A Guide to the Identification of Fish Remains from New Zealand Archaeological Sites

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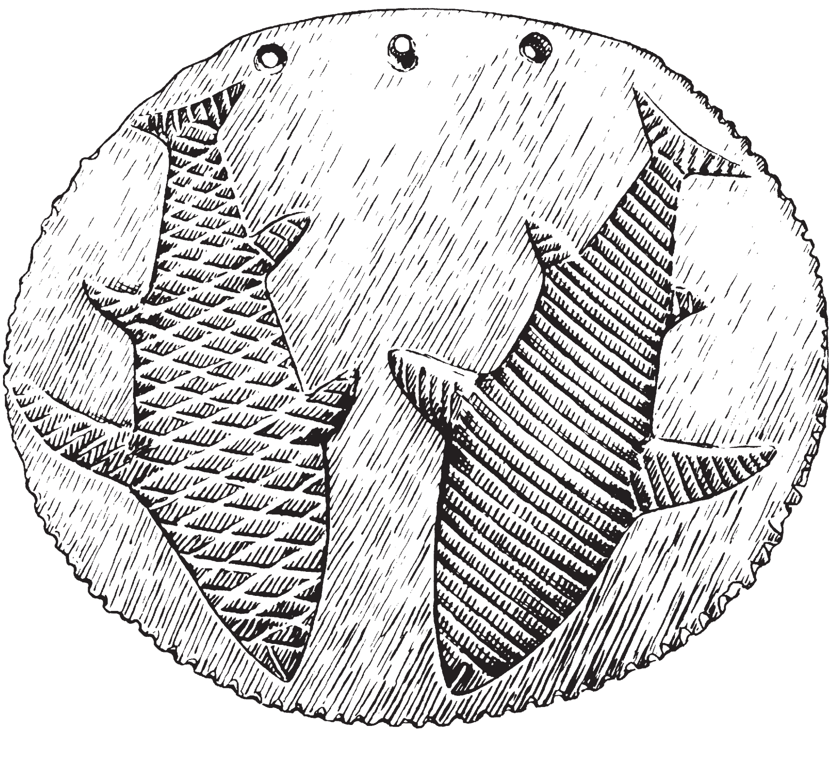

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Cover illustration: Slate breast pendant from Okain's Bay, Banks Peninsula (Thacker Collection), after Skinner (1974: 70-71). Skinner thought that the fish represented on this amulet could either be stylised bonito or albacore, or porbeagle shark. The body shape and fins are certainly strongly reminiscent of all three of the common mackerel sharks (Family Lamnidae) in New Zealand: *Carcharodon carcharias* (great white), *Lamna nasus* (porbeagle), and *Isurus oxyrinchus* (mako).

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A GUIDE TO THE IDENTIFICATION OF FISH REMAINS FROM NEW ZEALAND ARCHAEOLOGICAL SITES

INTRODUCTION

Fish remains are common in New Zealand archaeological sites, especially in coastal middens left by the pre-European Māori. These people came to New Zealand from the tropical Pacific, from some part of the region known as Eastern Polynesia. They brought with them a culture strongly maritime in its focus. This is hardly surprising, given the dominating influence of the sea in island Polynesia. Of course the marine environment in New Zealand is very different to that of the tropical Pacific, and the immigrant Polynesians needed to explore this and adapt their knowledge of fishing technology to the new fish types[1] and sea conditions they were confronted with.

The study of fish remains from archaeological sites is a relatively new field in both the Pacific and New Zealand, and offers opportunities to answer important questions about the process of human adaptation to new and changing environments, and also the response which the marine environment makes when humans begin to exploit its resources. This mutual interchange is one of the main areas of interest when archaeologists examine midden remains containing marine fauna. The second major area of interest is the way in which marine foods contribute to the overall food quest. Thus characterised, archaeological fish remains contribute knowledge to our understanding of human/environmental interactions and economy in prehistoric human societies.

Fundamental to these studies is the ability accurately to identify the bones of fish recovered from archaeological sites. There are now some excellent published guides to assist with fish bone identification in other countries (Casteel 1976, Courtemanche and Legendre 1985, Roselló-Izquierdo 1986, Cannon 1987, Wheeler and Jones 1989), but almost nothing of immediate relevance to New Zealand or the tropical Pacific region. The purpose of the present work is to help fill part of this gap for the common species in New Zealand.

Approximately 1,000 species of fish are found in New Zealand waters, but of these only a very small number were exploited to any significant degree by pre-European Māori. Some archaeological sites have only one or two fish types present, many have about ten, and a few have as many as 20 types. In all, only about 50 types are found in archaeological sites, and these are largely inshore fish which live amongst rocky weedy areas, or in open beaches, or rough ground slightly offshore (Leach and Boocock 1993). This makes the task of identifying bones much easier.

WHICH BONES SHOULD BE IDENTIFIED ?

The question of which bones should be identified is an important one, and there is not much agreement amongst archaeologists on this point. If there are only a few bones from a particularly

[1]The term **fish type** or **taxon** is used frequently in this volume in contexts where one might expect to see the term **species**. The choice of a less precise term in these contexts is deliberate and acknowledges that western European taxonomy does not have universal validity; indeed the status of species and genera appears to change more frequently than other forms of folk taxonomy, such as the nomenclature used by modern European fishermen (Paulin and Stewart 1985: 5), or terms used by Polynesians, many of which can be traced back to the ancestral Proto-Polynesian language. It also acknowledges that in identifying fish bones from archaeological sites, one is seldom able to identify to a taxonomic level this low (species) because the distinguishing characteristics are often features which do not survive intact in the archaeological record, such as distinct skin coloration, number of ray elements in the anal fin, etc. There is further discussion on this issue later.

significant site, then it is desirable to identify as many parts of the anatomy as possible to make sure that all fish types which are actually present are identified. However, typically, the material recovered in a midden excavation contains large numbers of fish bones, and for a number of reasons it is foolish to attempt to identify every single bone. We need to consider carefully precisely what we are trying to achieve before embarking on an immense amount of bone sorting and identification.

First and foremost is the objective of establishing the relative abundance of different fish types caught. This helps to define the first major characteristic of the prehistoric fish catch of a group of people, notably its overall composition. For example, the catch relative abundances might be 90% snapper[2], 5% gurnard, 3% red cod, and 2% tarakihi. Such figures are meant to convey what the catch would have looked like when laid out on a mat after a fishing trip. It does not convey the relative economic or dietary importance of each fish type, because the amount of food varies from one fish type to another, and also depends on the size of each fish caught. This matter will be discussed shortly. If a layer in a site has been deposited over a long period of time, then the catch composition which is reconstructed will smooth over differences in the catch from several or many fishing expeditions. This objective, of establishing the relative abundance of the catch, has a major influence on how one should go about identifying bones. Suppose, for example, it was easy to identify tarakihi vertebrae to their correct taxon, but difficult to distinguish the vertebrae of snapper, gurnard and red cod. We then set about to identify <u>all and as many bones as possible</u> in the collection. We would end up with a list of identifications which would be greatly dominated by tarakihi, since there are many vertebrae from each specimen. This simple list of identifications is known as the NISP (number of identified specimens). It should be obvious that the NISP is not related to the relative abundance of different fish types in the catch in any simple manner, but will depend a great deal on the ability to identify all anatomical components of the different taxa in the collection with equal confidence. It is well known that this ability is anything but even from one taxon to another[3].

A more sensible alternative is to abandon the attempt to identify <u>all and as many bones as possible</u>, and identify <u>only those parts of the anatomy which are characteristic of all taxa</u> one is likely to come across in a collection. This greatly limits the list of anatomical components which we need to deal with and, more importantly, simplifies the calculation of relative abundance of fish types. Intensive examination of different parts of the anatomy of common fishes from New Zealand and the nearby tropical Pacific has shown that the easiest bone to identify which all taxa possess is the dentary (Fig. 1). This bone is a complex one with many characteristics which change from one taxon to another, such as the type of teeth, their distribution and size along the tooth row or rows, the size and shape of the dentary symphysis, the angle and relative lengths of the two transverse processes, the curvature of the dental arch, the relative position of the two apexes where the transverse processes meet medially and laterally, and so on. This bone is most able to be identified to a suitably low taxonomic level for almost all taxa one might come across amongst those captured by pre-European people. This bone is therefore very suitable for establishing relative abundance in a fish catch. Should we therefore select only the dentaries for identification and discard the remainder ? For very large assemblages this approach may well provide a stable and reliable table of relative abundances; however, for small collections the vagaries of bone crushing may conspire

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[2]In this volume, common names are used throughout. Appendix 1 provides a cross-listing of common names against systematic binomials.

[3]This is not to suggest that the NISP is not a valuable measure of abundance. For instance, it has special value in exploring taphonomic issues, such as the deposition of different body parts according to social status or site function. The NISP, however, has very limited value in establishing the relative abundance of fish types, producing at best a distorted picture of the original fish catch.

to yield a less reliable table. It is therefore desirable to attempt identification of a second anatomical element.

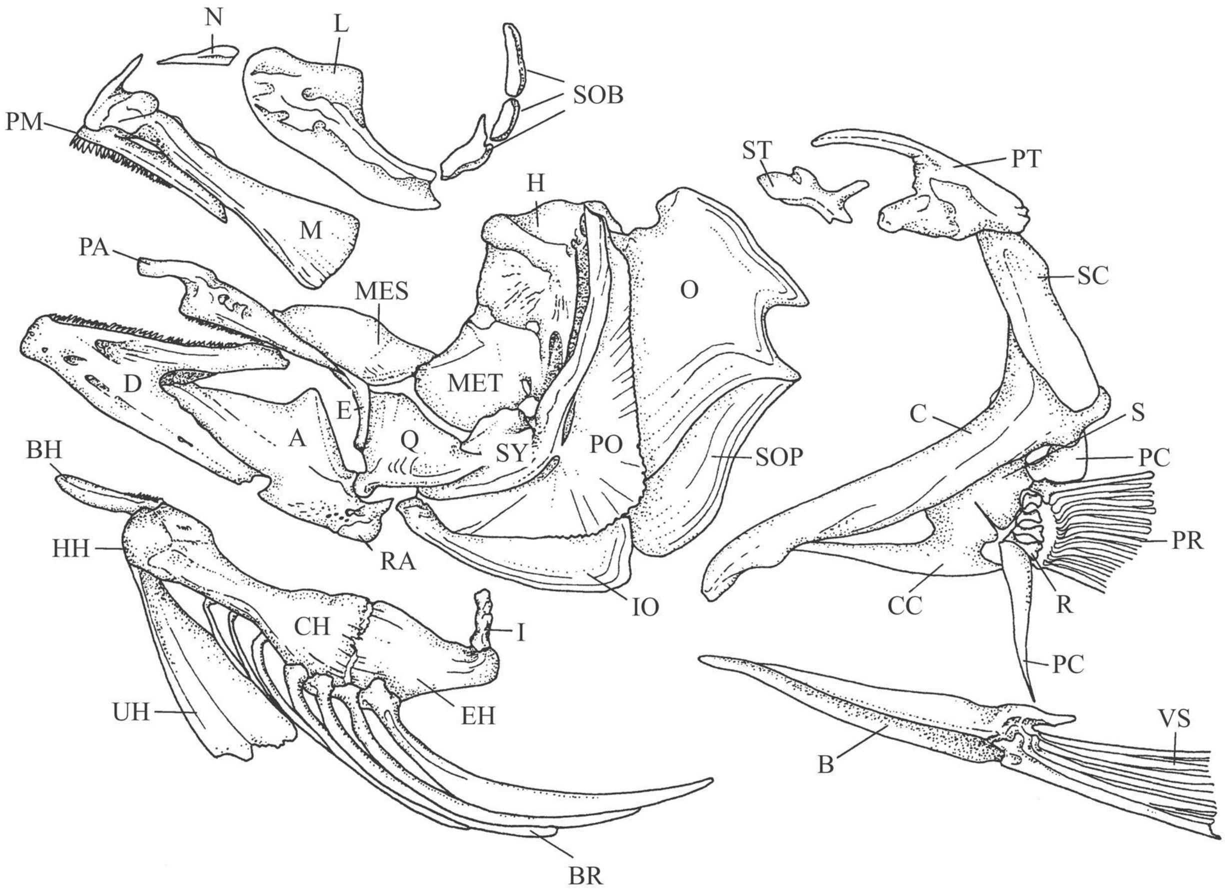

Figure 1: The main facial and appendicular bones of a typical fish (after Cannon 1987). See Appendix 2 for bone names.

The next most suitable bone, able to be identified to a low taxonomic level for almost all fish types we are confronted with, is the premaxilla. This bone does not have quite as many distinguishing characteristics as the dentary, but is almost as good for identification purposes. It is well worth while attempting to identify all premaxillas in a collection, in addition to the dentaries. Although this will increase the NISP value for any one taxon, it will not inflate the minimum number of individuals (MNI, see below). Identifying this second bone in the collection helps to offset the possibility that the dentaries of some specific taxon might be under-represented in the collection.

For similar reasons, a third bone, the articular, may be added to the list, in the quest to achieve an even more reliable list of relative abundance of fish types. The articular is not quite as good as the premaxilla for ease of identification across all taxa. By the time all the articulars are identified, the list of relative abundances for a sizeable collection of bones will be fairly stable.

The next most easily identified bone across the greatest number of taxa is the maxilla. In a large collection it is unlikely that the identification of these bones will have any influence on the list of relative abundances, but for small collections it may help to stabilise the list even further.

When this schema for identifying fish bones was first developed during archaeological research in Palliser Bay in 1969 (Leach 1976) the quadrate bone was also included in this list of anatomy which all fishes possess. Amongst the five paired cranial bones chosen for identification the quadrate is the least able to be identified across all taxa involved in common collections. It is therefore possible that identification errors can be made, adversely affecting the table of relative abundance. In large collections, it is not desirable to identify this bone. The extra effort yields little if any extra information, and may introduce more problems than it solves. For small collections it is worth while making the attempt to identify this part of the anatomy.

This does not complete the list of possible paired elements in the anatomy which could be used for establishing the relative abundance of fish types in a prehistoric catch. Others might include the pterygoid, the cleithrum, and the opercular. However, specimens of these bones have not been collected for a large number of species to test whether they are near universally characteristic of fish type, something which has been done for the five paired bones mentioned above. In any event, even if further bones were shown to have this property, it is very doubtful whether the extra effort required to identify them would significantly alter the table of relative abundance of fish types established by identifying the five bones already chosen.

Finally, some species of fish have highly characteristic anatomical components which are not present amongst all fishes, and have particular value in identification. These components are referred to as 'special bones', and some examples are worth enumerating. The specialised spines covering the skin of the porcupine fish are a good example. Each fish has approximately 500 of these elements, but if only one is found in a layer of an archaeological site, it is sufficient to establish that one specimen of this fish was present. Conversely, one would need to recover more than 500 spines from any one context to yield an MNI of two fish. Quantifying elasmobranch fishes poses a special problem in archaeology, since their skeleton does not contain bone but is composed of cartilage. However, some species do have hard parts and it is important to be able to identify these. For example, the tooth plates of the eagle ray are quite characteristic, so too are some ossified elements of the upper and lower jaws of ghost shark, dorsal spines of the spiny dogfish, etc. Some soil-chemical conditions favour the survival of vertebrae from elasmobranchs in relatively large numbers. Identification requires longitudinal X-rays which reveal semi-ossification patterns which are characteristic of species (Desse and Desse 1976). The necessary background research of building a suitable reference collection, X-raying the elements and studying them, has not yet been undertaken in New Zealand. It is not known what soil-chemical conditions are responsible for these occasional occurrences, but it could be alkaline soils, from fire-ash or breakdown of shellfish.

QUANTIFYING FISH BONES

From the foregoing it has been seen that there are several ways of obtaining a quantitative assessment of faunal remains, and some additional comments should be made about this. There is a large literature on this subject and many different approaches have been suggested, though not all have the same objective. Moreover, some measures of abundance are useful for more than one purpose. The most thorough analysis of the different measures can be found in Ringrose (1993) and Grayson (1984); there is also useful discussion on the topic relating to New Zealand faunal assemblages in Smith (1985: 107), and Smith and Anderson (1996).

A very simple measure of abundance would be to obtain the total **weight** of various taxa. In the case of shellfish remains, this method has a lot to recommend it as a simple and quite effective method for establishing the relative economic importance of different shellfish taxa. If one went to the trouble of counting all the left valves of the bivalves which contain the umbo, and the umbo of all the gastropods, and then worked out percentages of each taxon in this way, it would probably be indistinguishable from the percentages by weight of the same shell; assuming that the assemblage was a large one and not subject to sample bias. The second method described (counting the umbos) yields what is referred to as the **Minimum Number of Individuals** or **MNI**. This is defined as:

> **MNI** = The smallest number of individuals which is necessary to account for all of the skeletal elements of a taxon in a faunal assemblage.

In the example give here, the right values of the bivalves were ignored, and parts of gastropods which might have been identifiable to species but did not contain the umbo were also ignored. In other words, we selected a portion of the anatomy which each animal has only one of, and which is identifiable to species. There is a slightly different alternative to this which needs mentioning. People familiar with processing faunal assemblages will know that it is not always obvious at first glance whether a bivalve fragment with an umbo is the left valve or the right valve. To speed up operations, one could count both left and right valves, and at the end divide the total by two. This procedure yields the same MNI as before (within a small margin), assuming that the people depositing the shellfish remains did not, for some obscure reason (to baffle future archaeologists perhaps), sort the shells into left and right valves and dump them in different places. Strictly speaking the MNI would be the largest number of left or right valves, rather than the total number divided by 2; although the difference would be trivial for large assemblages. Similarly, some gastropods possess a hard operculum at the entrance to the animal. We could count these rather than the umbo of this species and still get the same MNI. Or, we could count both the umbos and opercula, and then use the larger number as the MNI.

The example being illustrated here concerns shellfish rather than fish, and is chosen deliberately because many of the issues involved in quantifying fauna are much easier to understand when there is less diverse anatomy involved. So far, we have considered that these animals have only two parts of their anatomical elements identifiable to species, the umbo (for all species) and the operculum (only present in some gastropods). This is a suitable point at which to introduce another term which is used in archaeozoology, the **Minimum Number of Elements** or **MNE**. In the example above, the total number of left and right valves is the MNE. This is sometimes referred to as the **Number of Identified Elements** or **NIE**, but the first term is preferred because we are seeking to find the minimum figure which will account for the fragments found. The term is thus defined:

> **MNE, NIE** = The smallest number of anatomical elements which is necessary to account for all of the fragments of this anatomical element of a taxon in a faunal assemblage.

In real archaeological sites, shellfish remains are usually fragmented to a greater or lesser extent, and even very small fragments can frequently be identified to species. This enables yet another term to be introduced, the **Number of Identified Specimens** or **NISP**. It is important to be absolutely clear as to what this means. Suppose we have bagged up all our archaeological field samples, and in one of the bags there are two valves of a bivalve species with surface markings of very distinctive character. During transport to the laboratory the two valves are damaged, and when tipped out, there are 35 fragments, each still clearly identifiable to species. The NISP value for the taxon in this one bag is 35, the MNE(NIE) is 2, and the MNI is 1. It is not altogether certain that all people quantifying fauna in the Pacific region are using the NISP in this manner. The term itself is somewhat ambiguous in its meaning, and would probably be best replaced with the term **Number of Identified Fragments**, or **NIF**. This term could not so easily be misunderstood. Unfortunately, the term NISP is in widespread usage and, despite its ambiguity, not likely to be supplanted. Thus, we can define these terms:

> **NIF, NISP** = The total number of identified fragments of any part of the anatomy of a taxon in a faunal assemblage.

I have described these terms in reverse order of abstraction. Normally as one works through faunal material, the opposite direction to this is followed. That is, one starts with numerous fragments, and then sorts these into anatomical elements, and later into taxa, and then finally to individual animals. That is, the process of abstraction is in the order:

NIF	Number of identified fragments (also known as NISP)
MNE	Number of identified elements (also known as NIE)
MNI	Minimum number of individuals

It may be observed that to work out the MNI, one must first know what the MNE(NIE) is. In other words, the MNE(NIE) is one of the steps towards establishing the MNI. The NIF(NISP), however, is not in the analytical pathway to establish either the MNE(NIE) or MNI; it is an independent measure, at a lower level of abstraction again. Which measure of abundance one should employ depends entirely on what objective one has; that is, what questions one is asking about the prehistoric people involved, using the faunal assemblage as a source of knowledge. Let us imagine that after analysis an assemblage produces the following results:

	NIF(NISP)	**MNE(NIE)**	**MNI**
Periwinkle, *Melagraphia aethiops*	1000	100	100
Cockle, *Austrovenus stutchburyi*	100	100	50

In this example, the periwinkle shells are very fragmented, whereas the cockle shells are all intact. The elements identified are umbos in each case. There are two umbos for each individual cockle (one on each valve), but only one for each periwinkle since it is a gastropod. The relative abundance of the two taxa is indicated by the final column, the MNI. This shows that for every cockle which was collected, eaten and dumped by this group of people, they collected, ate and dumped 2 periwinkles. Suppose the mean meat weight for the two species was 5 and 10 g per individual respectively, and the meat had the same caloric value for each species; then one can use the final column with MNI to deduce the relative importance of the two species in the diet of the people (100 x 5 g, and 50 x 10 g respectively). We conclude that the two species had equal dietary importance in the economy of these people.

It should be obvious that one cannot use the first column in the table to estimate the relative economic importance of the two species to the prehistoric group being studied. What the ratio of 10 to 1 for the two species (1000 to 100) reveals is something quite different. It shows that there has been differential fragmentation of the two species. There are a number of possible causes for this which would be examined in a real case. An obvious explanation in this example is that rather than going to the trouble of extricating the animal from these tiny periwinkle shells before consumption, the people were crushing the whole shells and making a soup with the shellfish. In the case of cockles, the complete lack of fragmentation shows us that food was extracted directly from each shell. Now in order to reach this conclusion, we must know what the MNE(NIE) is as well as the NIF(NISP). Patterns of differential fragmentation are only revealed when we have a yardstick to measure against. The simplest yardstick is the number of elements. Thus, we would work out the number of fragments compared with the number of whole elements, which in the simple case being considered, would be:

	NIF(NISP)/MNE(NIE)	**Fragmentation Ratio**
Periwinkle, *Melagraphia aethiops*	1000/100	10:1
Cockle, *Austrovenus stutchburyi*	100/100	1:1

These three basic measures of quantifying faunal remains may be put to good use when examining patterns of distribution of refuse to reveal functional and social patterning in prehistoric sites. For example, the ratio of MNE(NIE) to MNI (sometimes called the *Completeness Ratio*) tells us how much of each animal is represented in a site, and can be an excellent guide to whether animals were butchered on site or elsewhere. This ratio can be as low as 1:1 for large animals like seals, and as high as 12–20:1 in the case of dogs remains. Unusually low values of this ratio where only a few bones of large animals are transported to base camps or settlements has been dubbed the 'Schlepp Effect' (Daly 1969, Schiffer 1987: 69)

Clearly, all these measures have a useful role in archaeology. However, when considering dietary or economic questions, neither the NIF(NISP) nor the MNE(NIE) by themselves have a particularly useful role. Fundamental to the study of human economy is knowledge of the relative abundance of different taxa. The first requirement of this is the calculation of the MNI. It demands a lot more detailed attention in the analysis of faunal remains to work out, but if one has economic questions in mind, it is unavoidable. Unfortunately, there has been a tendency in recent years in the Pacific region for some scholars to publish NISP values for faunal assemblages, and not go to the extra trouble of calculating first the MNE(NIE), and then the MNI. This would be acceptable if the issues being investigated concerned taphonomy or social patterning within sites, either spatially or chronologically. However, this does not appear to be the case. NISP values are being published as a putative indication of relative abundance of fish types, which this measure is manifestly not (Rollet 1989: 224, 239; Allen and Steadman 1990: 31; Dye 1990: 74).

Now the cases considered above are very simple, referring to shellfish for which the number of anatomical elements is very low. When it comes to bird or fish remains, identification and quantification is much more difficult. With bird remains, a great deal of the skeleton can be identified to species. Even small fragments of the central shaft of limb bones can be identified by people with good comparative collections and the background knowledge to do so. Ron Scarlett, formerly the osteologist at the Canterbury Museum was able to do this with bird remains, and provided a wonderful service to archaeologists in New Zealand for many years. The large number of skeletal elements which he could identify from fragments has not only enabled species MNI to be calculated, but also comparative MNI for different body parts within the species. This has enabled studies of butchery patterns of small bird species (Leach 1979). For fish remains, this cannot be done to any significant extent. Although the different anatomical elements of fish can readily be identified, very few can be identified to species. This matter is discussed in detail below, but here it needs to be pointed out that the number of elements which can be identified to species varies a great deal from one species to another. Some examples should be mentioned — the porcupinefish has nearly 500 specialised dermal spines, so at the very least 500 elements can be identified for each individual in this taxon. Fishes in the box fish family (Ostraciidae) are covered in highly distinctive geometrical dermal plates. I have not counted them, but it is not as many as the porcupinefish. At the other end of the scale, a sting ray has one to three barbed stings, and normally that is all which survives in an archaeological site. At the risk of over-stating the case, the NIF(NISP) measure in archaeological fish research has no clear role in establishing the relative abundance of taxa (at least none which is obvious to me), and therefore has limited, if any, value in serious economic research, unless it is accompanied by higher level aggregations MNE(NIE) or MNI).

In the Archaeozoology Laboratory at the Museum of New Zealand, fish bone identifications are entered into a database program, especially written for this purpose, called *Kupenga* (this word is generic in the Pacific region for fishing net, traceable back to the Proto-Oceanic language as *KUPEGA*. Biggs and Clark, POLLEX 1996). This program runs under Windows 3.1 and is written in C++. Abundance calculations are then made by a series of supporting programs, such as *Nisp* (calculates NIF/NISP values), *FisMin* (calculates MNI), *FisTab* (makes Tables of MNI by site provenance), etc. These are purpose written in Turbo Pascal version 5, running under DOS 6. Because of the central importance of the MNI in arriving at estimates of relative abundance, a few comments are called for concerning *FisMin*.

FisMin requests an ‘archaeological assemblage’ to be specified. This concept is further discussed below, but may be briefly described here as a unique time/space unit in an archaeological site. The program searches the *Kupenga* database for all identifications from this provenance, and writes them to a temporary file. *FisMin* then iterates through all possible taxa employed during the identification work, and if these are present in the temporary file, calculates the MNI and writes this to the output file for this assemblage. Thus, the output file contains the MNI for each taxon for this assemblage. How does the program calculate MNI ? *FisMin* totals up all the identifications for each anatomical element in turn, and then divides each final total by the number which each of these elements has in one fish. For example, there are up to 500 dermal spines in any one individual porcupine fish, so the total is divided by 500. There is only 1 left dentary per fish, so the total for these bones is divided by 1. In a case where this final number is greater than zero, but less than 1.0, the MNI=1. In other words, if even 1 dermal spine is found of the porcupinefish then the MNI=1; but it takes 501 spines in any one assemblage to achieve MNI=2, and 1001 spines for MNI=3. At the end of this process, the MNI equals the largest number amongst those tabulated for all the anatomical elements for the chosen taxon in the chosen assemblage.

PATTERNS OF PROCESSING AND DISPOSAL OF RUBBISH

Could the patterns of processing or disposal of fish remains by a prehistoric group affect our ability to establish the character of the original catch, assuming we follow the identification schema suggested here ? The answer is a resounding Yes. But unfortunately, a positive answer would have to be given to any possible schema of identification. One could always hypothesise some unusual pattern of processing or disposal which would bias the table of relative abundance. For instance, if one were dealing with a prehistoric group who filleted their fish either at sea or where they landed, and then took the meat to their settlement, analysis of bones at the settlement would only yield a few spines and ribs, which are very difficult to identify. Another prehistoric group might have filleted some species and not others, or kept the heads as a delicacy and traded the bodies to another group, or cut the heads off at sea, or disposed of all village rubbish into the sea, etc. In short, any number of patterns of processing or disposal could conspire so that the reconstructed picture of a fish catch was badly wrong.

Over the years I have heard many criticisms of various forms of identification schema; most seem to me to be merely a counsel for despair, and not at all helpful. Since the schema suggested in this volume is so heavily biased towards key elements in the fish head, it is reasonable to raise the possible criticism that the prehistoric treatment of head and body might have been different, thereby introducing bias in an archaeological site. It is very common amongst Western European societies to cut the heads off fish and discard them as inedible; however, so far as I know it is universal amongst Pacific Island societies, including that of the New Zealand Māori, to favour the head as an important food delicacy, full of succulent juice and flavour. Given this behaviour, it is hard to imagine that any prehistoric society in this region cut the heads off and threw them away in a place which later archaeologists would not discover along with the rest of their midden debris.

This is not to suggest that one should not keep a watchful eye open for unusual patterns of processing or disposal. For example, if a collection clearly had a high or low proportion of vertebrae compared with head parts, then it would be useful to quantify this and seek explanations for the discrepancy. In 25 years of examining fish bone collections from all over New Zealand and the Pacific, I have yet to come across an assemblage where there was an obvious discrepancy between the relative abundance of head and body parts. However, it is clear from literature relating to archaeological sites in Europe that major discrepancies like this do occur, most clearly when specialised commercial fishing started to develop, including mass harvesting, drying, and trade or sale. Ethnographic records of the New Zealand Māori at the early period of European contact suggest that some fish types were split and dried in the sun and then stored for times of less abundance, or for trading with other communities. A sketch made by Heaphy c. 1840s (Auckland Institute and Museum Neg: B4827) of a drying rack with fish in Pakihi or Sandspit Island, Thames, shows the fish with their heads still intact. Best, in a translation of an old Māori passage (Best 1977: 54–55), records the removal of barracouta heads prior to drying and/or eating. It is not clear whether this removal was for discarding or for consumption separate from the body.

WHAT IS AN ASSEMBLAGE ?

When undertaking the task of building up a quantified picture of relative abundance of fish in a prehistoric catch it is necessary to have some unit of aggregation which has archaeological meaning in terms of the squares and layers in the original excavation. There are two main dimensions which archaeologists use when exploring patterns of continuity or change in human behaviour — one is the spatial dimension, and the other is time. In an archaeological site, the spatial dimension is represented by the squares laid out for excavation. All items recovered are catalogued according to the square they are recovered in, so that it is possible at a later stage to search for and describe aspects of spatial pattering. The time dimension is represented by the stratigraphic layer in which items are found, and again each item is similarly catalogued according to this unit, so that we can later examine the evidence for changes through time. An archaeological **assemblage** consists of all items recovered in any one unit of time and space (layer and square).

The degree of precision in defining assemblages during excavation greatly varies from one site to another and from one archaeologist to another. During some excavations every single item is recorded with three-dimensional coordinates using a theodolite or electronic equipment. The space/time assemblage in such cases is a very small cube of the site, perhaps a cubic cm. At the other end of the spectrum, some midden may be simply shovelled into sacks from a very large square of say 5 m by 5 m and from several clearly different stratigraphic layers, which in the view of the excavator represent in combination a very short period of dumping, such as a series of baskets of discarded rubbish during one season of occupation. During laboratory analysis, one should always follow the simple curatorial rule of never destroying information about provenance, and make sure to re-bag and record information according to the smallest unit of time and space which was recording during the original excavation. It is always possible to combine information, so recorded, into ever increasing units of time and space in the search for patterns of continuity or change; but one cannot work backwards from larger units to smaller ones if the provenance data are not fully retained.

The most common level of precision in recording the provenance of items in New Zealand archaeology is by square metre and stratigraphic layer, and this is therefore the most common unit defining an assemblage. In developing a method of quantifying fish remains, I have, wherever possible, used this unit for aggregation and calculation of MNI. In cases where the original recording in the site was of finer precision than this, the original provenance information is retained on all bags, but the information (identification by anatomy and fish type) is aggregated to square metre and layer before MNI are calculated. In cases where the units of recording were of larger size than square metre and layer, for example 25 m^2 and cultural Level (meaning several layers), then the unit of assemblage is unavoidably much larger.

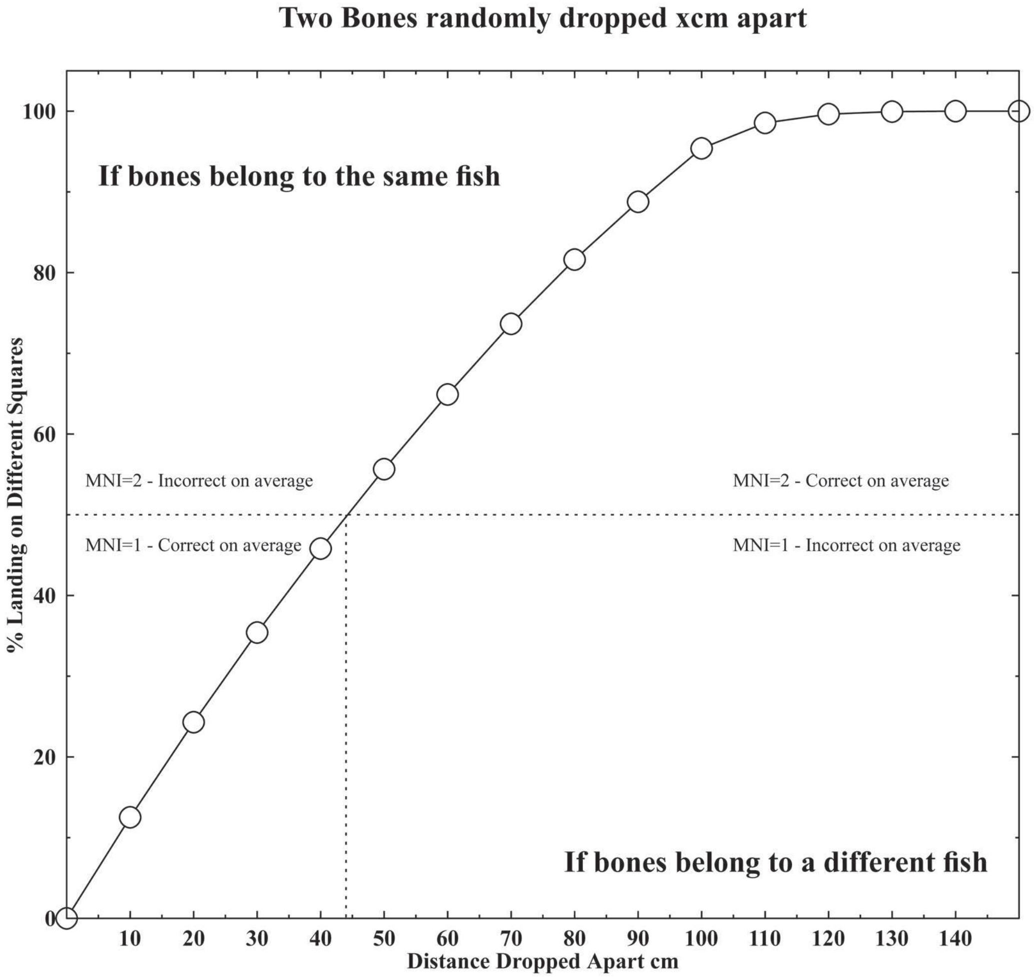

Figure 2: Results of 15 million simulations, randomly dropping two bones at different distances (x) apart to see how often they end up on the same or different squares measuring 1 x 1 m. If the two bones belong to the same individual fish they will have a higher probability of being incorrectly counted as MNI=2 when they are dropped over 44 cm apart. If the two bones belong to two different individuals they will have a higher probability of being incorrectly counted as MNI=1 when they are dropped less than 44 cm apart.

It might be thought that adopting the unit of assemblage as one layer in one m^2 is too small, and that it leads to inflated MNI. I do not see this as a problem. For one thing, if a left dentary of one fish type is found in one such square and a right dentary of the same fish type is found in another square, then on average these two bones will most probably belong to two different fish. By this method of recording provenance during the excavation (by m^2), these two bones can be separated by as little as 1 cm (across the line between two squares), or as much as 224 cm (the largest diagonal across two adjacent squares). The left and right dentaries of the same individual fish have a finite probability of being deposited on either sides of the line separating two squares, and thus of being counted as two fish rather than one; and it is intuitively obvious that the opposite is the case too — that say the left and right dentaries of two different individual fish have a finite probability of being deposited within any one square, and thus of being counted as one fish rather than two. The important question here is what these finite probabilities are. This question may be answered with a simple computer program which simulates the dropping of two bones millions of times at different distances apart, and which records how many times the bones land on the same square or different squares. The results (Fig. 2) show that two bones dropped up to 44 cm apart have on average a greater chance of landing on the same square, but over 44 cm there is a greater chance on average that they will land on two different squares. At distances of over 1.414 m (the diagonal of a 1 x 1 m square) they will always land on different squares. These results are not surprising if one thinks about it for a moment. In my view, it is a perfectly reasonable assumption that two paired bones of the same fish, say the left and right dentaries, will on average be separated by less than 44 cm in an archaeological site.

A second aspect of this issue of what is a reasonable size for the smallest unit of assemblage is to consider what would be the result if two paired bones of the same fish, say the left and right dentaries, were separated on average by more than 44 cm in an archaeological site. One might initially think that the absolute value of the MNI for each fish type would be inflated. However, this is not so, because by the same token the left dentary of a second fish is now much more likely to end up on the same square as the right dentary of the first, and be counted as one fish rather than two.

One could consider numerous versions of these thought experiments, and unwisely tinker with theoretical calculations. There is one over-riding consideration which should help to bring us down to earth, and that is to re-affirm that the objective of aggregating bone numbers is to obtain reliable estimates of the relative abundance of different fish types caught. That is, not the absolute MNI, but the proportions of different fishes in a prehistoric catch. When this is kept firmly in mind, the issue of whether the total MNI is slightly too low or too high assumes far less importance. Where the total MNI becomes important is when calculations are made about total food quantities represented by remains in a site, and comparison between major categories of food (fish compared with shellfish, or sea mammals, moa etc.).

Finally, it needs to be noted that a great deal of the research carried out on fish remains in New Zealand and the Pacific has been on collections which have been separated from artefactual evidence and set aside for study at some unknown future date. Some of the work leading up to this volume involved collections which were excavated 40 years previously. In many cases it is not possible to determine whether material in one bag labelled ‘Square Q47 Layer 12’ was from the same time period as another bag labelled ‘Square R28 Layer 12’. As any archaeologist knows, something labelled in the field as Layer 12 in one square is not necessarily the same stratigraphic horizon as Layer 12 in another. In such cases, aggregating all bones labelled ‘Layer 12’ regardless of square is potentially hazardous. In the case of unit level excavations, this problem is even worse. In the interests of employing one reasonably consistent system of aggregation, I have adopted the procedure outlined above.

ESTIMATING FISH SIZE

It has been emphasised above that the first and foremost objective in studying archaeological fish assemblages is to establish the relative abundance of different fish types caught, and that this helps to define the first major characteristic of the prehistoric fish catch of a group of people, notably the overall composition of their catch. A second important characteristic is the size-frequency composition of each fish type. It must be universal that fishermen like to catch big specimens of a fish, even if they do not always taste the best. Large specimens attract a lot of attention and form the basis of many tall stories about fishing. The use of large baited hooks will only catch larger specimens, while small hooks can catch larger fish as well as smaller ones. The size of mesh in a gill net influences the size-frequency diagram of each species. Finding an abundance of specimens of very small fishes in an archaeological site might hint at the use of fish poison or very fine mesh nets. It might also indicate that the nearby environment has been depleted of larger individuals by overfishing.

Establishing the size-frequency diagram for each fish type enables us to estimate age grades of target species, and to make far better estimates of the amount of food represented by fish remains. It provides important information for examining issues of resource impact, and more generally for understanding the relationship between people and their environment.

Establishing the relationship between bone size and fish length and body weight is a time-consuming task requiring 100–200 modern specimens to be collected and measured, and then boiled down so that bones can be extracted and measured. Work has begun on some of the major species which were important to the pre-European Māori, but it will be many years before this research is completed. We now have good quality information on snapper (Leach and Boocock 1994, Leach and Boocock 1995), blue cod (Leach *et al*. n.d.a), labrids (Leach and Anderson 1979b, Leach *et al*. n.d.b), kahawai (Leach *et al*. 1996a), barracouta (Leach *et al.* 1996b), greenbone, eels, and a few others. When measuring the archaeological bones one should always take the largest appropriate measurement which has been defined in these background studies. This is because the smaller measurements have a higher error associated with them when estimating original fish size.

What bones should be measured ? Should we measure all bones possible for a particular fish type or just one part of the anatomy ? This question arises from the fact that the NISP for a fish type always exceeds the MNI. For example, an assemblage might contain a NISP of 1000 paired cranial bones of snapper, and the MNI is 500 fish. When measuring the archaeological bones we would take one and only one measurement (the largest dimension) from any one bone, which in this case might be 700 bone measurements, since it will not always be possible to take a measurement on each of the 1000 bones. Clearly, we have more measurements than the MNI of 500. Is this a problem when estimating the size-frequency diagram for this fish type ? This matter has been carefully investigated (Leach and Boocock 1995: 24ff.), and it is concluded that the best approach is to use the 700 measurements, not 500. Taking the larger number of measurements is unlikely to introduce bias, so long as the assemblage is of a reasonable size.

TAXONOMIC LEVEL TO IDENTIFY TO

When it comes to identifying the type of fish from one of the five paired cranial bones or special bones discussed above it is very important to adopt a consistent approach to the level of precision of identification. There are several pitfalls which one must avoid and a few of these should be mentioned.

One has to accept that there is ongoing disagreement and revision taking place as to the taxonomy of fishes, and this can be very frustrating when trying to compare results obtained from different archaeological sites over an extended period of time. Bones identified ten years earlier as horse mackerel because they compared most closely with modern bones reliably identified to this species at the time may now require revisiting and comparing with new modern specimens because the taxonomy has been revised. Paulin made an interesting observation in the foreword to his book entitled *A Checklist of Fishes in the National Museum* (Paulin and Stewart 1985: 5) that:

> ...it has been shown that common names carefully chosen can be more stable than scientific names. For example, Gilchrist (1902) listed common and scientific names of South African fishes but today most of the scientific names are obsolete whereas the common names are still in use [citing Smith 1975].

Another problem arises from the fact that some parts of fish anatomy are more distinctive of a lower taxonomic level than other components. For example, the dentaries of barracouta and gemfish are easily distinguished, but their maxillas are more difficult to distinguish. Of a total MNI of 100 fish one might identify say 90 left dentaries as barracouta and 10 as gemfish, and then later attribute all 100 left maxillas to barracouta, and end up with an MNI of 110 instead of 100. Strictly speaking one should identify all these maxillas as Gempylidae family (including barracouta, gemfish, ruvettus etc.). It is difficult to process such complex data containing equivocal identifications. If software is used for MNI calculation at least the rules are completely explicit, since every single step in the process is programmed and applied consistently to all identifications of each fish type.

In New Zealand, there are only a few fish types which were consistently harvested by pre-European Māori, so this issue is not as important as in the nearby Pacific. There is only one species of snapper in New Zealand, for example. Occasionally, however, one finds a bone which looks like a snapper, but is slightly different. This may in fact be a straggler from Australia and belong to the same genus but another species. Although one would be forgiven for incorrectly identifying this as the New Zealand species, this error may conceal important palaeoecological information relating to ocean current shifts over time.

These sorts of problems can be avoided altogether by choosing a safe option of identifying all fish bones to a higher taxonomic level, say to family. This has the effect of minimising MNI which is acceptable, but unfortunately smears over potentially valuable information. With collections from the tropical Pacific, it is often necessary to identify only to family level, but for New Zealand this option seems unnecessarily restrictive, and potentially misleading. In the example given above with barracouta, if all bones were identified only to family level (Gempylidae), someone may later misinterpret this as implying that ruvettus was just as likely to be present as barracouta, whereas this is very unlikely to have been so. If we can reliably identify an individual dentary as barracouta we should do so, and if we cannot distinguish an individual maxilla better than barracouta/gemfish, we should not exceed this level of identification precision. In processing bones from a site, having identified hundreds of dentaries as being barracouta, and then moving on to the maxillas, it would be very tempting to adopt the line of thinking that they are all barracouta too. This is identical to not identifying the bones at all, and should be scrupulously avoided. The approach which I have adopted is to attempt identification of each bone to the lowest taxonomic level possible (for example to species), and worry at a later stage how best to treat the complex data which are thus derived.

WHAT ORDER OF ANATOMY SHOULD BE FOLLOWED IN IDENTIFICATION ?

The best approach is to identify bones in order of increasing difficulty. This helps one to gain confidence in the process of working through the contents of a site, and to minimise errors, particularly with the taxonomic level which can best be achieved. By far the easiest parts of the anatomy to identify are the special bones, and it is always best to start with these. The order I follow is as follows:

1. Special Bones
2. Dentary
3. Premaxilla
4. Articular
5. Maxilla
6. Quadrate

As mentioned above, sometimes the quadrates are not identified, particularly if the assemblage is a large one.

