS IN INTERPRETING MEASUREMENT DATA

While there is broad agreement in the overall size of range and peaks of the 5 principal gadid fishes, it is clear from section 6.5 that the different bone measurements do not always agree in fine detail. There may be several reasons for this.

Chapter 4 explored the relationship between fish size and element dimensions and showed that generally the prediction interval was between roughly 20-25% of the estimated length. Such margins of error mean that accurate size estimation is impossible. Furthermore, it is unlikely that the bones and otoliths measured are from the same individual fishes and so it is unreasonable to expect the estimated sizes of the fishes based on different elements to be identical. Given that large numbers of bones have been destroyed at the site and the differential preservation is likely to be random, it is not surprising that discrepancies occur.

In Chapter 2 the errors inherent in measurement data were discussed. There are two measurements which are likely to be less reliable than others. While taking the P1 measurement of ling premaxillae it was not always easy to fit the callipers snugly into the base of the condyle. Thus this measure may tend to exaggerate the size of ling. In addition, the depth of the dentary bone at the symphysis (D2) of all species is now considered to be a less reliable measurement than the depth at the foramen (D1) for two reasons. Bone at the symphysis is more likely to be eroded than at the foramen. This erosion is not always conspicuous. Furthermore, it is possible that some of the modern data for this measurement may be unreliable as traces of dried cartilage were present on a few of the modern specimens.

7.4 TAPHONOMIC LOSS

There is much evidence that very large amounts of fish bone have disappeared from the site. Tables 36, 37, 40 & 41 show that in Area 3 and 9 where preservation was not at its best, many species are represented by few fragments. In Area 4 (Tables 38 & 39), where preservation was at its best, the numbers of bone fragments for each taxon also show huge losses had occurred. Furthermore direct evidence of taphonomic loss can be found on the many chewed and eroded bones and otoliths (Table 43). While it is not possible to be certain of the causes of this erosion, the most likely one is digestion. Chewed bone fragments testify to this. It is impossible to estimate how many fish remains were removed from the record by scavengers.

It is most interesting to note that Colley (1983b), in her study of fish remains from Orkney sites, noted very few gnawed bones. This may be because most of the material she studied was less well preserved than that from Freswick. Consequently, the elusive signs of chewing and other erosive processes may have been less conspicuous.

The Freswick assemblages also produced ample evidence that fish remains were burnt. Fenton (1978, 195) describes rubbish disposal practices in the Orkney and Shetland Isles and shows how much domestic rubbish was burnt and then discarded onto middens. The evidence from Freswick is entirely consistent with this. Some of the bone was burnt white, indicating temperatures of several hundred degrees C. (Nicholson forthcoming), while many deposits contained unidentifiable fragments of fish bone burnt black or bluish. These fragments are likely to be but a small fraction of the bone consumed by fires as burning renders fish bones very fragile.

Given that the remains were collected by sieving samples and carefully picking out fish remains from dried residues sieved on 2 mm aperture mesh, all but the smallest otoliths should have been recovered. If complete bones and otoliths were present, roughly equal numbers of each element might be expected. If account is taken of the number of identifiable fragments that bones and otoliths can break into, then cleithra fragments might be expected to be the most abundant, with otoliths being the least abundant.

There is huge taphonomic loss, even in well preserved assemblages. In fact, the best preserved assemblages show loss more clearly than poorly preserved ones (Maltby, 1985), because in poorly preserved assemblages (bone surface abraded or disintegrating) surface details such as gnawing and butchery marks have disappeared. The subtle signs of scavenger damage and blade injuries are more conspicuous on well-preserved material.

Some archaeologists have calculated the meat weights and calorific values of the whole animals represented in archaeological deposits in order to examine the relative importance of different species in the diet of the site's inhabitants. Such a procedure cannot be justified in the present study because to do so requires making estimates such as the length of time the deposits were accumulating, the amount of bone removed from the site by scavengers and the amount of bone accidentally deposited in midden deposits. Clearly such estimates cannot be readily verified and the procedure necessarily compounds error upon error.

7.5 EVIDENCE OF FISH PROCESSING

Given the numbers of large cod and ling bones identified and the methods of recovery used at Freswick, the numbers of bones of fish species eaten by large gadids is remarkably small. If whole fish were being processed at the site it might be expected that large numbers of bones of a wide range of small to medium sized fishes of gadid prey species would be present. While no attempt was made to identify all small bones found at the site, all cleithra, dentaries, premaxilla and otoliths were collected. The absence of large numbers of cod and ling prey fishes in the deposits suggests that the fish were gutted prior to arriving at the parts of Freswick Links excavated in 1980-82.

Ross (1883) mentions how once unhooked the large gadid fishes are immediately bled and gutted on board ship. Fenton (1978) also mentions that traditionally fishermen from the Orkneys and Shetlands removed the head and part of the backbone at sea. The evidence from Freswick suggests that gutting at least was carried out at some other place than the excavated parts of Freswick Links in Norse times.

More direct evidence of fish processing can be found in the Freswick assemblage of large gadid bones. One of the main reasons for systematically recording cleithra, dentaries, otoliths and premaxillae is the quest for evidence of fish processing. Sites receiving processed fish waste are expected to be dominated by cranial elements with few cleithra and associated bones, while sites where processed fish is consumed are likely to yield assemblages dominated by cleithra and vertebrae. Post medieval cod bone assemblages from Exeter were dominated by cleithra and supracleithra and Wilkinson (1979, 75) used evidence of this to suggest the presence of 'split fish where the viscera, head and anterior part of the backbone have been removed to leave a solid body of meat'.

That fish processing was carried out at or very near Freswick Links is evident from the small number of bones bearing knife and other blade marks. These marks are typical of those left when fillets are removed from large fishes. However, very few of the bones bore knife or other blade injuries. To understand this it is important to know a little about fish processing methods. Ross (1883) describes fish processing in Scotland and describes how, once split along the belly (an action that leaves no marks on bones), the viscera of haddock are removed with the head leaving the shoulder (including the cleithrum) with the body. This separation is effected by passing the forefinger and thumb of the left hand around the 'neck' of the fish and seizing the head in the right hand. The vertebrae are dislocated at the base of the skull by a straight backward jerk and a sharp pull whereby the muscles and skin of the pectoral girdle are detached from the base of the skull. Thus the body and cleithrum (and associated bones) are separated leaving no cut marks on bones. It is also possible to decapitate fishes larger than haddock using this procedure (Alec Wares, pers comm.).

Further evidence of fish processing may at first sight be the small number of cleithrum fragments compared with other elements. As cleithra are typically removed from the carcass with fillets to support the fish during drying, it is tempting to suggest that the small numbers of cleithra are evidence for fish processing. The numbers of fragments of cleithra are consistently lower than the numbers of dentaries, otoliths and premaxillae. However, the numbers of dentaries, otoliths and premaxillae are not similar and show that differential preservation of fish remains has occurred. Thus the small number of cleithrum fragments may have resulted from differential decay. Trampling on a single cod skeleton (chapter 3) showed that dentaries, otoliths and premaxillae were more resistant to mechanical damage than cleithra. Clearly one experiment is not sufficient to draw definite conclusions; however, it does suggest that the low numbers of cleithra may be attributed to differential decay rather than to human activity.

Chapter 8

SUMMARY AND CONCLUSIONS

The main objective of this study was to examine a large sample of well-preserved fish remains in order to gain insights into their potential and limitations in archaeological research. Prior to 1980, studies of archaeological Pictish and Norse fish remains in northern Scotland were largely confined to the analysis of small or medium-sized samples of fish remains, usually recovered by hand-collecting larger fish bones from excavated deposits. These analyses were usually carried out by museum staff who never visited the excavations but simply reported on material received.

As a result, early interpretations can easily be criticized. They were prone to over-estimate the importance of human activities in forming the deposits and to ignore features of the assemblage that may relate to its taphonomic history. These failings resulted from too great a separation between field work and the identification of ancient remains. Poor recovery of animal and plant remains at archaeological sites is also an important factor. In the years since 1980, considerable progress has been made in integrating fieldwork, investigating modern assemblages of fish remains and refining methods of post-excavation analysis. These exciting developments have allowed a more balanced view of the significance of fish remains to emerge.

The sampling and recovery procedures, developed for this study, were successful in yielding large numbers of bones and otoliths free from the biases associated with hand-collected assemblages. The fish remains thus form an extremely important collection for comparison with other sites in the region.

During the course of the investigation, experiments were undertaken to assess the ability of fish bones to survive processes which are likely to occur on human occupation sites. These experiments demonstrated that fish bone is extremely vulnerable to decay compared with mammal bone and that some elements survive better than others. The bones and otoliths that do survive in archaeological deposits are likely to be a small and probably heavily biased sample of those brought onto the site. Examples of modern deposits of fish remains accumulated by piscivorous mammals share many features (e.g. species composition and element distribution) with fish waste accumulated by humans. When these observations are taken into account the limitations of archaeological assemblages emerge.

While interpretation based on the kinds of fishes present and their relative abundance in the deposits is likely to be sound, the numbers of different elements of fishes can be highly influenced by element robustness. Thus detailed analyses of the numbers of different elements are unlikely to provide useful insights into fish exploitation. Much of the patterning observed in archaeological assemblages of fish remains simply reflects the ability of different elements to survive.

Investigations into the relationship between fish total length and the size of cleithra, dentaries, otoliths and premaxillae have made it possible to predict the size of fishes from their bones within statistically determined confidence limits. While this development has the advantage of providing an objective method for making size estimations, it has demonstrated the amount of variation in bone and otolith size of fishes of the same length. Size estimations made by comparing archaeological remains with the same element from a small, medium and large modern specimen in most instances will provide as accurate a picture of fish size.

Identification of the remains has shown that many different kinds of fishes were represented in the deposits, but in considering both the numbers of identified bones and the frequency of occurrences of the various fish taxa in the sediment samples, the assemblage is dominated by the remains of three species of gadid fishes, cod, Gadus morhua, saithe, Pollachius virens and ling, Molva cf. molva. although there are some problems with the identification of saithe remains.

It appears that large cod, ling and saithe were caught by line fishing in waters up to about 60 fathoms deep. Young saithe were more likely to be caught very close to the shore.

Many other kinds of fishes were present in the deposits. While most were probably incidental catches, some of the remains suggest non-human scavengers and other agents contributed fish bones to the deposits.

Perhaps the most significant result to emerge from the study is the astonishing similarity in the kinds of fishes represented in Pictish and Norse deposits at Freswick. While different kinds of fishing methods may have been used in the two periods, there is no evidence of changes in the kinds of fish remains deposited at the site in the different periods of occupation. The fish remains suggest the human populations living at Freswick exploited the locally abundant fish populations for several centuries without adversely affecting species diversity. Fishing is best seen as one subsistence activity within a variety of tasks which occupied the inhabitants of Freswick Links.

The potential of the Freswick material for further analysis is great. Once full stratigraphic analysis of the site is complete it will be possible to explore the distribution of species across the site in more detail. Where future work might more profitably be directed is in the study of relative robustness of the bones of large gadid fishes. Comparing the abraded bones and otoliths with modern specimens which have been subjected to a variety of treatments (e.g. acid dissolution, abrasion by dry sand and rolled in sand water mixtures) using the scanning electron microscope may show how the ancient material was treated. Once such studies have been undertaken, it might be possible to read more from the patterns of element distribution in the Freswick assemblage than has been thought valid at this time.