SORTING, RE-BAGGING AND IDENTIFICATION PROCESS

The process of identifying fish remains initially seems very daunting, but when it is broken down into a series of discrete steps, the task is greatly simplified. This is very like the problem of building a car at a vehicle assembly plant. The overall task seems impossibly complex, but when it is broken down into a simple step-by-step procedure, the final objective becomes feasible. The steps I follow are set out below:

Step 1: Curatorial System

A large number of the collections I deal with were excavated by other people, and the details recorded on bags are many and varied. Specimens in bags are tipped out and sorted into different categories many times. This means that provenance details are re-written numerous times. These details must be clearly understood and written in neat durable handwriting. If a large amount of detail requires continual transcribing it is understandable that handwriting can deteriorate to illegibility. It is therefore desirable to reduce the amount of handwriting to the bare minimum, but always ensuring that the first rule of good curation is held to — never destroy archaeological information — if it was important to write something on a bag at the time of excavation, then it is important to retain it.

I distinguish between four different kinds of data written on an archaeological bag, each considered separately and written on a separate panel on the bag. Some comments are called for on each of these categories:

Panels 1 and 2
Non-repeatable essential information on space (Panel 1) and time (Panel 2) provenance: This records the original square and stratigraphic layer where the items were found in the archaeological site (II/15, Layer 6B). This information should not be changed at some later date. For example, if the contents of a site were later interpreted as belonging to, for example, three different cultural phases (Classic Māori) or geomorphological facies (Erosion Zone), it would be a breach of the first rule of good curation to substitute the higher level interpretation for the original provenance data. It is always possible to go forwards (layer to phase, which is a higher level of interpretation), but it is impossible to go backwards (phase to layer).

Panel 3
Non-repeatable but less essential information: Numerous things are written on bags which are not so essential for analysis of faunal material, but which nevertheless must not be destroyed, even in the interests of simplified re-bagging. Examples are "extensive evidence of burning in this square", or the date and initials of the person writing details on the bag. In all such cases, this information is entered into a computer database, and a simple catalogue number issued. This number is then written on the new bag during re-bagging. It is much simpler to write this, and encourages more consistent quality handwriting when thousands of bags must be written on.

Panel 4
Repeatable non-essential information: These are comments which someone has written on the bag like "rat pelvis", or "contains left tibiotarsus of pigeon". These comments refer to information which can be recovered if it is discarded. In almost all these cases, I do not transcribe this information.

Finally, occasionally I come across problems with interpreting original handwriting on bags, especially if a language other than English is used, or if there is extensive use of symbolic expressions, which mean a great deal to the original excavator, but are quite opaque to the person doing the sorting work. An example is the custom of one well known archaeologist who circles an arabic numeral to indicate uncertain stratigraphic provenance, and puts it in a square box when it is certain. Variations on this theme involve the use of upper and lower case alphabet characters, and distinguishing between levels and layers by use of roman and arabic numerals. Unfamiliarity with these customs on the part of excavators writing on the original bags means that a large number of variations occur. There are occasions, such as later selection of material for radiocarbon dating, when the original writing assumes great importance. In cases when these sorts of issues might arise later, I allocate a simple catalogue number to each bag, write this on both the new and old bag and box up the old bags and keep them.

Thus, each new bag has three ingredients on it. A typical example of what an individual bag looks like when completed is given below.

Panel 1	**Koko**
Panel 1	**II/10**
Panel 2	**L–4**
Panel 3	**AA678**
Panel 4	**2 L dent greenbone**

The three panels involved deserve some additional comment:

> *Non-repeatable essential information on space and time provenance*: The first three lines contain the all-important information about the original provenance, and are written on the plastic bag with an acetone-based ink marker pen. This type of ink etches into the plastic and even if the ink fades with exposure to ultra-violet, it remains readable. **Koko** is an abbreviation of Kokohuia, which is the name of the archaeological site, and is written on every bag. I try to avoid less meaningful site names like N164/678, which may not be immediately understood by the person reading the label, and may be incorrectly written during re-bagging. I am in favour of a small amount of abbreviation which encourages clearer handwriting on bags. **II/10** is the original information of the spatial provenance within the site. The Roman II may refer to a large square, and the arabic numeral 10 to a smaller square within it. **L–4** is an abbreviation of Layer 4, and again minimises the number of characters requiring to be transcribed many times over.
>
> *Non-repeatable but less essential information*: This is contained within the catalogue number **AA678**. It is not necessary to rewrite all this information continually, so the catalogue number is used in its place. If it later becomes important to examine all additional information, then it can be looked up in the catalogue. This information is also written on the plastic bag using an acetone-based ink marker pen.
>
> *Repeatable non-essential information*: This is contained in the field **2 L dent greenbone**, and may be somewhat cryptic and not necessarily consistent in style. In this particular case, this can be translated as 2 left dentaries of *Odax pullus*. This information is written on a removable sticky label and attached to the bag. It can be peeled off and thrown away without compromising any of the original information.

Step 2: Initial Sort

Bags of faunal material arrive in various states of sorting by others. The person carrying out the excavation may already have sorted material into major categories such as shell remains, bird bones, fish, etc. and passed on the “fish remains” to me for analysis. This first sort is surprisingly difficult, and unless the person doing it is expert in both anatomy and taxonomy many errors will be made at this stage. The person who later handles the bird bones will find pieces of mammal and have to pass these on to the person identifying mammal bones, and vice versa. The effect of this toing and froing is that tables of MNI and NISP have to be re-calculated, possibly several times. This can be very frustrating for all concerned.

I consider the initial sort to be the most difficult task in handling faunal remains, and is best carried out serially starting with one of the experts involved in identification, say the bird bone expert. This person would remove all the bird bone and re-bag it, leaving a residue. This residue can then be passed on to the mammal expert for removal of mammal bones, etc. Such a procedure minimises mis-bagging. I am sure that there will be many who think that this suggestion is unnecessarily cumbersome, and that most archaeologists can easily handle the first sort without a lot of problems. Personally, I greatly prefer it when I receive the whole unsorted faunal collection so I can remove the fish remains from it myself, rather than entrust this part of the process to someone who cannot recognise vestiges of ghost shark ossicles and throws them aside thinking they are pieces of broken shell, or who sees the flimsy vestiges of a lamprey’s sucker mechanism and thinks it is one of the cervical vertebrae of a rat or very small bird and consigns it to the wrong person for identification. The problems do not stop there. The shell expert will eventually see the ghost shark remains and consign it to the "don't know" box, or worse still — discard it altogether as unidentifiable rubbish. Many such problems occur at the stage of initial sorting of faunal material, and most are easily avoided by adopting the attitude that the initial sort is the task requiring the greatest expertise rather than the least. Unfortunately, this seldom occurs.

Step 3: Sort by Anatomy

Assuming that I now have a series of bags which only contain fish bones, the next part of the process I follow is to tip out each bag and sort according to anatomy and then re-bag the material, exactly duplicating the information on each bag sorted. I set up one large tray for tipping the bag into, and a series of small trays labelled as follows:

special
dentary
premaxilla
articular
maxilla
quadrate
grunts
re-sort (bird, artefacts, rat, mammal, stone, etc.)
fish remains not identified

The first six of these require no additional comment except to say that many of these bones will be fragmented and it is only after a great deal of experience that one learns to identify a small fragment of these standard items of anatomy mixed up with the dross. I always make a habit of working systematically through the pile of bones in the large tray so that each fragment is seen once and classified accordingly. I use a pair of long nose tweezers for this task and work along an edge of the pile, sweeping a fragment as "fish remains not identified" in the corner of the tray if it is not one of the first eight categories listed above, and removing an item if it is. By working away at an edge of the pile in this way, each fragment is separately examined. A newcomer to this task often tries to observe the whole pile and recognise a fragment of standard anatomy, remove it, and then return attention to the whole pile again. This might be done repeatedly until nothing further can be seen in the pile and then the rest dumped into "fish remains not identified". This is a poor procedure to follow. Each fragment does not get a uniform chance of being recognised for what it is, and many useful items are missed. It is far better to work at an edge of the pile, look at each item in turn and classify it as one of the nine categories listed above, and then move on to the next fragment.

While carrying out this anatomical sort, one should keep a watchful eye for evidence of butchering and any other unusual marks on bones. On large fish, one may find sharp cut marks on the dentary surface for example. Dogs and rats can leave characteristic tooth puncture marks on bones. Species which are usually captured with lures often show damage in a particular place on the premaxilla or dentary, removing a tooth or causing other damage. Any such bones I bag separately, and provide some annotations on a label, before placing the bag in the appropriate anatomical tray.

The multi-stage process described here for sorting and identifying bones involves several rounds where bags are opened, tipped out, worked on, and re-bagged into an ever increasing number of bags, rather like the chain-gang method at a New Zealand freezing works, or a vehicle assembly plant. The main difference is that the same person is involved at each step of the process rather than different people. The only bagged material not seen many times is that which is placed in the 'fish remains not identified' group. For this reason, during the sorting process, we adopt the adage *if in doubt keep it*. This means, don't put it in the 'fish remains not identified' tray unless you are sure you don't want to see the bone again. It is false economy to spend a great deal of time on a particular bone at the stage of sorting according to anatomy. If one is unsure about the anatomical identity of a particular bone, the best procedure is to put it in the 'grunts' category, and carry on. By the time you get to looking at the grunts, your knowledge of the assemblage is usually greatly improved, and you can cope with the oddities more quickly and easily.

What is a grunt ? It is a bone which is causing a headache of some kind. Usually it is something so unfamiliar that you are uncertain even what the anatomy is, let alone the species. At the end of the sorting process, if there are a lot of grunts, I send them to a colleague with wide knowledge of bones, not just fish, and ask for some clues. I can recall an occasion 20 years ago when a particular bone caused great misery amongst a group of archaeologists sorting fish remains from the Chatham Islands. No one in the group had the slightest idea what the anatomy of this bone was. It measured about 30 x 10 mm, and was curved and about 4 mm thick, with a somewhat rectangular cross-section, and very regular shape. The group had been working on fauna for several months, sorting many thousands of fish bones, and this mysterious bone kept ending up in the grunt box. "What kind of fish could have such a bone ?" one person asked. In desperation, the expedition leader asked me if I had ever seen such a bone before. With a sense of the occasion I was able to announce that it was not a fish bone but a fish hook, admittedly not a complete hook, but most of the shank nevertheless. This cause predictable embarrassment, but also revealed an important point, that when you have your nose deeply into one type of problem you can become quite myopic, and unable to recognise things which would otherwise seem quite common. This is the main reason why I had adopted the sorting procedure described here. It allows one to focus intently on one job at a time, and do it very well indeed. It is always instructive, during the anatomical sort, to note just how clever one becomes in recognising minute fragments of the standard anatomy of fishes. This is very helpful in swelling the final MNI values. It also enables highly evolved and divergent anatomy of rare species to be identified for what they are. So long as you adopt the adage *if in doubt keep it*, a fish hook fragment will be retained for later examination. The anatomical sort should be thought of as identifying anatomy, not fish type, nor fish hooks, nor some other category. If it is placed in the tray 'fish remains not identified' it means 'I know that it is a fragment of the cranium of a fish, but it is not part of the standard anatomy'. It should not be thought of as 'I have no idea what this bone fragment is'. If this is the case, it should be placed in the grunt tray, to be looked at again later.

The tray called 're-sort (bird, artefacts, rat, mammal, stone etc.)' is where you put all the things which were incorrectly sorted during **Step 2: Initial Sort**. During the anatomical sort, it is not advisable to spend any time on trying to separate these out; they should simply be re-bagged for later examination.

The final category, called 'fish remains not identified' is a very important one, and should not be thought of as a discarding category. Increasing attention is being given to anatomical elements other than those involved in the process described in this volume, and that is a welcome development. The ratio of head bones to vertebrae can be used to identify fish cleaning practices, preferential allocation of body parts to different social groups, identification of functionally different spatial elements in a site (food preparation area and eating area for example). Cranial fragments can be used for radiocarbon dating, for chemical analysis, amino acid studies, relative dating from nitrogen content, genetic diversity studies, etc. These are a few examples among numerous lines of enquiry which the non-standard anatomy can be used for. Needless to say, 'fish remains not identified' are boxed up and kept for posterity in our Laboratory. Several examples can be pointed to where this category was discarded to the rubbish dump, and in my view it is a great pity. I can mention the very large and important collections from the following where this has happened:

Site	**Site No**	**Fish MNI**
Waihora, Chatham Islands	C240/283	4197
CHA, Chatham Islands	C240/681	884
CHB, Chatham Islands	C240/680	4978
Long Beach, Otago	I44/23	5770
Shag River Mouth, Otago	J43/2	2134

We have reasonable quality information about fishing from 126 archaeological sites in New Zealand so far, amounting to a total MNI of 40,433 fish. These five sites alone contribute an MNI of 17,963 towards this total; that, is over 44% of the entire collections in New Zealand. Only the standard anatomy of fish remains has been kept from these five excavations. I think this is lamentable.

Step 4: Identification of Fish Type

Newcomers to fish identification always believe that this stage of the process is the most difficult, whereas it is actually relatively straightforward. The Initial Sort and Anatomical Sort are much more difficult than this part of the process. The best order to follow was outlined above as being:

1 Special Bones
2 Dentary
3 Premaxilla
4 Articular
5 Maxilla
6 Quadrate

This order is one of increasing difficulty in identifying taxa. The special bones are quite simple, the dentary slightly more difficult, and the quadrate by far the hardest.

In our Laboratory, the comparative collection of modern fish is housed in two ways, one part on special display boards, and the remainder in cardboard boxes. Whole skeletons of fish specimens are kept in boxes. Multiple specimens (100 to 200) of individual species are used for metrical analysis in the estimation of live fish size and weight from archaeological bones. Only the five paired cranial elements and special bones of these specimens are kept. Each bone is labelled and the bones from each fish are kept in a square plastic petri dish. These dishes are kept in boxes. Finally, the five cranial bones and special bones from one individual of each species are mounted on specially designed display boards for use in routine identification. These are housed on shelves on six bays (one bay for each anatomical element, arranged in the order described above). Each bay has a series of deep shelves, with 120 mm spacing. There are 14 shelves in each bay. On each shelf is placed a 5 mm thick hardboard measuring 840 x 590 mm. This has a high density white surface capable of being cleaned with compressed steam. On a board with dentaries the left and right bone of each species is glued in place, one above the other, one with the medial and the other with the lateral surface uppermost. About 50 bones from 25 species are mounted on each board. About 300 species are thus mounted from New Zealand and the tropical Pacific. The location of any one species on a board and shelf is identical from one bay to another.

A bag of dentaries, for example, is tipped out into a tray, and sorted first into groups according to type of fish and then into left and right bones. A large specimen of one fish type is then compared with the dentaries on the display boards until the best match is found. All identifications are made to the lowest taxonomic level possible. The level at which New Zealand fish bone can be identified varies from one taxon to another. For example, amongst the order Anguilliformes, the cranial anatomy of the conger eel *Conger verreauxi* is characteristic to species level, easily distinguished from the freshwater eels, Family Anguillidae. However, within Anguillidae, it is not nearly as easy to distinguish the two species in New Zealand, the short-finned eel *Anguilla australis* and the long-finned eel *Anguilla dieffenbachii*. The most similar dentary to our bone could be the long-finned eel, but the identification *Anguilla dieffenbachii* would not be entered as such on a bag. Instead the identification would be entered as *Anguilla* cf. *dieffenbachii*, indicating that this species is the most similar in the comparative collection, but although the genus is certain the species is not. We are fortunate that in New Zealand (unlike the tropical Pacific) there are relatively few common species, and there is not a great deal of ambiguity in identifying to species level. Notable exceptions are amongst the Labridae family and the various species of mackerel. It is hoped that more careful study of the anatomy of the labrids in future will enable a lower level of identification than to family. The different species have somewhat different habitats, and this could be a useful guide to prehistoric use of different fishing zones.

When the identification is made, it is written on a small sticky label using a simple form of abbreviation, such as:

1LD cf. Spotty

This means one left dentary, and the closest species is *Notolabrus celidotus*, but not necessarily this species.

Step 5: Entering Data into Kupenga Software

When all the material has been identified, the next step is entering the data into the purpose written database, known as *Kupenga*. This program was written to minimise problems of entering data by hand into computer files. Once again, we follow the same anatomical order used during the identification work. The bags of one anatomical group, for example dentaries, are sorted on a bench by species, and if possible grouped into like squares and layer. This greatly speeds up the data entry process. The software is set up so one makes a series of choices with a mouse, starting with a major region (New Zealand, Chatham Islands, Pacific, Europe, etc.), and then in the following order:

1: An archaeological site within the chosen region
2: A square within the site
3: A layer within the square
4: Number of bones
5: Anatomy
6: Taxon

This closely follows the panels of information on the bag which were earlier described. The software generates a serial number which is then written on the bag. This bag number has a number of uses. At some later stage, should the identification be revised in any way, it is possible to change the specific entry in the database, as well as easily locate the bag. This greatly simplifies any re-analysis of the site information. In many cases, at a later stage, bones are measured for estimation of live fork length and weight. The measurements are coded with this bag number, and software picks up the provenance information to permit aggregation of measurements by stratigraphic layer. The software which does this identifies any outliers, such as particularly small or large fish specimens, and prints out the information with the bag number, so the specific bone can be easily located and the measurements checked. This apparently simple objective could be a formidable undertaking without such a system. During analysis of the catch data for barracouta from Long Beach some 15,558 bone measurements were made. These computer generated bag numbers, cross-linked as they are between the bags and various databases, permitted outliers to be checked quickly and efficiently.

During use of *Kupenga*, it is only necessary to change one or two of the entries listed above from one bag to the next. In other words, information stays the same between entries unless it is altered. The presentation on the screen is designed to be similar to the presentation on the bag so it is easy to check that the data are correct. Pre-sorting of the bags into groups, as described above, ensures as few changes as possible during the data entry process. It is possible to make errors of course, and these are written down in a work book, and corrected later by manual editing. Only one person in the Laboratory is permitted to edit the database.

In the early stages of development of this database system (Leach 1986) the information from bags was entered into a computer file by hand, using an ascii word processor. Following several years use of this method, *Kupenga* was developed as an alternative. There were two equally important reasons for abandoning the manual system. Firstly, *Kupenga* greatly speeds up data entry. Secondly, we found that there was a relatively high rate of errors. This was because the information was entered into the database using numeric codes, requiring the operator to translate the information on the bag using lookup tables. For example, a bag may have 'red cod' or *Pseudophycis bachus* written on it. This is translated to the numeric code 35 and entered into the computer file. Because *Kupenga* is an exact mirror of what is on the bag, this form of error was effectively eliminated. The database itself still consists of numeric codes, but these are hidden from the user. At the present time, the database contains records on 169,546 bones (NISP).

Step 6: Calculation of Relative Abundance

This is effected with software which interrogates the *Kupenga* database for any chosen assemblage, assembles the information for each taxon in turn and calculates the NISP and MNI. Each anatomical element is associated with a numeric value which specifies how many of these elements are found in one fish. Examples are: left dentary 1, erectile spine 1 (Balistidae), dermal spines 500 (Diodontidae), vertebrae 80. Although any one fish may only have 1 left dentary, the number of vertebrae a fish has depends on the species. Even within a species, the number of vertebrae varies a little from one individual to another. Some ranges for different groups of fishes are (after Wheeler and Jones 1989):

Tetradontiformes	15–17
Perciforms	23–40
Cypriniformes	25–50
Clupeiformes	45–65
Salmoniformes	50–60
Gadiformes	55–75

The value of 80 we have adopted for vertebrae represents a conservative choice. With the information relating to an assemblage for any one taxon tabulated by anatomy, it is a simple matter to calculate both the NISP and MNI. The NISP is simply the sum of all the identified bones, and the MNI is the largest number in the column which contains the number of bones for each part of the anatomy divided by the number per fish for that anatomical element. An example is given below. This relates to blue cod from the site known as Waihora in the Chatham Islands (Site C240/283).

Left Dentary	1520	
Right Dentary	1495	
Left Premaxilla	1668	**MNI=1,668**
Right Premaxilla	1638	
Left Articular	226	
Right Articular	188	
Left Maxilla	1402	
Right Maxilla	1497	
Left Quadrate	324	
Right Quadrate	343	
NISP	**10,301**	

There are several notable features of this summary. There are differences between the number of left and right bones identified. In the case of the dentary the left bone is favoured by 1.7%, for the articular the left is again favoured by 20.2%, the right quadrate by 5.9%, the left premaxilla by 1.8%, and the right maxilla by 6.8%. These are quite large discrepancies, and are a suitable caution against relying too much on statistics deriving from small-sized assemblages. This is a reasonably large assemblage, and even here there are notable differences between the numbers of identified left and right sided bones. It is also interesting that articular and quadrate identifications are much lower than for other parts of the anatomy. This is a reflection of the greater difficulty involved in identifying these anatomical elements to correct taxon from very small fragments. We have found over the years that the number of quadrate identifications is consistently lower than for other bones. This not only reflects difficulty in identifying to taxon from fragments, but also from whole quadrates. For this reason, when large assemblages are being processed, we sometimes do not identify quadrates, but set them aside for future reference. The articular poses different problems. Usually this bone is relatively easy to identify to a useful taxonomic level, but not in all cases. There are more problems with fragments of blue cod articulars than with some other taxa.

In the list above the NISP is 10,301 and the MNI is 1,668. The MNI is simply the largest number in the table for any one element of anatomy, because in the case of these bones, there is only one per fish.

USING THIS IDENTIFICATION GUIDE

For a number of reasons I have avoided trying to lay out the bones on the display boards following a strict taxonomic order. The main reason is that if one were to attempt to do this one would have to leave blank spaces for bones of rarer species so they could be put in correct position as they progressively came to hand over a long period of time as the comparative collection was augmented. This effectively means that one would have to make provision for approximately 1000 species. With such an arrangement, most boards would have hardly any bones on them, and the system would be quite unwieldy. The arrangement of specimens on my display boards is not systematic, although similar sized species tend to be grouped together. As new species are collected, they are simply mounted at the end of the last board. The illustrations accompanying this volume are also not in taxonomic order. They have been chosen from those on the display boards, and are organised partly by size and partly by morphology. As one uses either the boards or the illustrations here, it will be found that most of the shapes are eventually committed to memory. That is, one very infrequently comes across a bone which is not immediately recognised. Giving the correct name to it is not the same thing. That is where comparative material is used. I have found that over a period, one memorises where particular bones are on the display boards, particularly if they are organised approximately by size, because size is one of the first important clues to identity.

The illustrations are arranged as follows:

Anatomy	**Side**	**No Illustrations**	**No Species**
Special Bones	Various	8	11
Dentary			37
	Left	8	
	Right	8	
Premaxilla			37
	Left	8	
	Right	8	
Articular			37
	Left	8	
	Right	8	
Maxilla			37
	Left	8	
	Right	8	
Quadrate			37
	Left	8	
	Right	8	
Total		**88**	**45**

It will be noticed that there are eight illustrations for each part of the anatomy. The order of presentation of fish type is the same from one part of the anatomy to another. Illustrations are provided for both the left and right bones. This makes things considerably easier when identifying bones, by avoiding the necessity to convert a figure mentally to its mirror image. Thus, for standard anatomy there are four illustrations for each bone. For example — the left dentary medial aspect, the left dentary lateral aspect, the right dentary medial aspect, and the right dentary lateral aspect. On the display boards, there are only two views available — left dentary medial aspect, and right dentary lateral aspect. If one has a small fragment of a right dentary where the important characteristics are contained on the medial surface, one has to compare this with the medial surface on the left rather than right bone. This requires some mental gymnastics, and can be very confusing at times. This is why all four views are provided of the bones illustrated here, to make it as easy as possible for use with real bones and especially with fragments. It may be observed that the left and right bones are genuinely mirror images of each other. The right bones were drawn in each case, and the illustrations for the left bones produced using computer software.

No scales are provided on the illustrations. Most bones are illustrated at life size using large specimens to show as much anatomical detail as possible. In cases where only small specimens were available, the bones were drawn at an enlarged scale of up to twice size to capture fine detail. Since the size of each species varies a great deal depending on age without significant change in anatomical features, adding scales to the illustrations would not be useful.

In using the illustrations, one first identifies what anatomy the bone is, say left premaxilla, and then simply turns to the start of the 8 illustrations of left premaxillas, and works through each of the 37 species until the best match is found. If the system described earlier is followed, of sorting first by anatomy and then, when starting the identification process, of sorting by fish type before attempting to identify taxa, you will find that the process is greatly simplified, and confidence boosted.

It is not possible to provide illustrations of all the standard anatomy of all species one could find in New Zealand archaeological sites, and even if one could do so, illustrations are not a substitute for a well organised comparative collection. However, the 37 species provided here with paired cranial anatomy, and 8 additional species with special bones, give a good cross-section of the most common species found in sites in New Zealand, and provide a suitable starting point. The illustrations are listed in Table 1.

TABLE 1

List of species and anatomy illustrated for assistance with identification

Porcupinefish	*Allomycterus jaculiferus*	Five paired cranial bones
Spotty	*Notolabrus celidotus*	Inferior and superior pharyngeal clusters
Butterfish, Greenbone	*Odax pullus*	Inferior and superior pharyngeal clusters
Eagle ray	*Myliobatis tenuicaudatus*	Articulated tooth plates
Broad squid	*Sepioteuthis bilineata*	Beaks
Elephantfish	*Callorhinchus milii*	Tooth plates
Leatherjacket	*Parika scaber*	Erectile dorsal spine
Southern spiny dogfish	*Squalus acanthias*	Dorsal spine
Snapper	*Pagrus auratus*	Tail spines
Elephantfish	*Callorhinchus milii*	Dorsal spine
Shorttail stingray	*Dasyatis brevicaudatus*	Barbed spine
Eagle ray	*Myliobatis tenuicaudatus*	Barbed spine
Lamprey	*Geotria australis*	Semi-ossified mouth parts
Ling	*Genypterus blacodes*	Palatine bone
Red gurnard	*Chelidonichthys kumu*	Opercular
Spotty	*Notolabrus celidotus*	Otolith
Barracouta	*Thyrsites atun*	Five paired cranial bones
Frostfish	*Lepidopus caudatus*	Five paired cranial bones
Gemfish	*Rexea solandri*	Five paired cranial bones
Estuary stargazer	*Leptoscopus macropygus*	Five paired cranial bones
Rock cod	*Lotella rhacinus*	Five paired cranial bones
Ling	*Genypterus blacodes*	Five paired cranial bones
Snapper	*Pagrus auratus*	Five paired cranial bones
Trevally	*Pseudocaranx dentex*	Five paired cranial bones
Southern pigfish	*Congiopodus leucopaecilus*	Five paired cranial bones
Spotty	*Notolabrus celidotus*	Five paired cranial bones
Butterfish, Greenbone	*Odax pullus*	Five paired cranial bones
Yellowbelly flounder	*Rhombosolea leporina*	Five paired cranial bones
Grey mullet	*Mugil cephalus*	Five paired cranial bones
Marblefish	*Aplodactylus arctidens*	Five paired cranial bones
Yellowfin tuna	*Thunnus albacares*	Five paired cranial bones
Skipjack tuna	*Katsuwonus pelamis*	Five paired cranial bones
Albacore/Albacore tuna	*Thunnus alalunga*	Five paired cranial bones
Pilotfish	*Naucrates ductor*	Five paired cranial bones
Blue maomao	*Scorpis violaceus*	Five paired cranial bones
Trumpeter	*Latris lineata*	Five paired cranial bones
Blue warehou	*Seriolella brama*	Five paired cranial bones
Horse mackerel	*Trachurus novaezelandiae*	Five paired cranial bones
Blue mackerel	*Scomber australasicus*	Five paired cranial bones

TABLE 1 Continued

John dory	*Zeus faber*	Five paired cranial bones
Kahawai	*Arripis trutta*	Five paired cranial bones
Red cod	*Pseudophycis bachus*	Five paired cranial bones
Red gurnard	*Chelidonichthys kumu*	Five paired cranial bones
Tarakihi	*Nemadactylus macropterus*	Five paired cranial bones
Blue moki	*Latridopsis ciliaris*	Five paired cranial bones
Red scorpionfish	*Scorpaena papillosus*	Five paired cranial bones
Sea perch	*Helicolenus barathri*	Five paired cranial bones
Blue cod	*Parapercis colias*	Five paired cranial bones
Māori chief	*Paranotothenia angustata*	Five paired cranial bones
Hapuku/Groper	*Polyprion oxygeneios*	Five paired cranial bones
Kingfish, Yellowtail kingfish	*Seriola lalandi*	Five paired cranial bones
Long-finned eel	*Anguilla dieffenbachii*	Five paired cranial bones
Conger eel	*Conger verreauxi*	Five paired cranial bones

NOTES ON COMMON IDENTIFICATION PROBLEMS

Although the illustrations accompanying this volume should be relatively easy to use unaided by text, it may be useful to provide some notes on particular features and problems which may be encountered. I do not think it would be useful to comment systematically on every single illustration. Instead, I provide comments on each of the pages of Special Bones, and then some general comments on each of the standard cranial bones. Finally, I have some comments on problems which relate to particular species.

Special Bones I: shows the main bones of the porcupine fish. Clearly the two dentaries and the two premaxillas are fused together. Fragments of these are relatively easy to identify, but a common error is to mis-identify whether the bone is a dentary or premaxilla. There is an obvious difference in the shape of the arches. The most anterior part of the premaxilla has quite a sharp angle to it, compared with the smooth curve of the dental arch. Other standard bones of this fish illustrated here are quite unusual compared with other fishes, and not always seen for what they are during the anatomical sort. The maxilla in particular is quite an unusual shape.

Special Bones II: provides views of pharyngeal bones of both a spotty and a greenbone. These bones are exceptionally durable and have a far higher survival and identification rate than other parts of the standard anatomy of these fish. Siding the superior elements is very difficult, particularly when they are fragmented. If we are processing a large assemblage, where there are many hundreds of these bones, it is not cost effective to spend the great deal of time which is required to side them, particularly as the error rate is high when this is attempted. Instead, I have adopted the procedure of alternating the side as they appear, and taking note of this in a work-book. Thus, the first superior pharyngeal cluster (SPC) to appear is labelled as the left bone (LSPC), and noted in the work book; the next is booked as a right bone and so on. This same procedure is followed when carrying out standard measurements on these bones for purposes of fork length and weight estimation.

Although the greenbone is the only member of this family in New Zealand, there are many species in the Labridae family to which the spotty belongs. Anatomically, the different species within the Labridae family are very similar, and most difficult to identify reliably. Although some parts of the anatomy are distinctive of some species, most are not. It would create errors in calculating MNI if one part of the anatomy was identified to species level, and another to family level. For this reason, we would normally only identify this fish type to family level.

This group of fishes were very important to some communities of prehistoric people in New Zealand, and the different species have somewhat different habitats. It would be very useful to carry out an intensive study of the cranial anatomy of the New Zealand labrids, to see whether more refined identifications could be made, and then re-analyse some of the archaeological collections where these fish are abundant.

Special Bones III: shows one of the articulated plates from an eagle ray. These often baffle people sorting through archaeological fauna during the initial stages of analysis, and are frequently put in the grunt box by mistake. Once a specimen is seen for what it is such an error is not made again, because these bone elements are highly distinctive. I have also illustrated the keratin rich beaks of a common squid. In exceptional preservation conditions, these elements can survive relatively intact. They are more likely to be found in the kind of soil environment which favours the survival of crayfish mandibles (Leach and Anderson 1979a), which are also rich in protein and low in dense calcareous matter. We believe that alkaline conditions rich in phosphates might be the favoured environment for preservation.

Special Bones IV: These unusual bones are very dense and have a high survival rate, despite belonging to a cartilaginous species, the elephantfish, of the family Callorhinchidae. The smaller vomerine bones should not be mistaken for the main elements of a smaller specimen. The dotted line drawn on these specimens indicates a swollen calcareous region which sometimes survives when the remainder has been eaten away by soil acids. These swollen portions might easily be mistaken for shell fragments, except that they are composed of a more amorphous calcareous material than shellfish. Not illustrated here are specimens of the closely related family of ghost sharks, Chimaeridae, which have very similar bony elements in the jaws, with a texture distinct from the elephantfish. The ghost fish is a deep water species and would not normally be found in archaeological sites. However, it has been found in sites in the Chatham Islands. An illustration would not easily show the difference between elephantfish and ghost shark, and it is advisable to become familiar with hand specimens to avoid any error in identification.

Special Bones V: This shows several distinctive spines which are quite common. The spine top left, which is very durable and has an articulating surface at one end, is a dorsal erectile spine. It is covered in small tooth-like projections and is characteristic of the Balistidae family. In New Zealand there is only one common species, *Parika scaber*, or leatherjacket. There is only one of these spines per individual. The cranial elements of Balistidae are very small and easily lost during sieving. These spines are therefore valuable markers of the presence of this species.

The spine shown top right is permanently erect on the southern spiny dogfish. There are two of these spines per individual. The portion of the spine exterior to the flesh has a hardened enamel-like surface, and can survive in archaeological sites long after the keratinous bulk of the spine has dissolved.

Bottom right illustrates a large spine which is similar in composition to the dogfish example. However, it is much larger, and has clear denticulations along both lateral edges of the posterior surface. It belongs to the elephantfish, and there is only one spine per individual.

Bottom left shows some very distinctive spines which occur in large numbers in sites in the North Island. I used to collect these spines for several years not knowing what they were, and they were confined to the grunt box category until their origin was discovered accidentally. They have an unusual articular surface at one end, and are rather reminiscent of one element of the clasper anatomy of sharks, which are part of their reproductive organs. However, the source of these spines is much more mundane. They form part of the articulating spines in the tail of the New Zealand snapper, which join on to the ultimate vertebra. Specimens from old individuals always look like an important bone to retain during sorting. There is a large number of these spines for each individual fish, and I do not use them in the identification process. Because of their unusual characteristics, it is useful to know what they are.

Special Bones VI and VII: These illustrate the anterior and posterior surfaces of the barbed spines of the stingray and eagle ray respectively. These bones are sometimes mistaken for delicate artefacts. They are sometimes actually incorporated in artefacts, such as ceremonial spears in the Pacific. The barbing runs along a far greater length of the spines in the eagle ray than in the stingray and in whole specimens this may enable the species to be identified. However, they often occur broken, and usually they cannot be identified to species. The number of spines per individual varies, but is usually one for an eagle ray and two or more for a stingray.

Special Bones VIII Many unusual elements occur in faunal collections from New Zealand coastal middens and can be quite baffling. As pointed out above, we keep these elements in the grunt box and eventually discover what they are. This page illustrates a few of the more distinguishable elements amongst many possible ones which could occur. In the top row are the unusual mouth parts of the lamprey. These elements are not very durable, and have never been found in New Zealand archaeological sites so far. This is possibly because they are being overlooked. They are drawn at twice natural size.

Palatine bones are sometimes very distinctive for a particular species, in this case the ling. It is possible that palatine bones may be as reliably identifiable to species as the quadrate. The problem here is whether we can identify all the common species from the palatine alone, in the same way that we can for the dentary and other bones.

The surface texture of some bones can be very distinctive. The bone illustrated bottom left is an example. This is from the red gurnard and the texture alone can indicate the presence of this species, even though the anatomy of a small fragment may not be identifiable.

Finally, on the bottom right is illustrated an example of an otolith. There are several pairs of otoliths in each individual fish, but one pair is much larger than the others. Otoliths are reasonably easily identified to species, and are well-known as being the repository of much valuable information. They can be used for aging a fish, seasonal dating, as a record of palaeo-climatic information, and so on. There is one overriding practical problem, however, for their widespread use in faunal analysis — we do not have a reliable systematic method for extracting them from archaeological deposits. Until a method is developed and proven to be effective in recovering the bulk of otoliths without bias, these highly important elements will remain in the too hard category. Some years ago I had some experimental research carried out in the School of Mines at Otago University. The laboratories there were especially equipped for systematically extracting pre-defined elements from large quantities of sediment. A number of extraction techniques were tested with samples of otoliths in midden soils mixed with shell and bone fragments. None proved anywhere near as effective as would be needed. The most promising was an elutriation column, which could possibly be developed for such a purpose. The only existing alternative at the moment is laborious hand searching using a low power binocular microscope. Although this is a daunting prospect, it has been done effectively by Fitch (1969). In one case, 12.7 m^3 of soil was double screened through 1/8th inch mesh sieves, and 7,357 otoliths were recovered belonging to 10 species. Analysis of the fish bones revealed 20 species. Fitch studied an additional 0.5 m^3 from the site, and wet sieved the residue through a stack of two sieves, 2 mm and 1 mm respectively (and some at 0.5 mm mesh).

After sun-drying he systematically examined the residue a tablespoon full at a time with six power binocular microscope. The list of fishes from the site swelled from 20 to 45 species as a result. One species alone accounted for 7,655 otoliths. Otolith studies are still at the infant stage in New Zealand archaeology, but we can expect important developments in the future (Weisler 1993).

The Dentary: After the special bones, this bone is the easiest to identify to fish type. Some of the illustrations provided show teeth still present, and others do not. This fairly reflects archaeological bones too. Snapper and ling, for example, often have their teeth missing or broken off. There is a myth that snapper exfoliate their teeth, possibly seasonally (Shawcross 1967: 116-119), but this is not correct. In snapper, as in many other species of fish, if teeth get broken from hard use they can be replaced, and it is easy to see in archaeological specimens a series of tooth buds underneath functional teeth. The broken off teeth in snapper are especially obvious because of their large molarform shape. The teeth of a relative of the New Zealand snapper which is common in the Pacific, *Monotaxis grandoculis*, widely known as *Mu*, has even larger molarform teeth, and the caps of these are frequently found in archaeological sites, disconnected from the dentary or premaxilla. There is a sharp boundary between the enamel cap of these types of teeth and the dentine which is set into the bone. This is clearly a line of weakness, and the tooth breaks along this line. It is difficult to trace the origin of this myth about seasonal exfoliation, but it could be due in part to the observation of Hauraki Gulf fishermen that school snapper, which consist of young fish taking part in an inshore migration, have very sharp teeth. Older fish at other times of the year have blunt rounded teeth. These two observations may have led to the idea that the young fish exfoliate their teeth at some stage, giving way to an adult form. However, it appears that this conclusion is incorrect. These young fish have been feeding in mid-water on various soft foods, unlike older individuals which crush hard shelled animals like shellfish on the bottom. By old age their teeth show clear signs of a long history of wear and tear, and no hint of seasonal refurbishment.

With many species, parts of the transverse ramus of the dentary are easily broken away, but there is usually sufficient on even small fragments to identify to a satisfactory taxonomic level.

The Premaxilla: In many species, the transverse process is often broken in archaeological sites, but usually the anterior portion of the bone is sufficient for the fish type to be identified. The vertical process is sometimes very easily detached, as it is only partially fused with the transverse process. This is especially so with kahawai (Series 6) and blue cod (Series 7)

The Articular: As with the premaxilla, the transverse process is frequently broken when recovered from archaeological sites. This is an excellent bone for identification of fish type, with a great deal of anatomical differentiation. Even very tiny fragments of the articular can be used, especially in the vicinity of the articular notch which connects to the quadrate. It is useful to pay particular attention to the articular of eel species (Series 8) because these bones are specialised and quite unlike other articulars. They may not be recognised as articulars without this familiarity. In some species the retroarticular is not completely fused with the body of the articular (See Fig. 1), and this may be missing on an archaeological specimen. This can be confusing when trying to find a close match unless it is realised that this portion of the articular is absent. This bone is commonly absent in kahawai and tarakihi (Articular 6).

The Maxilla: These bones are surprisingly easy to identify to fish type. When you examine the display boards with upwards of 300 species mounted, they look rather similar to each other. However, if one follows the sorting procedure described above, when it comes to the maxilla, choose a large bag full so there are several species present in reasonable abundance. When they are sorted into fish types in the tray, you will then have a range for any one species. This is a useful starting point. The curvature of these bones is not easy to illustrate, but is often a very good guide to identification. The main region of anatomical differentiation is the articular surface, where the maxilla surrounds the vertical process of the premaxilla. There are many subtleties in the shape of this part which permit reliable identification.

Note that in Series 8, no bones are illustrated for the two eel species because these bones are not present in these animals. This is an embryological curiosity.

The Quadrate: This bone is by far the hardest to identify reliably across all the possible fish types present in New Zealand archaeological sites. They are the least differentiated amongst the five standard bones in the head. As with the maxilla, if one starts with a large bag with several species present, and can sort these into types and observe a range of individuals, this helps a great deal. It will be noted that the articular surface has two condyles. The relative size of these and the angle they make with the body of the quadrate changes quite a lot from one species to another.

Note that in Series 4 there are no drawings for the blue maomao. Our only specimen of this species was very small, and the quadrates were damaged during processing.

Problems with Particular Species:

In the series of illustrations labelled **1** (Dentary 1, Articular 1, etc.), barracouta, frostfish and gemfish appear. These can be very difficult to separate, and special care must be taken with these identifications. Frostfish and gemfish can be expected to occur only rarely in collections, but their presence, even in small numbers, may be very important. Frostfish, for example, is an excellent seasonal indicator, because it is washed up on beaches in the middle of winter. The bones of these fish are rich in oil and fragment easily. Often the dentary is only represented by a small part of the symphysis area. This is sufficient for reliable identification and for fork length estimation, but one must be thoroughly familiar with the other species first.

In series **3** the bones of marblefish are shown. These bones are not often recovered archaeologically, although I am sure they are present. They are not very distinctive anatomically, and may be mistaken for broken fragments of some other species. This is a pity because it is clear from records made by Peter Buck that this was an important species for the Māori at least on the East Coast of the North Island and eastern part of the Bay of Plenty (Buck 1925: 612 ff.).

Likewise, bones of flounder are not often identified. Their bones are small and thin, and fragments of them may easily be mistaken for unidentifiable dross. The maxilla, for example, is rather unlike that from other fishes. Only the right bones of the yellowbelly flounder are illustrated in the accompanying drawings. The left bones are highly specialised, and not easily recognised as part of the standard anatomy described in this volume. The best way of becoming familiar with these bones is to obtain a modern specimen and study it carefully, and commit the unusual forms to memory.

In series **4** illustrations of the bones of various species of tuna are shown. I always keen a sharp eye open for these bones, which have yet to be found in any New Zealand archaeological site. They are common in some sites in the Pacific.

Bones of horse mackerel and blue mackerel are illustrated in series **5**. The bones of these two species can be very difficult to distinguish and it is best to become familiar with a range of modern specimens. It should also be noted that the bones of these fish resemble trevally (series 2). Once again, only familiarity with modern specimens rather than illustrations can help here.

Another problem is illustrated in series **7**. This is with the red scorpionfish and the sea perch. Their bones can be very similar indeed. There is a striking difference in the shape and character of the opercular, which is relatively smooth in the case of Sea perch. These bones will be picked up during identification of the Special Bones.

Blue cod and Māori chief are also difficult to identify reliably without familiarity with modern comparative material. It will be noted that the chin on the dentary of Māori chief is much more pronounced (Dentary 7). However, the best method for separating the two species is by examining the relative position of the two margins (medial and lateral) between the two branches of the transverse ramus on the dentary. In the case of blue cod, the lateral margin is considerably further forward than the medial margin. In the Māori chief, these two margins are much closer together.

Series **8** shows the bones of the freshwater eel and conger eel. These are anatomically very similar, but have a completely different tooth form. Freshwater eels have small conical shaped teeth, whereas the teeth of conger eels have a width much greater than the length. The teeth are normally absent on archaeological bones, but their distinctive patterns are preserved along the surface of the dentary and premaxilla. It is possible to distinguish the two species of freshwater eel, but this is best done after familiarity with a range of modern comparative material, particularly the vomer.

CONCLUDING COMMENTS

It should not be forgotten that the purpose of identifying fish bones and other faunal remains from archaeological sites is to provide a better understanding of past human behaviour. The subject matter of archaeology should be about people going about their daily, seasonal, and annual activities. Sometimes this is lost sight of as one struggles with minute details of fish bone anatomy, counting huge piles of shellfish, or measuring growth rings on otoliths with a microscope. In a flight of fancy, one could imagine that this labour intensive detailed research could be carried out by some slave or boffin diligently working away out of sight in a corner of the laboratory, occasionally passing on 'results' by e-mail to the archaeologist, who could then concentrate on the really important things — the reconstruction, description and understanding of prehistoric life-ways. Sadly, but perhaps just as well, such an arrangement will never come about. Studies of the debris left behind by prehistoric people is driven by an interaction between question and answer, in which the question should always comes first. That is, before embarking on a study of faunal material, one should have very clearly defined questions in mind, and devise suitable research strategies to answer them. This is not something which can be left to an uneducated serf working away alone in the back room of a Museum somewhere. The person asking the questions (the archaeologist) should be intimately involved at all stages of faunal analysis. So often, tables of MNI or NISP are presented in archaeological reports as if they speak for themselves; they do not. They only speak when they answer some useful question, posed before the analysis began. Unfortunately, faunal analysis, by its very nature is extremely time consuming and requires extensive background knowledge. It is perfectly understandable that many people working with faunal collections effectively run out of steam at the very point when they get to first base; that is, when they finally get to the stage of assembling tables of relative abundance of various fishes, shellfish, birds, etc.; and have no energy left to return to the opening issues which initiated the research in the first place, exploring the way in which some ancient human community gathered and processed its food, and the subtle interactions between the food quest and the local environment from which it derives. Anything which can be done to make the task of identifying faunal remains easier, so that a greater portion of energy is devoted to the real subject matter of prehistory — people — is a worthwhile accomplishment. This volume is offered as a small step in that direction.