At other Pictish and Norse sites excavation should concentrate on recovering comparable samples of fish remains by adopting similar recovery methods to those employed at Freswick.

The use of 1 mm aperture sieves is necessary to recover small otoliths, and large amounts of sediment need to be processed to recover the most readily identified bones of food fishes.

The approach used at Freswick concentrated on recovering a large amount of material, selectively examining the remains and interpreting it cautiously. It is hoped that this work has highlighted the need for careful excavation, analysis and interpretation in order to exploit the potential of fish remains in archaeological research.

REFERENCES

Anderson, J. (1874). Notes on the relics of the Viking Period of the Northmen in Scotland, illustrated by specimens in the Museum, Proceedings of the Society of Antiquaries of Scotland 10, 536-594.

Baldwin, J. R. (ed.), (1982). Caithness. A cultural crossroads. Scottish Society for Northern Studies: Edinburgh.

Balme, J. (1983). Prehistoric fishing in the lower Darling, western New South Wales, pp. 19-32. In Grigson, C. and Clutton-Brock, J. (eds.). Animals and archaeology, 2. Shell middens, fishes and birds, British Archaeological Reports International Series, 183.

Barker, G. (1975). To sieve or not to sieve, Antiquity 49, 61-3.

Barry, G. (1793). Orkney: Kirkwall and St Ola 1793. A reprint from the First Statistical Account of Scotland. Pentland Press: Thurso

Batey, C. E. (1982). The late Norse site of Freswick, pp. 45-49, In Baldwin, J. R. (ed.). Caithness. A cultural crossroads. Scottish Society for Northern Studies: Edinburgh.

Batey, C. E. (1987). Freswick Links, Caithness. A re-appraisal of the Late Norse site in its context. British Archaeological Reports British Series 179 (2 vols). Oxford.

Batey, C. E., Jones, A. K. G., Morris, C. D. and Rackham, D. J. (1981). Excavations and survey at Freswick Links, and Freswick Castle, 1979-80. Summary Report. University of Durham: Durham.

Batey, C. E., Jones, A. K. G., Morris, C. D., Rackham, D. J. and Rains, M. J. (1983). Excavations and survey at Freswick Links, 1981-82. Summary Report. University of Durham: Durham.

Batey, C. E., Morris, C. D., and Jones, A. K. G., (1982). Freswick Links, Caithness, progress report on survey and excavations, 1981, pp. 54-8. In Harding, A. F. and Haselgrove, C. C., (eds.). Archaeological reports for 1981, University of Durham and University of Newcastle upon Tyne Archaeological Reports 5, (Durham).

Batey, C. E. Morris, C. D. and Rackham, D. J. (1984). Freswick Castle, Caithness: report on rescue excavations carried out in 1979, Glasgow Archaeological Journal 11, 83-118.

Bedford, B. C. (1983). A method for preparing sections of large numbers of otoliths embedded in black polyester resin, Journal du Conseil _ Conseil Permanent International pour l' Exploration de la Mer 41, 4-12.

Beeley, J. G. and Lunt, D. A. (1980). The nature of the biochemical changes in softened dentine from archaeological sites, Journal of Archaeological Science 7, 371-377.

Behrensmeyer, A. K. and Hill, A. P. (eds.). (1980). Fossils in the making: vertebrate taphonomy and paleoecology. University of Chicago Press: Chicago.

Bertelsen, E. (1942). Contributions to the biology of the coalfish (Gadus virens L.) in Faroe waters, Meddelelser fra Kommisionen for Danmarks Fiskeri- og Havundersøgelser, Serie - Fiskeri 11, 1-68.

Bigg, M. A. and Perez, M. A. (1985). Modified volume: a frequency-volume method to assess marine mammal food habits, pp. 277-83, In Beddington, J. R., Beverton, R. J. H. and Lavigne, D. M. (eds.) Marine mammals and fisheries. George Allen and Unwin: London.

Binford, L. (ed.), (1977). For theory building in archaeology. Academic Press: London.

Binford, L. (1978). Nunamuit ethnoarchaeology. Academic Press: London.

Binford, L. (1981). Bones, Ancient men and modern myths. Academic Press: London.

Binford, L. and Bertram, J. B. (1977). Bone frequencies and attritional processes, pp. 77-153. In Binford, L. (ed.). For theory building in archaeology. Academic Press: London.

Blacker, R. W. (1974). Recent advances in otolith studies, pp.

67-90. In Jones, F. R. H. (ed.), Sea fisheries research. Elek Science: London.

Bodner, C. C. and Rowlett R. M. (1980). Separation of bone, charcoal and seeds by chemical flotation, American Antiquity 45(1), 110-6.

Brain, C. K. (1967). Hottentot food remains and their bearing on the interpretation of fossil bone assemblages, Scientific Papers of the Namib Desert Research Station32, 1-11.

Brain, C. K. (1969). The contribution of Namib Desert Hottentots to an understanding of australopithecine bone accumulations, Scientific Papers of the Namib Desert Research Station 39, 13-22.

Brain, C. K. (1981). The hunters or the hunted? an introduction to African cave taphonomy. University of Chicago Press: Chicago.

Brinkhuizen, D. C. (1989). Ichthyo-archeologisch onderzoek: methoden en toepassing aan de hand van Romeins vismateriaal uit Velsen (Nederland). Ph. D. Thesis. Rijkuniversiteit Groningen: Netherlands.

Bron, J. E. (1987). An investigation of the survival and fragmentation of fish bone elements subjected to mechanical stress, with particular reference to the interpretation of archaeological fish bone assemblages. M. Sc. Thesis, University College London, Institute of Archaeology.

Cannon, D. Y. (1987). Marine fish osteology. Archaeology Press Simon Fraser University: Burnaby, British Columbia.

Carlander, K. D. (1969). Handbook of freshwater fishery biology, 1. Iowa State University Press: Ames, Iowa.

Carlander, K. D. (1977). Handbook of freshwater fishery biology, 2. Iowa State University Press: Ames, Iowa.

Casteel, R. W. (1976). Fish remains in archaeology and paleo-environmental studies. Academic Press: London.

Chaplin, R. E. (1971). The study of animal bones from archaeological sites. Academic Press: London.

Chasler, C. R. (1972). An investigation into some mechanical and physical properties of cellular and acellular bone in teleost fish. Unpublished B.Sc. dissertation, University of York: York, England.

Cherry, J. F., Gamble, C. and Sheenan, S. (eds.), (1978). Sampling in contemporary British archaeology. British Archaeological Reports, 50.

Childe, V. G. (1943). Another Late Viking house at Freswick, Caithness, Proceedings of the Society of Antiquaries of Scotland 77, 5-17.

Clark, J. G. D. (1948). The development of fishing in prehistoric Europe, Antiquaries Journal 28, 45-85.

Clark, J. G. D. (1980). Mesolithic prelude, the palaeolithic-neolithic transition in Old World prehistory. Edinburgh University Press: Edinburgh.

Clason, A. (1986). Fish and archaeology, pp. 1-8. In Brinkhuizen, D. C. and Clason, A. T. (eds.) Fish and archaeology: studies in osteometry, taphonomy, seasonality and fishing methods, British Archaeological Reports International Series, 294.

Coles, J. (1971). The early settlement of Scotland, excavations at Morton, Fife, Proceedings of the Prehistoric Society 37, 284-366.

Collette, B. B. and Naunen, C. E. (1983). Food and Agriculture Organisation species catalogue, Vol. 2. Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos and related species known to date. Food and Agriculture Organisation Fisheries Synopsis 125 (2), 1-137.

Colley, S. M. (1983a). Interpreting prehistoric fishing strategies: an Orkney case study, pp. 157-171. In Grigson, C. and Clutton-Brock, J. Animals and Archaeology: 2. Shell middens, fishes and birds. British Archaeological Reports International Series, 183.

Colley, S. M. (1983b). The role of fish bone studies in economic archaeology, with special reference to the Orkney Isles. Unpublished Ph. D. thesis, University of Southampton, England.

Colley, S. M. (1984). Some methodological problems in the interpretation of fish remains from archaeological sites in Orkney, pp. 117-31. In Desse-Berset, N. (ed.). 2nd fish osteoarchaeology meeting, C.N.R.S. Centre de recherches archéologiques. Notes et Monographies Techniques, 16.

Colley, S. M. (1989). The fish remains, pp. 248-259, fiche pp. IV A9-13 below; pp. IV B1-E5 below, In Morris, C. D. The Birsay Bay Project. Volume 1, Coastal sites beside Brough Road, Birsay, Orkney. Excavations 1976-1982. University of Durham, Department of Archaeology Monograph Series 1, Durham.

Crampton, C.B. and Carruthers, R. G. (1914). The geology of Caithness. Memoirs of the Geological Survey of Scotland: Edinburgh.

Cruse, R. J. and Harrison A. C., (1983). Excavation at Hill Road, Wouldham, Archaeologia Cantiana 99, 81-108.

Curle, A. O. (1939). A Viking settlement at Freswick, Caithness. Report on excavations carried out in 1937 and 1938. Proceedings of the Society of Antiquaries of Scotland 73, 71-110.

Desse, J. (1984). Propositions pour une réalisation collective d'un corpus: fiches d'identification et d'exploitation métrique du squelette des poissons, pp. 67-86. In Desse-Berset, N. (ed.) 2nd fish osteoarchaeology meeting, C.N.R.S. Centre de recherches archéologiques. Notes et Monographies Techniques, 16.

Desse, J., Desse-Berset, N. and Rocheteau, M. (1987a). Contribution a l'osteometrie de la perche (Perca fluviatilis Linné, 1758). Fiches d'osteologie animale pour l'archéologie Series A: Poissons No, 1. Centre de Recherches Archéologiques du CNRS.

Desse, J., Desse-Berset, N and Rocheteau, M. (1987b). Contribution à l'ostéométrie du mulet Liza (Liza) ramada Risso, 1826 (= Mugil capito Cuvier, 1829). Fiches d'osteologie animale pour l'archéologie Series A: Poissons No 2. Centre de Recherches Archéologiques du CNRS.

Donaldson, A. M., Jones, A. K. G. and Rackham, D. J. (1980). Barnard Castle, Co. Durham. A dinner in the Great Hall: report on the contents of a fifteenth-century drain, Journal of the British Archaeological Association 133, 74-96.

Edwards, A. J. H. (1925). Excavations of a chambered cairn at Ham, Caithness and of a hut circle and two earth houses at Freswick Links, Proceedings of the Society of Antiquaries *of Scotland* 59, 85-94.

Edwards, A. J. H. (1927). Excavations of graves at Akergill and of an earth house at Freswick Links, Caithness, and a discovery of a Viking grave at Reay, Caithness, *Proceedings of the Society of Antiquaries of Scotland* 62, 160-82.

Efremov, J. A. (1940). Taphonomy: new branch of paleontology, *Pan-American Geologist* 74(2), 81-93.

Enghoff, I. B. (1983). Size distribution of cod (*Gadus morhua* L.) from a Mesolithic settlement at Vedbaek, North Zealand, Denmark, *Videnskabelige Meddelelser fra dansk naturhistorisk Forening* 144, 83-97.