ACKNOWLEDGEMENTS

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APPENDIX 1: NOMENCLATURE CROSS-REFERENCE

List of Illustrated Species (Alphabetically by Systematic Binomial)

1	*Allomycterus jaculiferus*	Porcupinefish
2	*Anguilla dieffenbachii*	Long-finned eel
3	*Aplodactylus arctidens*	Marblefish
4	*Arripis trutta*	Kahawai
5	*Callorhinchus milii*	Elephantfish
6	*Chelidonichthys kumu*	Red gurnard
7	*Conger verreauxi*	Conger eel
8	*Congiopodus leucopaecilus*	Southern pigfish
9	*Dasyatis brevicaudatus*	Shorttail stingray
10	*Genypterus blacodes*	Ling
11	*Geotria australis*	Lamprey
12	*Helicolenus barathri*	Sea perch
13	*Katsuwonus pelamis*	Skipjack tuna
14	*Latridopsis ciliaris*	Blue moki
15	*Latris lineata*	Trumpeter
16	*Lepidopus caudatus*	Frostfish
17	*Leptoscopus macropygus*	Estuary stargazer
18	*Lotella rhacinus*	Rock cod
19	*Mugil cephalus*	Grey mullet
20	*Myliobatis tenuicaudatus*	Eagle ray
21	*Naucrates ductor*	Pilotfish
22	*Nemadactylus macropterus*	Tarakihi
23	*Notolabrus celidotus*	Spotty
24	*Odax pullus*	Butterfish, Greenbone
25	*Pagrus auratus*	Snapper
26	*Paranotothenia angustata*	Māori chief
27	*Parapercis colias*	Blue cod
28	*Parika scaber*	Leatherjacket
29	*Polyprion oxygeneios*	Hapuku, Groper
30	*Pseudocaranx dentex*	Trevally
31	*Pseudophycis bachus*	Red cod
32	*Rexea solandri*	Gemfish
33	*Rhombosolea leporina*	Yellowbelly flounder
34	*Scomber australasicus*	Blue mackerel
35	*Scorpaena papillosus*	Red scorpionfish
36	*Scorpis violaceus*	Blue maomao
37	*Sepioteuthis bilineata*	Broad squid
38	*Seriola lalandi*	Kingfish, Yellowtail kingfish
39	*Seriolella brama*	Blue warehou
40	*Squalus acanthias*	Southern spiny dogfish
41	*Thunnus alalunga*	Albacore, Albacore tuna
42	*Thunnus albacares*	Yellowfin tuna
43	*Thyrsites atun*	Barracouta
44	*Trachurus novaezelandiae*	Horse mackerel
45	*Zeus faber*	John dory

List of Illustrated Species (Alphabetically by Common Name)

APPENDIX 2: BONES IN THE FACIAL AND APPENDICULAR SKELETON

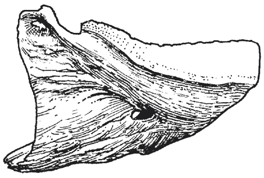
See Figure 1

A	Articular	N	Nasal
B	Basipterigium	O	Opercle
BH	Basihyal	PA	Palatine
BR	Branchiostegal	PC	Postcleithrum
C	Cleithrum	PM	Premaxilla
CC	Coracoid	PO	Preopercle
CH	Ceratohyal	PR	Pectoral Ray
D	Dentary	PT	Posttemporal
E	Ectopterygoid	Q	Quadrate
EH	Epihyal	R	Radial
H	Hyomandibular	RA	Retroarticular
HH	Hypohyal	S	Scapula
I	Interhyal	SC	Supracleithrum
IO	Interopercle	SOB	Suborbital
L	Lachrymal	SOP	Subopercle
M	Maxilla	ST	Supratemporal
MES	Mesopterygoid	SY	Symplectic
MET	Metapterygoid	UH	Urohyal
		VS	Ventral Spine

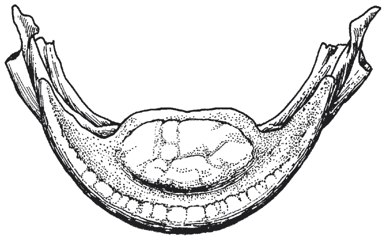
Anatomical Drawings

Special Bones I

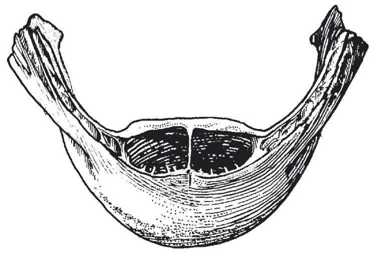
Allomycterus jaculiferus - porcupine fish



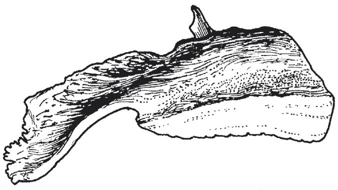
Dentary
Lateral aspect



Dentary
Dorsal aspect

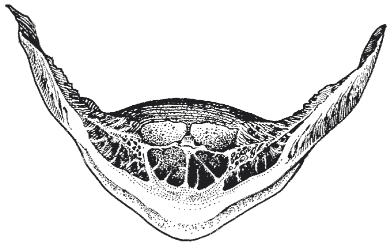


Dentary
Ventral aspect

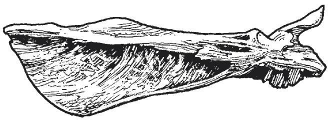


Premaxilla
Lateral aspect

Premaxilla
Ventral aspect

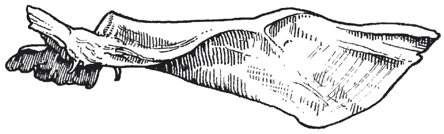


Premaxilla
Dorsal aspect

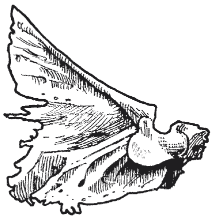


Right maxilla
Lateral aspect

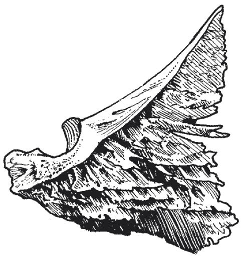
Right maxilla
Anterior aspect



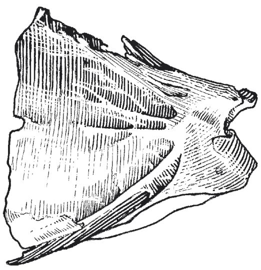
Right maxilla
Medial aspect



Right articular
Medial aspect

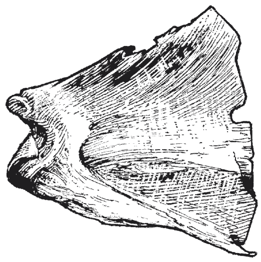


Right articular
Lateral aspect



Right quadrate
Medial aspect

Right quadrate
Anterior aspect

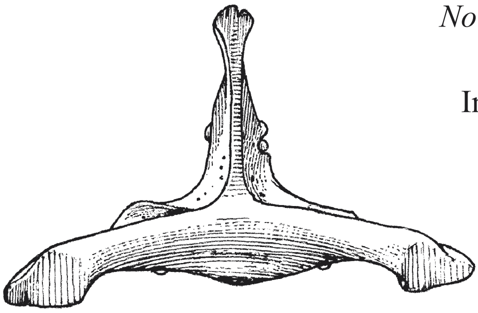


Right quadrate
Lateral aspect

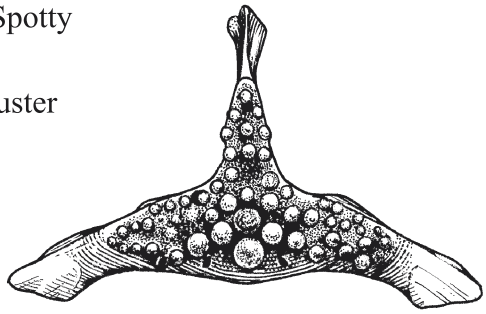
Special Bones II

Notolabrus celidotus - Spotty

Inferior pharyngeal cluster

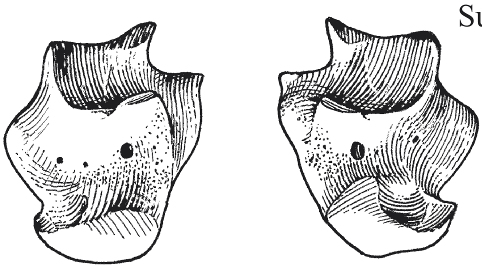


Inferior aspect

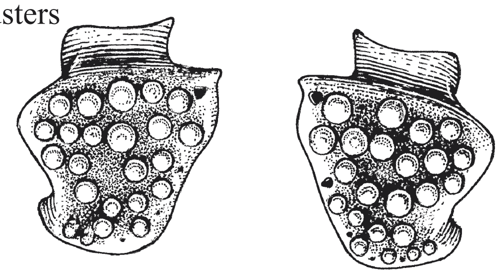


Superior aspect

Superior pharyngeal clusters



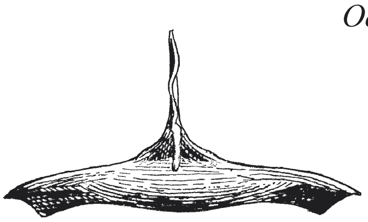
Left Right
Superior aspect



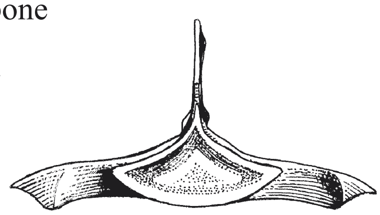
Right Left
Inferior aspect

Odax pullus - Butterfish, Greenbone

Inferior pharyngeal cluster

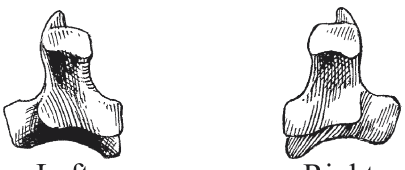


Inferior aspect

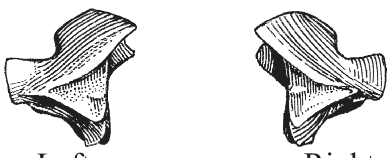


Superior aspect

Superior pharyngeal clusters



Left Right
Superior aspect

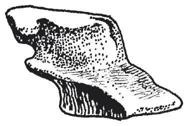


Left Right
Inferior aspect

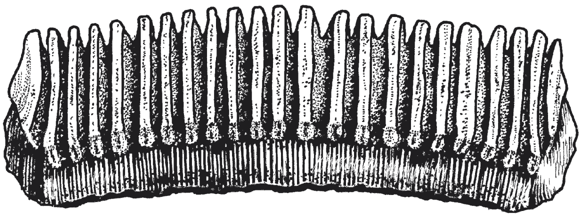
Special Bones III

Myliobatis tenuicaudatus - Eagle ray

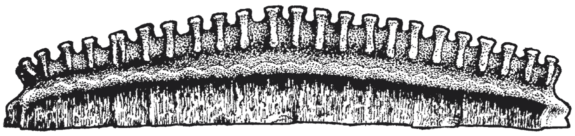
Articulated tooth plate (maxillary)



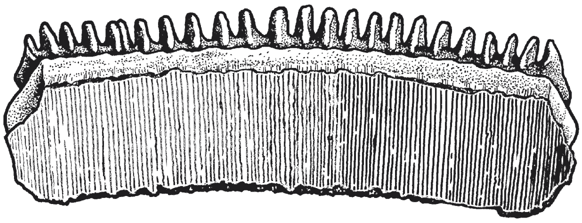
Lateral aspect



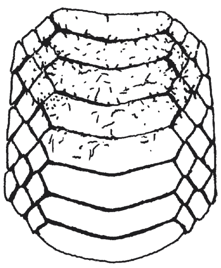
Superior aspect



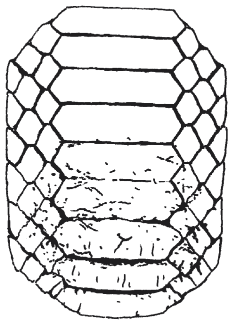
Anterior aspect



Inferior aspect



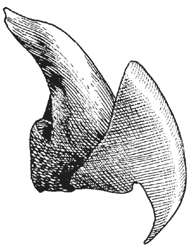
Mandibular plates



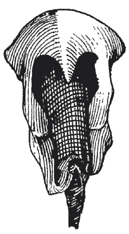
Maxillary plates

Sepioteuthis bilineata - Broad squid

Upper beak

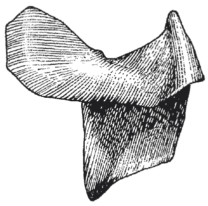


Lateral aspect

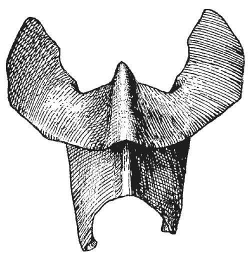


Inferior aspect

Lower beak



Lateral aspect



Anterior aspect

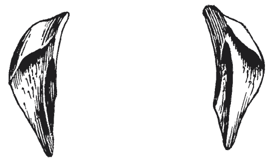
Special Bones IV

Callorhinchus milii - Elephantfish

Vomerine tooth plates

Right Left

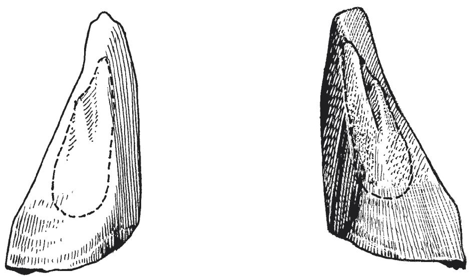
Inferior aspect



Left Right

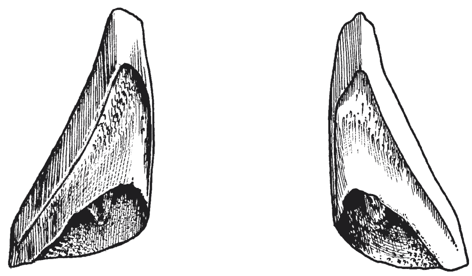
Superior aspect

Palatine tooth plates



Right Left

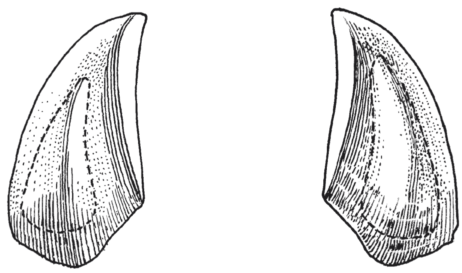
Inferior aspect



Left Right

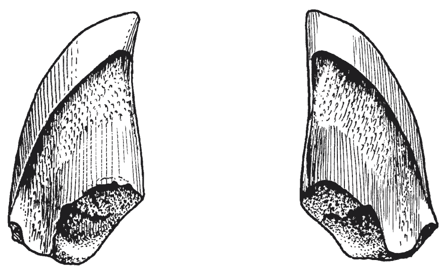
Superior aspect

Dentary tooth plates



Left Right

Superior aspect

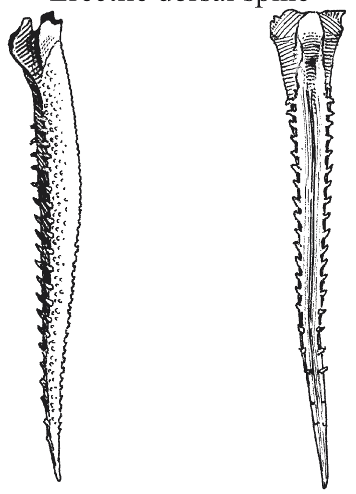


Right Left

Inferior aspect

Special Bones V

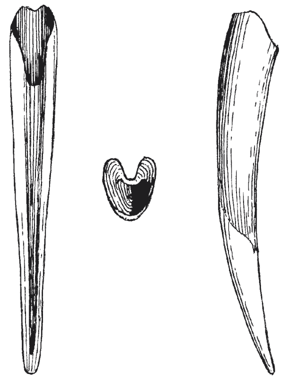
Parika scaber - Leatherjacket
Erectile dorsal spine



Lateral aspect

Posterior aspect

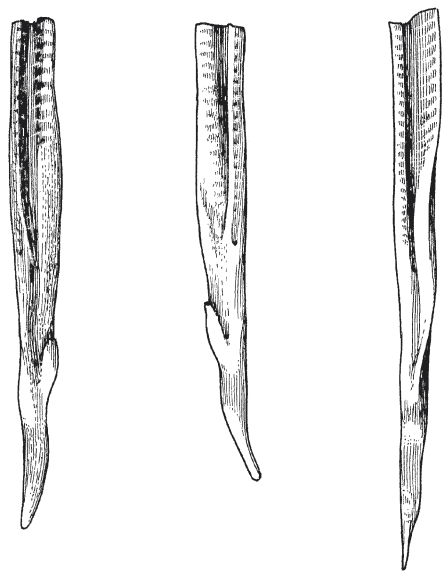
Squalus acanthias - Southern spiny dogfish
Dorsal spine



Posterior aspect

Lateral aspect

Pagrus auratus - Snapper



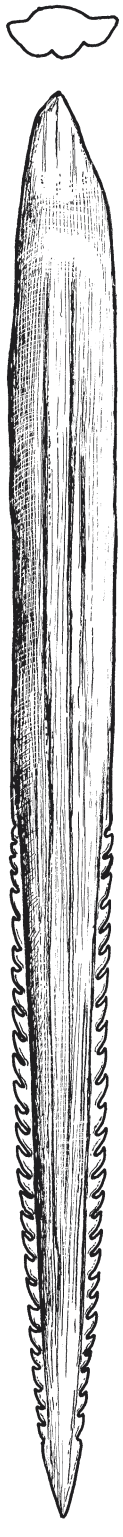
Tail spines

Callorhinchus milii
- Elephantfish

Dorsal spine
Lateral aspect

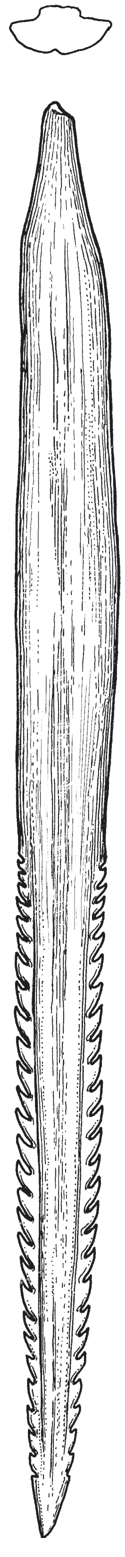
Special Bones VI

Barbed spine
Anterior aspect



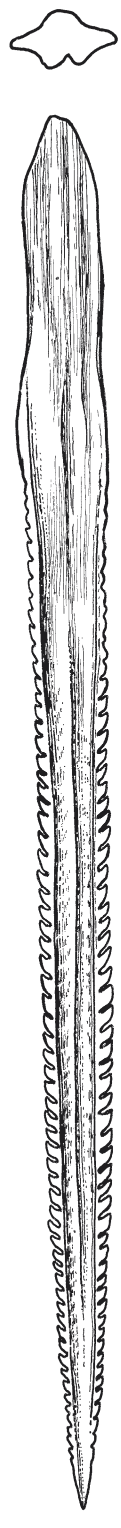
Dasyatis brevicaudatus
Shorttail stingray

Barbed spine
Anterior aspect



Dasyatis brevicaudatus
Shorttail stingray

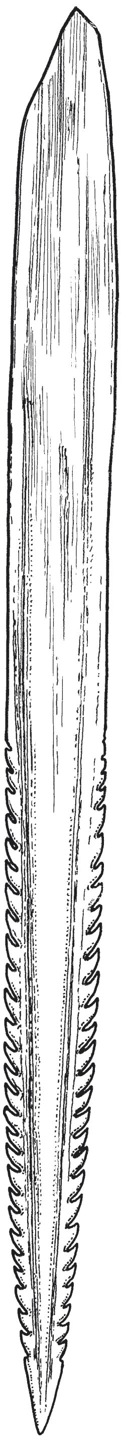
Barbed spine
Anterior aspect



Myliobatis tenuicaudatus
Eagle ray

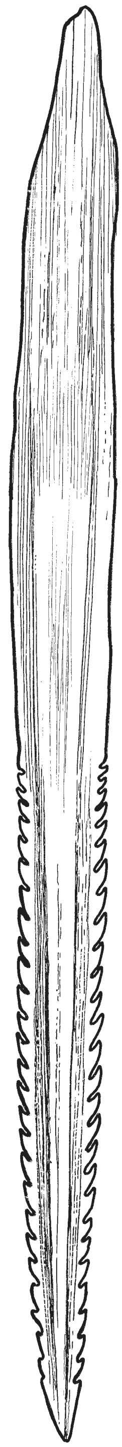
Special Bones VII

Barbed spine
Posterior aspect



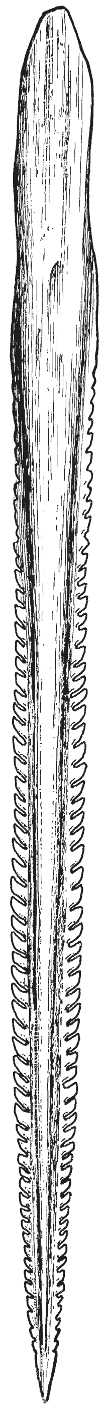
Dasyatis brevicaudatus
Shorttail stingray

Barbed spine
Posterior aspect



Dasyatis brevicaudatus
Shorttail stingray

Barbed spine
Posterior aspect



Myliobatis tenuicaudatus
Eagle ray

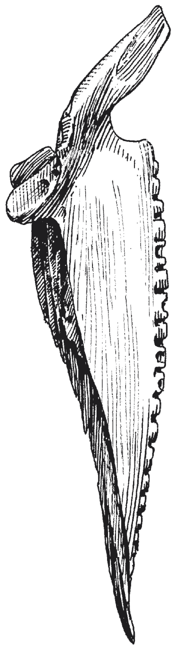
Special Bones VIII

Geotria australis - Lamprey

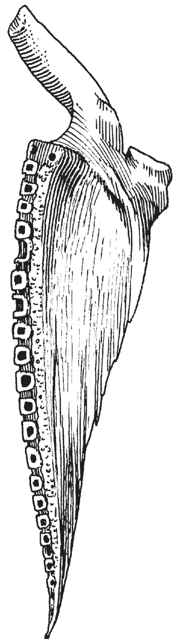
Semi-ossified mouthparts

Genypterus blacodes - Ling

Right palatine

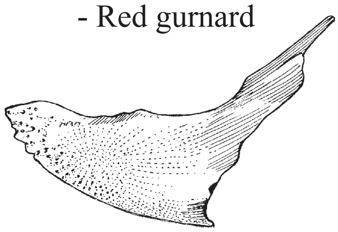


Lateral aspect



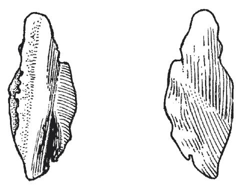
Medial aspect

Chelidonichthys kumu
- Red gurnard



Right opercular
Lateral aspect

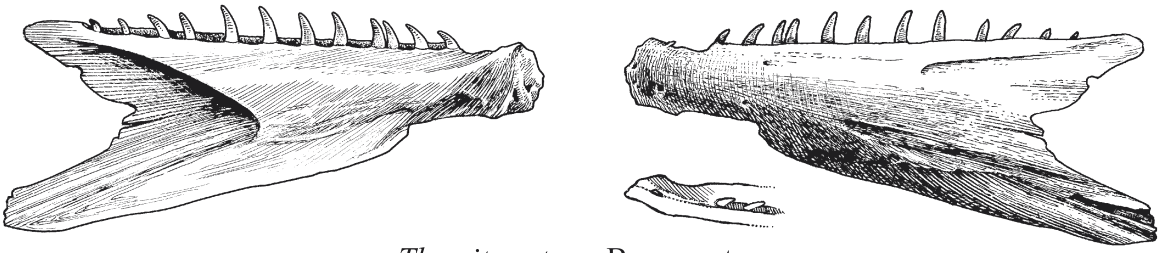
Notolabrus celidotus
- Spotty



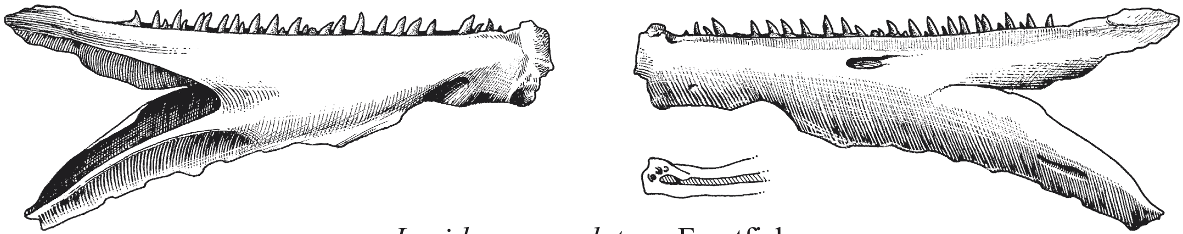
Otolith

The Left Dentary 1

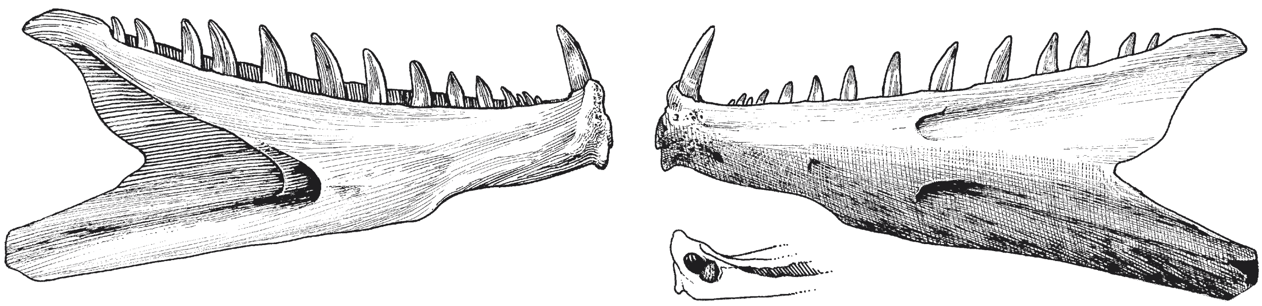
Medial aspect **Lateral aspect**



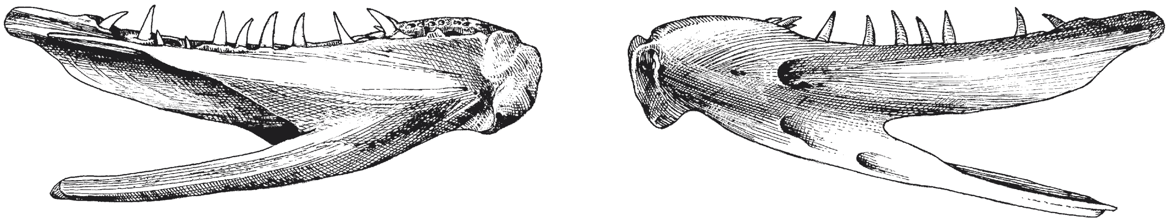
Thyrsites atun - Barracouta



Lepidopus caudatus - Frostfish



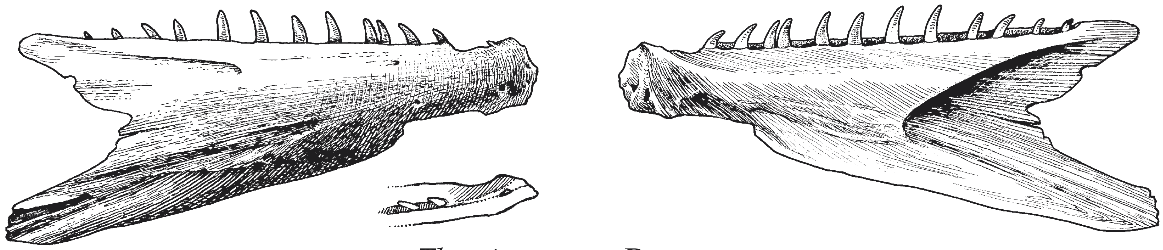
Rexea solandri - Gemfish



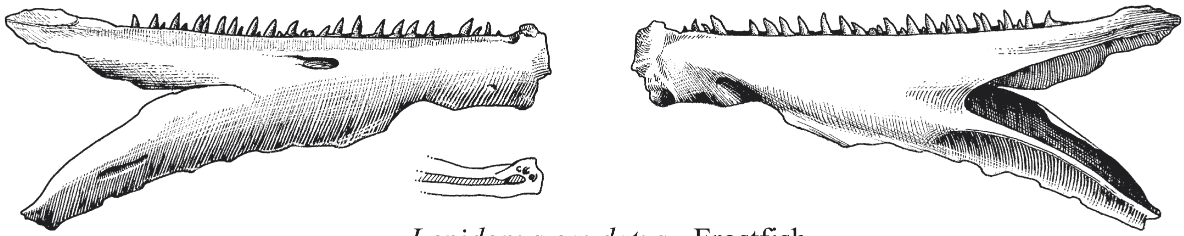
Leptoscopus macropygus - Estuary stargazer

The Right Dentary 1

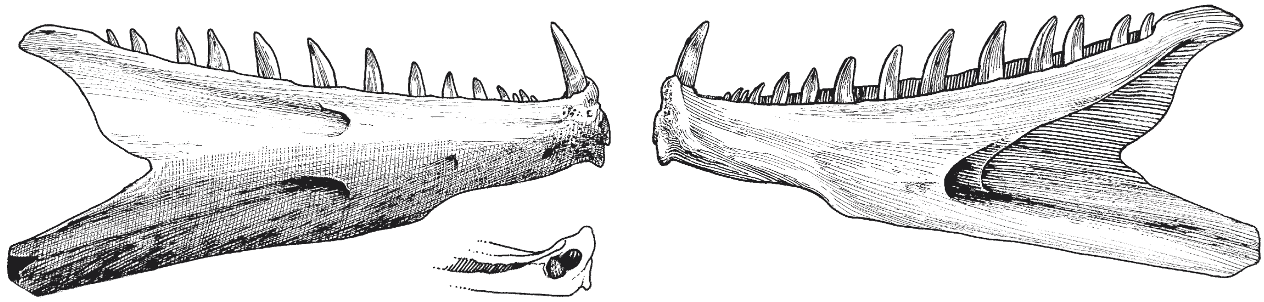
Lateral aspect **Medial aspect**



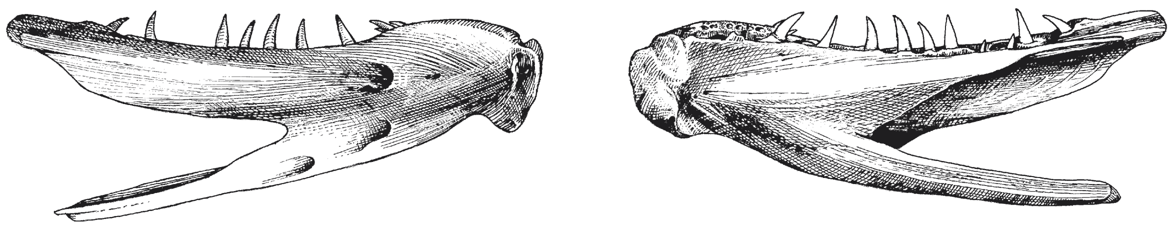
Thyrsites atun - Barracouta



Lepidopus caudatus - Frostfish



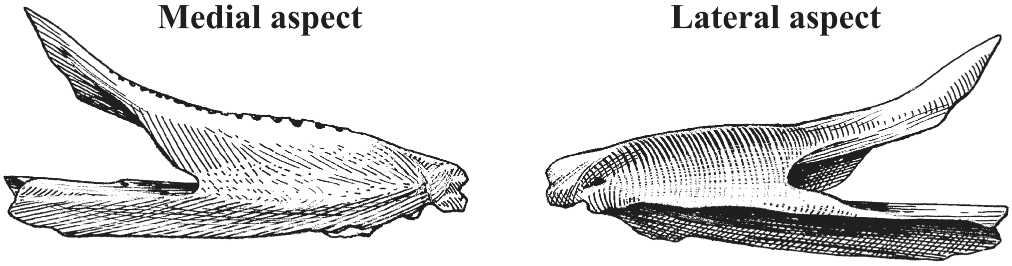
Rexea solandri - Gemfish



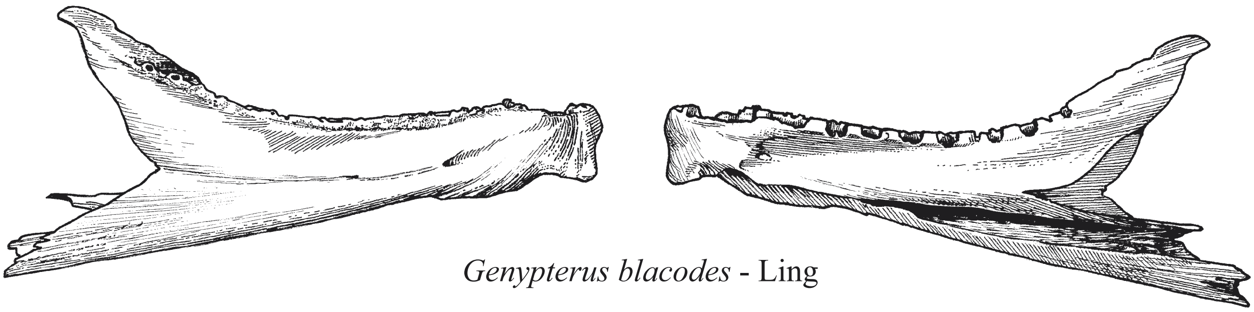
Leptoscopus macropygus - Estuary stargazer

The Left Dentary 2

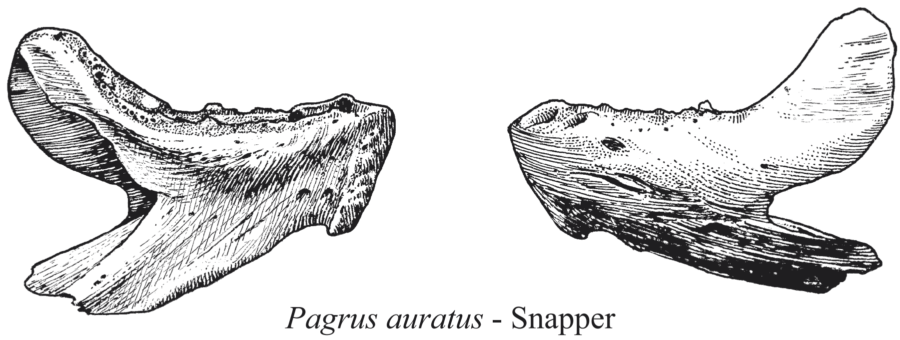
Medial aspect **Lateral aspect**



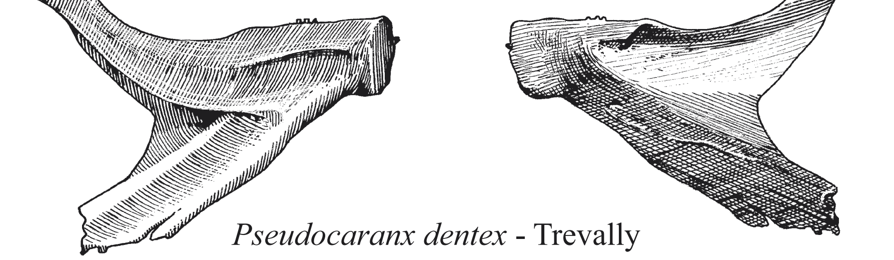
Lotella rhacinus - Rock cod



Genypterus blacodes - Ling



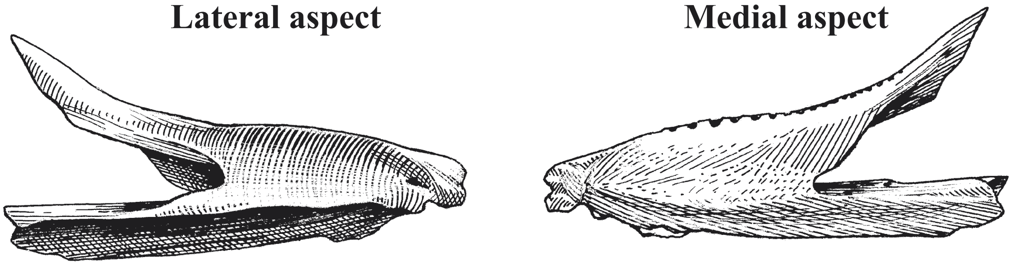
Pagrus auratus - Snapper



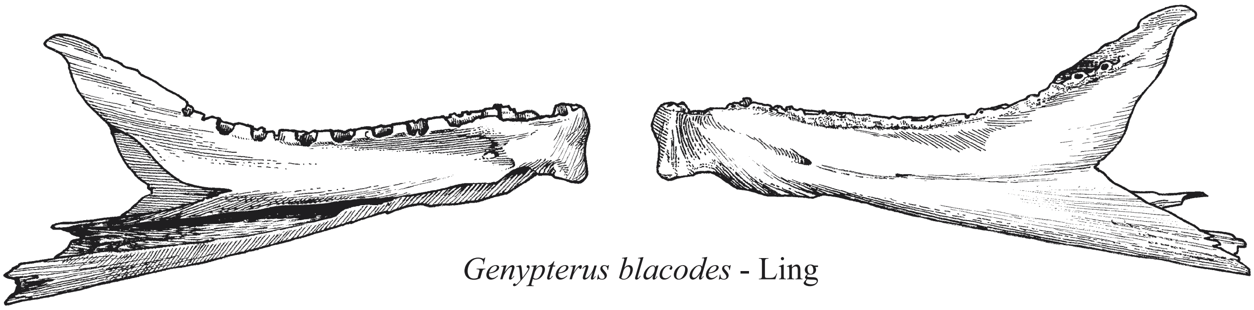
Pseudocaranx dentex - Trevally

The Right Dentary 2

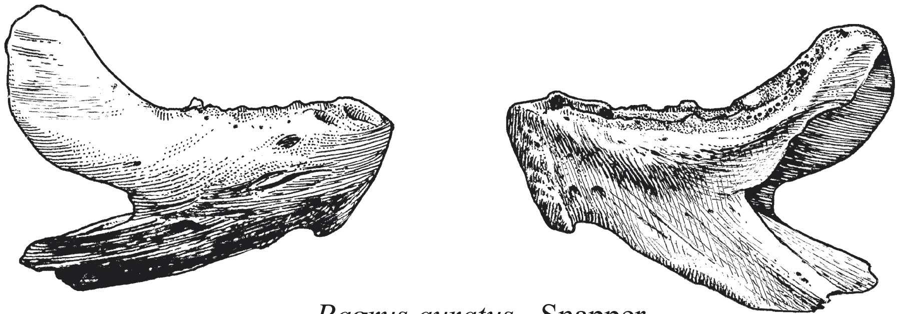
Lateral aspect **Medial aspect**



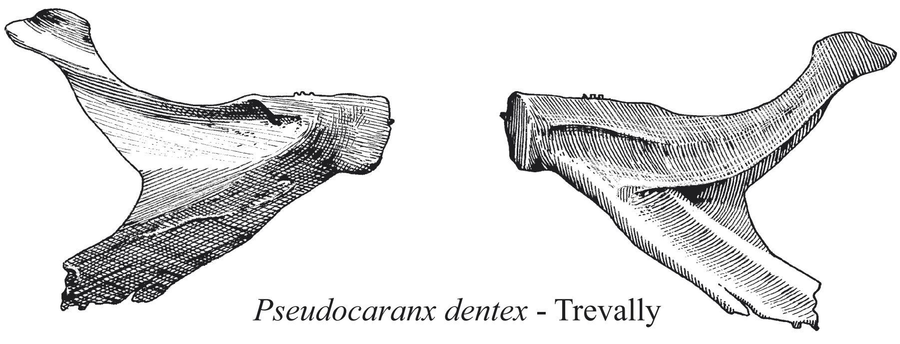
Lotella rhacinus - Rock cod



Genypterus blacodes - Ling



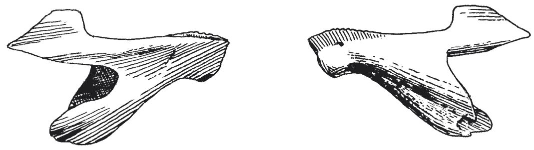
Pagrus auratus - Snapper



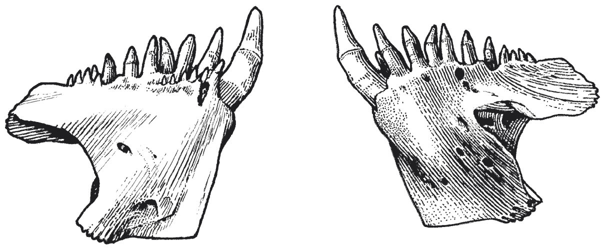
Pseudocaranx dentex - Trevally

The Left Dentary 3

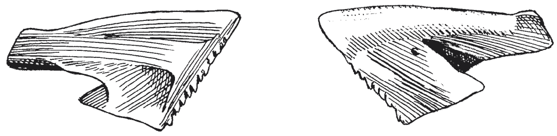
Medial aspect **Lateral aspect**



Congiopodus leucopaecilus - Southern pigfish



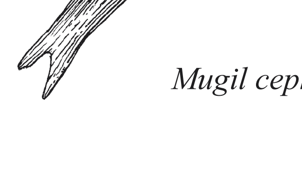
Notolabrus celidotus - Spotty

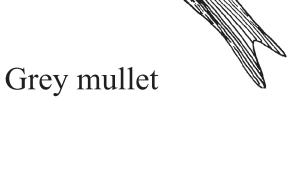


Odax pullus - Butterfish, Greenbone

(see text - page 33)

Rhombosolea leporina - Yellowbelly flounder



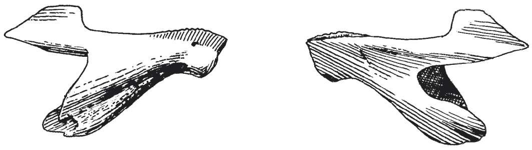


Mugil cephalus - Grey mullet

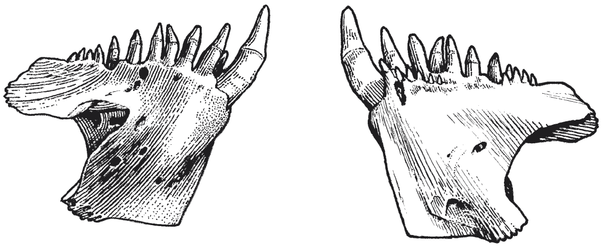
Aplodactylus arctidens - Marblefish

The Right Dentary 3

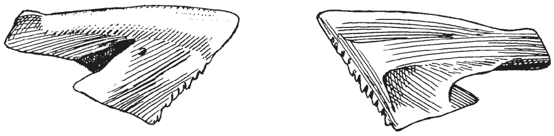
Lateral aspect **Medial aspect**



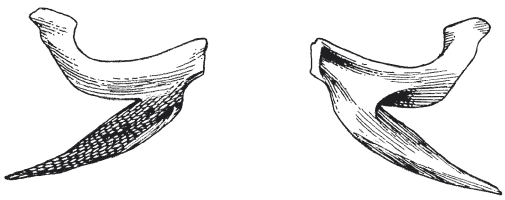
Congiopodus leucopaecilus - Southern pigfish



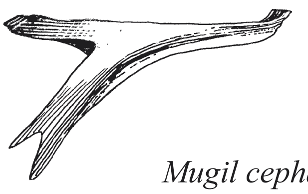
Notolabrus celidotus - Spotty

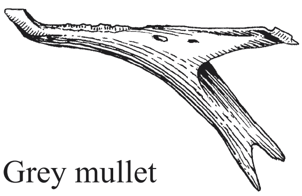


Odax pullus - Butterfish, Greenbone



Rhombosolea leporina - Yellowbelly flounder



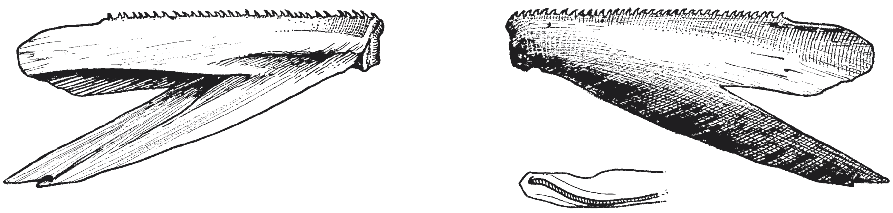


Mugil cephalus - Grey mullet

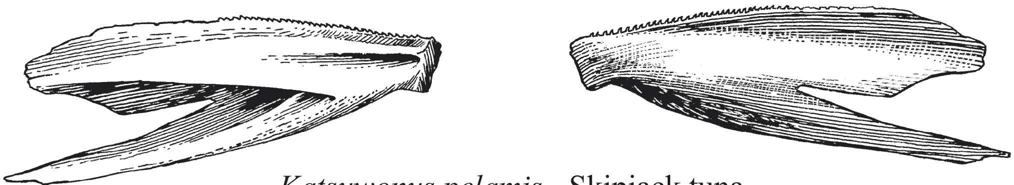
Aplodactylus arctidens - Marblefish

The Left Dentary 4

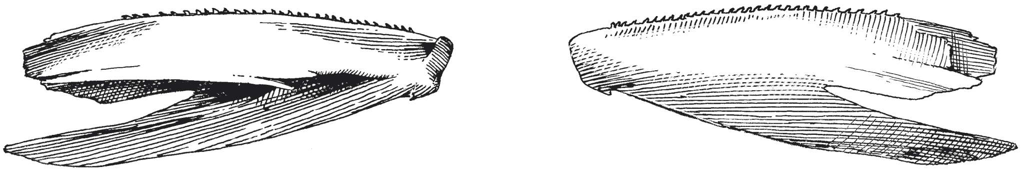
Medial aspect **Lateral aspect**



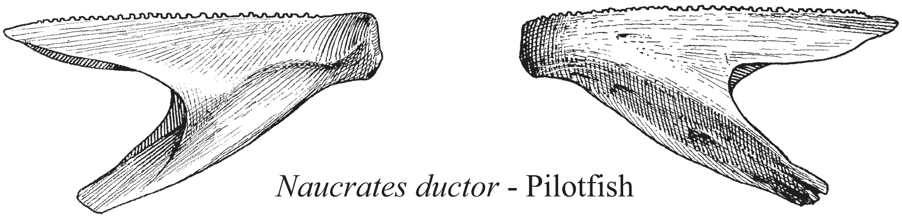
Thunnus albacares - Yellowfin tuna



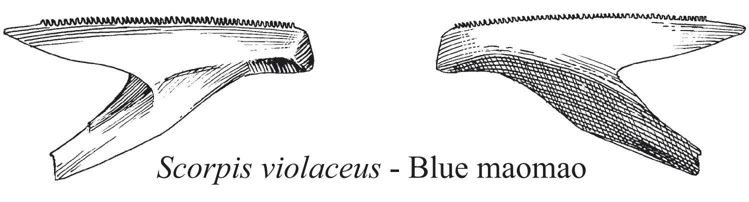
Katsuwonus pelamis - Skipjack tuna



Thunnus alalunga - Albacore, Albacore tuna



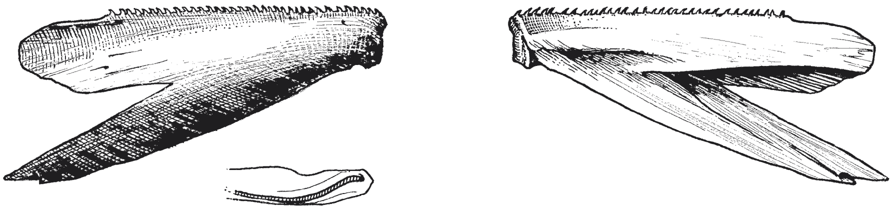
Naucrates ductor - Pilotfish



Scorpis violaceus - Blue maomao

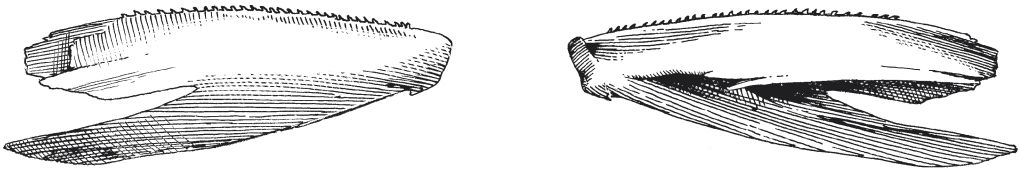
The Right Dentary 4

Lateral aspect **Medial aspect**

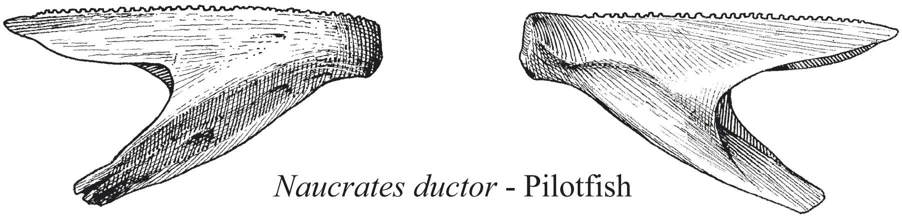


Thunnus albacares - Yellowfin tuna

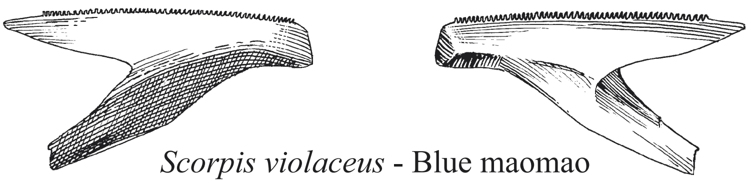
Katsuwonus pelamis - Skipjack tuna



Thunnus alalunga - Albacore, Albacore tuna



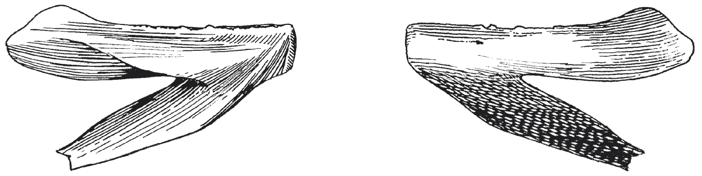
Naucrates ductor - Pilotfish



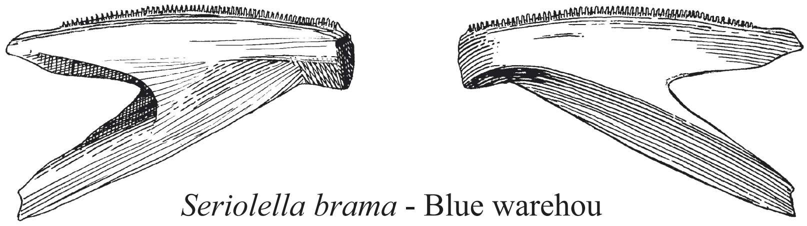
Scorpis violaceus - Blue maomao

The Left Dentary 5

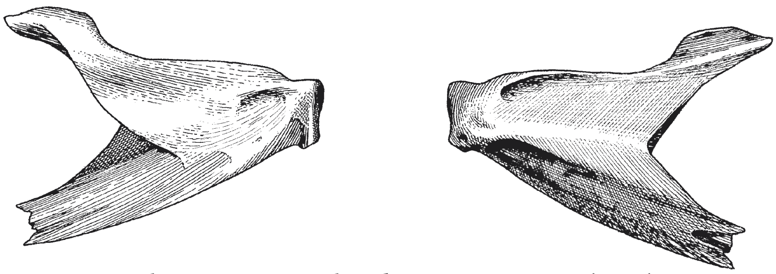
Medial aspect **Lateral aspect**



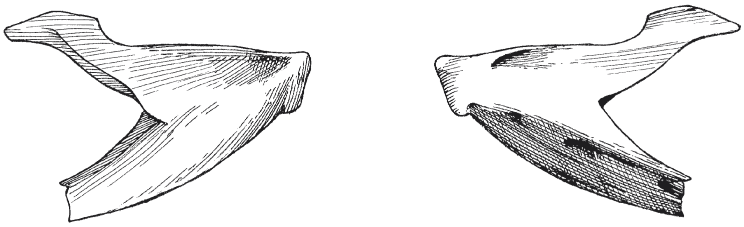
Latris lineata - Trumpeter



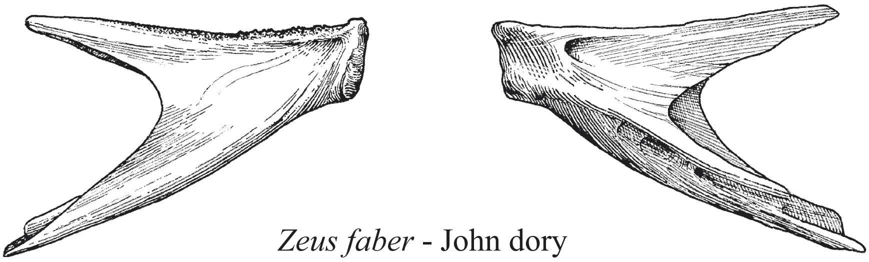
Seriolella brama - Blue warehou



Trachurus novaezelandiae - Horse mackerel



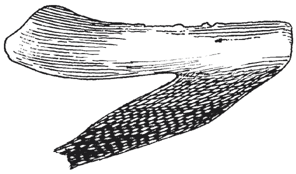
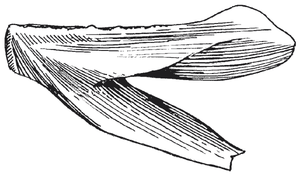
Scomber australasicus - Blue mackerel



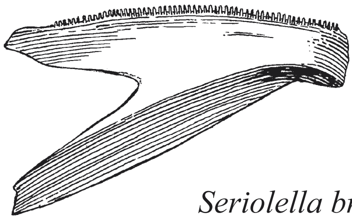
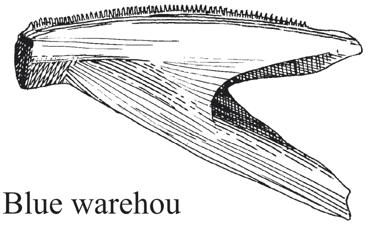
Zeus faber - John dory

The Right Dentary 5

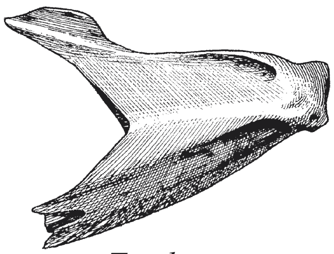
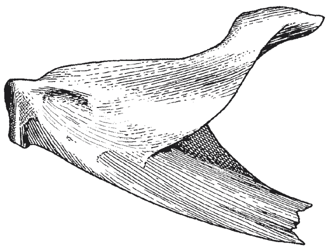
Lateral aspect **Medial aspect**

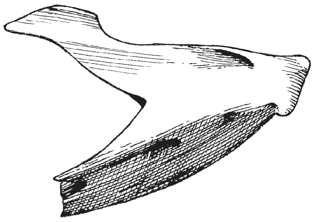
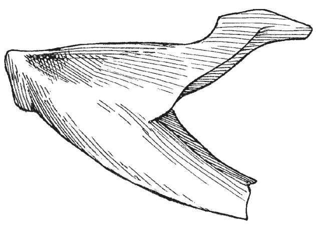
Latris lineata - Trumpeter

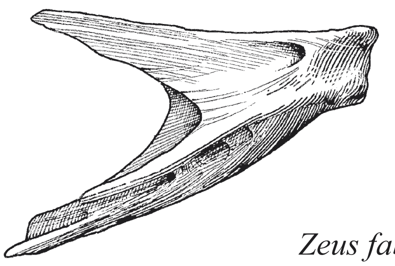
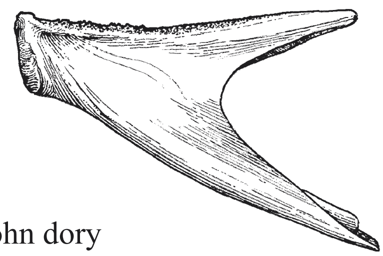
Seriolella brama - Blue warehou

Trachurus novaezelandiae - Horse mackerel

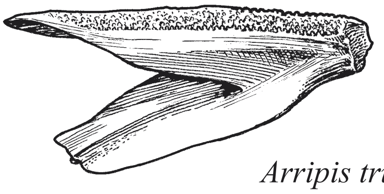
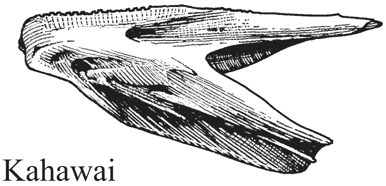
Scomber australasicus - Blue mackerel

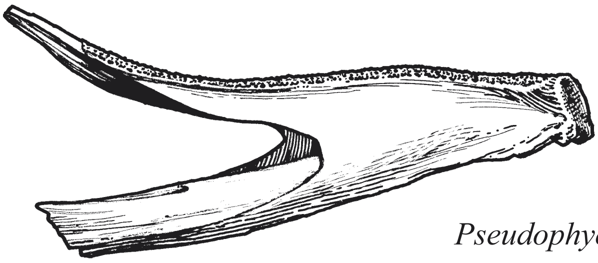
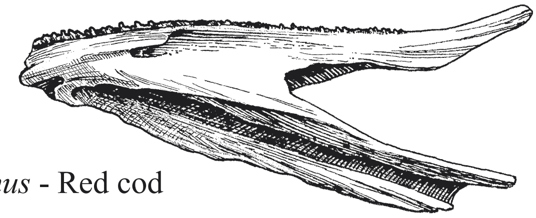
Zeus faber - John dory

The Left Dentary 6

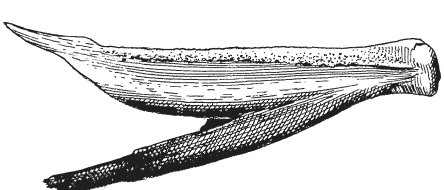
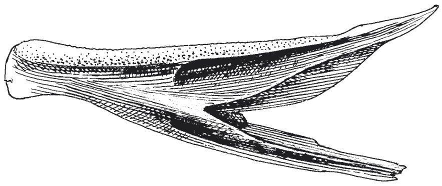
Medial aspect **Lateral aspect**

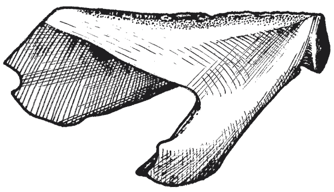
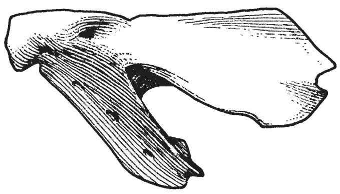
Arripis trutta - Kahawai

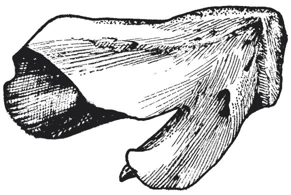
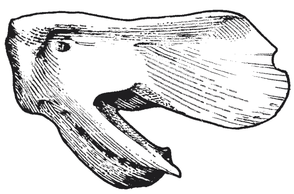
Pseudophycis bachus - Red cod

Chelidonichthys kumu - Red gurnard

Nemadactylus macropterus - Tarakihi

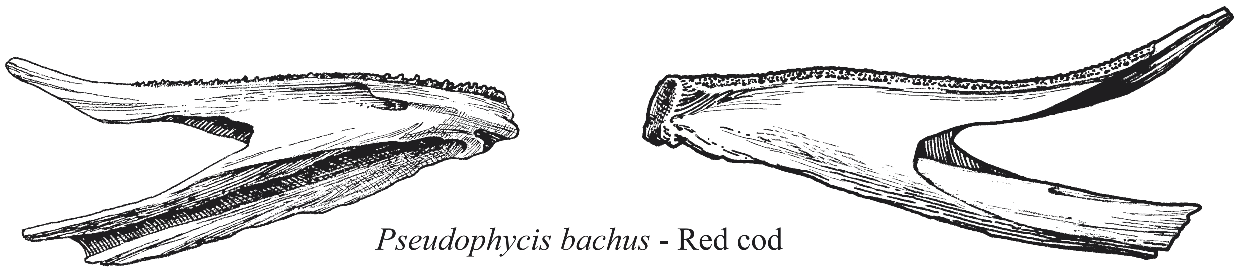



Latridopsis ciliaris - Blue moki

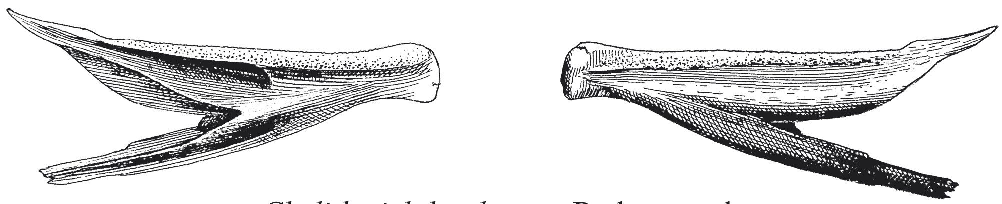
The Right Dentary 6

Lateral aspect **Medial aspect**

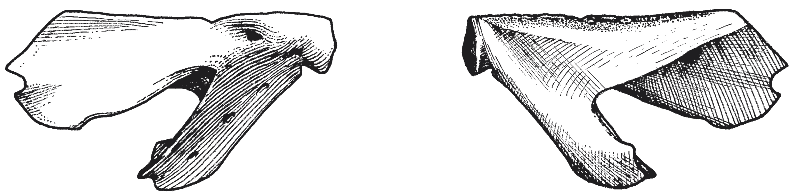
Arripis trutta - Kahawai



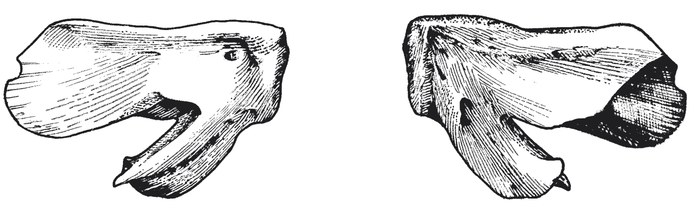
Pseudophycis bachus - Red cod



Chelidonichthys kumu - Red gurnard



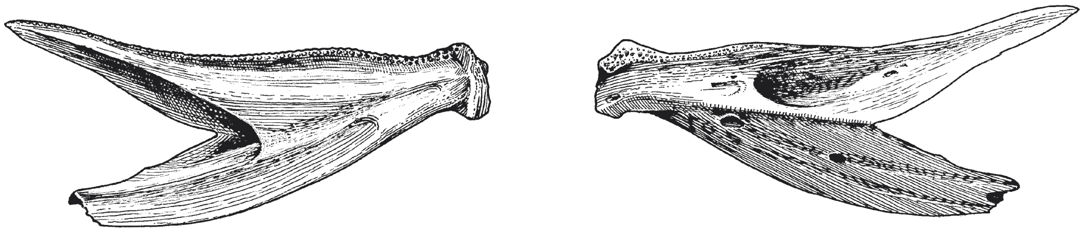
Nemadactylus macropterus - Tarakihi



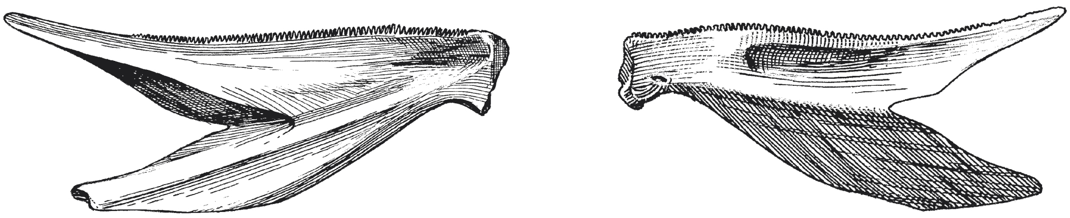
Latridopsis ciliaris - Blue moki

The Left Dentary 7

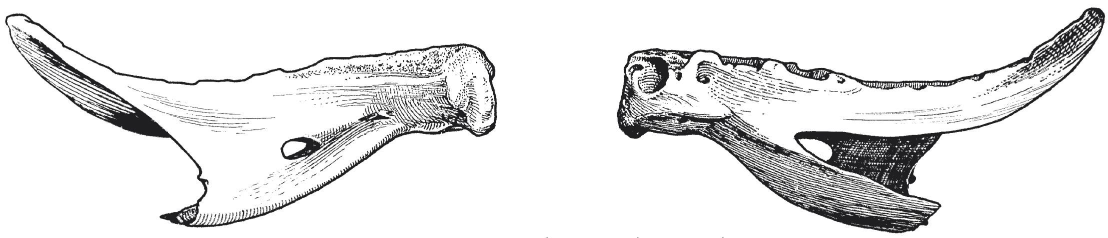
Medial aspect **Lateral aspect**



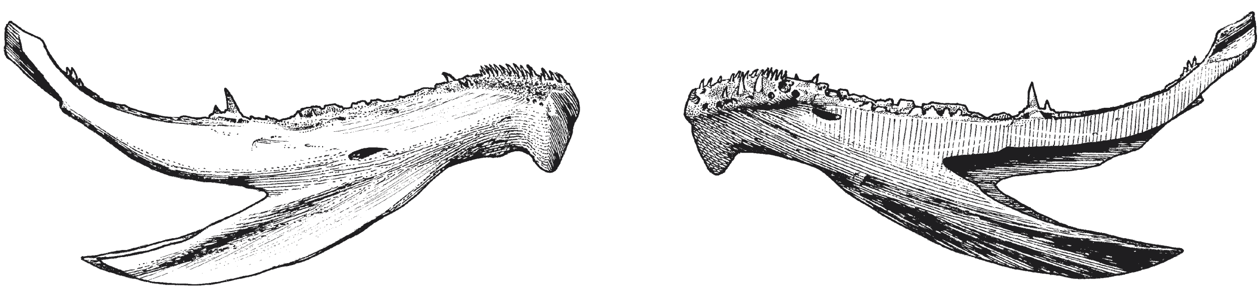
Scorpaena papillosus - Red scorpionfish



Helicolenus barathri - Sea perch



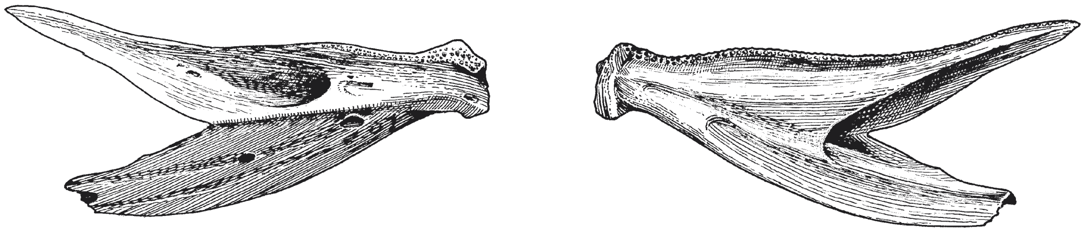
Parapercis colias - Blue cod



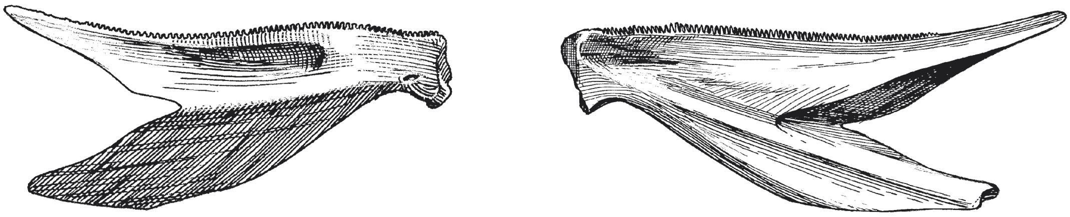
Notothenia angustata - Maori chief

The Right Dentary 7

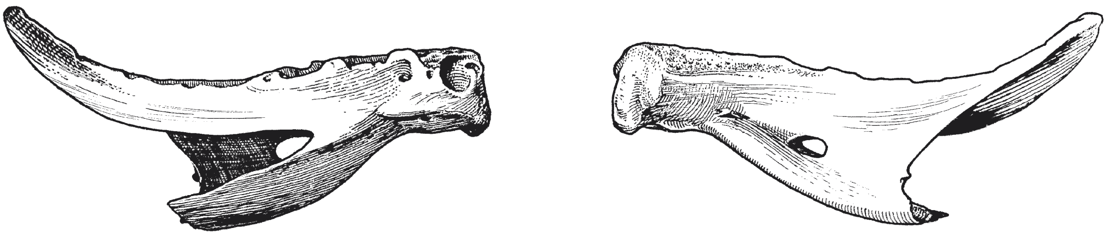
Lateral aspect **Medial aspect**



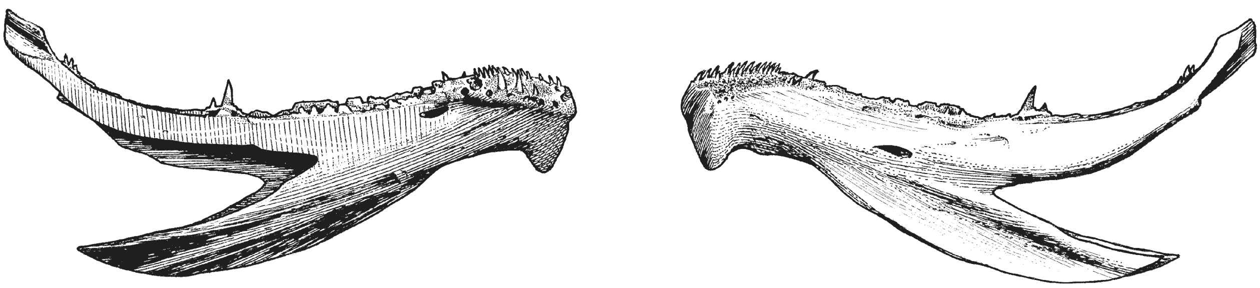
Scorpaena papillosus - Red scorpionfish



Helicolenus barathri - Sea perch



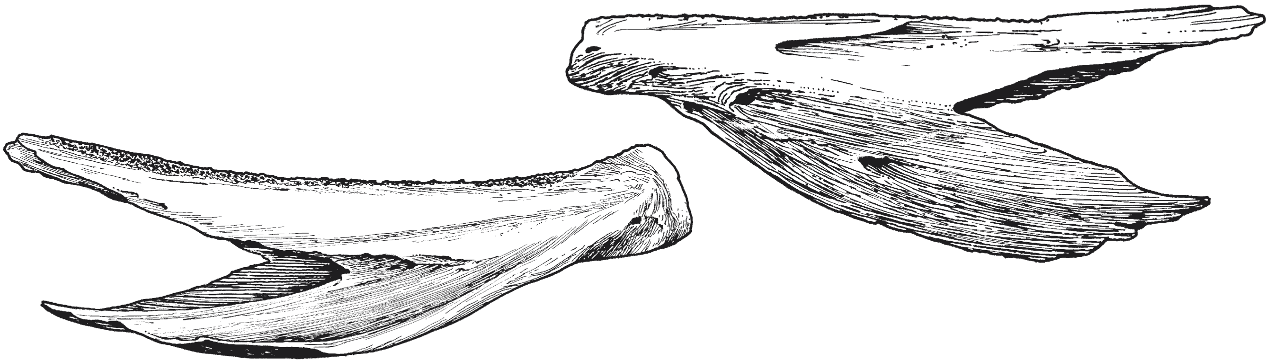
Parapercis colias - Blue cod



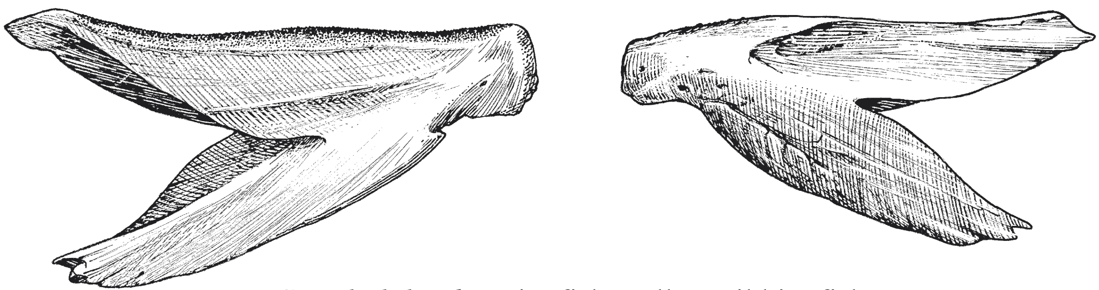
Notothenia angustata - Maori chief

The Left Dentary 8

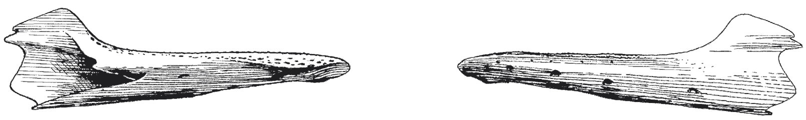
Medial aspect **Lateral aspect**



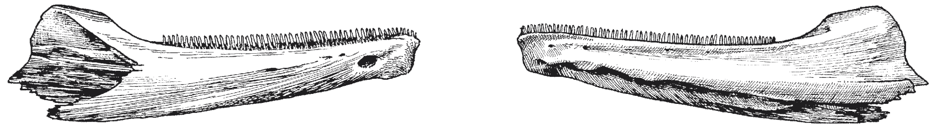
Polyprion oxygeneios - Hapuku, Groper



Seriola lalandi - Kingfish, Yellowtail kingfish



Anguilla dieffenbachii - Long-finned eel

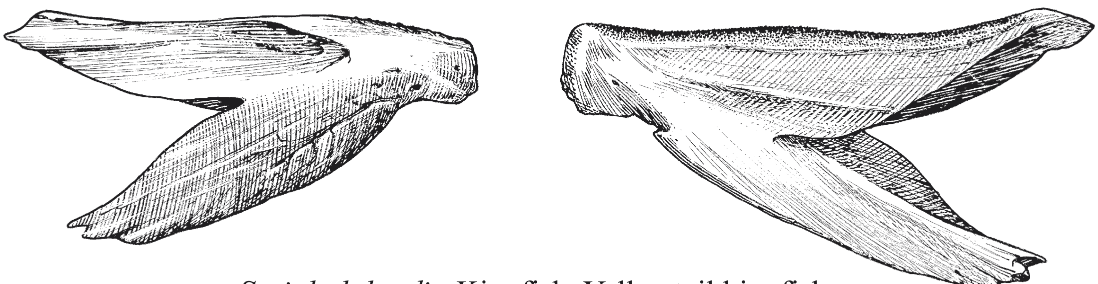


Conger verreauxi - Conger eel

The Right Dentary 8

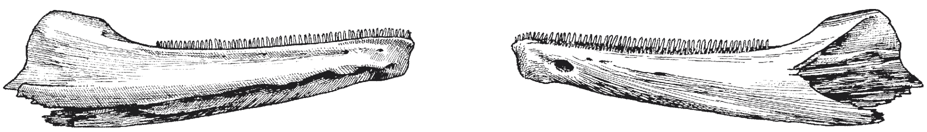
Lateral aspect **Medial aspect**

Polyprion oxygeneios - Hapuku, Groper



Seriola lalandi - Kingfish, Yellowtail kingfish

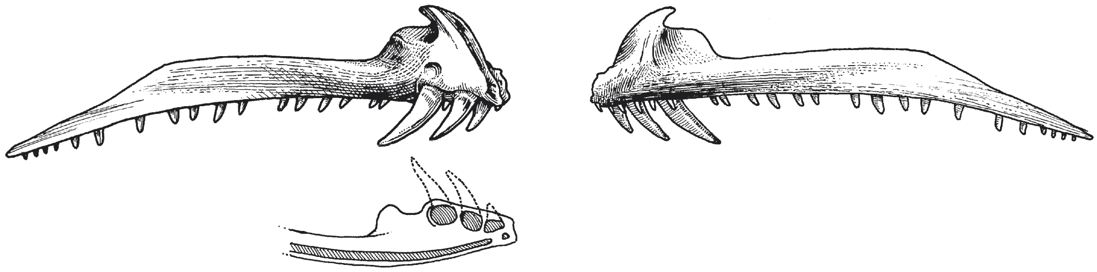
Anguilla dieffenbachii - Long-finned eel



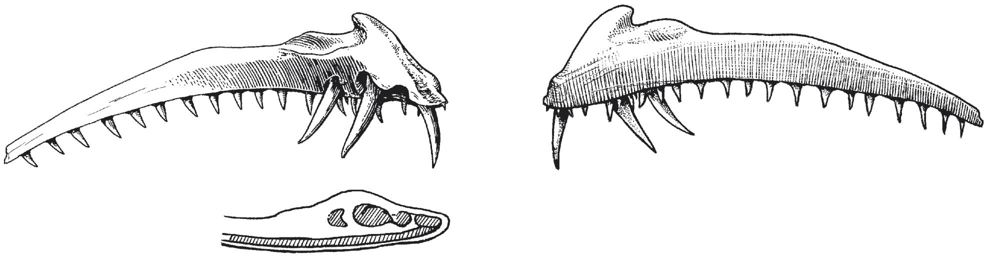
Conger verreauxi - Conger eel

The Left Premaxilla 1

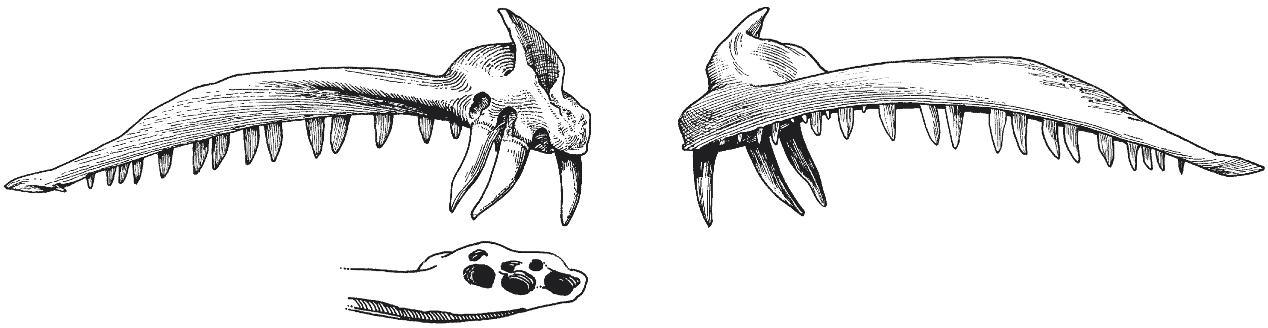
Medial aspect **Lateral aspect**



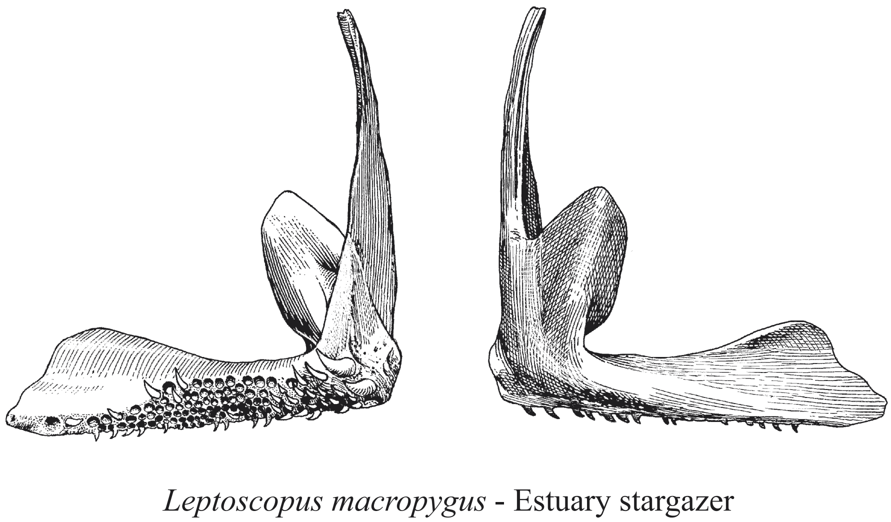
Thyrsites atun - Barracouta



Lepidopus caudatus - Frostfish



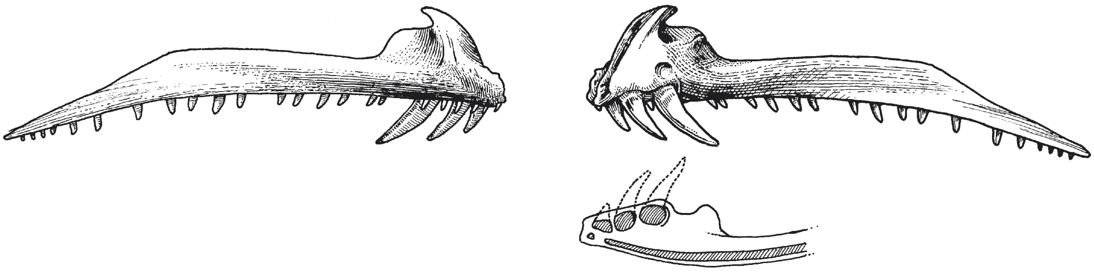
Rexea solandri - Gemfish



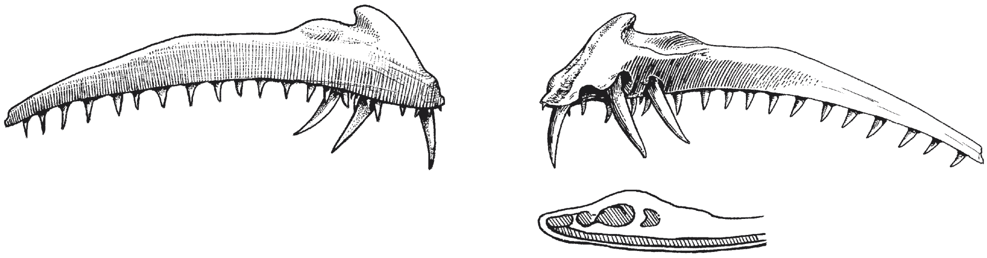
Leptoscopus macropygus - Estuary stargazer

The Right Premaxilla 1

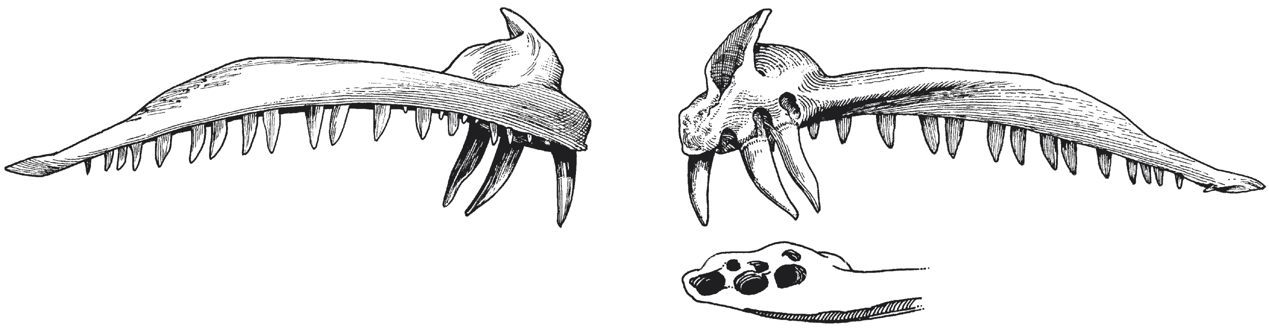
Lateral aspect **Medial aspect**



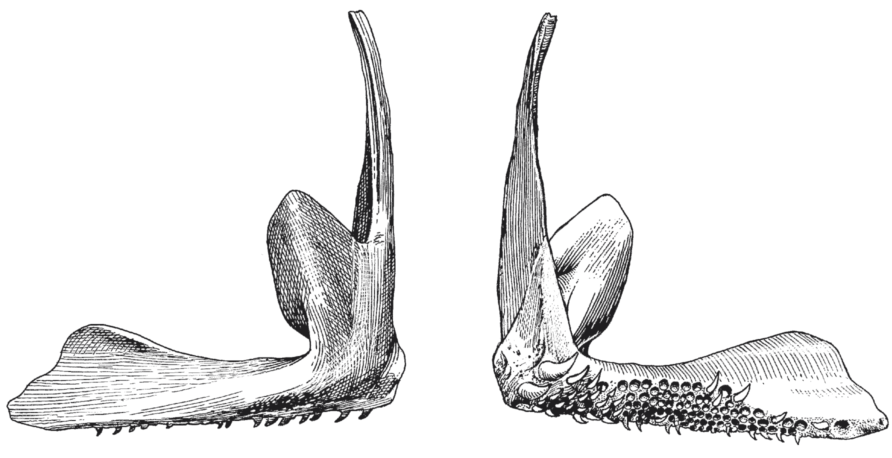
Thyrsites atun - Barracouta



Lepidopus caudatus - Frostfish



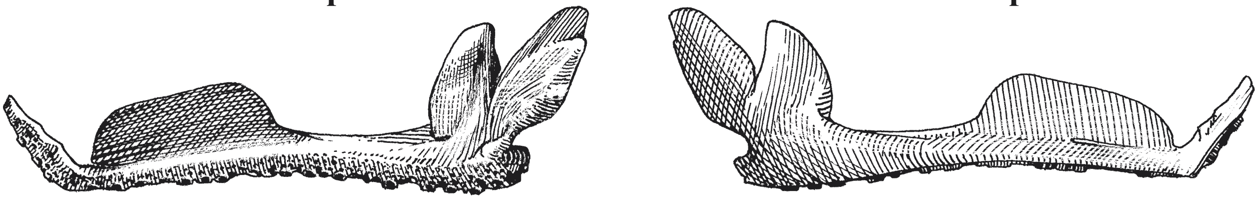
Rexea solandri - Gemfish



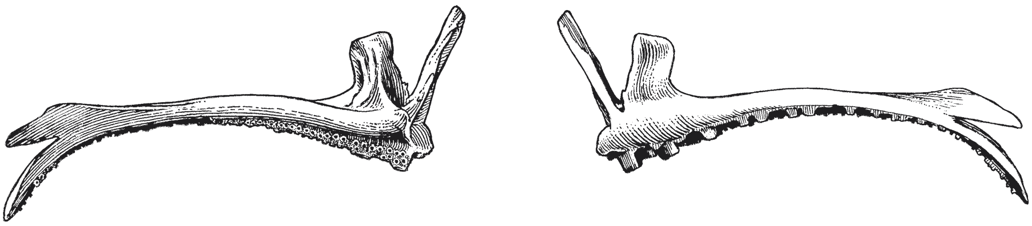
Leptoscopus macropygus - Estuary stargazer