Erlinge, S. (1968). Food studies on captive otter *Lutra lutra* L., *Oikos* 19 (2), 259-70.

Fenton, A. (1978). *The Northern Isles, Orkney and Shetland*. John Donald, Edinburgh.

Follett, W. I. (1967). Fish remains from coprolites and midden deposits at Lovelock Cave, Churchill County, Nevada, *University of California Archaeological Survey Report* 70, 94-115.

Frost, G. A. (1926). A comparative study of the otoliths of the Neopterygian fishes (continued). XIII. Order Anacanthini,*Annals and Magazine of Natural History. Series 9* 18, 483-491.

Gifford, D. P. and Behrensmeyer, A. K. (1978). Observed depositional events at a modern human occupation site in Kenya, _Quaternary Research_ 8, 245-66.

Gilbertson, D. D., Kent, M. and Pyatt, F. B. (1985). _Practical ecology for geography and biology: survey, mapping and data analysis_. Hutchinson: London.

Goodlad, A. (1971). _Shetland fishing saga_. The Shetland Times: Lerwick, Scotland.

Green, R. H. (1979). _Sampling design and statistical methods for environmental biologists_. John Wiley: New York.

Grieg, S. (1940). _Viking Antiquities in Scotland_. Volume 2 of _Viking antiquities in Great Britain and Ireland_ ed. Shetelig, H. Videnskapelign Forskingsford, Aschehoug: Oslo.

Guerreschi, A. (1973). A mechanical sieve for archaeological excavations, _Antiquity_ 47, 234-5.

Günther, A. C. L. G. (1880). _An introduction to the study of fishes_. Black: Edinburgh.

Hallström, A. (1979). Die Fischknocken, pp. 422-92. In Boessneck, J., Driesch, A. von den and Sternberger, L. (eds.). _Eketorp - Befestigung und Siedlung auf Öland (Schweden). Die Fauna_. Almquist and Wikseil International: Stockholm, Sweden.

Halstead, L. B. (1974). Vertebrate hard tissues. Wykeham: London.

Hamilton, J. R. C. (1956). Excavations at Jarlshof, Shetland. Ministry of Works Report No. 1. Edinburgh.

Harcourt, R. A. (1969). Animal remains, pp. 113-4. In Rahtz, P. A. Rahtz, P. A. Excavations at King John's Hunting Lodge, Writtle, Essex, (1955-7). Society for Medieval Archaeology Monograph, 3.

Harder, W. (1964). Handbuch der Binnenfischerei Mitteleuropas: Anatomie der Fische. E. Schweizerbart'sche Verlagsbuchhandlung: Stuttgart.

Harder, W. (1975). Anatomy of fishes. E. Schweizerbart'sche Verlagsbuchhandlung: Stuttgart.

Härkönen, T. (1986). Guide to the otoliths of the bony fishes of the northeast Atlantic. Danbui ApS: Denmark.

Harrington, R. W. (1955). The osteocranium of the American cyprinid fish Notropis bifrenatus, with an annotated synonymy of teleost skull bones, Copeia 1955, 267-90.

Heinrich, D. (1985). Die Fischreste aus der frügeschichtlichen Marschensiedlung beim Elisenhof in Eiderstedt. Schriften aus der Archäologisch-Zoologischen Arbeitsgruppe Schleswig-Kiel 9. Kiel

Heinrich, D. (1986). Fishing and the consumption of cod (Gadus morhua L. 1758) in the middle ages, pp 42-52. In Brinkhuizen, D. C. and Clason, A. T. (eds.). Fish and archaeology, British Archaeological Reports International Series, 294.

Heinrich, D. (1987). Untersuchungen an mittelalterlichen Fischresten aus Schleswig, Ausgrabung Schild 1971-75. Ausgrabungen in Schleswig, Berichte und Studien 6. Karl Wachholtz Verlag: Neumünster.

Höglund, H. (1972). On the Bohuslän herring during the great herring fishery period in the eighteenth century, Reports for the Institute of Marine Research, Lysekil, Series Biology No. 20, 1-86.

Huntley J. P. (1985). Pollen analytical investigations at Freswick, Caithness. Palaeoenvironmental Studies Service, University of Durham: Durham.

Hureau, J. C. and Monod, Th. (1979). Check-list of the fishes of the north-eastern Atlantic and of the Mediterranean (Clofnam). Unesco: Paris.

Imbrie, J. (1956). Biometrical methods in the study of invertebrate fossils, Bulletin of the American Museum of Natural History 108, 215-52.

Izquierdo, E. R. (1986). Contribución al Atlas Osteológico de los Teleósteos Ibéricos. I Dentario y Articular.

Colección de Estudios. Ediciones de la Universidad Autonóma de Madrid: Madrid.

Jarman, H. N., Legge, A. J. and Charles, J. A. (1972). Retrieval of plant remains from archaeological sites by froth flotation, pp. 39-48. In Higgs, E. S. (ed.) Papers in economic prehistory. Cambridge University Press: Cambridge.

Jollie, M. (1986). A primer of bone names for the understanding of actinopterygian head and pectoral girdle skeletons,Canadian Journal of Zoology **64**, 365-79.

Jolly, T. (1794). Caithness: Dunnet, Olrig and Reay, 1793-4. A reprint from the First Statistical Account of Scotland. Pentland Press: Thurso

Jones, A. K. G. (1976). The fish remains, pp. 170-6. In Black, G. Excavations in the sub-vault of the Misericorde of Westminster Abbey. Transactions of the London and Middlesex Archaeological Society **27**, 135-78.

Jones, A. K. G. (1978). Fish remains, passim, 171-2, 220, 414-8, 466-7 & 601. In Bird, J., Graham, A. J., Sheldon, H. and Townend, P. (eds.). Southwark excavations 1972-1974. Parts I and II. Southwark and Lambeth Archaeological Excavation Committee. Joint Publication, **No. 1**, London and Middlesex Archaeological Society.