The Left Premaxilla 2

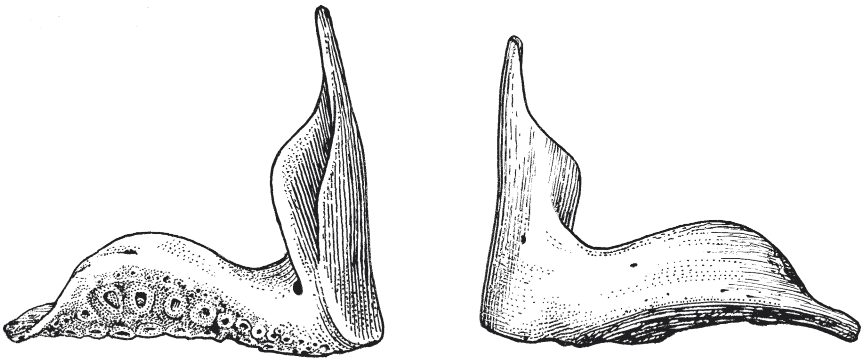
Medial aspect **Lateral aspect**



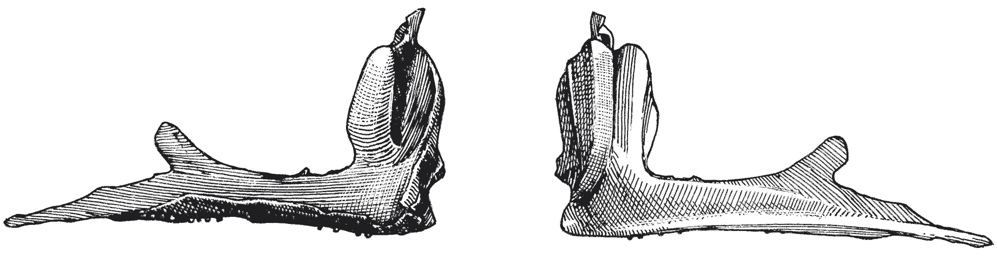
Lotella rhacinus - Rock cod



Genypterus blacodes - Ling



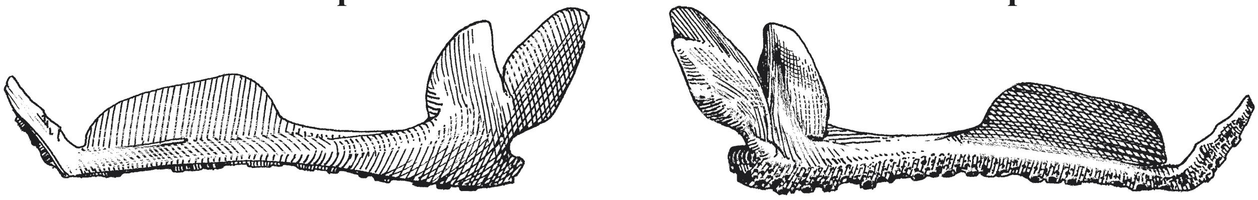
Pagrus auratus - Snapper



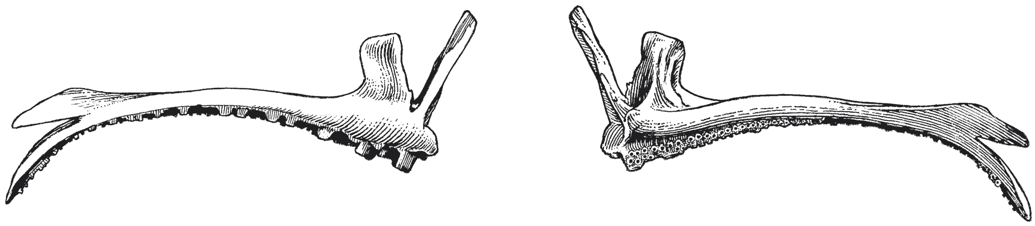
Pseudocaranx dentex - Trevally

The Right Premaxilla 2

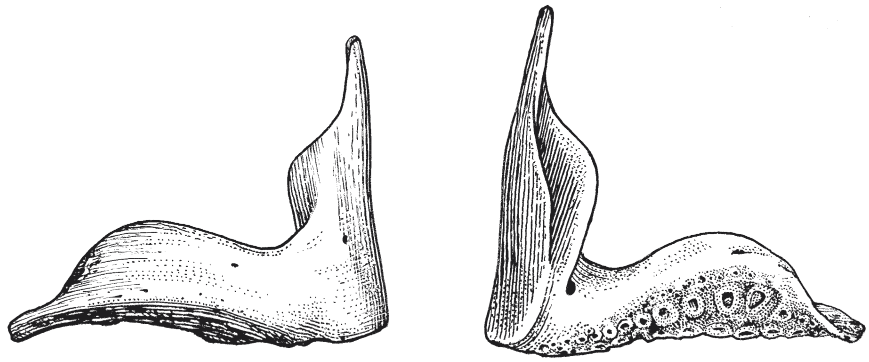
Lateral aspect **Medial aspect**



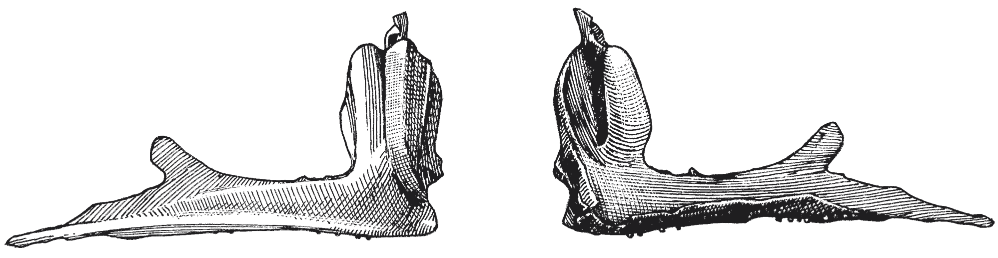
Lotella rhacinus - Rock cod



Genypterus blacodes - Ling



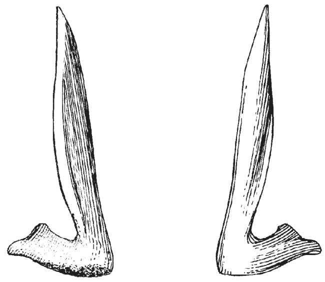
Pagrus auratus - Snapper



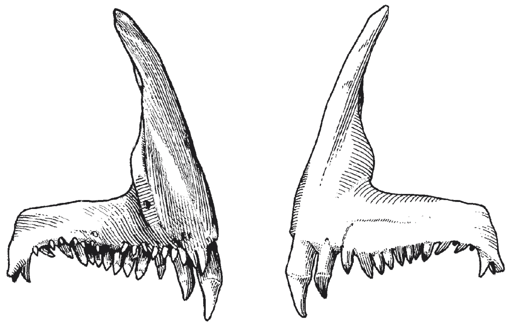
Pseudocaranx dentex - Trevally

The Left Premaxilla 3

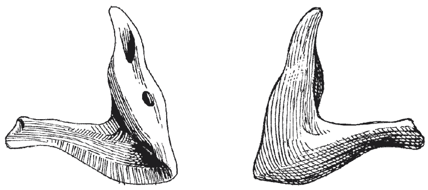
Medial aspect **Lateral aspect**



Congiopodus leucopaecilus - Southern pigfish



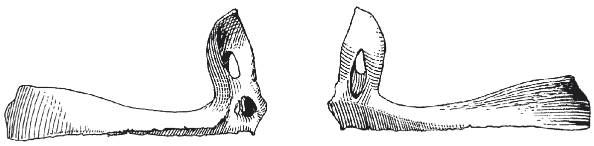
Notolabrus celidotus - Spotty



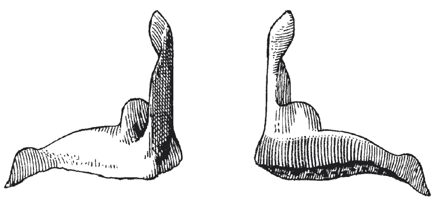
Odax pullus - Butterfish, Greenbone

(see text - page 33)

Rhombosolea leporina - Yellowbelly flounder



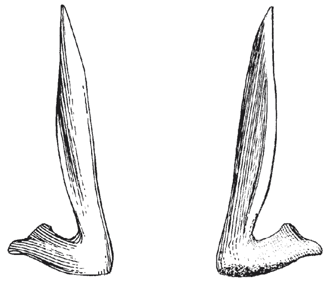
Mugil cephalus - Grey mullet



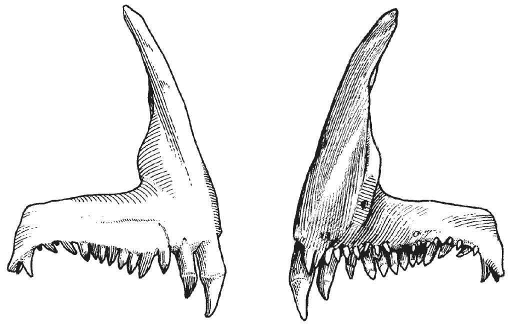
Aplodactylus arctidens - Marblefish

The Right Premaxilla 3

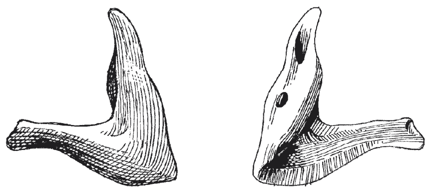
Lateral aspect **Medial aspect**



Congiopodus leucopaecilus - Southern pigfish

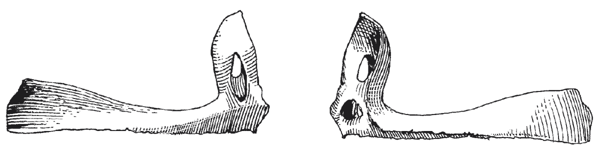


Notolabrus celidotus - Spotty

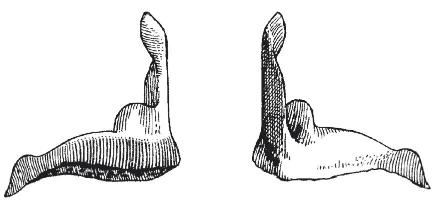


Odax pullus - Butterfish, Greenbone

Rhombosolea leporina - Yellowbelly flounder



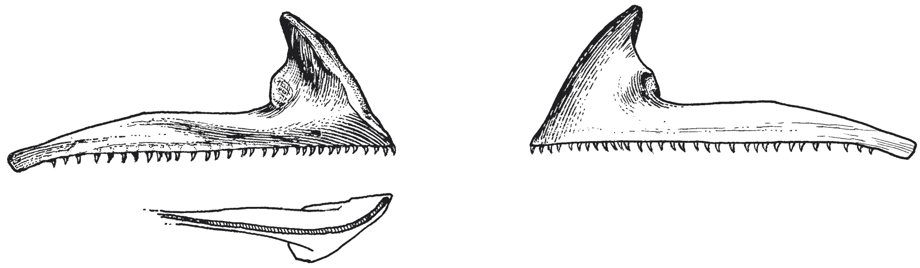
Mugil cephalus - Grey mullet



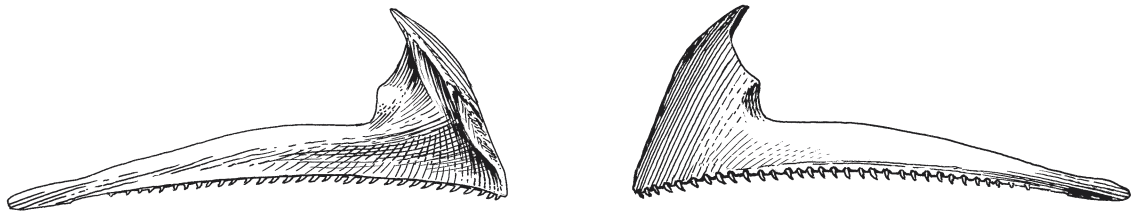
Aplodactylus arctidens - Marblefish

The Left Premaxilla 4

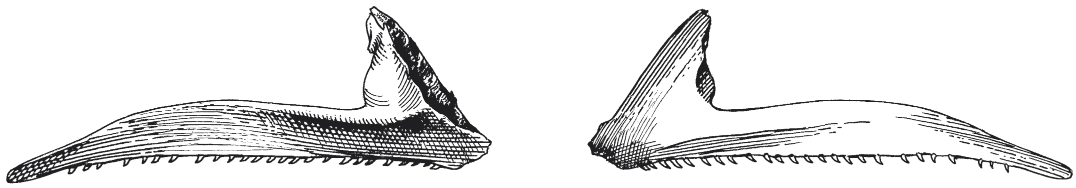
Medial aspect **Lateral aspect**



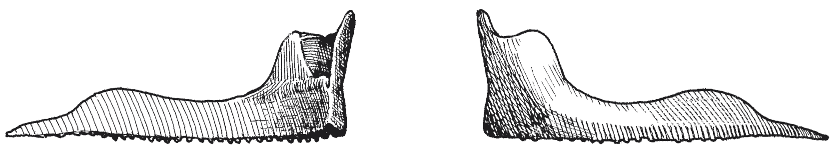
Thunnus albacares - Yellowfin tuna



Katsuwonus pelamis - Skipjack tuna



Thunnus alalunga - Albacore, Albacore tuna

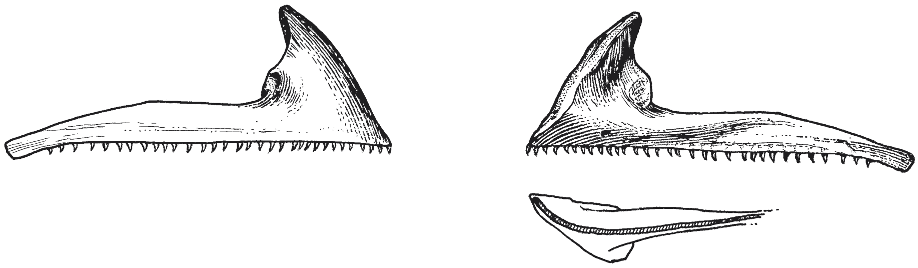


Naucrates ductor - Pilotfish

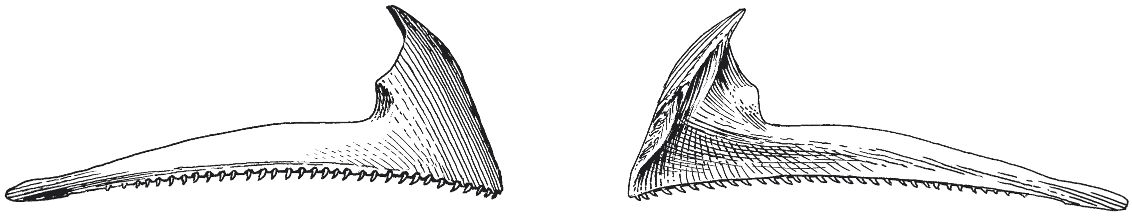
Scorpis violaceus - Blue maomao

The Right Premaxilla 4

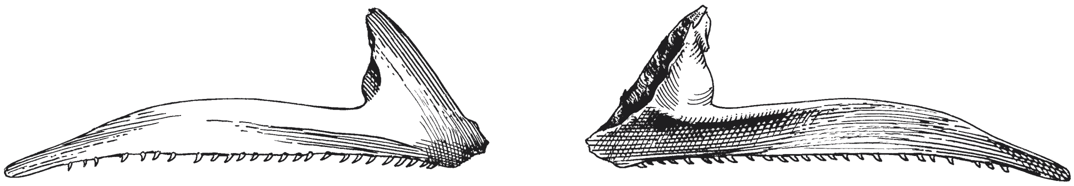
Lateral aspect **Medial aspect**



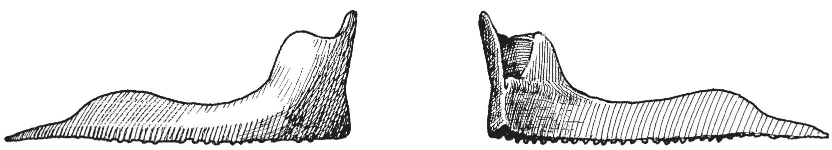
Thunnus albacares - Yellowfin tuna



Katsuwonus pelamis - Skipjack tuna



Thunnus alalunga - Albacore, Albacore tuna

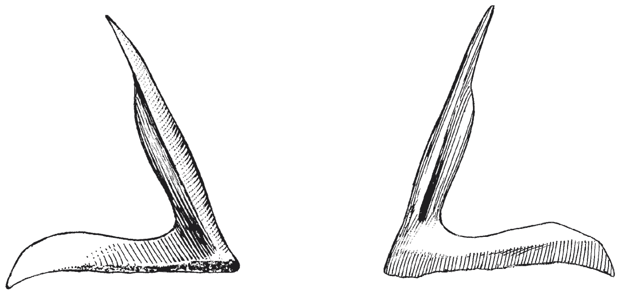


Naucrates ductor - Pilotfish

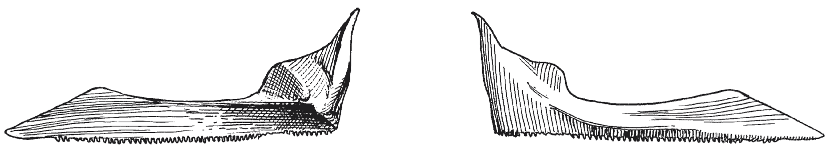
Scorpis violaceus - Blue maomao

The Left Premaxilla 5

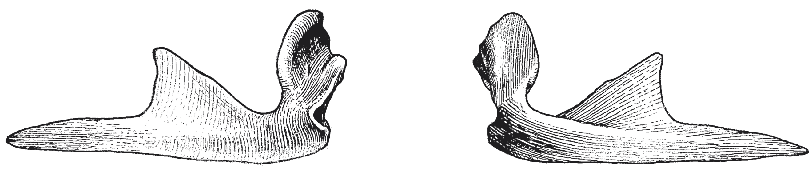
Medial aspect **Lateral aspect**



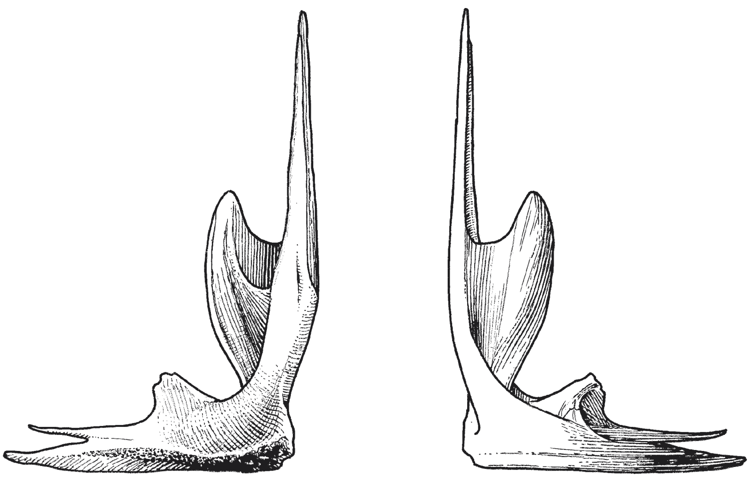
Latris lineata - Trumpeter



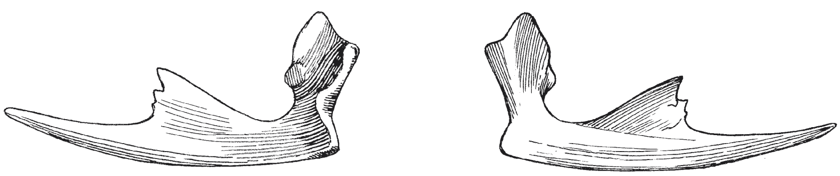
Seriolella brama - Blue warehou



Trachurus novaezelandiae - Horse mackerel



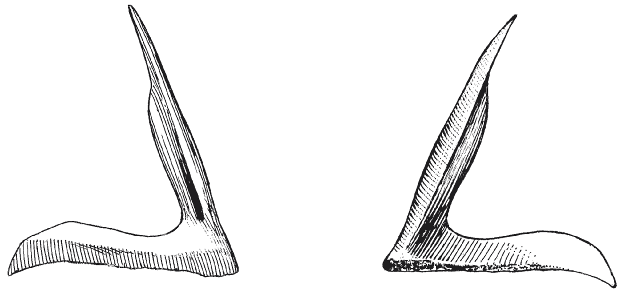
Scomber australasicus - Blue mackerel



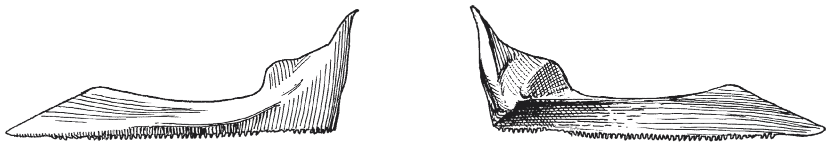
Zeus faber - John dory

The Right Premaxilla 5

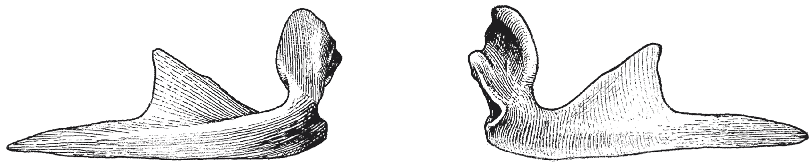
Lateral aspect **Medial aspect**



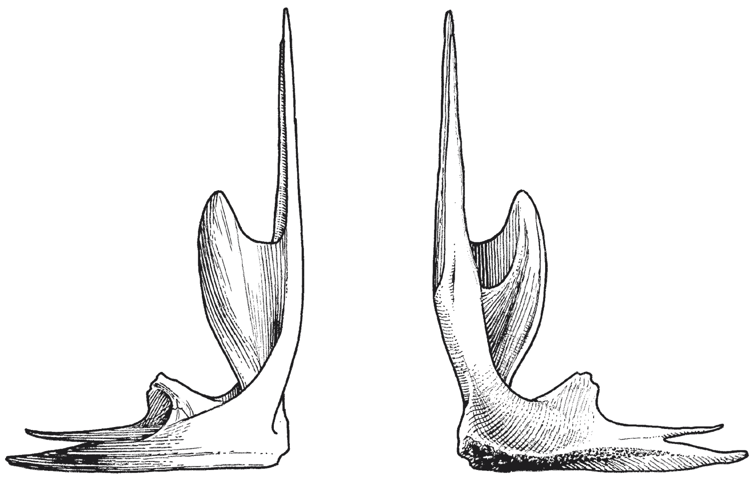
Latris lineata - Trumpeter



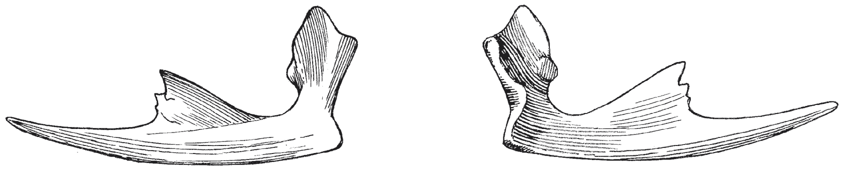
Seriolella brama - Blue warehou



Trachurus novaezelandiae - Horse mackerel



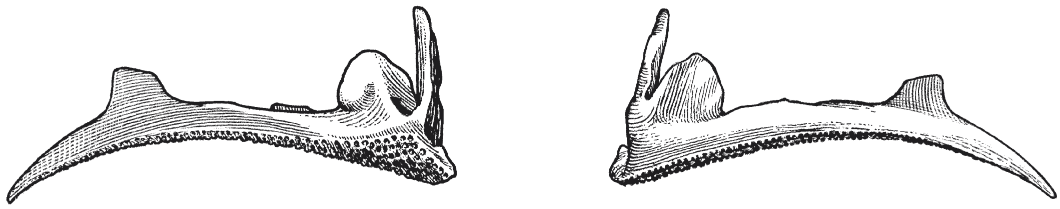
Scomber australasicus - Blue mackerel



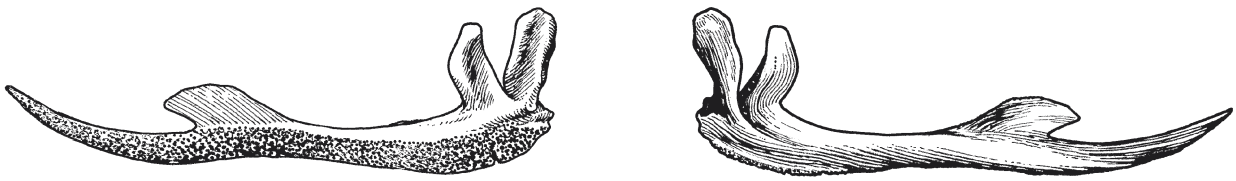
Zeus faber - John dory

The Left Premaxilla 6

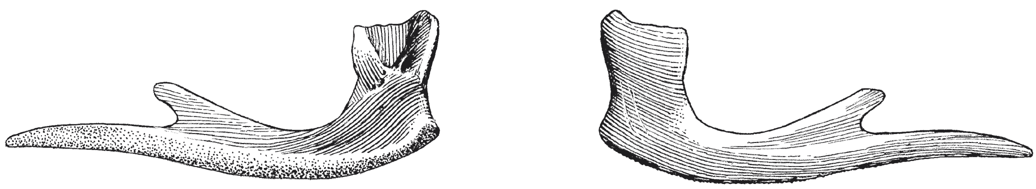
Medial aspect **Lateral aspect**



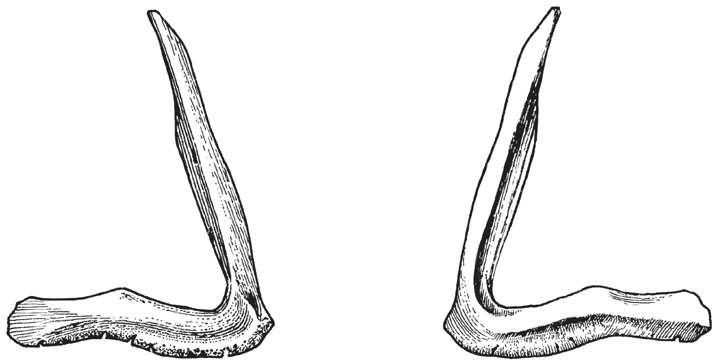
Arripis trutta - Kahawai



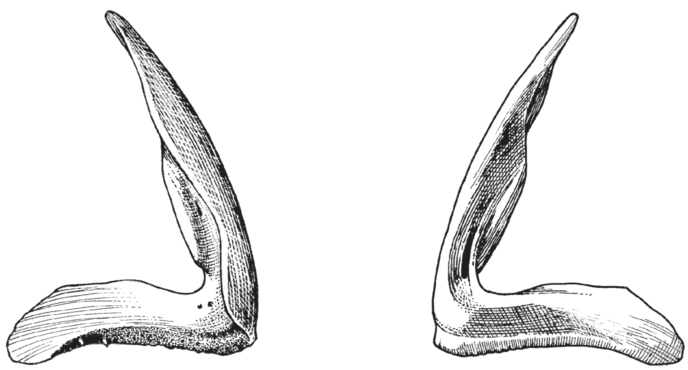
Pseudophycis bachus - Red cod



Chelidonichthys kumu - Red gurnard



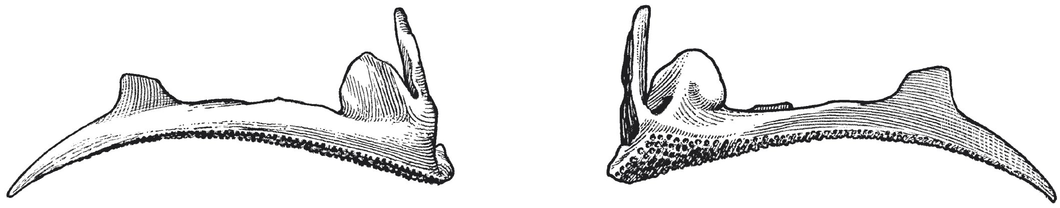
Nemadactylus macropterus - Tarakihi



Latridopsis ciliaris - Blue moki

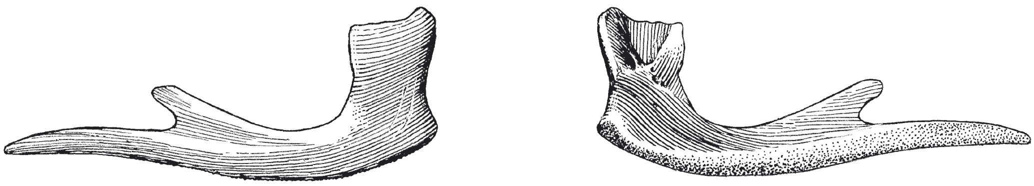
The Right Premaxilla 6

Lateral aspect **Medial aspect**

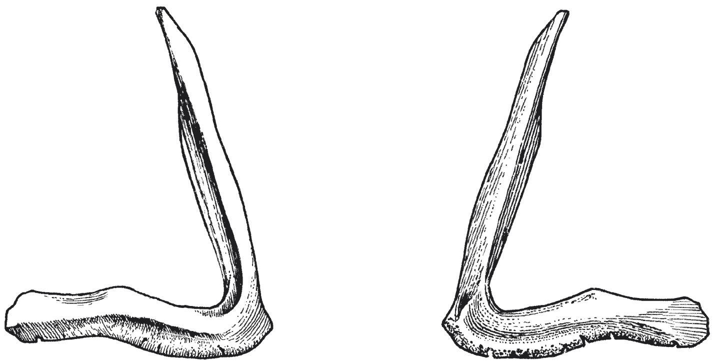


Arripis trutta - Kahawai

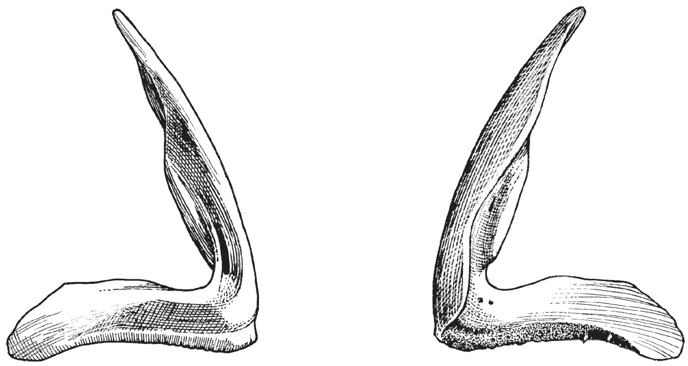
Pseudophycis bachus - Red cod



Chelidonichthys kumu - Red gurnard



Nemadactylus macropterus - Tarakihi

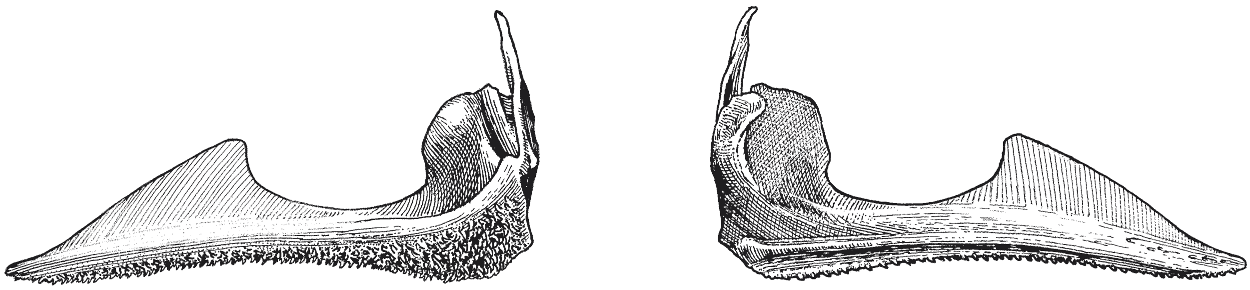


Latridopsis ciliaris - Blue moki

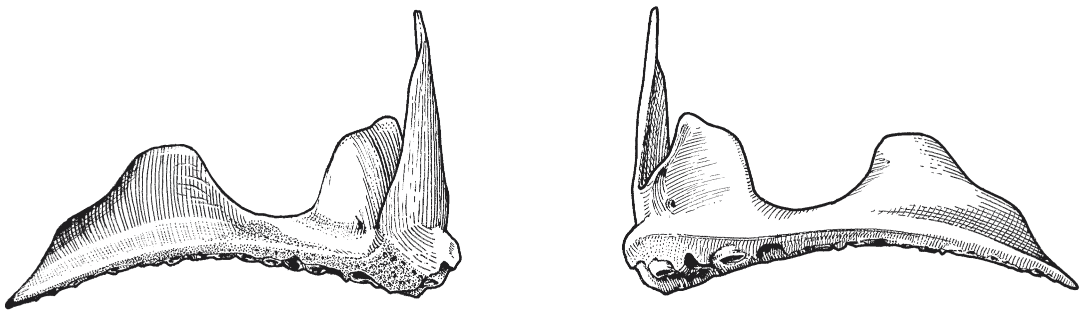
The Left Premaxilla 7

Medial aspect **Lateral aspect**

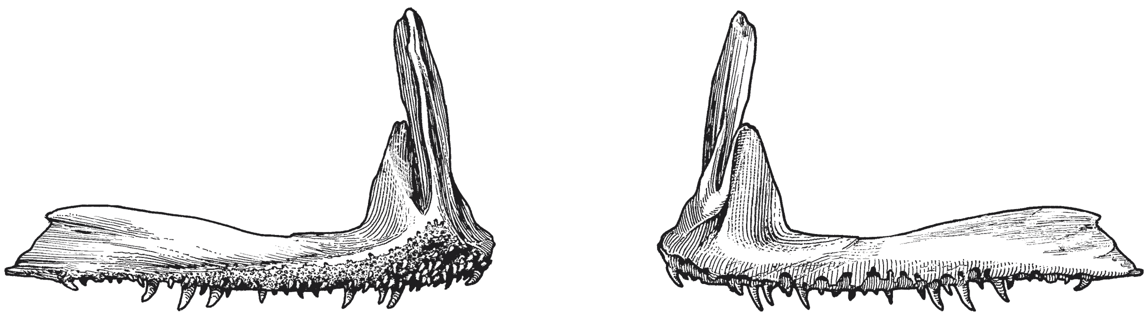
Scorpaena papillosus - Red scorpionfish



Helicolenus barathri - Sea perch



Parapercis colias - Blue cod

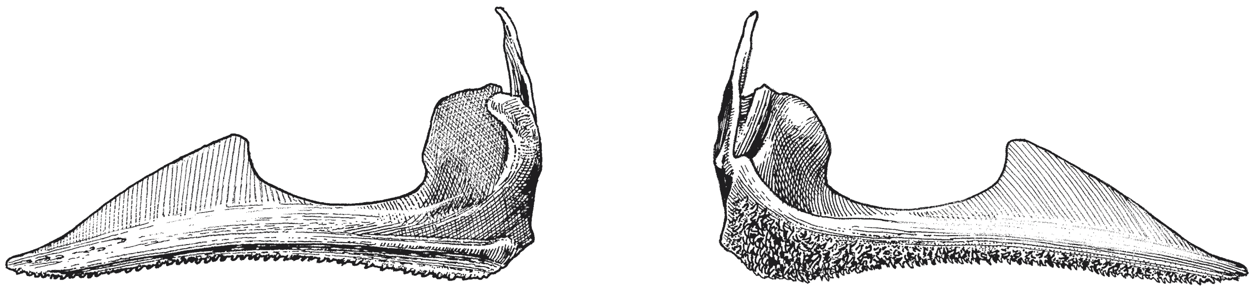


Notothenia angustata - Maori chief

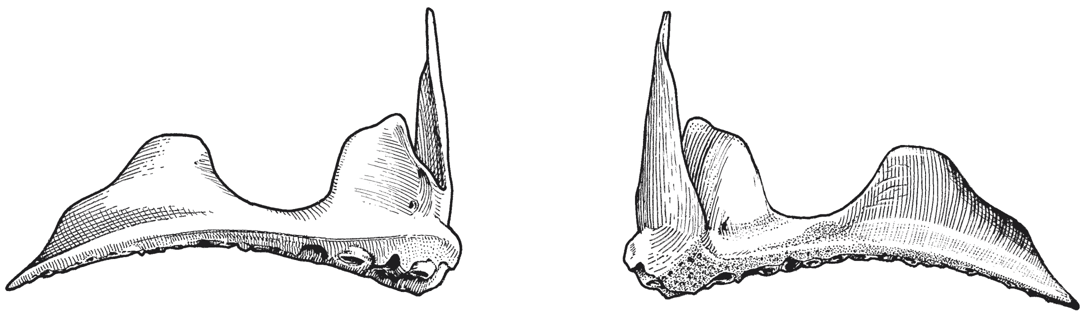
The Right Premaxilla 7

Lateral aspect **Medial aspect**

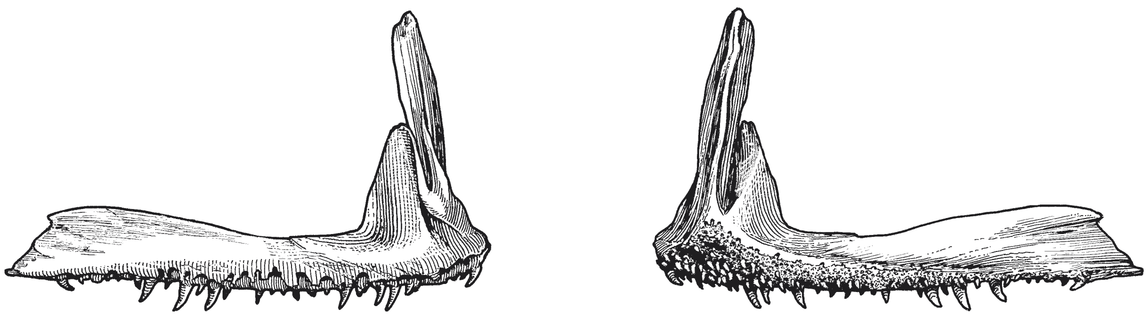
Scorpaena papillosus - Red scorpionfish



Helicolenus barathri - Sea perch



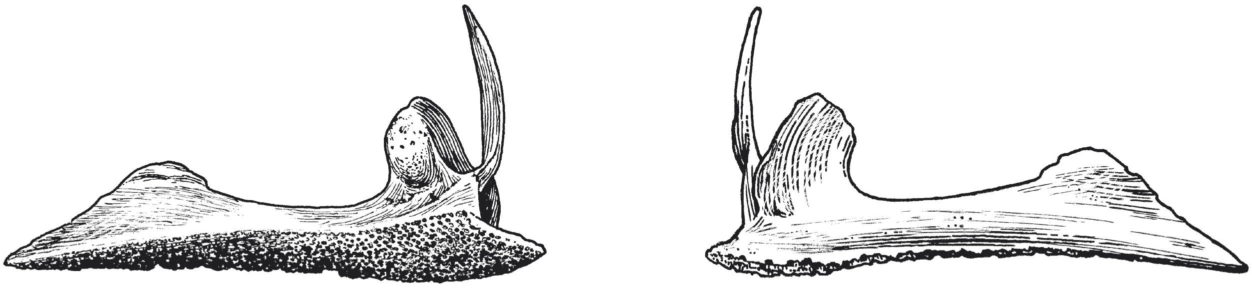
Parapercis colias - Blue cod



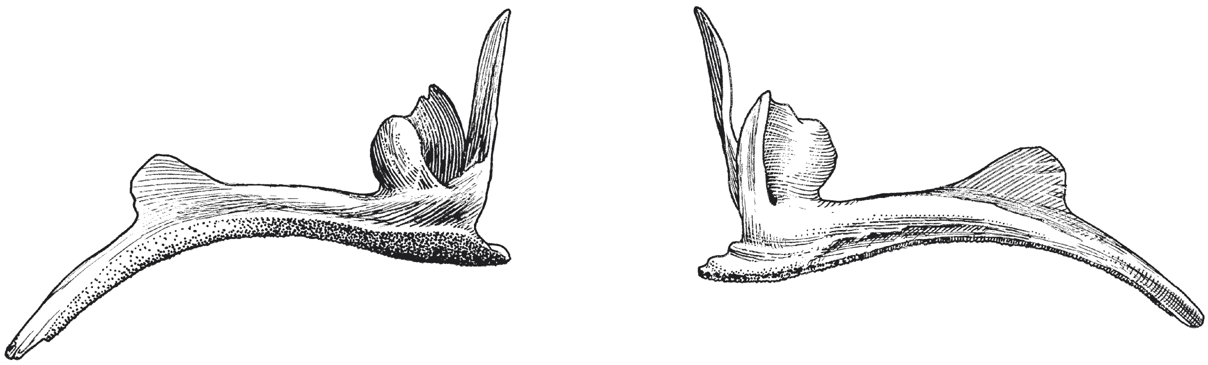
Notothenia angustata - Maori chief

The Left Premaxilla 8

Medial aspect **Lateral aspect**

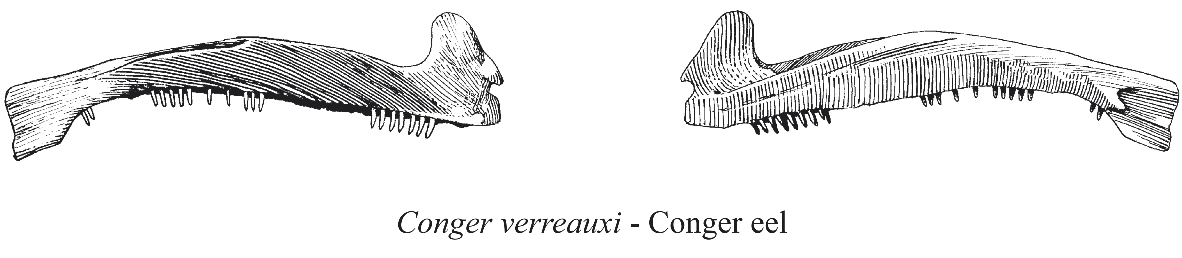


Polyprion oxygeneios - Hapuku, Groper



Seriola lalandi - Kingfish, Yellowtail kingfish

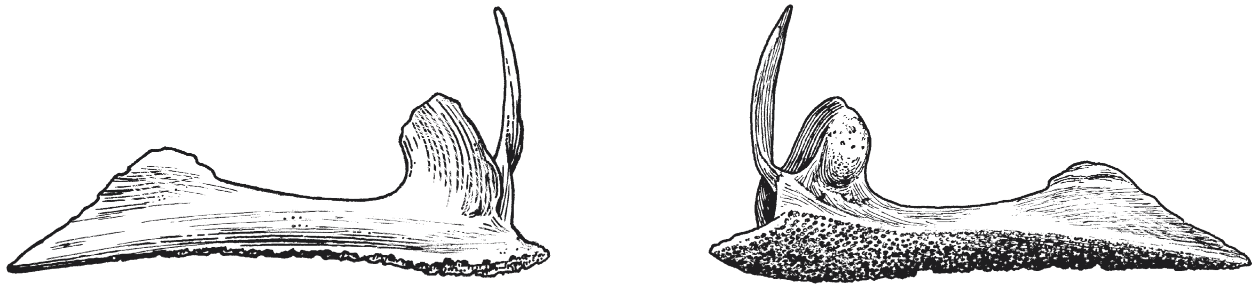
Anguilla dieffenbachii - Long-finned eel



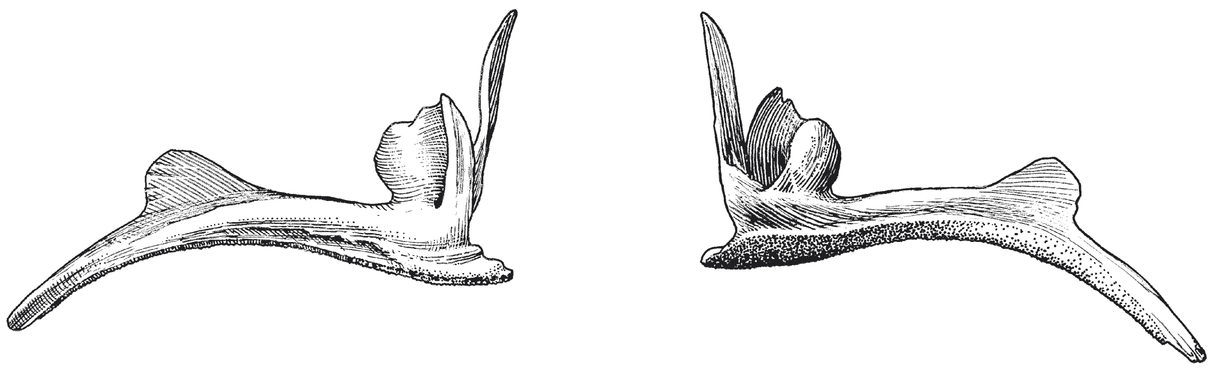
Conger verreauxi - Conger eel

The Right Premaxilla 8

Lateral aspect **Medial aspect**



Polyprion oxygeneios - Hapuku, Groper



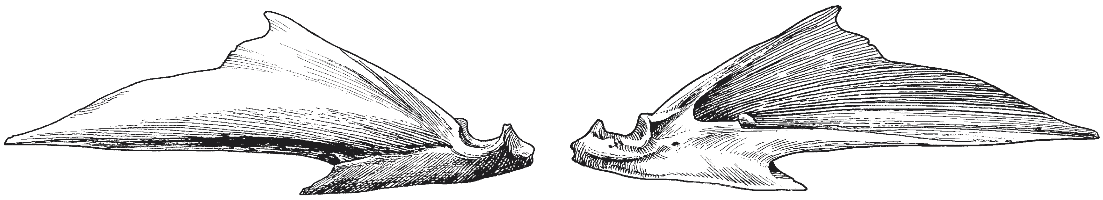
Seriola lalandi - Kingfish, Yellowtail kingfish

Anguilla dieffenbachii - Long-finned eel

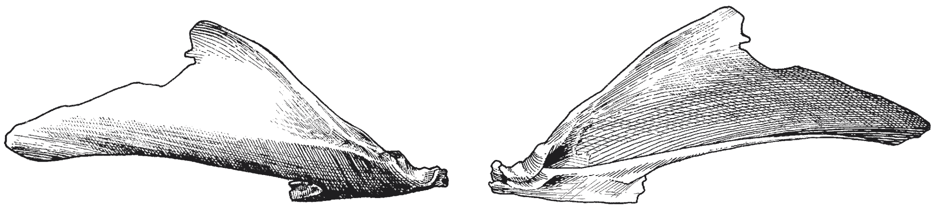
Conger verreauxi - Conger eel

The Left Articular 1

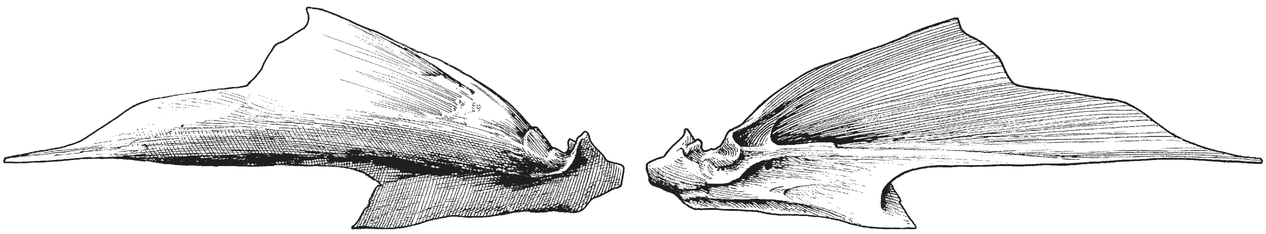
Medial aspect **Lateral aspect**



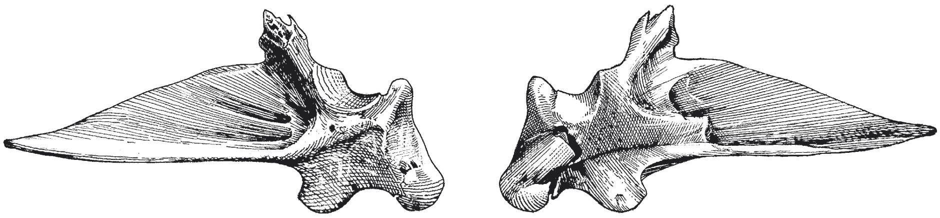
Thyrsites atun - Barracouta



Lepidopus caudatus - Frostfish



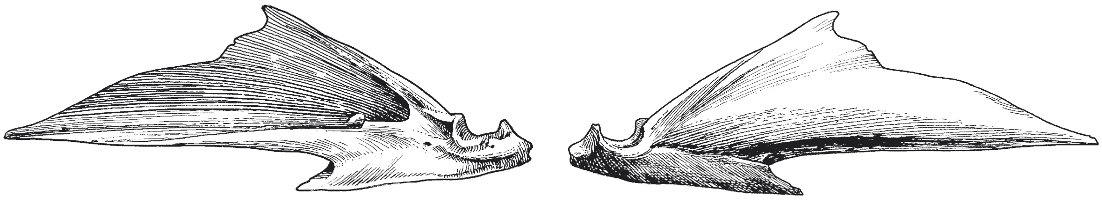
Rexea solandri - Gemfish



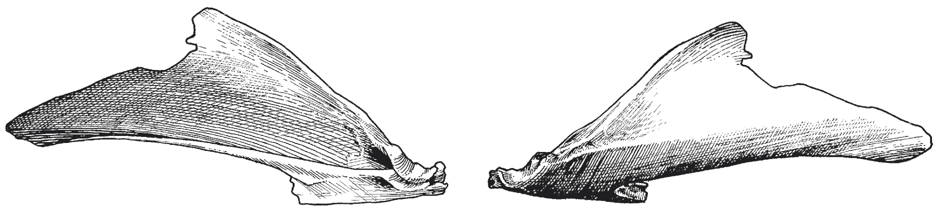
Leptoscopus macropygus - Estuary stargazer

The Right Articular 1

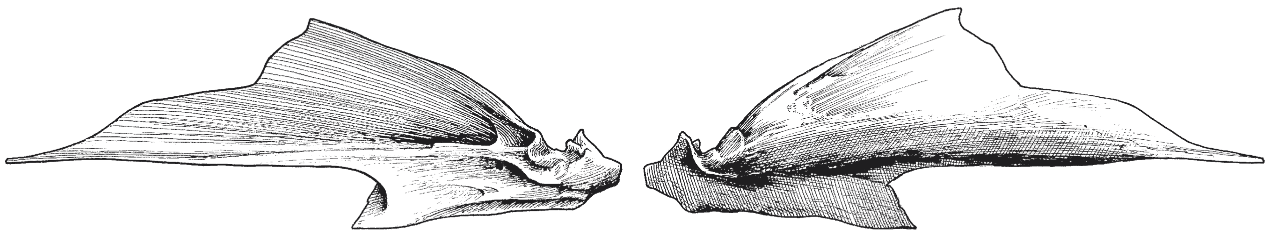
Lateral aspect **Medial aspect**



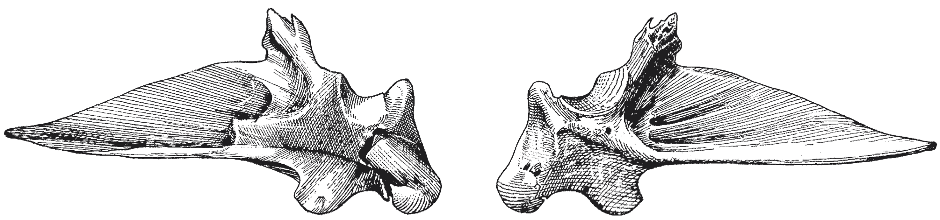
Thyrsites atun - Barracouta



Lepidopus caudatus - Frostfish



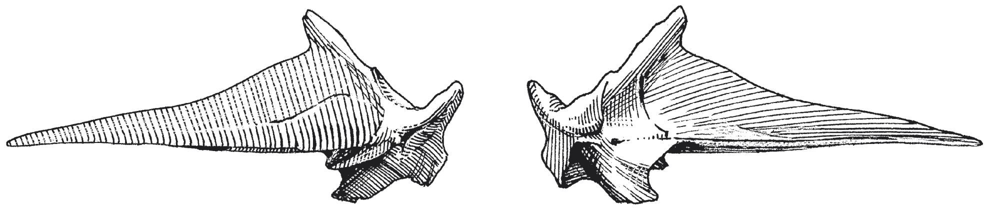
Rexea solandri - Gemfish



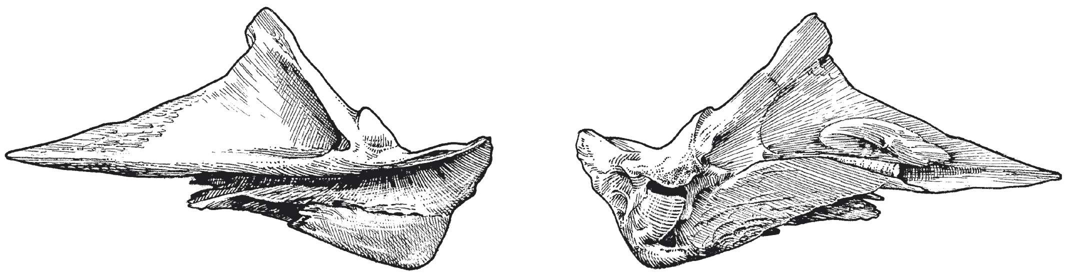
Leptoscopus macropygus - Estuary stargazer

The Left Articular 2

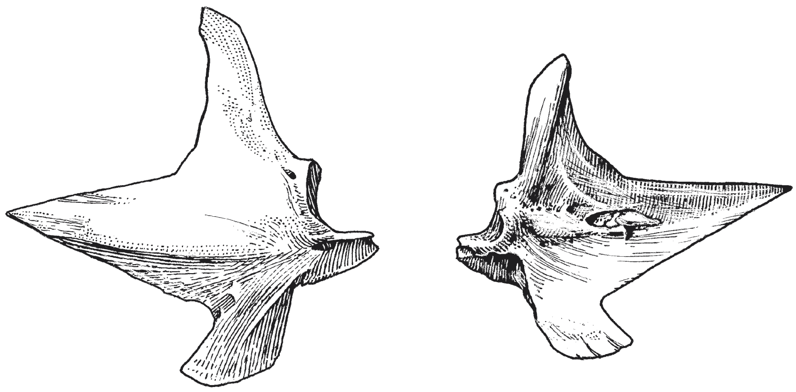
Medial aspect **Lateral aspect**



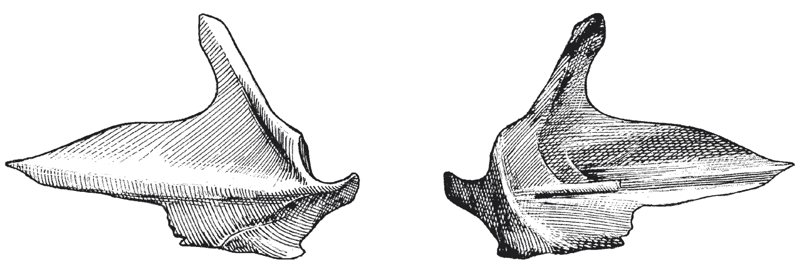
Lotella rhacinus - Rock cod



Genypterus blacodes - Ling



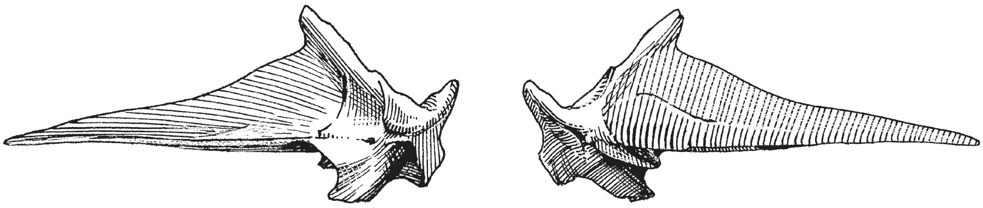
Pagrus auratus - Snapper



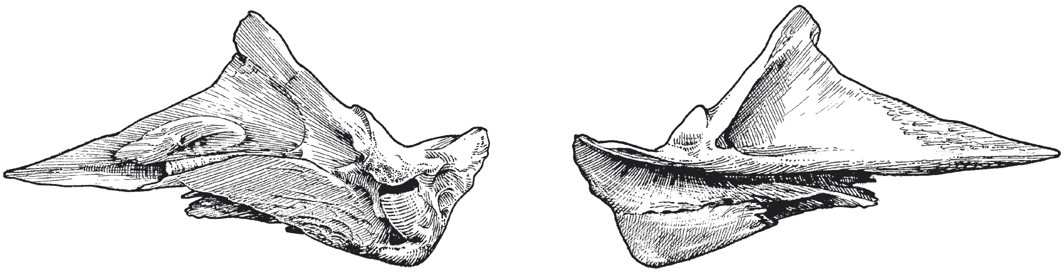
Pseudocaranx dentex - Trevally

The Right Articular 2

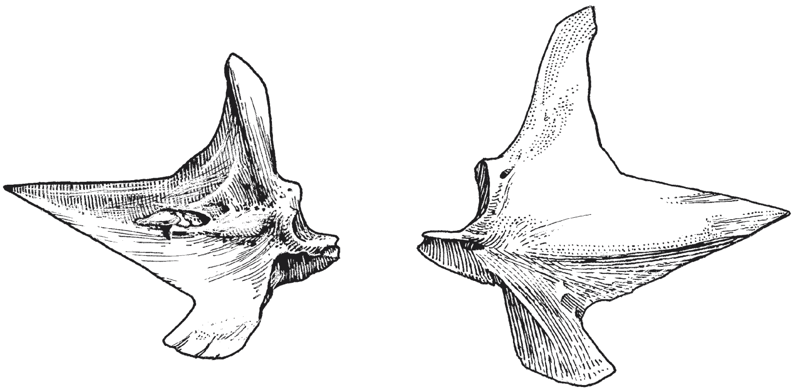
Lateral aspect **Medial aspect**



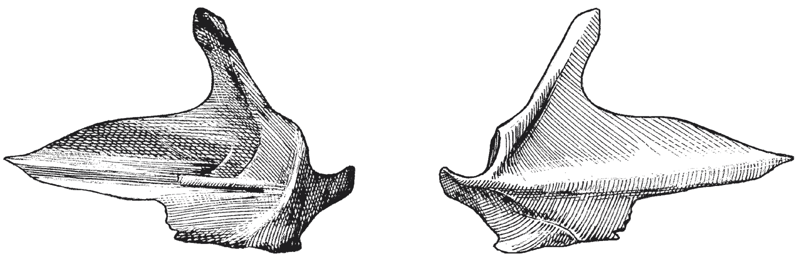
Lotella rhacinus - Rock cod



Genypterus blacodes - Ling



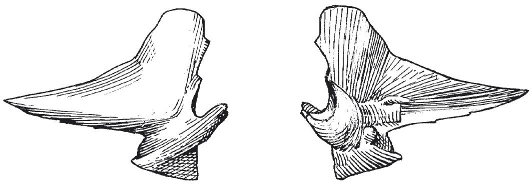
Pagrus auratus - Snapper



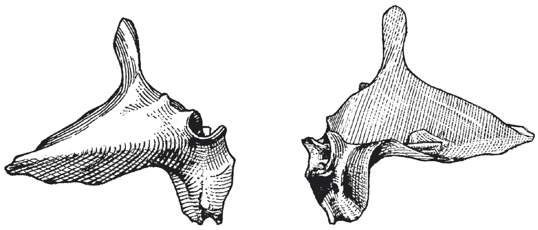
Pseudocaranx dentex - Trevally

The Left Articular 3

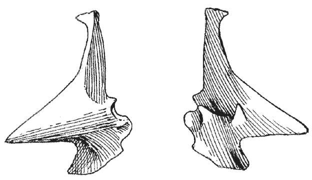
Medial aspect **Lateral aspect**



Congiopodus leucopaecilus - Southern pigfish



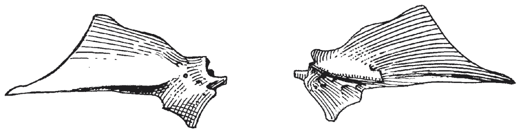
Notolabrus celidotus - Spotty



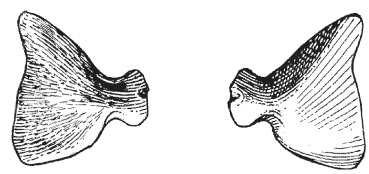
Odax pullus - Butterfish, Greenbone

(see text - page 33)

Rhombosolea leporina - Yellowbelly flounder



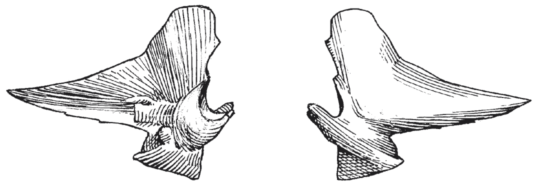
Mugil cephalus - Grey mullet



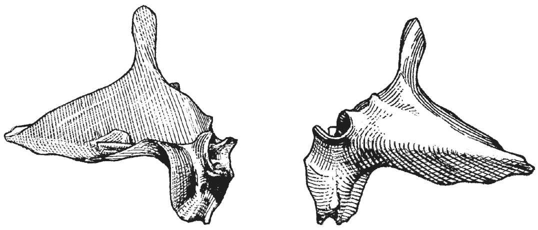
Aplodactylus arctidens - Marblefish

The Right Articular 3

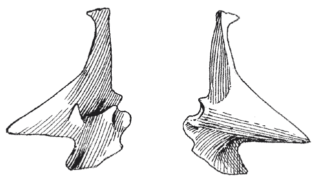
Lateral aspect **Medial aspect**



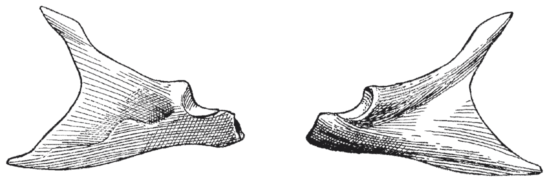
Congiopodus leucopaecilus - Southern pigfish



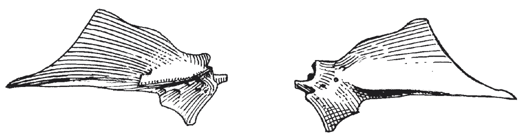
Notolabrus celidotus - Spotty



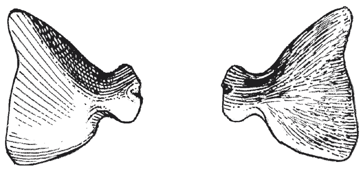
Odax pullus - Butterfish, Greenbone



Rhombosolea leporina - Yellowbelly flounder



Mugil cephalus - Grey mullet

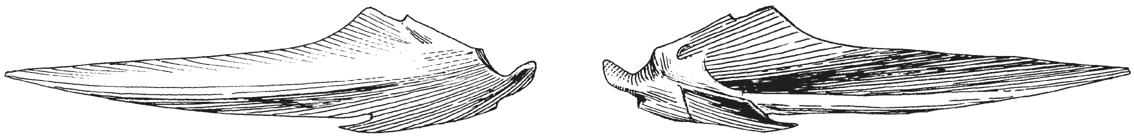


Aplodactylus arctidens - Marblefish

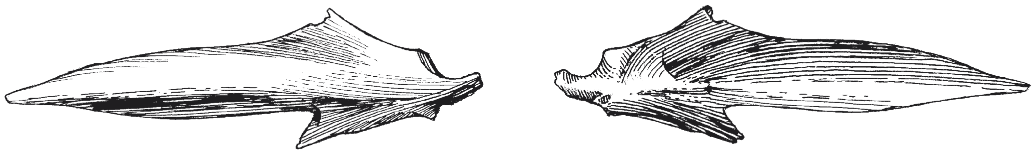
The Left Articular 4

Medial aspect **Lateral aspect**

Thunnus albacares - Yellowfin tuna

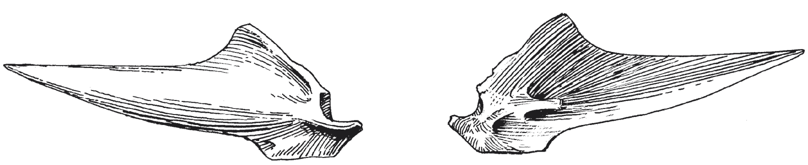


Katsuwonus pelamis - Skipjack tuna



Thunnus alalunga - Albacore, Albacore tuna

Naucrates ductor - Pilotfish

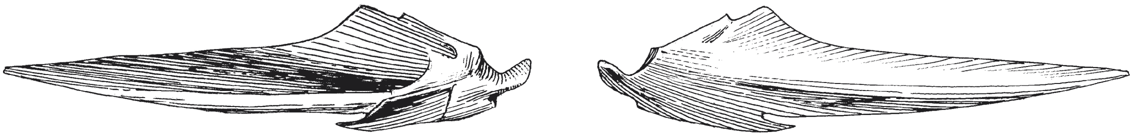


Scorpis violaceus - Blue maomao

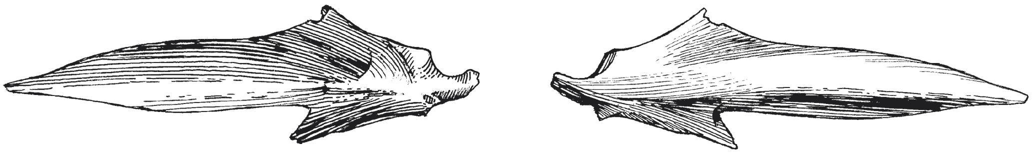
The Right Articular 4

Lateral aspect **Medial aspect**

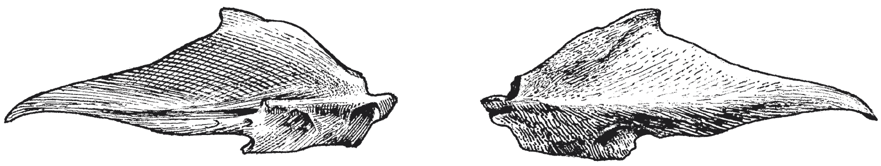
Thunnus albacares - Yellowfin tuna



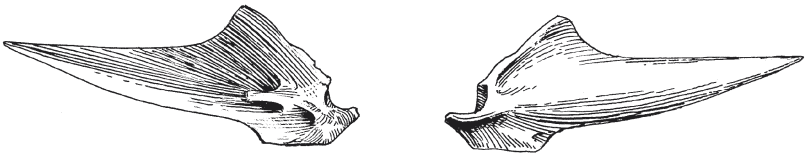
Katsuwonus pelamis - Skipjack tuna



Thunnus alalunga - Albacore, Albacore tuna



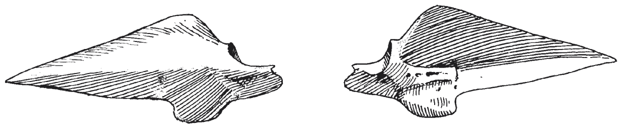
Naucrates ductor - Pilotfish



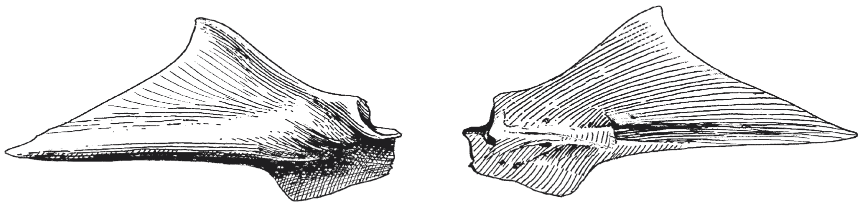
Scorpis violaceus - Blue maomao

The Left Articular 5

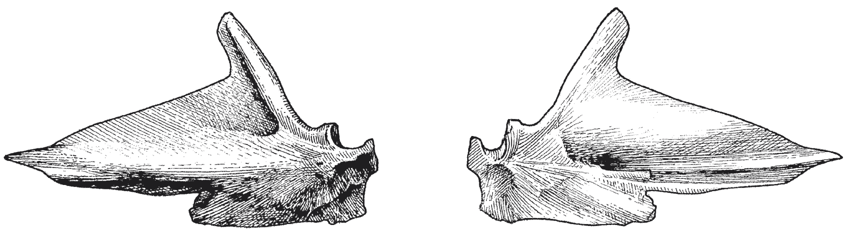
Medial aspect **Lateral aspect**



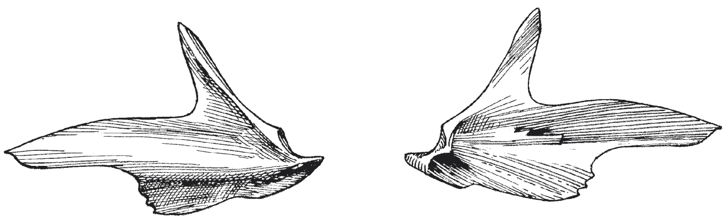
Latris lineata - Trumpeter



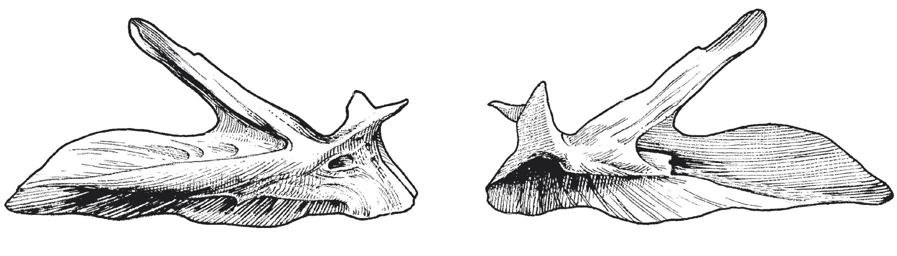
Seriolella brama - Blue warehou



Trachurus novaezelandiae - Horse mackerel



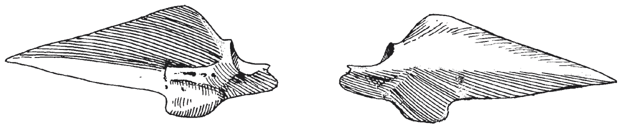
Scomber australasicus - Blue mackerel



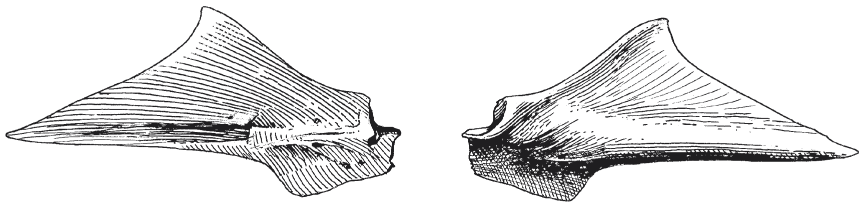
Zeus faber - John dory

The Right Articular 5

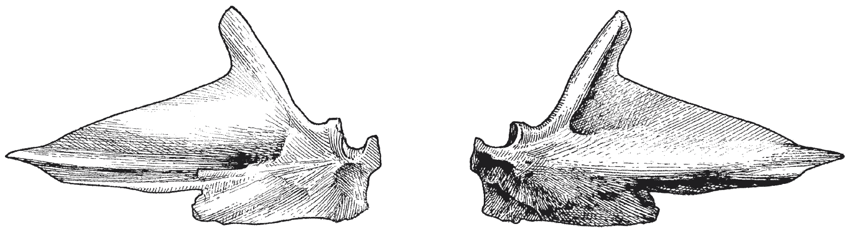
Lateral aspect **Medial aspect**



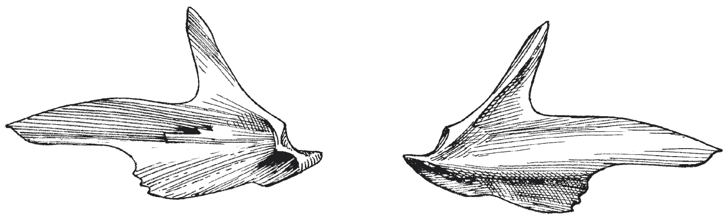
Latris lineata - Trumpeter



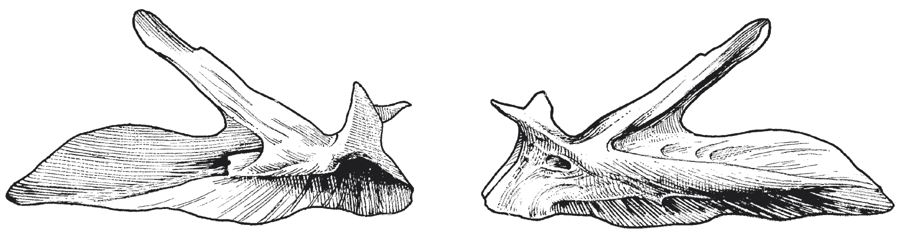
Seriolella brama - Blue warehou



Trachurus novaezelandiae - Horse mackerel



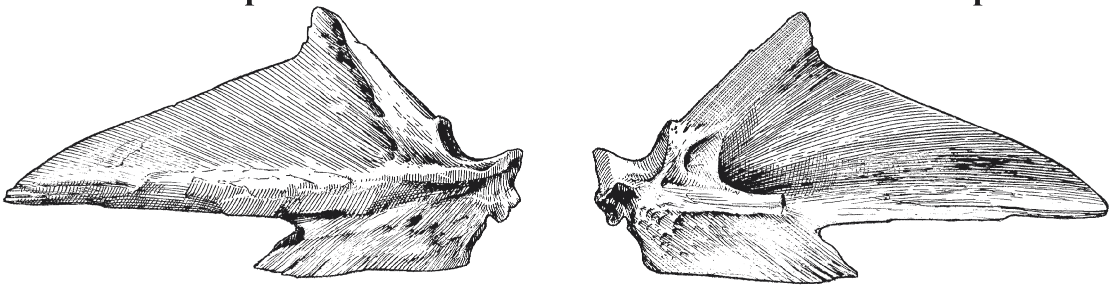
Scomber australasicus - Blue mackerel



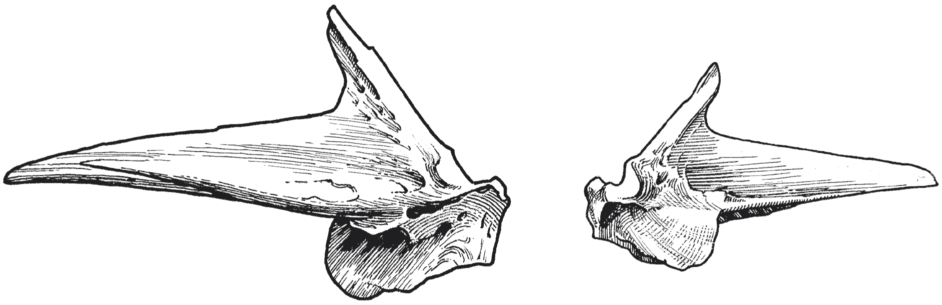
Zeus faber - John dory

The Left Articular 6

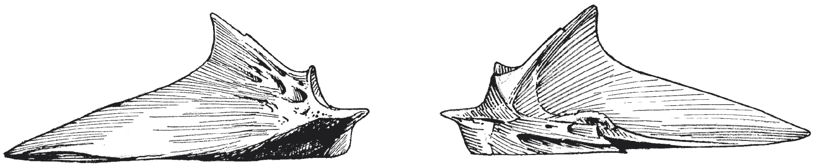
Medial aspect **Lateral aspect**



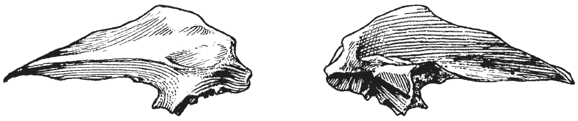
Arripis trutta - Kahawai



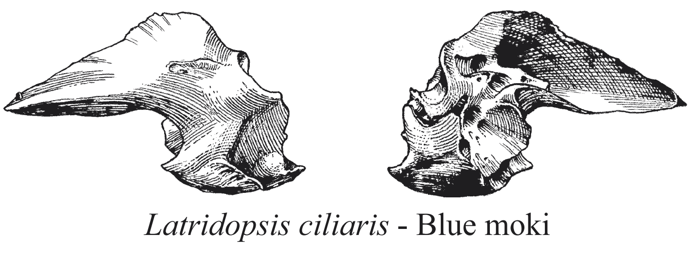
Pseudophycis bachus - Red cod



Chelidonichthys kumu - Red gurnard



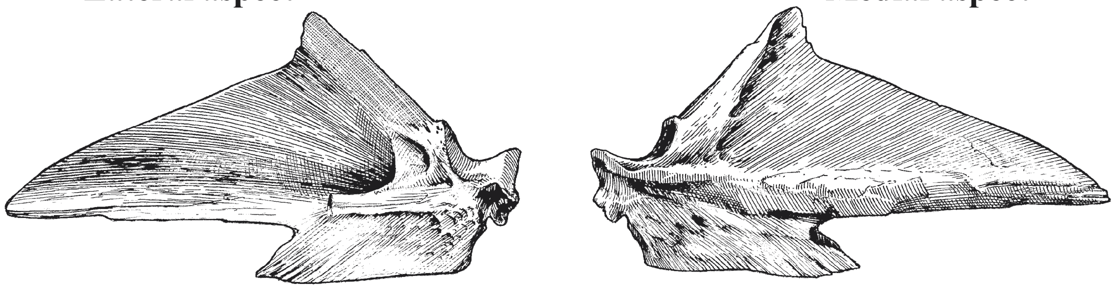
Nemadactylus macropterus - Tarakihi



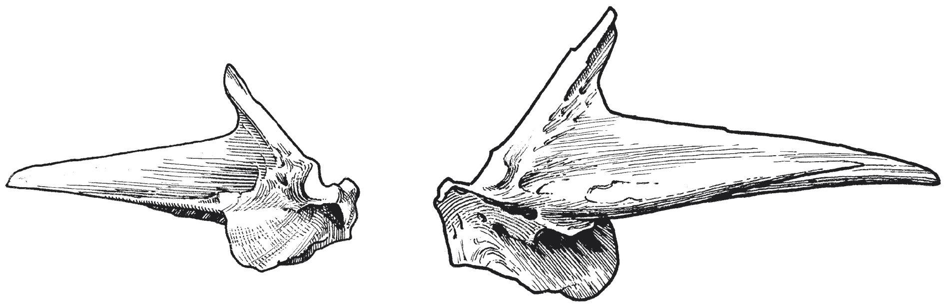
Latridopsis ciliaris - Blue moki

The Right Articular 6

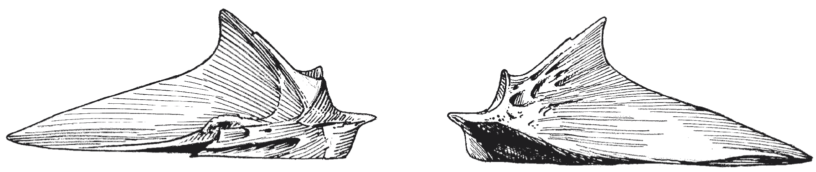
Lateral aspect **Medial aspect**



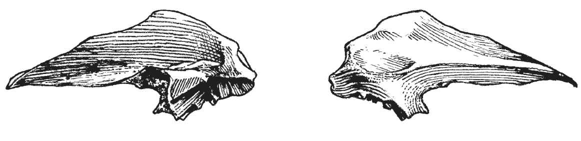
Arripis trutta - Kahawai



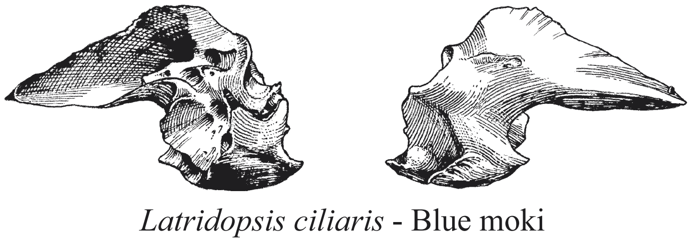
Pseudophycis bachus - Red cod



Chelidonichthys kumu - Red gurnard



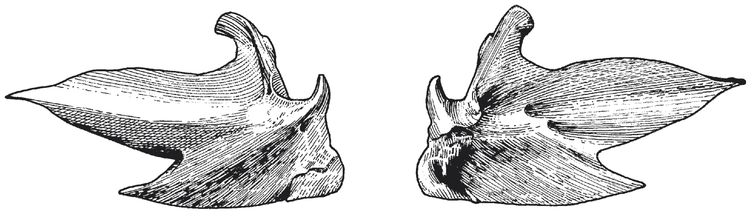
Nemadactylus macropterus - Tarakihi



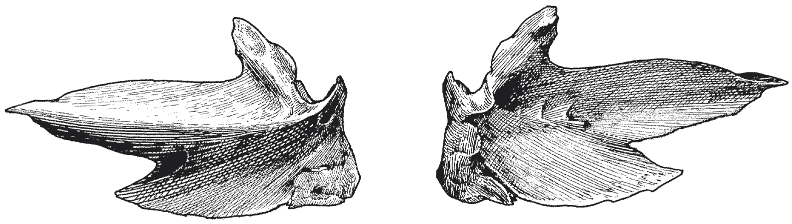
Latridopsis ciliaris - Blue moki

The Left Articular 7

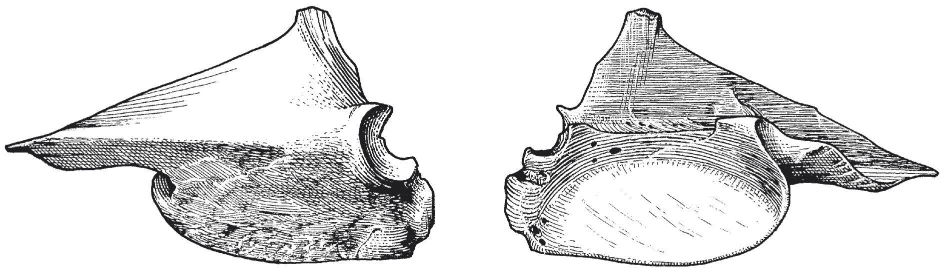
Medial aspect **Lateral aspect**



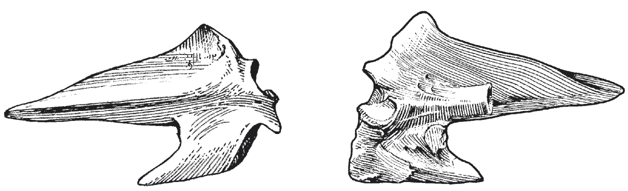
Scorpaena papillosus - Red scorpionfish



Helicolenus barathri - Sea perch



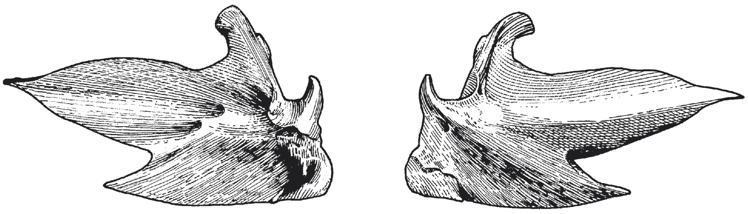
Parapercis colias - Blue cod



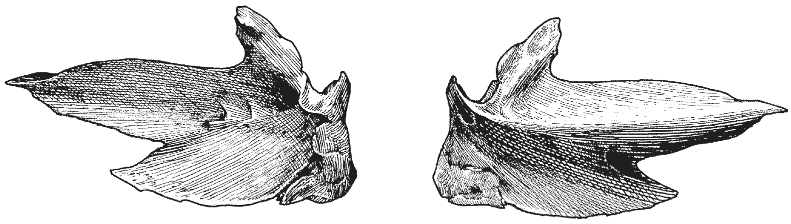
Notothenia angustata - Maori chief

The Right Articular 7

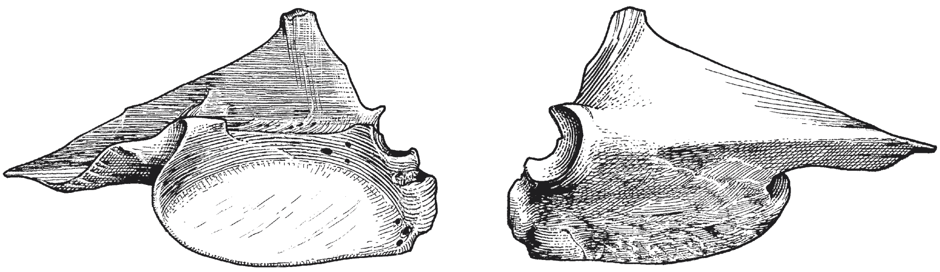
Lateral aspect **Medial aspect**



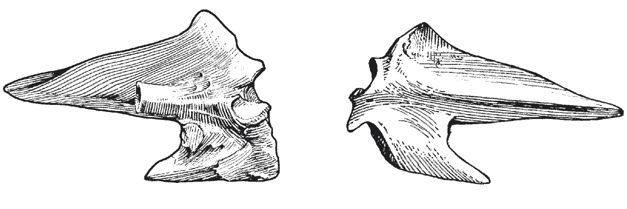
Scorpaena papillosus - Red scorpionfish



Helicolenus barathri - Sea perch



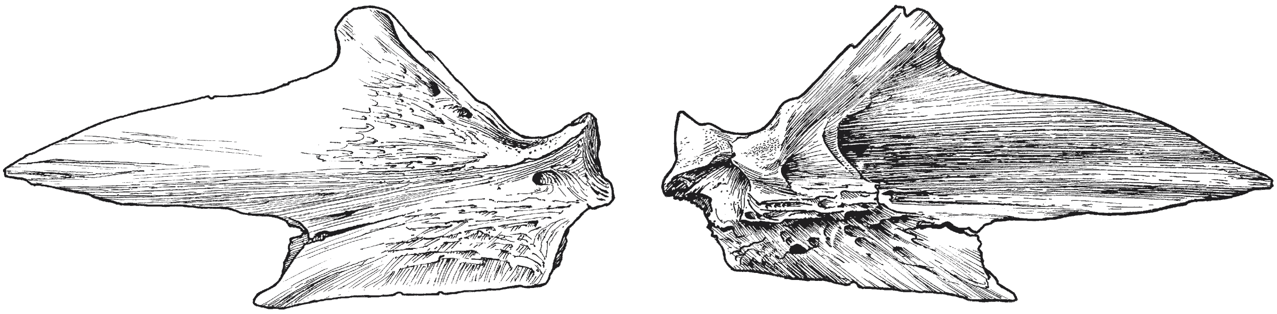
Parapercis colias - Blue cod



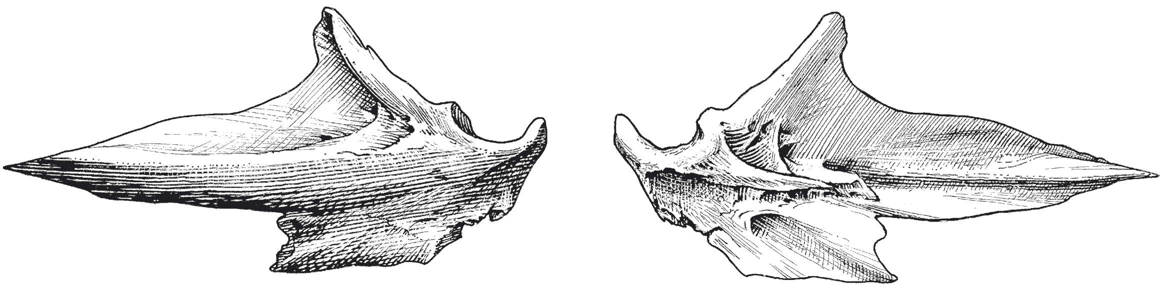
Notothenia angustata - Maori chief

The Left Articular 8

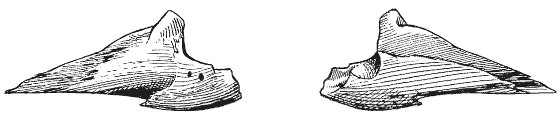
Medial aspect **Lateral aspect**



Polyprion oxygeneios - Hapuku, Groper



Seriola lalandi - Kingfish, Yellowtail kingfish

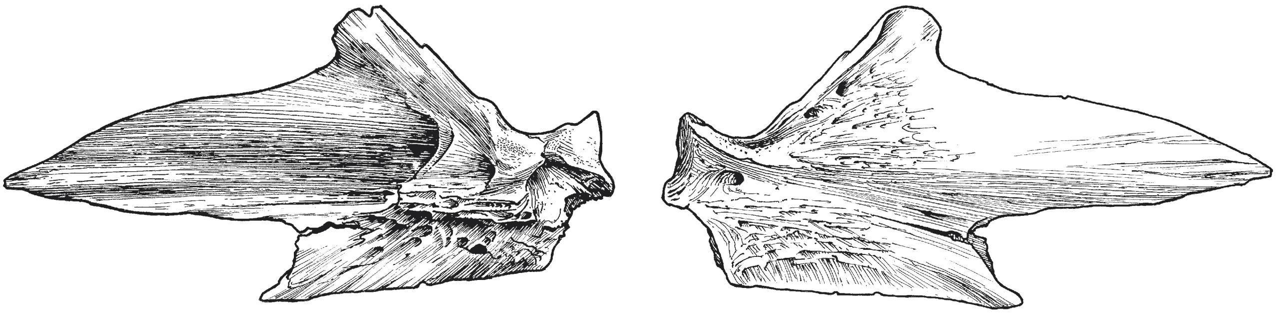


Anguilla dieffenbachii - Long-finned eel

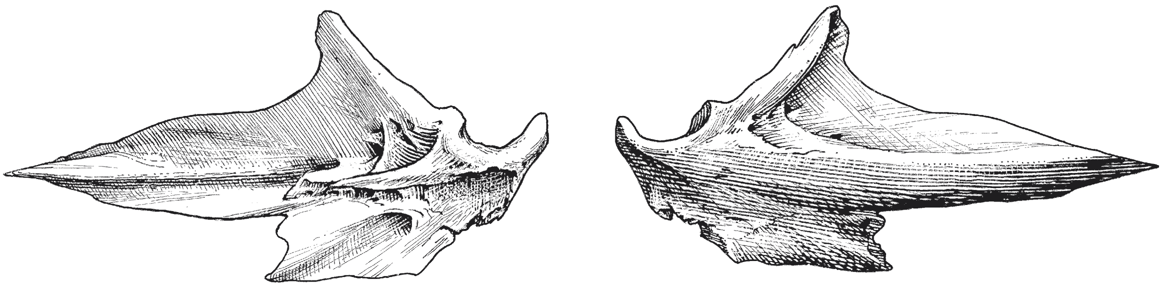
Conger verreauxi - Conger eel

The Right Articular 8

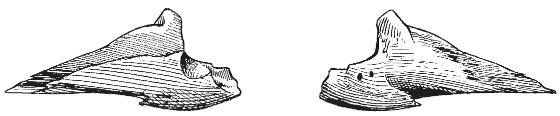
Lateral aspect **Medial aspect**



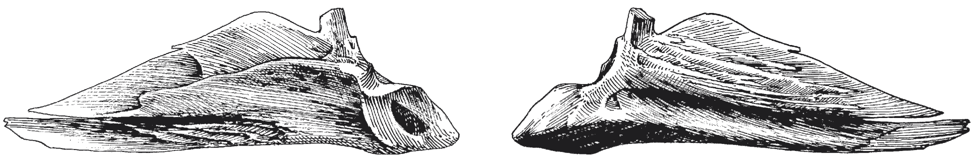
Polyprion oxygeneios - Hapuku, Groper



Seriola lalandi - Kingfish, Yellowtail kingfish



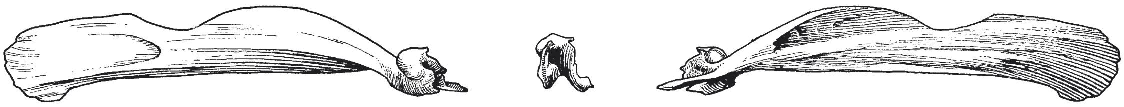
Anguilla dieffenbachii - Long-finned eel