Jones, A. K. G. (1983). A comparison of two on-site methods of wet-sieving large archaeological soil samples, Science and Archaeology 25, 9-12.

Jones, A. K. G. (1984a). Some effects of the mammalian digestive system on fish bones, pp. 61-5. In Desse-Berset, N. (ed.). 2nd fish osteoarchaeology meeting, C.N.R.S. Centre de recherches archéologiques. Notes et Monographies Techniques, 16.

Jones, A. K. G. (1984b). Fish, p. 111, microfiche III-IV. In Batey, C. E., Morris, C. E. and Rackham, D. J. (eds.), Freswick Castle, Caithness: report on excavations carried out in 1979, Glasgow Archaeological Journal 2, 83-218.

Jones, A. K. G. (1986a). Fish bone survival in the digestive systems of the pig, dog and man, some experiments, pp. 53-61. In Brinkhuizen, D. C. and Clason, A. T. (eds.). Fish and archaeology, British Archaeological Reports International Series, 294.

Jones, A. K. G. (1986b). Provisional remarks on fish remains from Anglo-Scandinavian deposits at 16-22 Coppergate, York, pp. 192-9. In Creswell, R. and Bailey, S. (eds.). Proceedings of the Institute of Fisheries Management 16th Annual Study Course, Institute of Fisheries Management.

Jones A. K. G., Jones, J. J. M. and Spriggs, J. A. (1986). Results of a second marker trial, Circaea 4, 69-70.

Jones, A. K. G. and Scott, S. A. (1985). The fish bones, pp.

223-8. In Atkin, M., Carter, A. and Evans, D. H. Excavations in Norwich 1971-1978 part II, East Anglian Archaeology 26.

Kenchington, T. J., Carter, J. A. and Rice, E. L. (forthcoming). The indispensability of non-artefactual data in underwater archaeology. (Authors address: Underwater archaeology Society of Nova Scotia, Maritime Museum of the Atlantic, 1675 Lower Water Street, Halifax, Nova Scotia, B3J 1S3, Canada.) Article sumbitted to the Journal of Marine Archaeology.

Kenward, H. K., Hall, A. R. and Jones, A. K. G. (1980). A tested set of techniques for the extraction of animal and plant macrofossils from waterlogged archaeological deposits, Science and Archaeology 22, 3-15.

Kennedy, M. (1969). The sea angler's fishes. Stanley Paul: London.

Leach, F. (1986). A method for the analysis of Pacific Island fishbone assemblages and an associated database management system. Journal of Archaeological Science 13, 147-59.

Lepiksaar, J. (1981). Osteologia. I. Pisces. Privately distributed, Göteborg.

Lepiksaar, J. and Heinrich, D. (1977). Untersuchungen an Fischresten aus der frühmittelalterlichen Siedlung Haithabu, Berichte über die Ausgrabungen in Haithabu, 10.

Levitan, B. (1982). Excavations at West Hill Uley, The sieving and sampling programme. Western Archaeological Trust: Gloucester.

Maltby, J. M. (1985). Patterns in faunal assemblage variability, pp. 33-74. In Barker G. and Gamble C. Beyond domestication in prehistoric Europe. Academic Press: London.

Mann, R. H. K. and Beaumont, W. R. C. (1980). The collection, identification and reconstruction of lengths of fish prey from their remains in pike stomachs, Fisheries Management 11(4), 169-72.

Mantle, S., Ramsey, R., Maynard, D. and Williams, G. (1984). Wet sieving at Llawhaden, Dyfed, Circaea 2(3), 141-3.

Meek, A. (1916). The migrations of fish. Arnold: London.

Morales, A. and Rosenlund, K. (1979). Fish bone measurements, an attempt to standardise the measuring of fish bones from archaeological sites. Steenstrupia: Copenhagen.

Morris, C. D. (1989). The Birsay Bay Project. Volume 1, Coastal sites beside Brough Road, Birsay, Orkney. Excavations 1976-1982. University of Durham, Department of Archaeology Monograph Series 1, Durham.

Morris, C. D., Batey, C. E. and Rackham, D. J. (forthcoming). Excavations at Freswick Links, Caithness, 1980-82: The cliff side. Report submitted to the Scottish Development Department for publication.

Morrison, J. (1793). Caithness: Canisbay 1793. A reprint from the First Statistical Account of Scotland. Pentland Press: Thurso.

Moss, M. L. (1961) Osteogenesis of acellular teleost fish bone, American Journal of Anatomy 108, 99-109.

Mueller, J. W. (1975). Sampling in archaeology. University of Arizona Press: Tucson.

Mummery, J. H. (1924). The microscopic and general anatomy of the teeth human and comparative. Oxford University Press: Oxford.

Murphy, P. (1983). Studies on the environment and economy of a Bronze Age Fen-edge site at West Row, Mildenhall, Suffolk, a preliminary report, Circaea 1(2), 49-57.

Nicolaisen, W. F. H. (1982). Scandinavians and Celts in Caithness: the place-name evidence, pp. 75-85. In Baldwin, J. R, (ed.). Caithness. A cultural crossroads. Scottish Society for Northern Studies: Edinburgh.

Nicholson, R. A. (n.d.) The fish bones from Skaill, Deerness. Report submitted for publication to M. Gelling, University of Birmingham.

Nicholson, R. A. (forthcoming) Burnt bones what value to archaeology? In Jonsson, L. (ed.) Papers presented at the 5th meeting of the International Council of Archaeolzoologists Fish Remains Working Group, Gothenburg, Sweden, September 1989.