Conger verreauxi - Conger eel

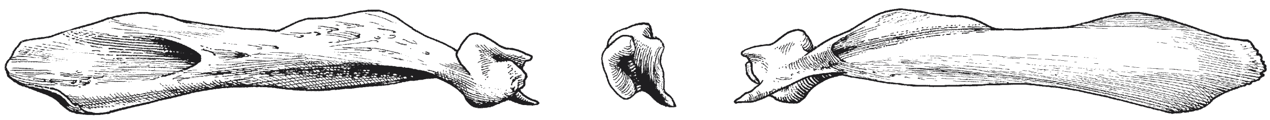
The Left Maxilla 1

Medial aspect **Lateral aspect**

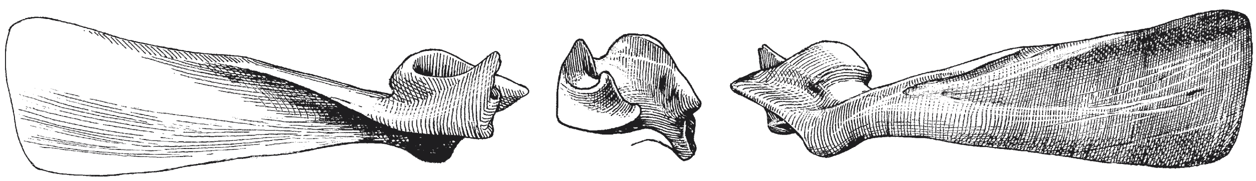


Thyrsites atun - Barracouta

Lepidopus caudatus - Frostfish



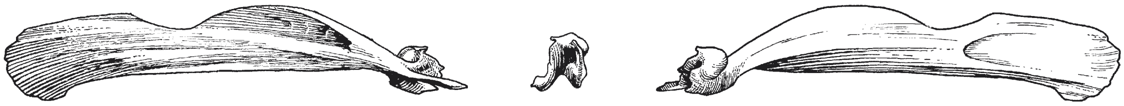
Rexea solandri - Gemfish



Leptoscopus macropygus - Estuary stargazer

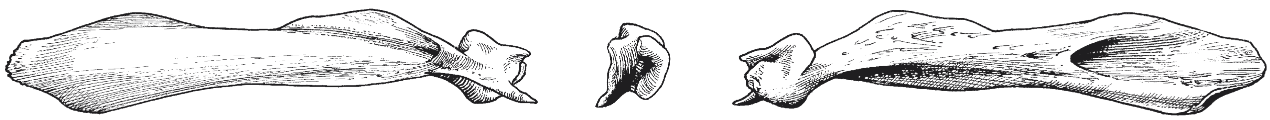
The Right Maxilla 1

Lateral aspect **Medial aspect**

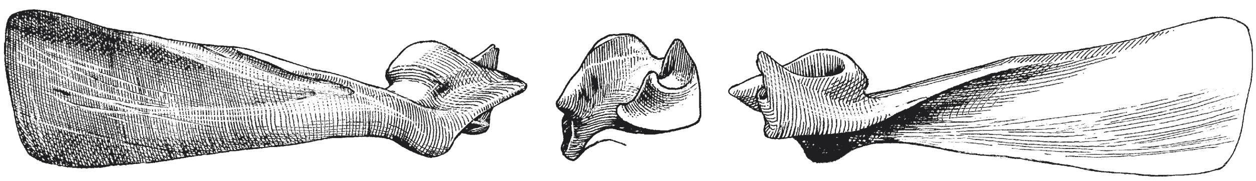


Thyrsites atun - Barracouta

Lepidopus caudatus - Frostfish



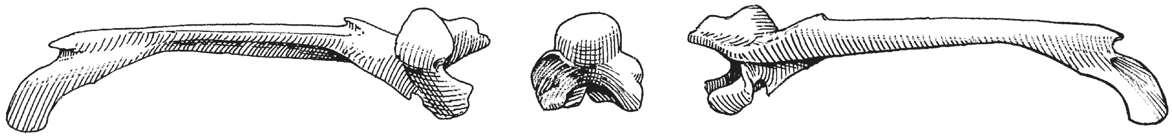
Rexea solandri - Gemfish



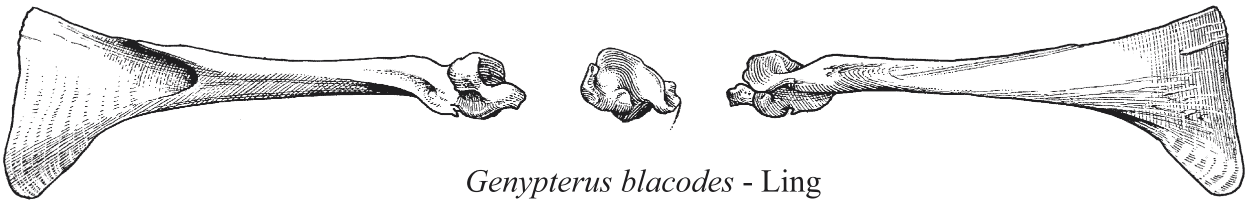
Leptoscopus macropygus - Estuary stargazer

The Left Maxilla 2

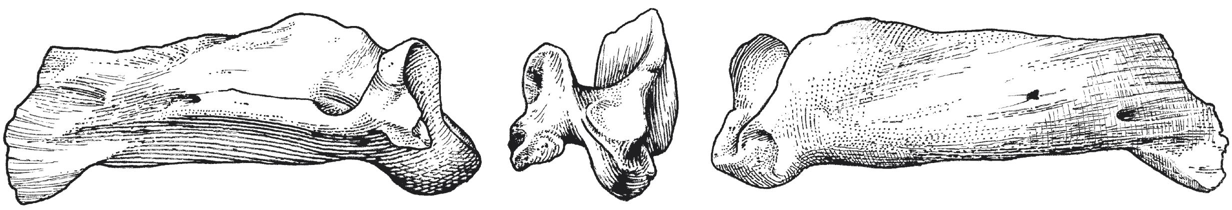
Medial aspect **Lateral aspect**



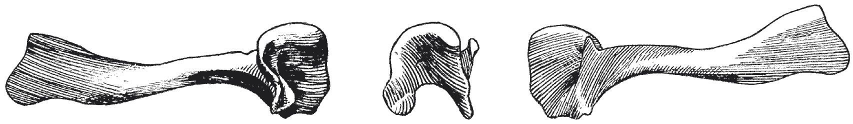
Lotella rhacinus - Rock cod



Genypterus blacodes - Ling



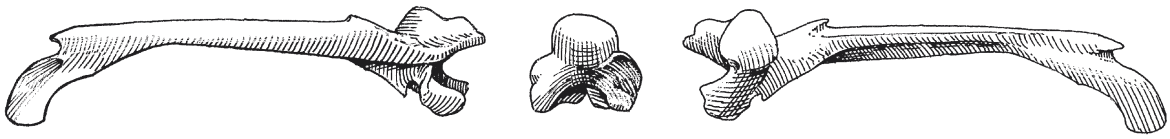
Pagrus auratus - Snapper



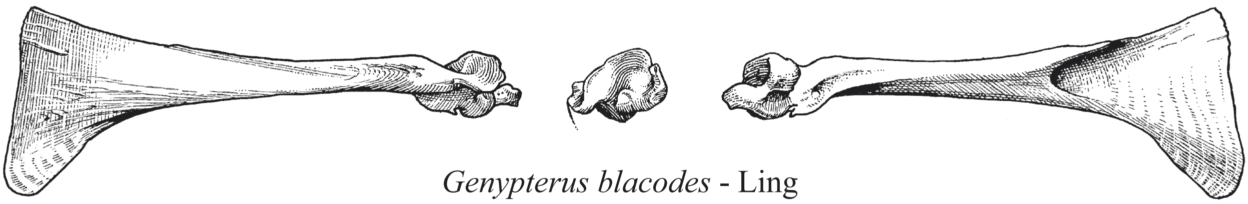
Pseudocaranx dentex - Trevally

The Right Maxilla 2

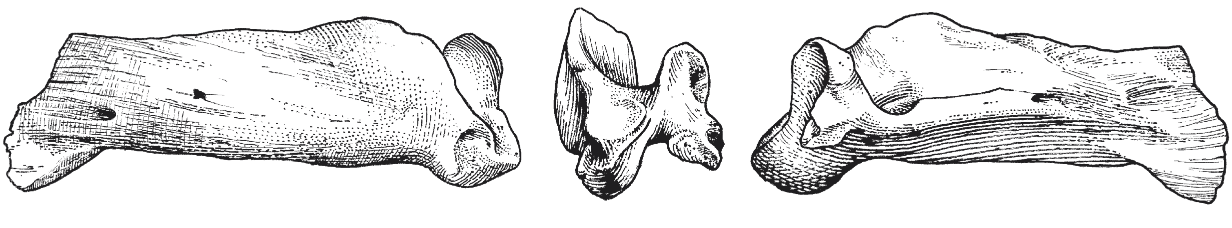
Lateral aspect **Medial aspect**



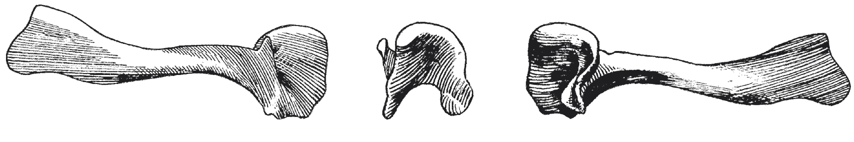
Lotella rhacinus - Rock cod



Genypterus blacodes - Ling



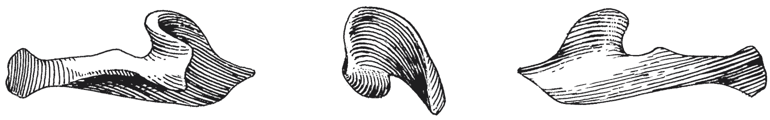
Pagrus auratus - Snapper



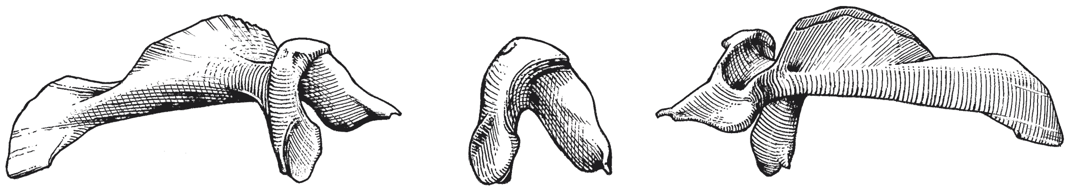
Pseudocaranx dentex - Trevally

The Left Maxilla 3

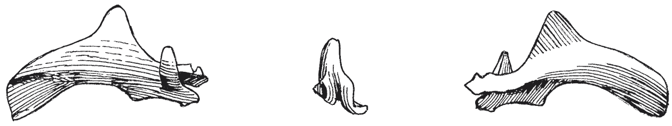
Medial aspect **Lateral aspect**



Congiopodus leucopaecilus - Southern pigfish



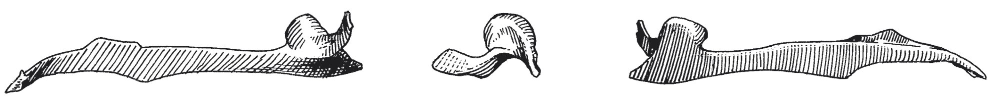
Notolabrus celidotus - Spotty



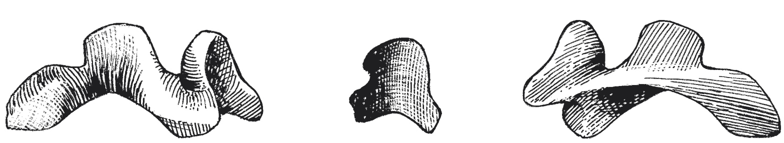
Odax pullus - Butterfish, Greenbone

(see text - page 33)

Rhombosolea leporina - Yellowbelly flounder



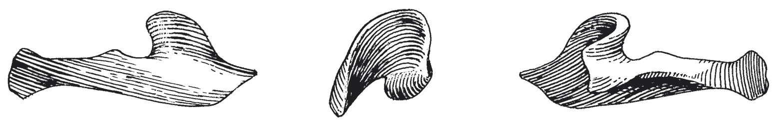
Mugil cephalus - Grey mullet



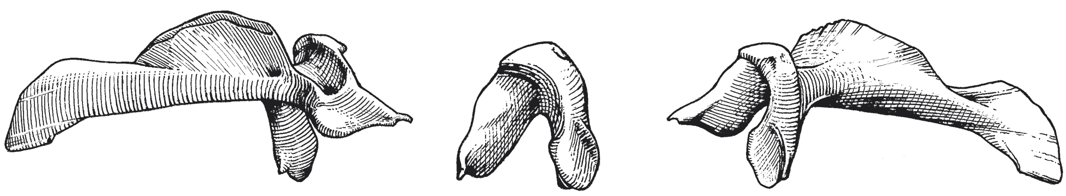
Aplodactylus arctidens - Marblefish

The Right Maxilla 3

Lateral aspect **Medial aspect**

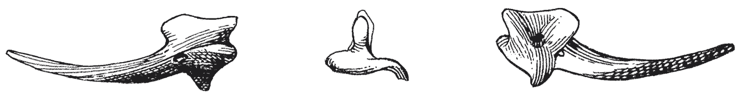


Congiopodus leucopaecilus - Southern pigfish

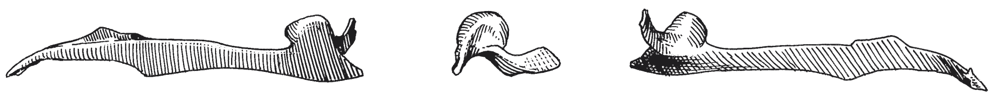


Notolabrus celidotus - Spotty

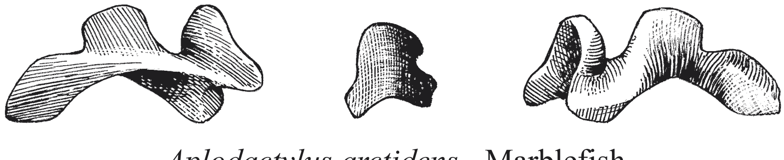
Odax pullus - Butterfish, Greenbone



Rhombosolea leporina - Yellowbelly flounder



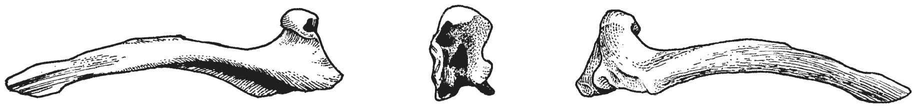
Mugil cephalus - Grey mullet



Aplodactylus arctidens - Marblefish

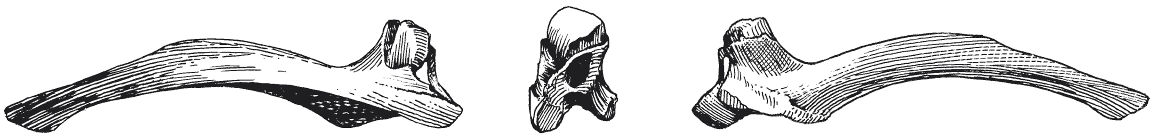
The Left Maxilla 4

Medial aspect **Lateral aspect**



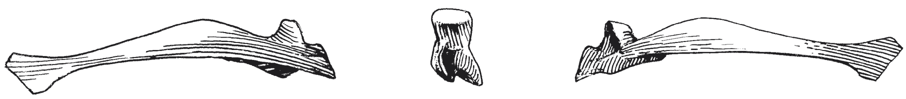
Thunnus albacares - Yellowfin tuna

Katsuwonus pelamis - Skipjack tuna



Thunnus alalunga - Albacore, Albacore tuna

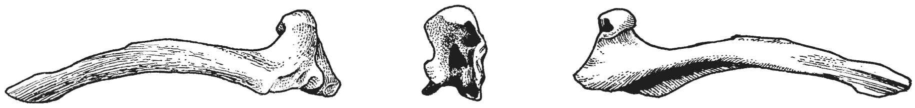
Naucrates ductor - Pilotfish



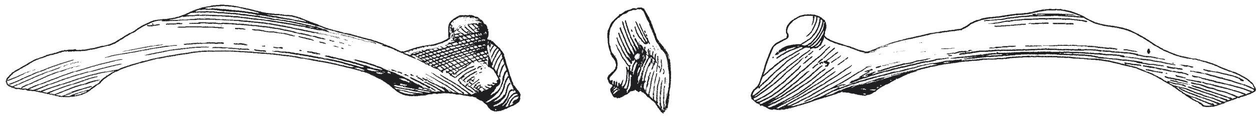
Scorpis violaceus - Blue maomao

The Right Maxilla 4

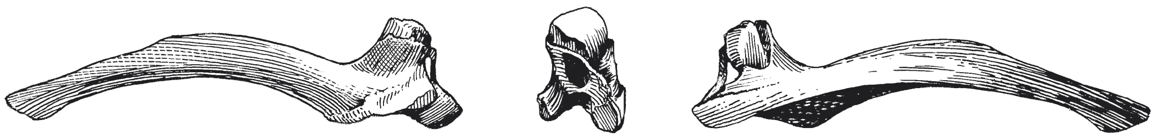
Lateral aspect **Medial aspect**



Thunnus albacares - Yellowfin tuna

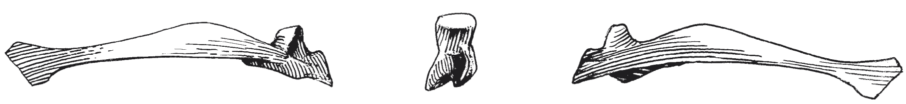


Katsuwonus pelamis - Skipjack tuna



Thunnus alalunga - Albacore, Albacore tuna

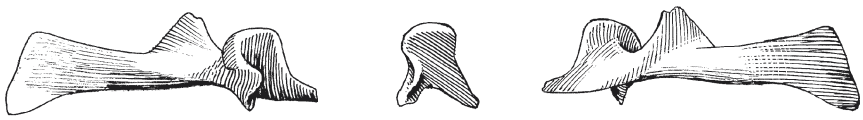
Naucrates ductor - Pilotfish



Scorpis violaceus - Blue maomao

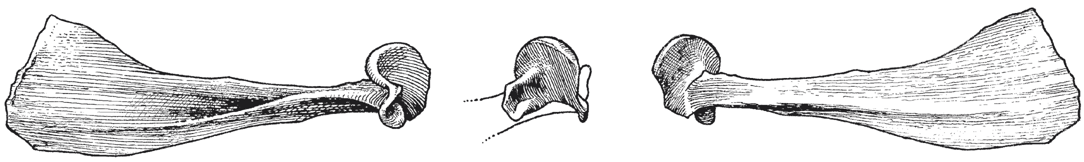
The Left Maxilla 5

Medial aspect **Lateral aspect**

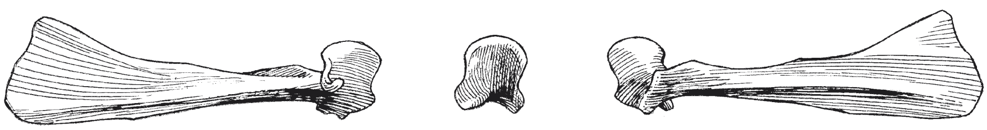


Latris lineata - Trumpeter

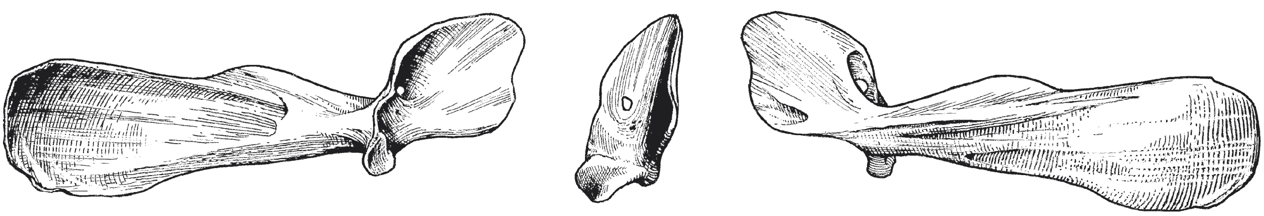
Seriolella brama - Blue warehou



Trachurus novaezelandiae - Horse mackerel



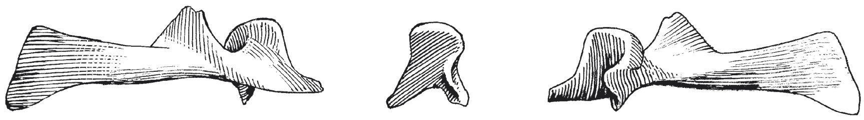
Scomber australasicus - Blue mackerel



Zeus faber - John dory

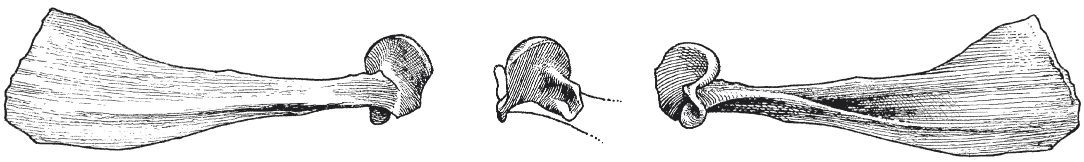
The Right Maxilla 5

Lateral aspect **Medial aspect**

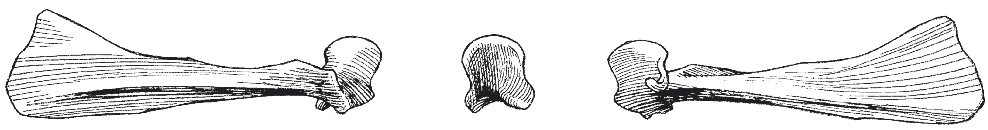


Latris lineata - Trumpeter

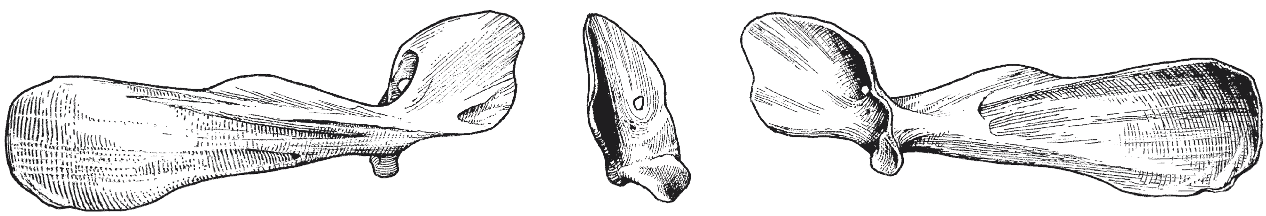
Seriolella brama - Blue warehou



Trachurus novaezelandiae - Horse mackerel



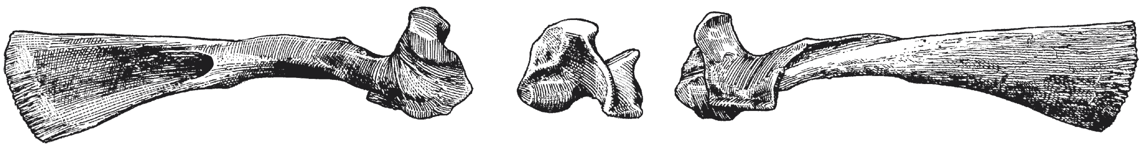
Scomber australasicus - Blue mackerel



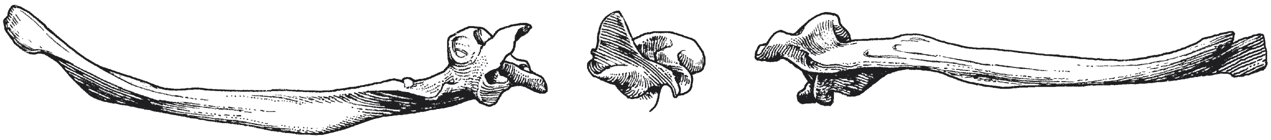
Zeus faber - John dory

The Left Maxilla 6

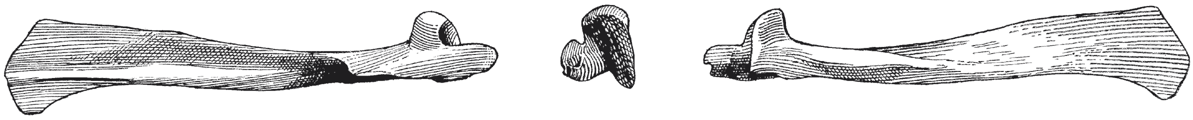
Medial aspect **Lateral aspect**



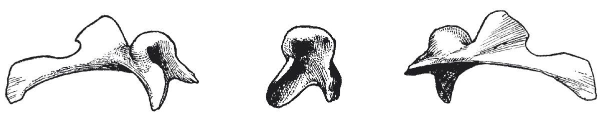
Arripis trutta - Kahawai



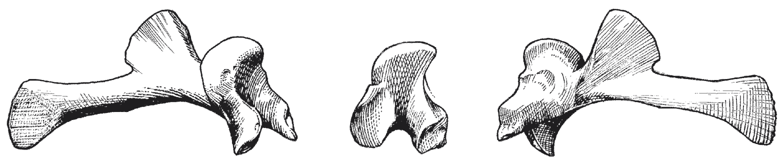
Pseudophycis bachus - Red cod



Chelidonichthys kumu - Red gurnard



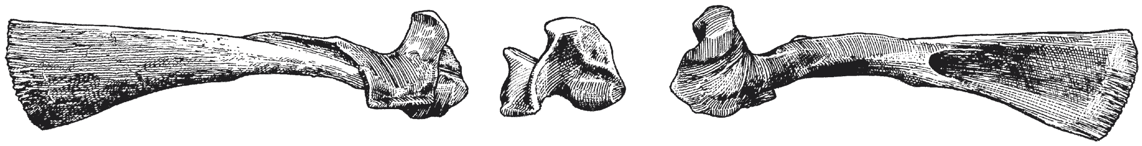
Nemadactylus macropterus - Tarakihi



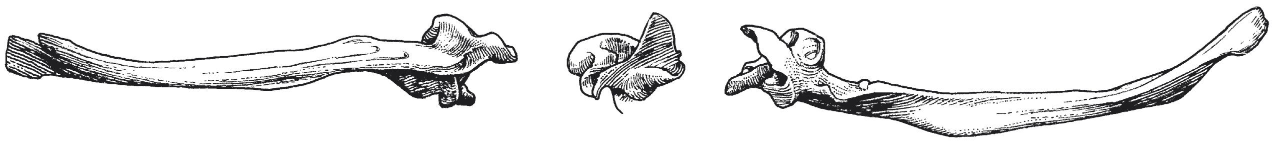
Latridopsis ciliaris - Blue moki

The Right Maxilla 6

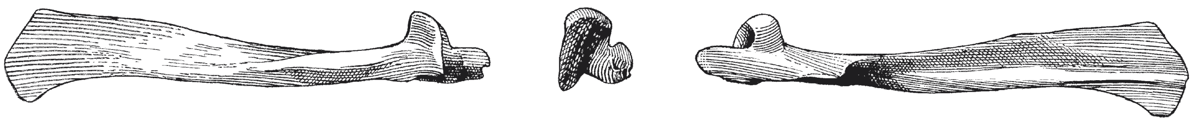
Lateral aspect **Medial aspect**



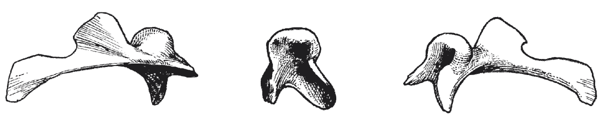
Arripis trutta - Kahawai



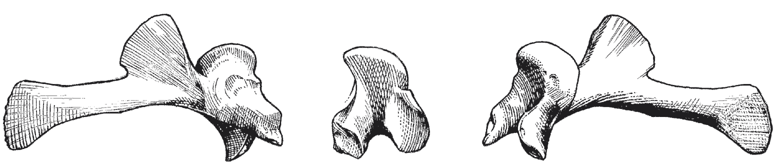
Pseudophycis bachus - Red cod



Chelidonichthys kumu - Red gurnard



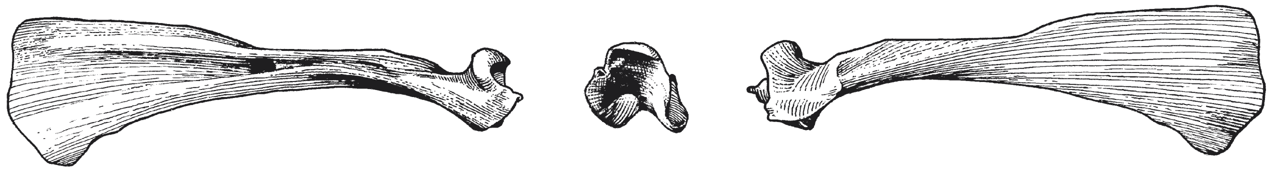
Nemadactylus macropterus - Tarakihi



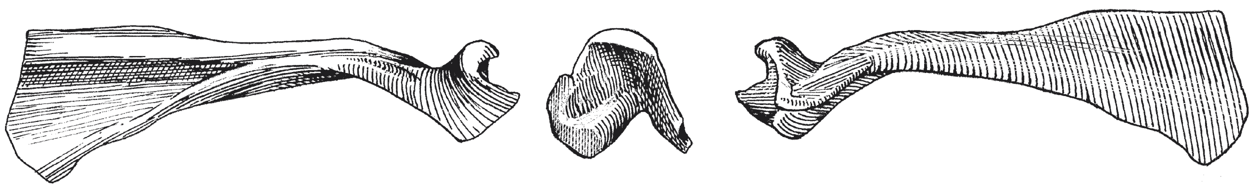
Latridopsis ciliaris - Blue moki

The Left Maxilla 7

Medial aspect **Lateral aspect**



Scorpaena papillosus - Red scorpionfish



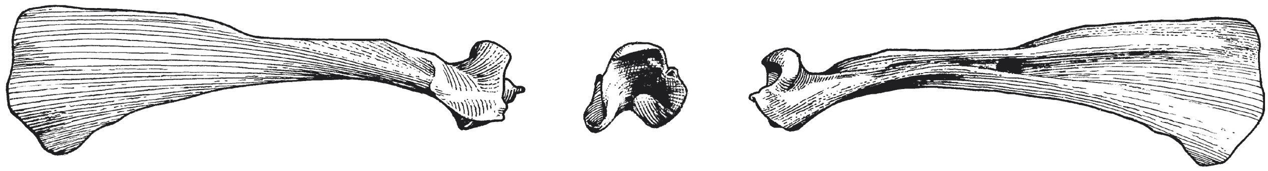
Helicolenus barathri - Sea perch

Parapercis colias - Blue cod

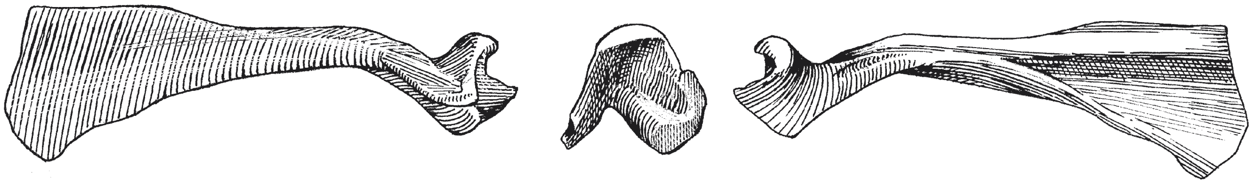
Notothenia angustata - Maori chief

The Right Maxilla 7

Lateral aspect **Medial aspect**



Scorpaena papillosus - Red scorpionfish



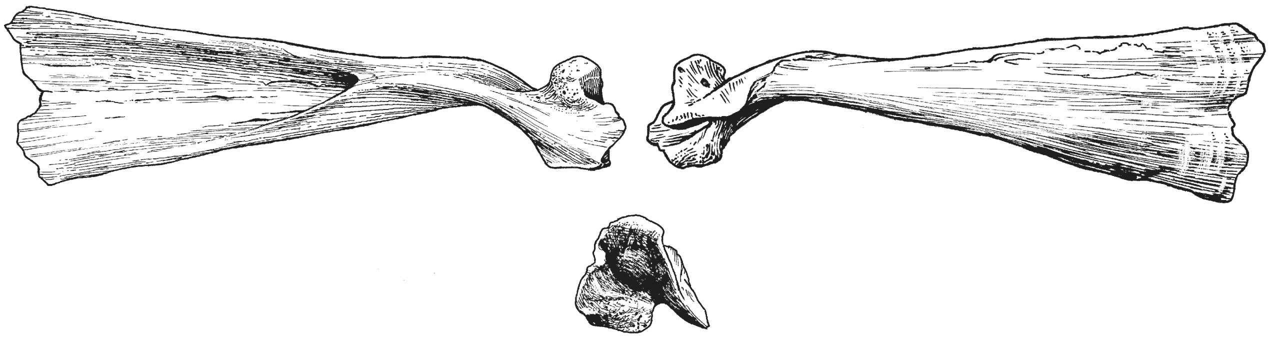
Helicolenus barathri - Sea perch

Parapercis colias - Blue cod

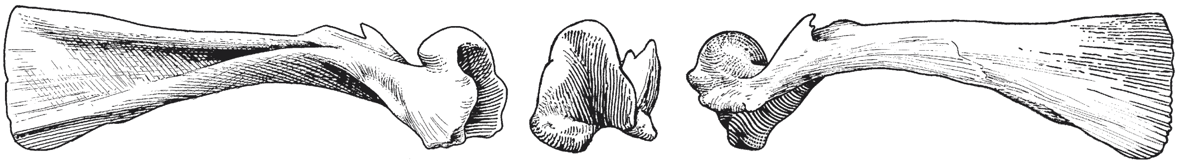
Notothenia angustata - Maori chief

The Left Maxilla 8

Medial aspect **Lateral aspect**



Polyprion oxygeneios - Hapuku, Groper



Seriola lalandi - Kingfish, Yellowtail kingfish

(not present in this species)

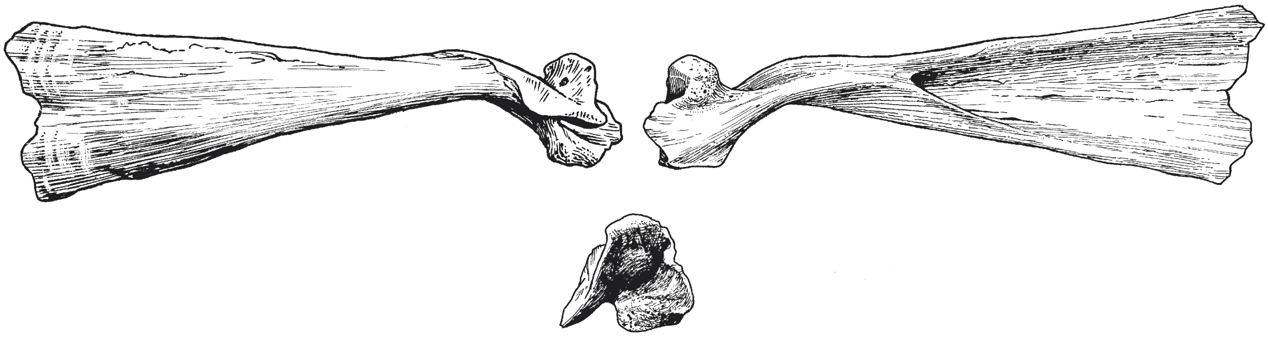
Anguilla dieffenbachii - Long-finned eel

(not present in this species)

Conger verreauxi - Conger eel

The Right Maxilla 8

Lateral aspect **Medial aspect**



Polyprion oxygeneios - Hapuku, Groper

Seriola lalandi - Kingfish, Yellowtail kingfish

(not present in this species)

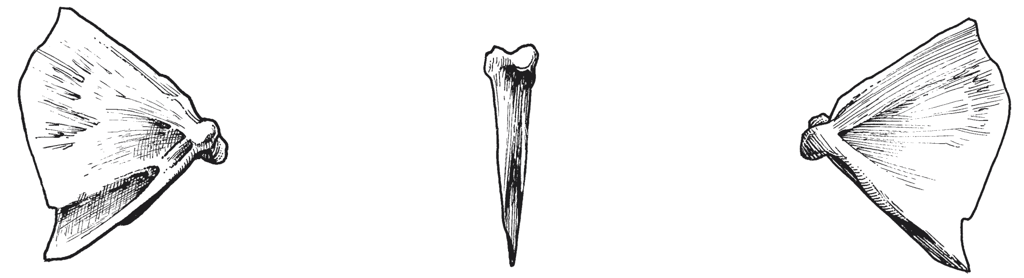
Anguilla dieffenbachii - Long-finned eel

(not present in this species)

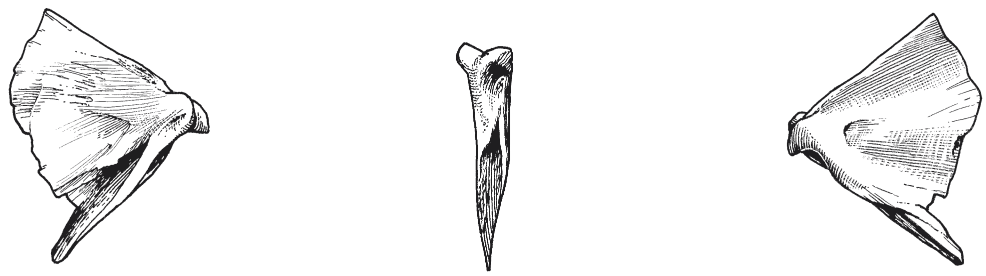
Conger verreauxi - Conger eel

The Left Quadrate 1

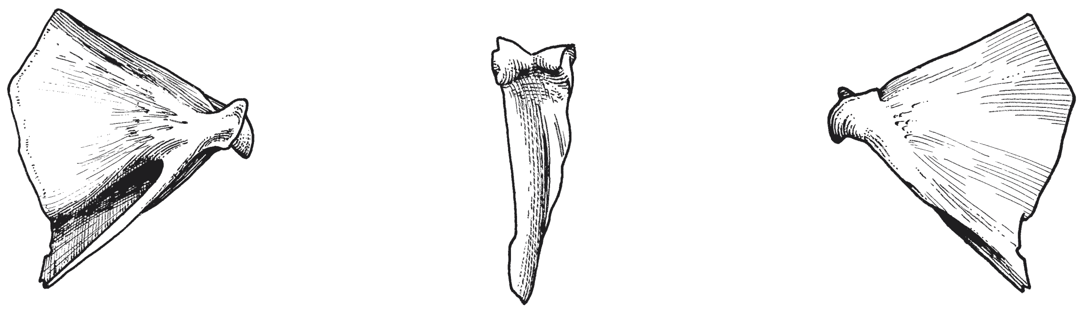
Medial aspect **Lateral aspect**



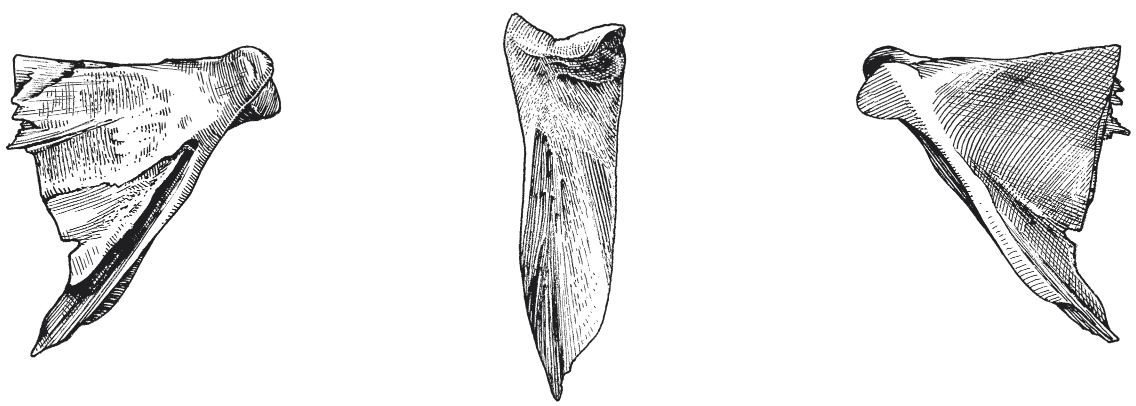
Thyrsites atun - Barracouta



Lepidopus caudatus - Frostfish



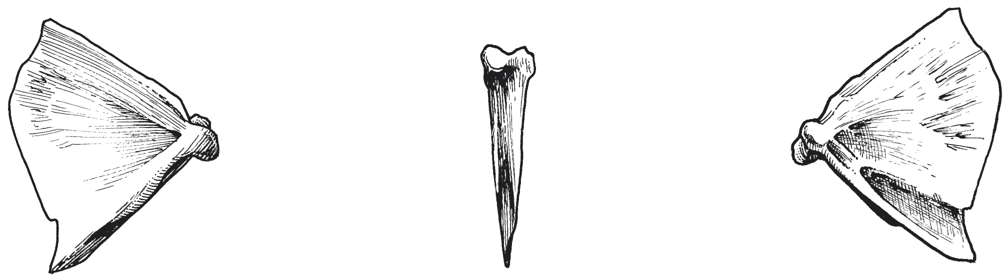
Rexea solandri - Gemfish



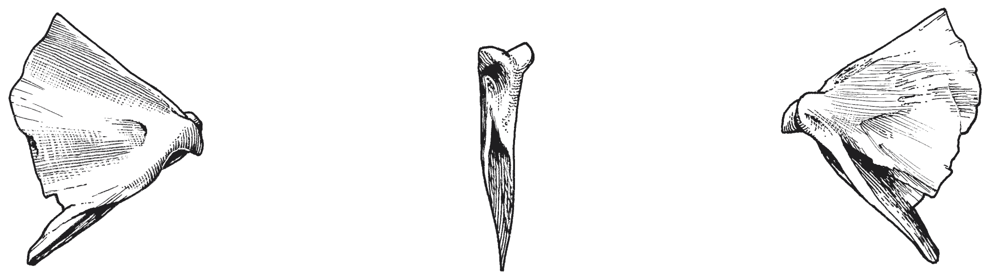
Leptoscopus macropygus - Estuary stargazer