Noddle, B. (1980). Identification and interpretation of the mammal bones, pp. 377-412. In Wade-Martins, P. North Elmham, East Anglian Archaeology 9, 1-660.

Noe-Nygaard, N, (1983). The importance of aquatic resources to mesolithic man at inland sites in Denmark, pp. 125-42. In Grigson, C. and Clutton-Brock, J. (eds.). Animals and archaeology, 2. Shell middens, fishes and birds, British Archaeological Reports International Series 183.

Nolf, D. and Steurbaut, E. (1989). Evidence from otoliths for establishing relationships between gadiforms and other groups, pp. 37-111. In Cohen, D. Papers on the systematics of gadiform fishes. Natural History Museum of Los Angeles County, Science Series, No. 32: Los Angeles.

O'Connor, T. P. (1983). Aspects of site environment and economy at Caerleon Fortress Baths, Gwent, pp. 105-13. In Proudfoot, B. (ed.). Site, environment and economy, Symposia of the Association for Environmental Archaeology 3, British Archaeological Reports International Series, 173.

O'Connor, T. P. (1985). On quantifying vertebrates - some sceptical observations, Circaea 3, 27-30.

O'Connor, T. P. (1988) Bones from General Accident site. Archaeology of York 15/3 Council for British Archaeology: London.

O'Connor, T. P. (1989). Bones from Anglo-Scandinavian levels at 16-22 Coppergate. Archaeology of York 15/4.

Olsen, H. (1967). Fisk. Varanger-Funnene IV Osteologisk materiale innledning - fisk - fugl, Tromsø Museums Skrifter 7(4), 19-78.

Olsen, S. J. (1968). Fish amphibian and reptile remains from archaeological sites. Part 1. South-eastern and southwestern United States, Papers of the Peabody Museum of Archaeology and Ethnology, Harvard University 56 (2).

Omand, D. (1972a). The Caithness Book. Highland Printers Ltd: Inverness.

Omand, D. (1972b). The Ice Age, pp. 26-32. In Omand, D.The Caithness Book. Highland Printers Ltd: Inverness.

Payne, S. (1972). Partial recovery and sample bias. The results of some sieving experiments pp. 49-63. In Higgs, E. S. (ed.) Papers in economic prehistory. Cambridge University Press, Cambridge.

Payne, S. and Munson, P. J. (1985). Ruby and how many squirrels? The destruction of bones by dogs, pp. 31-48.

In Fieller, N. R. J., Gilbertson, D. D. and Ralph, N. G. A. (eds.). Palaeobiological Investigations, Research design, methods and data analysis, Symposia of the Association for Environmental Archaeology No. 5B. British Archaeological Reports International Series, 266.

Peglar, S. (1979). A radiocarbon-dated pollen diagram from Loch of Winless, Caithness, New Phytologist 82, 245-63.

Pitcher, T. J. and Hart, J. B. (1982). Fisheries ecology. Croom Hill: London.

Platt, M. (1939). The animal bones pp 109. In Curle, A. O. A Viking settlement at Freswick, Caithness. Report on excavations carried out in 1937 and 1938, Proceedings of the Scottish Society of Antiquaries 73, 71-110.

Prime, J. H. (1979). Observations on the digestion of some gadoid fish otoliths by a young common seal, International Council for the exploration of the sea. Document CM 1979/N:14.

Rackham, D. J. (1983). Faunal sample to subsistence economy, some problems in reconstruction, pp. 251-77. In Jones, M. (ed.), Integrating the subsistence economy, Symposia of the Association for Environmental Archaeology No. 4. British Archaeological Reports International Series, 181.

Rackham, D. J. (1986). An analysis of animal remains. pp 348-349. In Morris, C. D. and Emery, N. 1986. Excavation of a Chapel and a Churchyard of the Brough of Deerness, Orkney, 1975-7, Proceedings of the Society of Antiquaries of Scotland **116**, 301-374.

Rackham, D. J., Batey, C. E., Jones, A. K. G. and Morris, C. D. (1984). Freswick Links, Caithness: report on environmental survey, 1979, Circaea 2(1), 29-55.

Reinman, F. M. (1967). Fishing, an aspect of Oceanic economy: an archaeological approach, Fieldiana, Anthropology **56** 95-208.

Reinsch, H. H. (1976). Köhler und Steinköler Pollachius virens und P. pollachius. A. Ziemsen Verlag: Wittenburg.

Richards, J. D. and Ryan, N. S. (1985). Data processing in archaeology. Cambridge University Press: Cambridge.

Rojo, A. (1986). Live length and weight of cod (Gadus morhua) estimated from various skeletal elements, North American Archaeologist **74** (4), 329-51.

Ross, J. Jr., (1883). Curing and preserving fish in Scotland and its Islands, pp. 106-29. In Herbert, D. (ed.).Fish and fisheries, a selection from the prize essays of the International Fisheries Exhibition, Edinburgh, 1882. William Blackwood and Sons: Edinburgh.

Saxon, J. (1975). The fossil fishes of the north of Scotland 2nd ed. Caithness Books: Thurso.

Shipman, P. (1981). *Life history of a fossil - an introduction to taphonomy and paleoeconomy*. Harvard University Press: Cambridge, Massachusetts.

Sinclair, J. (1791-9) *Statistical Accounts of Scotland*. William Creech: Edinburgh.

Small, A. (1966). Excavations at Underhoull, Unst, Shetland, *Proceedings of the Society of Antiquaries of Scotland* **98**, 225-45.

Small, A. (1968). Historical geography of Norse Viking colonisation of the Scottish Highlands, *Norsk Geografisk Tidsskrift* **22**, 1-16.

Smith, N. J. H. (1981). *Man, fishes and the Amazon.* Columbia University Press: New York.

Starks, E. C. (1901). Synonymy of the fish skeleton, *Washington Academy of Sciences* **3**, 507-39.

Struever, S. (1968). Flotation techniques for the recovery of small-scale archaeological remains, *American Antiquity* **33**(3), 353-62.

Stinton, F. (1985). British Quaternary fish otoliths, *Proceedings of the Geological Association* **96** (3), 199-215.

Stone, J. and Saunders, R. (1987). Magnetohydrostatic separation of conodonts from residues, pp 69-74. In Austin, R. (ed.) Conodonts: investigative techniques and applications. Ellis Horwood Ltd for the British Micropalaentological Society: Chichester.

Stuart, A. J. (1982). Pleistocene vertebrates in the British Isles. Longmans: London and New York.

Sutherland, W. (1794). Caithness: Wick 1794. A reprint from the First Statistical Account of Scotland. Pentland Press: Thurso.

Taylor, A. B. (1938). The Orkneyinga Saga; a new translation with introduction and notes. Oliver and Boyd: Edinburgh and London.

Templeman, W. and Squires, H. J. (1956). Relationship of otolith lengths and weights in the haddock, *Melanogrammus aeglefinus* (L.), to the rate of growth of the fish, Journal of the Fishery Research Board of Canada **13**, 467-87.

Topp, R. W. and Cole, C. F. (1968). An osteological study of the sciaenid genus *Sciaenops* Gill (Teleostei, Sciaenidae). Bulletin of Marine Science **18**, 902-45.

Traquair, R. H. (1894). A monograph of the fishes of the Old Red Sandstone of Britain. Part II No. 1. Palaeographical Society Monographs: London.

Uerpmann H. -P. (1973). Animal bone finds and economic archaeology, a critical study of the 'osteo-archaeological' method, World Archaeology 4(3), 307-22.

Van Neer, W. (1986). Some notes on the fish remains from Wadi Kubbaniya (Upper Egypt; late palaeolithic), pp. 103-13. In Brinkhuizen, D. C. and Clason, A. T. (eds.), Fish and archaeology, British Archaeological Reports International Series, 294.

Van Neer, W. (1989). Contribution à l'ostéométrie de la perche du Nil Lates niloticus (Linnaeus, 1758), Fiches d'osteologie animale pour l'archéologie Series A: Poissons No. 5. Centre de Recherches Archéologiques du CNRS.

Wainwright, F. T. (1962). The Northern Isles. Thomas Nelson: Edinburgh and London.

Walters, I. (1984). Gone to the dogs: a study of bone attrition at a central Australian campsite, Mankind 14 (5), 389-400.

Ward, D. J. (1984). Collecting isolated microvertebrate fossils, Zoological Journal of the Linnean Society 82, 245-59.

Wheeler, A. C. (1969). The fishes of the British Isles and north west Europe. Macmillan: London.

Wheeler, A. (1977a). The fish bones from Buckquoy, Orkney, pp. 211-4, In Ritchie, A. Excavations of Pictish and Viking-age farmsteads at Buckquoy, Orkney, Proceedings of the Society of Antiquaries of Scotland 108, 174-227.

Wheeler, A. (1977b). Fish bone, pp. 403-8. In Clark, H and Carter, A. (eds.) Excavation in King's Lynn, 1963-70. Society for Medieval Archaeology Monograph Series No. 7.

Wheeler, A. (1978a). Problems of identification and interpretation of archaeological fish remains, pp. 69-75. In Brothwell, D. R., Thomas, K. D. and Clutton-Brock, J. (eds.) Research problems in archaeolzoology. Occasional papers of the Institute of Archaeology: London.

Wheeler, A. (1978b). Key to the fishes of northern Europe. Warne: London.

Wheeler, A. (1979a). The fish bones, pp. 144-9. Renfrew, C. Investigations in Orkney, Reports of the Research Committee of the Society of Antiquaries of London, 38.

Wheeler, A. (1979b). The tidal Thames. Routledge and Kegan Paul: London.

Wheeler, A. and Jones, A. K. G. (1976). Fish remains, pp. 208-24. In Rogerson, A. Excavations on Fuller's Hill, Great Yarmouth, East Anglian Archaeology 2, 131-245.

Wheeler, A, and Jones, A. K. G. (1989). Cambridge Manuals in Archaeology: Fishes. Cambridge University Press: Cambridge.

Wheeler, A. and Locker, A. (1985). The estimation of size in sardines (*Sardina pilchardus*) from amphorae in a wreck at Randello, Sicily, *Journal of Archaeological Science* 12, 97-100.

Wigforss, J., Lepiksaar, J., Olsson, O. I. and Påsse, T. (1983). Bua Vastergård - en 8000 år gammal kustboplats, *Arkeologi i Västsverige*, 1, Göteborgs Arkeologiska Museum.

Wilkinson, M. (1979). The fish remains pp 74-81. In Maltby, M. Faunal studies on urban sites, the animal bones from Exeter, 1971-1975, *Exeter Archaeological Reports*, 2.

Wilkinson, M. (1981). *The study of fish remains from British archaeological sites*. Unpublished Ph. D. thesis, University of Sheffield, England.

Williams, D. (1973). Flotation at Sīrāf, *Antiquity* 47, 198-202.

Williams, T. and Bedford, B.C. (1974). The use of otoliths for age determination, pp. 114-23. In Bagenal, T. B. (ed.) *Aging in fish*. Unwin: Old Woking.

Williamson, H. C. (1902). A comparison between the cod (*Gadus callarias* Linn.), the saithe (*Gadus virens* Linn.) and the lythe (*Gadus pollachius* Linn.), in respect to certain external and osteological characters, *Annual Report of the Fisheries Board for Scotland* 20 (3), 228-87.