The Right Quadrate 1

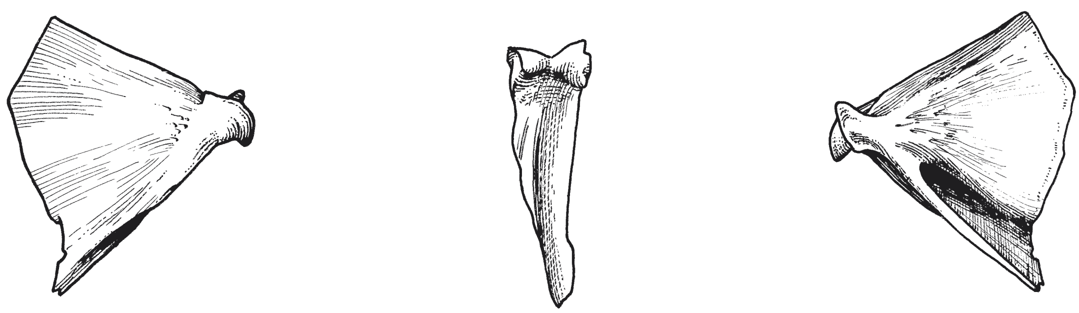
Lateral aspect **Medial aspect**



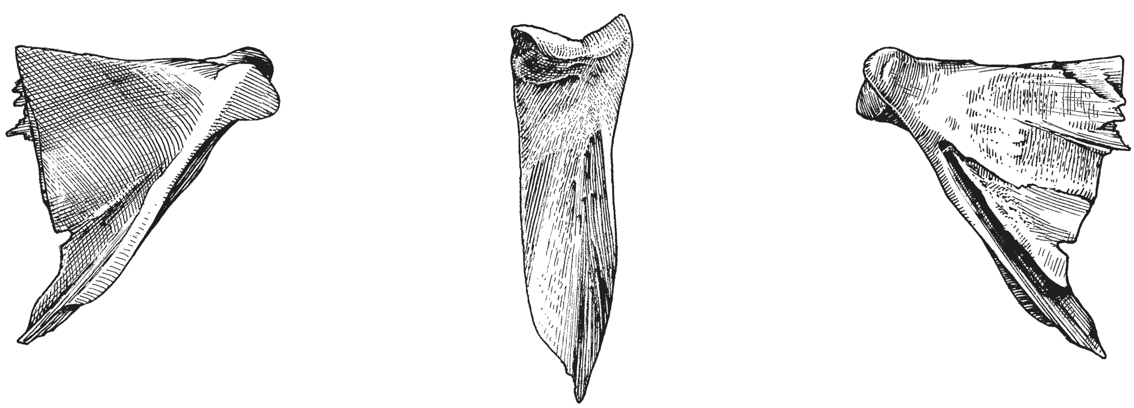
Thyrsites atun - Barracouta



Lepidopus caudatus - Frostfish



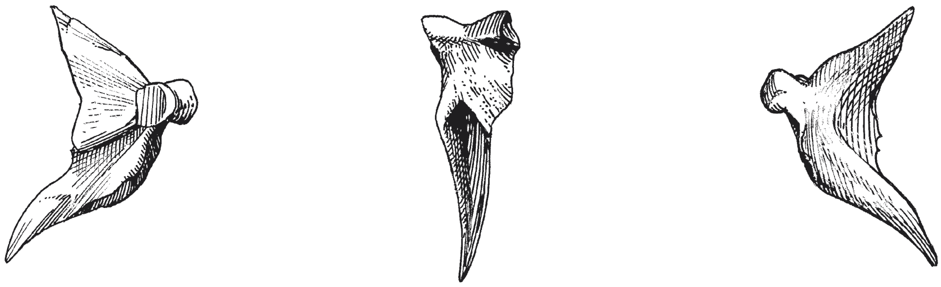
Rexea solandri - Gemfish



Leptoscopus macropygus - Estuary stargazer

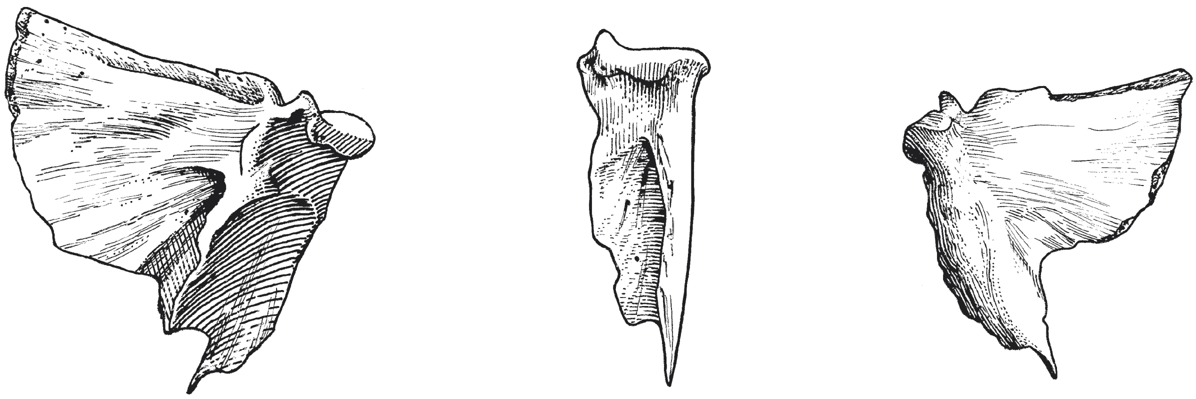
The Left Quadrate 2

Medial aspect **Lateral aspect**



Lotella rhacinus - Rock cod

Genypterus blacodes - Ling

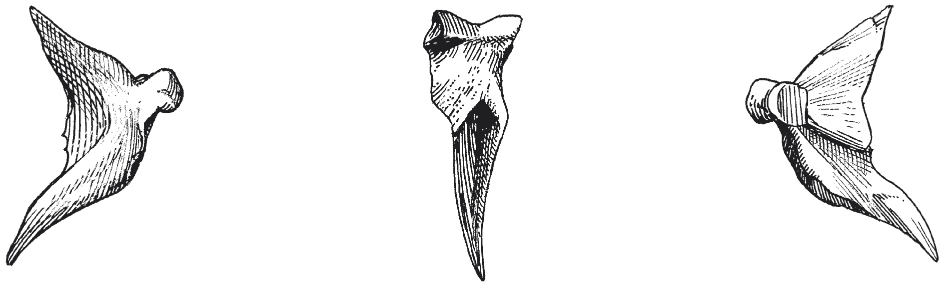


Pagrus auratus - Snapper

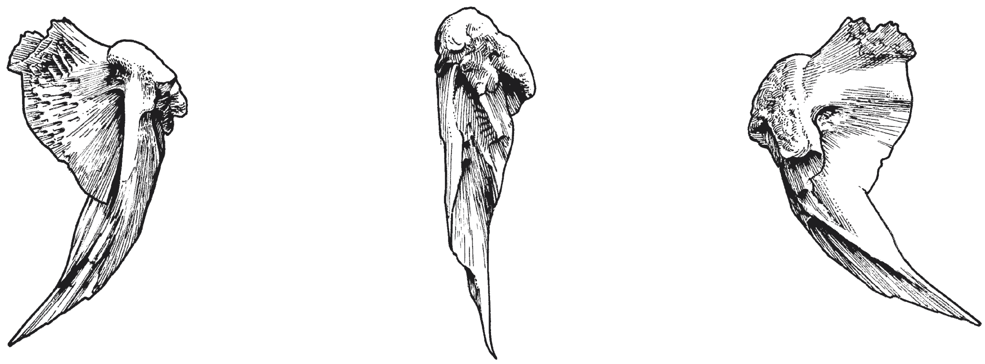
Pseudocaranx dentex - Trevally

The Right Quadrate 2

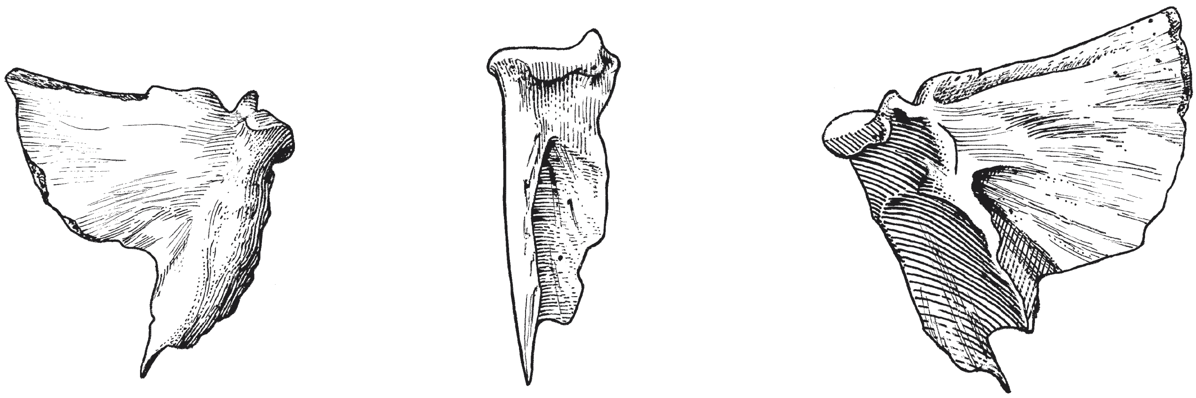
Lateral aspect **Medial aspect**



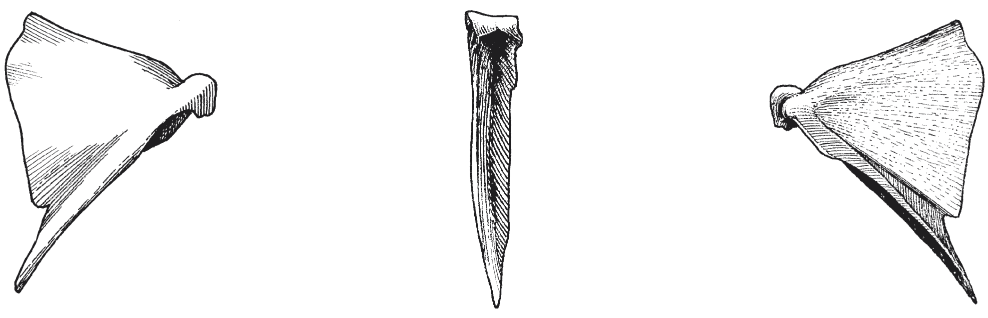
Lotella rhacinus - Rock cod



Genypterus blacodes - Ling



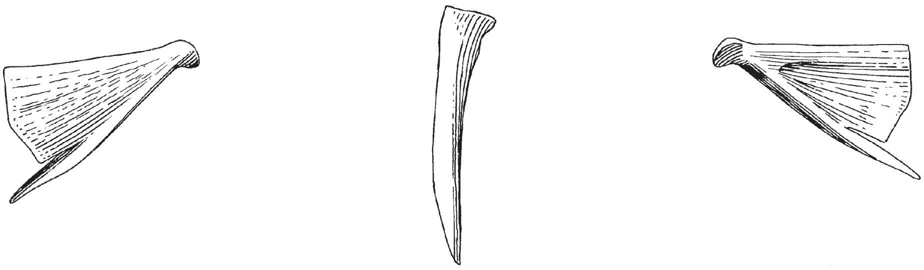
Pagrus auratus - Snapper



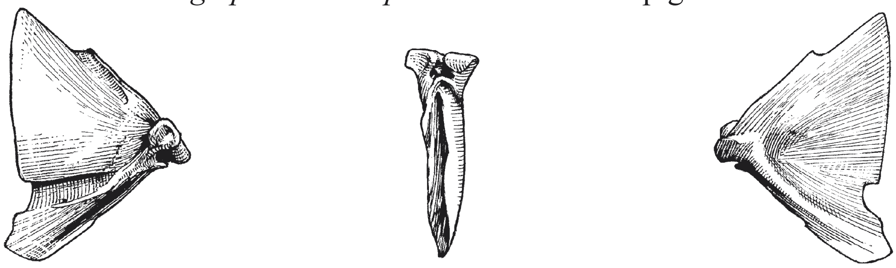
Pseudocaranx dentex - Trevally

The Left Quadrate 3

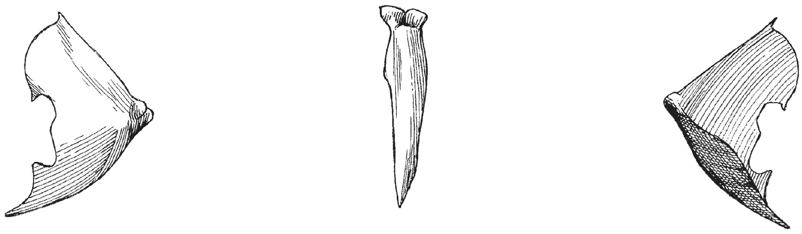
Medial aspect **Lateral aspect**



Congiopodus leucopaecilus - Southern pigfish



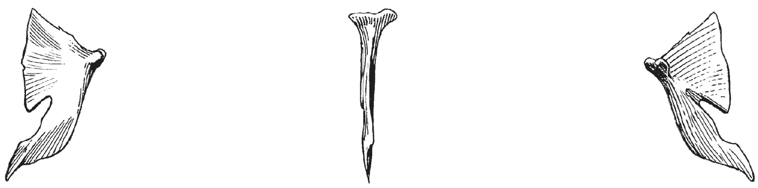
Notolabrus celidotus - Spotty



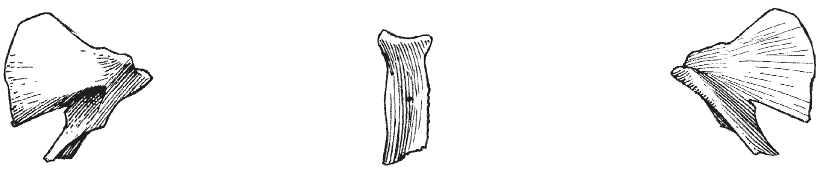
Odax pullus - Butterfish, Greenbone

(see text - page 33)

Rhombosolea leporina - Yellowbelly flounder



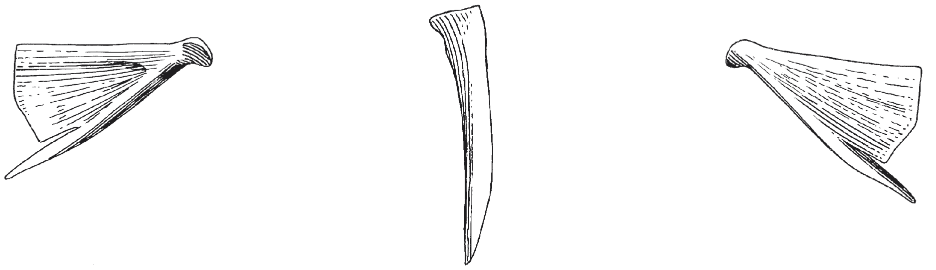
Mugil cephalus - Grey mullet



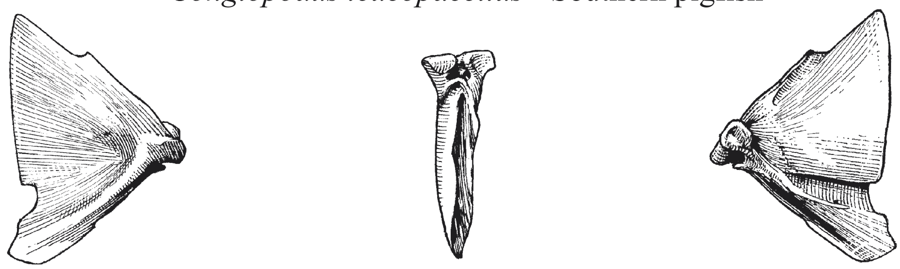
Aplodactylus arctidens - Marblefish

The Right Quadrate 3

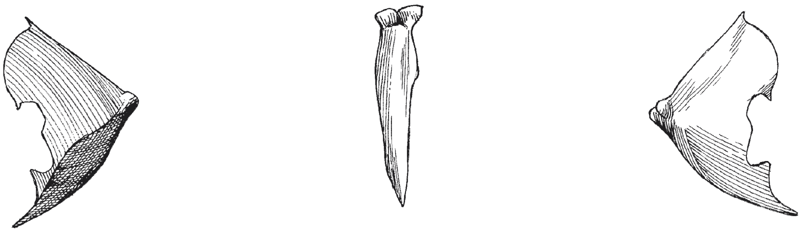
Lateral aspect **Medial aspect**



Congiopodus leucopaecilus - Southern pigfish



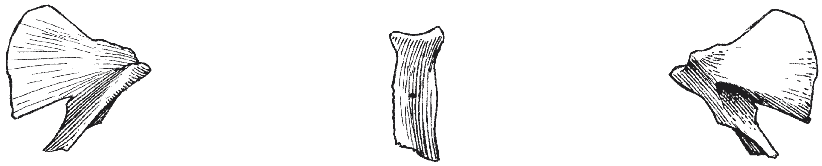
Notolabrus celidotus - Spotty



Odax pullus - Butterfish, Greenbone

Rhombosolea leporina - Yellowbelly flounder

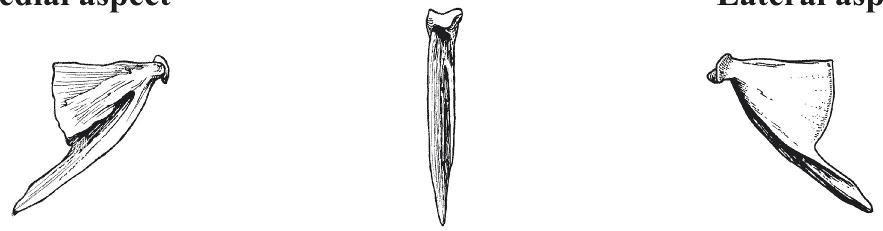
Mugil cephalus - Grey mullet



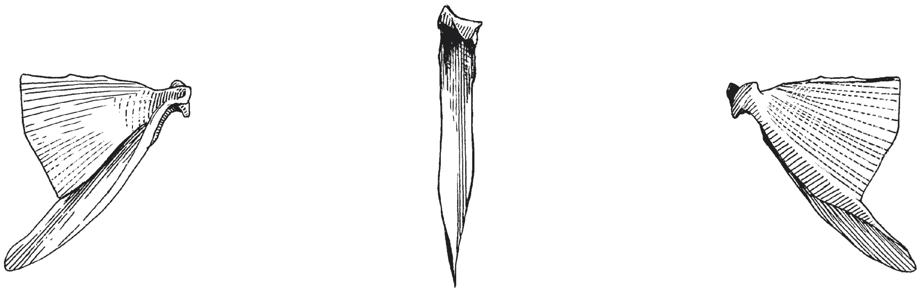
Aplodactylus arctidens - Marblefish

The Left Quadrate 4

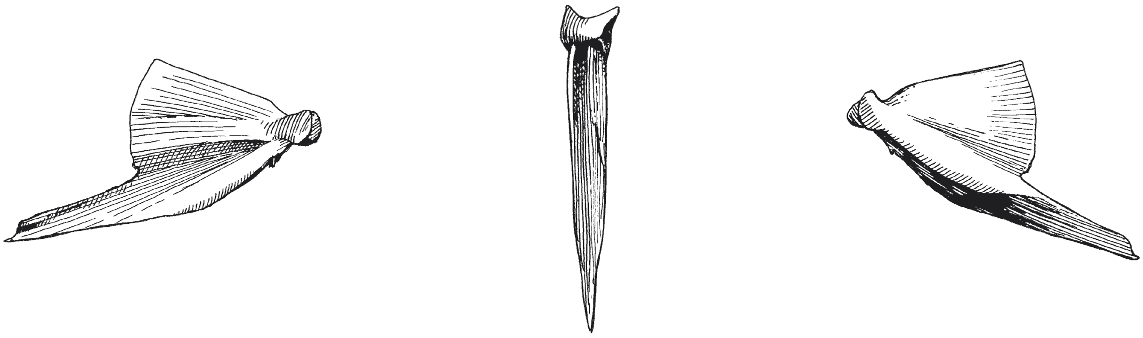
Medial aspect **Lateral aspect**



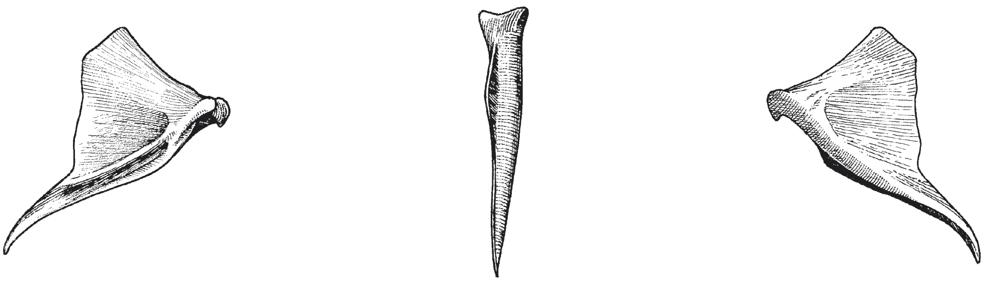
Thunnus albacares - Yellowfin tuna



Katsuwonus pelamis - Skipjack tuna



Thunnus alalunga - Albacore, Albacore tuna



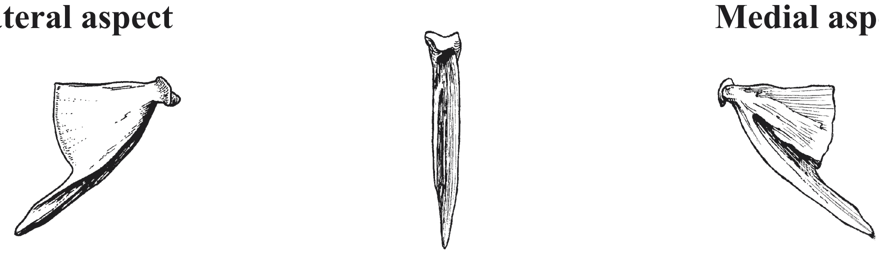
Naucrates ductor - Pilotfish

(see text - page 33)

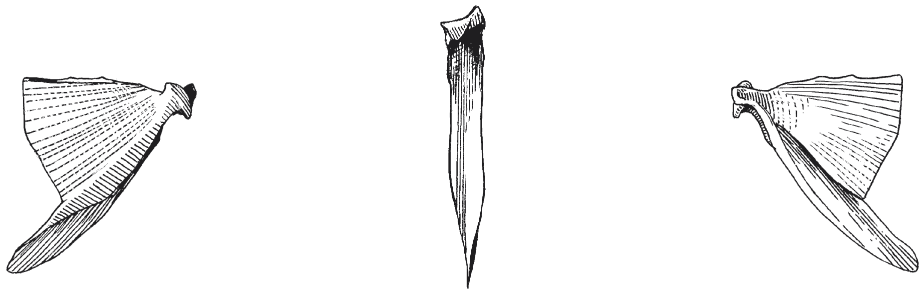
Scorpis violaceus - Blue maomao

The Right Quadrate 4

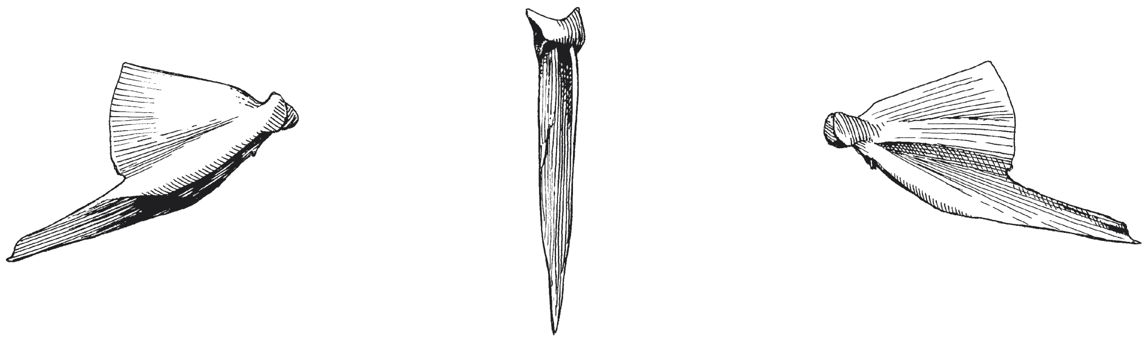
Lateral aspect **Medial aspect**



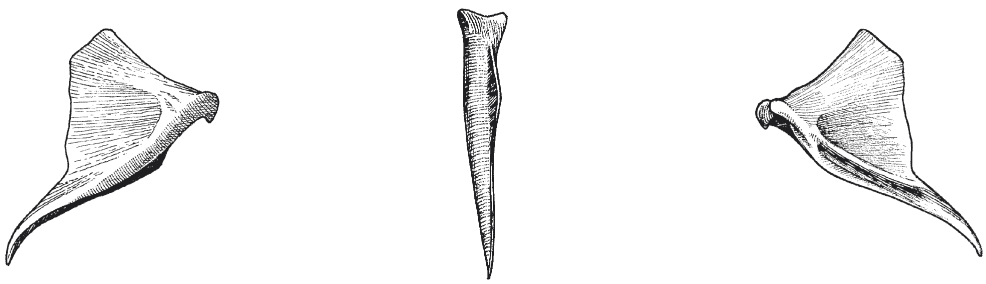
Thunnus albacares - Yellowfin tuna



Katsuwonus pelamis - Skipjack tuna



Thunnus alalunga - Albacore, Albacore tuna



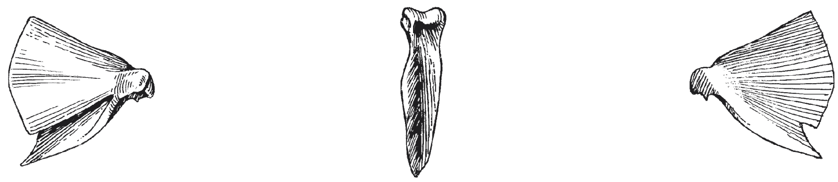
Naucrates ductor - Pilotfish

(see text - page 33)

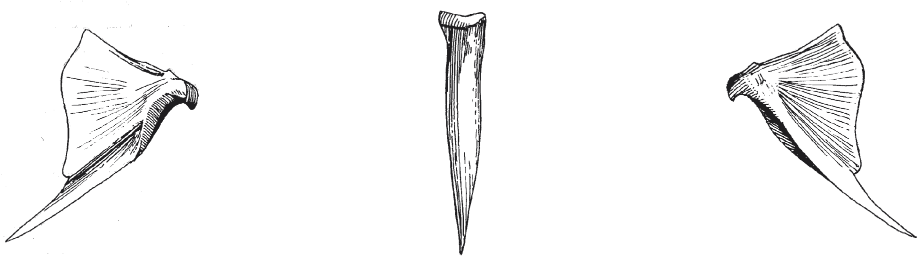
Scorpis violaceus - Blue maomao

The Left Quadrate 5

Medial aspect **Lateral aspect**



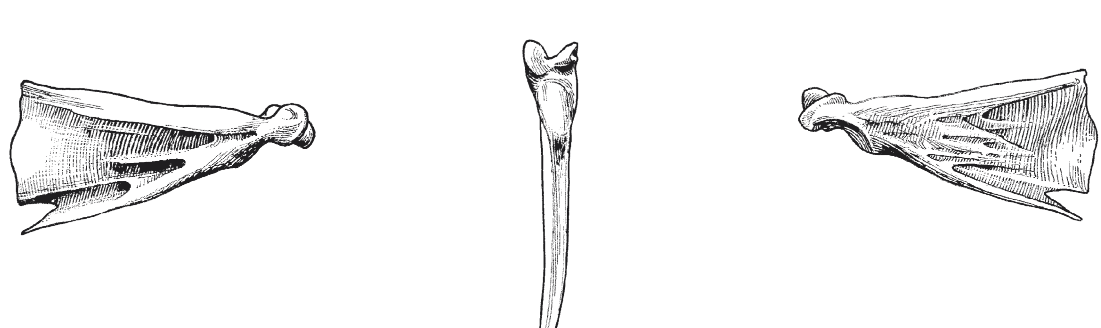
Latris lineata - Trumpeter



Seriolella brama - Blue warehou

Trachurus novaezelandiae - Horse mackerel

Scomber australasicus - Blue mackerel

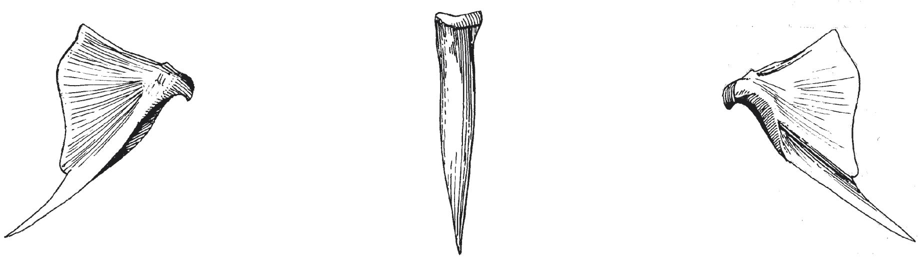


Zeus faber - John dory

The Right Quadrate 5

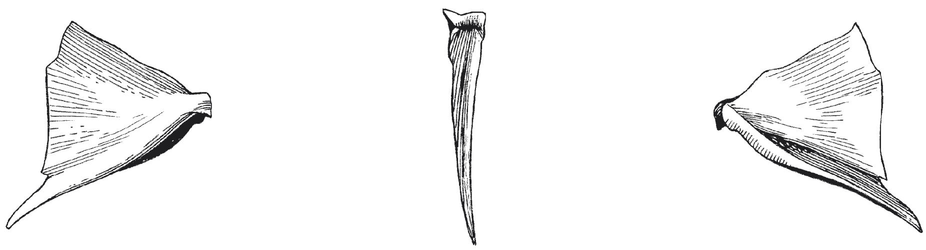
Lateral aspect **Medial aspect**

Latris lineata - Trumpeter

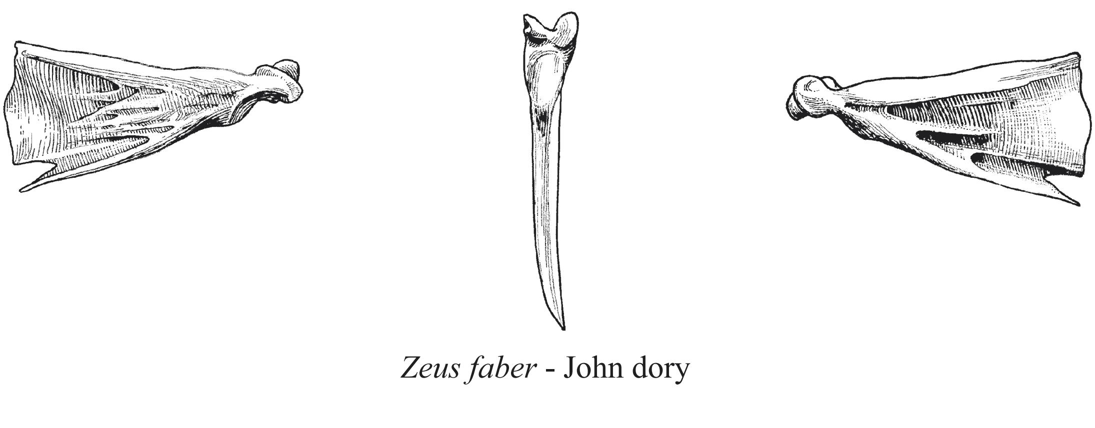


Seriolella brama - Blue warehou

Trachurus novaezelandiae - Horse mackerel



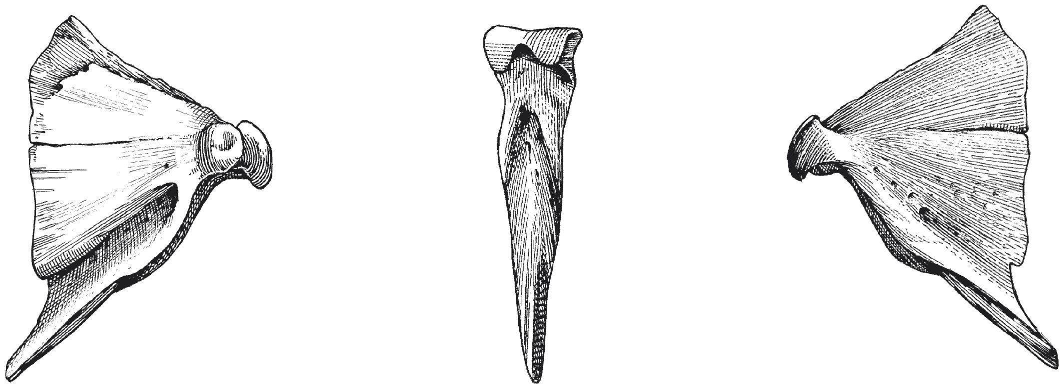
Scomber australasicus - Blue mackerel



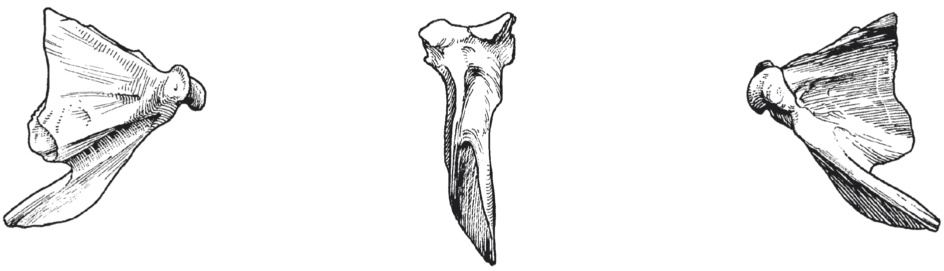
Zeus faber - John dory

The Left Quadrate 6

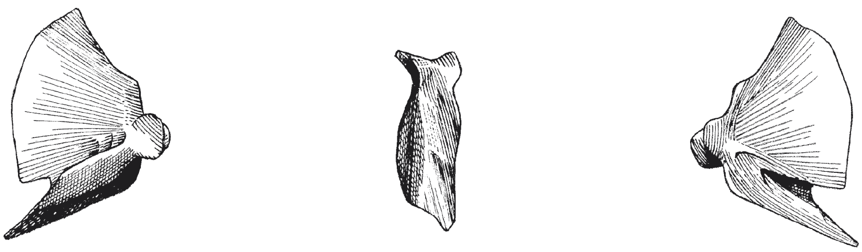
Medial aspect **Lateral aspect**



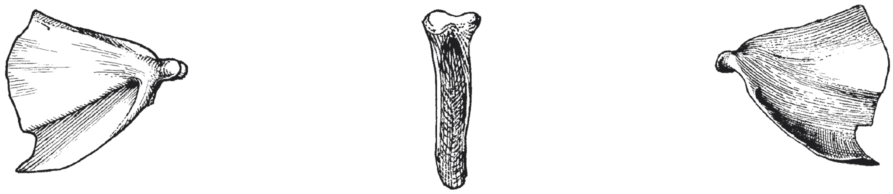
Arripis trutta - Kahawai



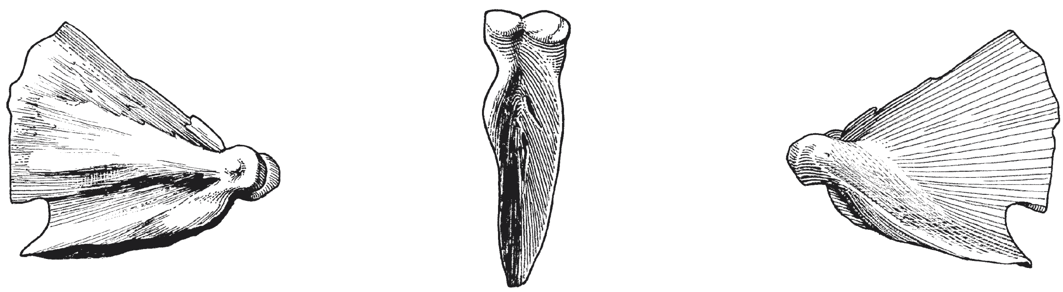
Pseudophycis bachus - Red cod



Chelidonichthys kumu - Red gurnard



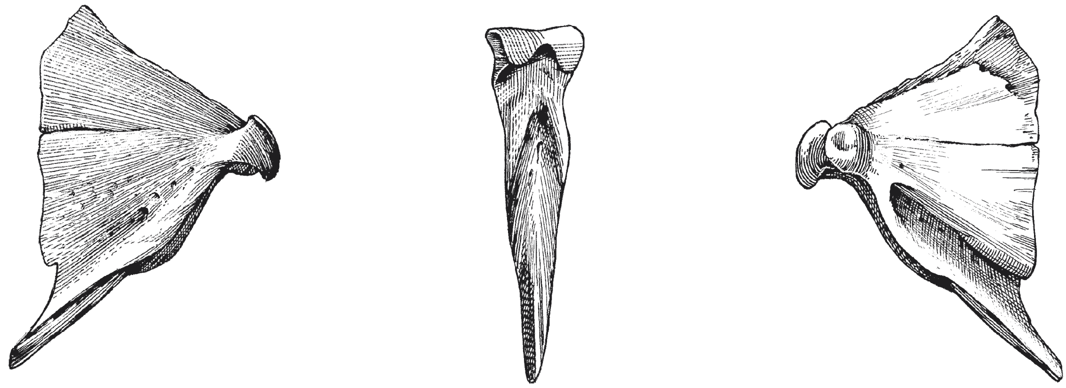
Nemadactylus macropterus - Tarakihi



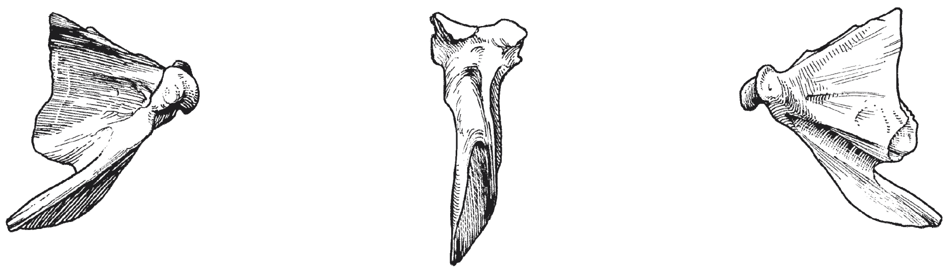
Latridopsis ciliaris - Blue moki

The Right Quadrate 6

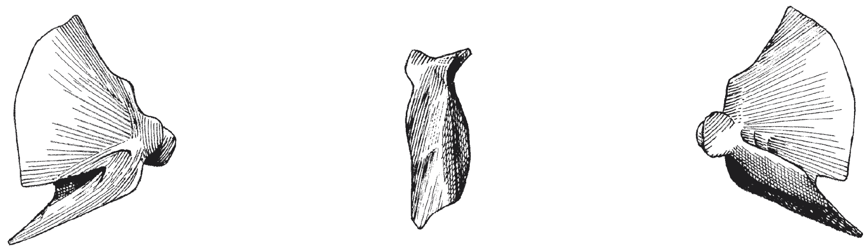
Lateral aspect **Medial aspect**



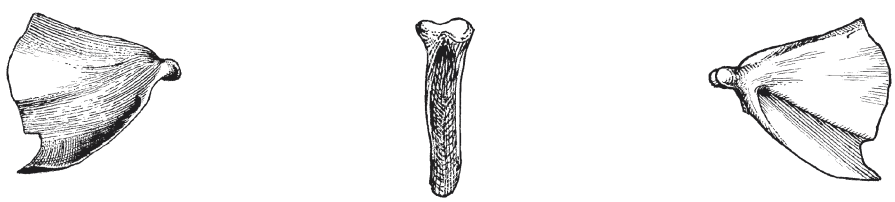
Arripis trutta - Kahawai



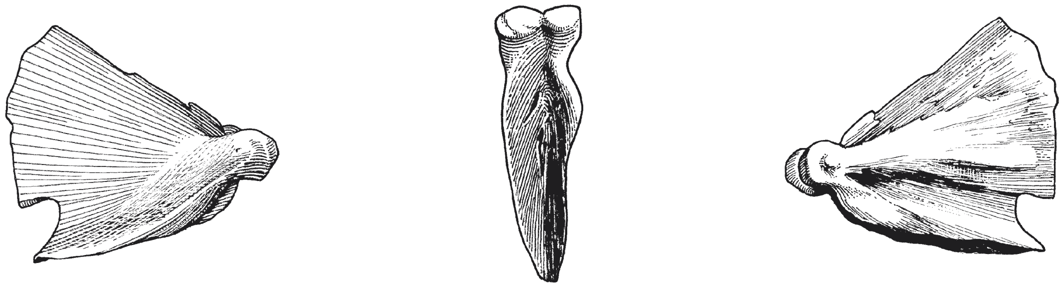
Pseudophycis bachus - Red cod



Chelidonichthys kumu - Red gurnard



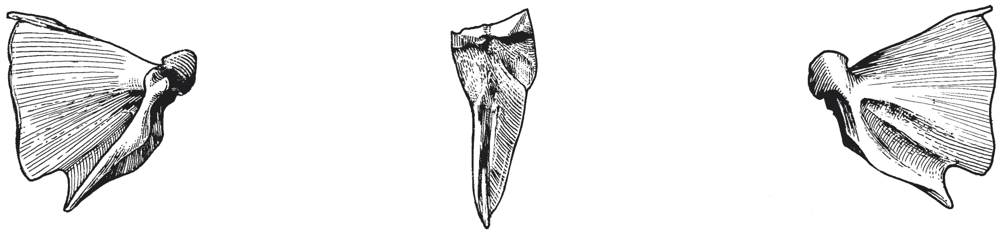
Nemadactylus macropterus - Tarakihi



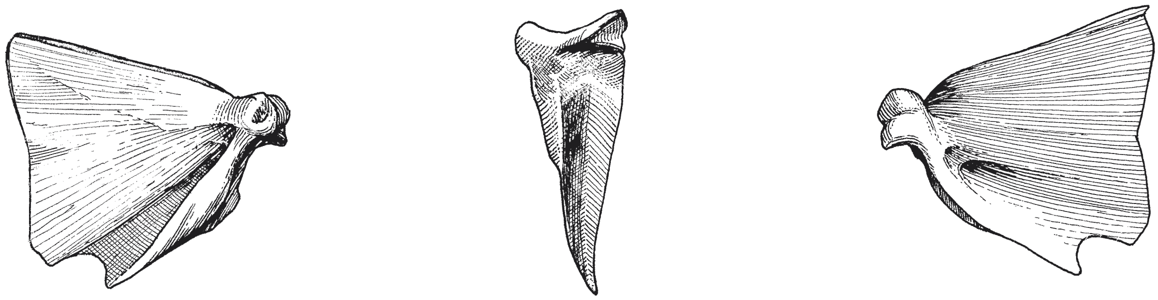
Latridopsis ciliaris - Blue moki

The Left Quadrate 7

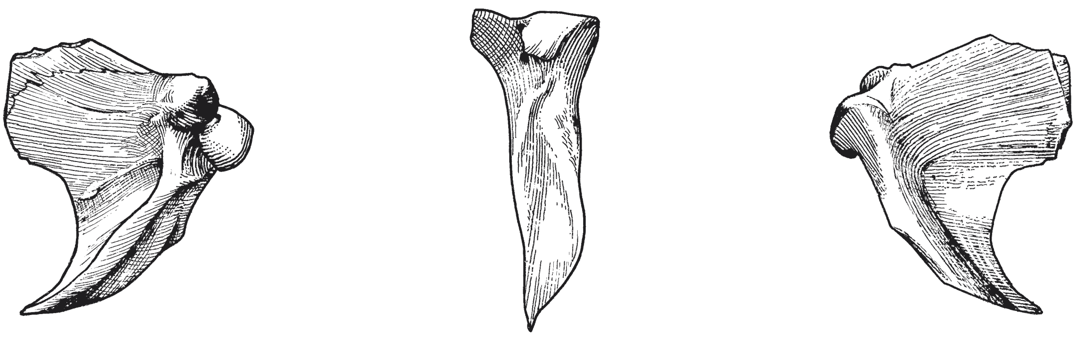
Medial aspect **Lateral aspect**



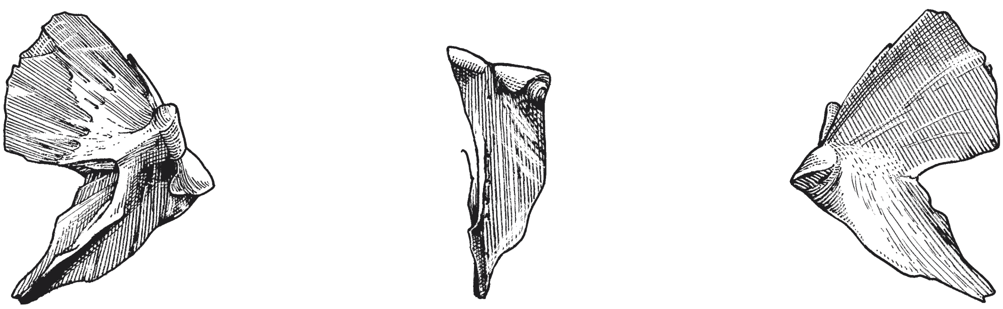
Scorpaena papillosus - Red scorpionfish



Helicolenus barathri - Sea perch



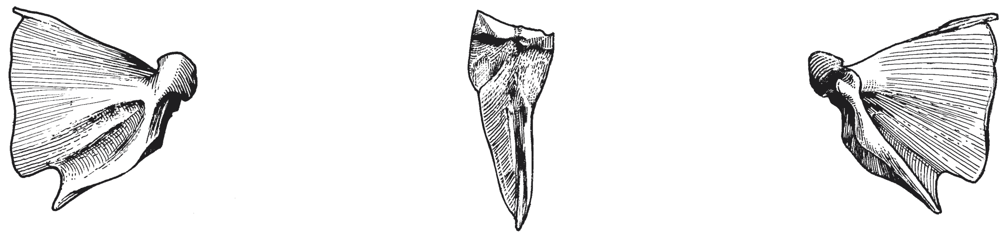
Parapercis colias - Blue cod



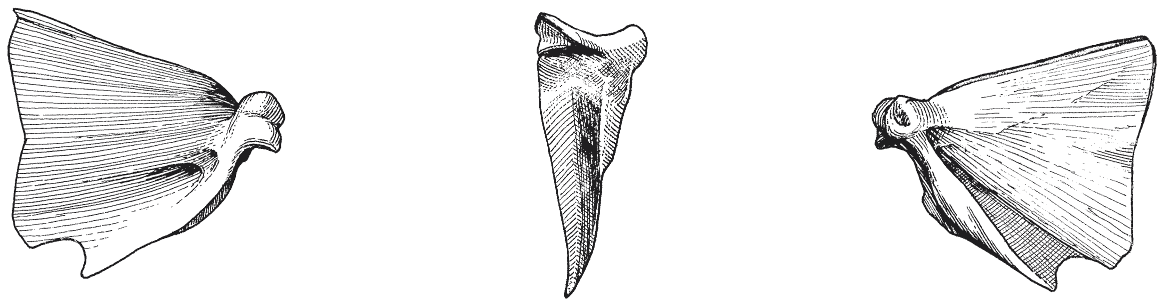
Notothenia angustata - Maori chief

The Right Quadrate 7

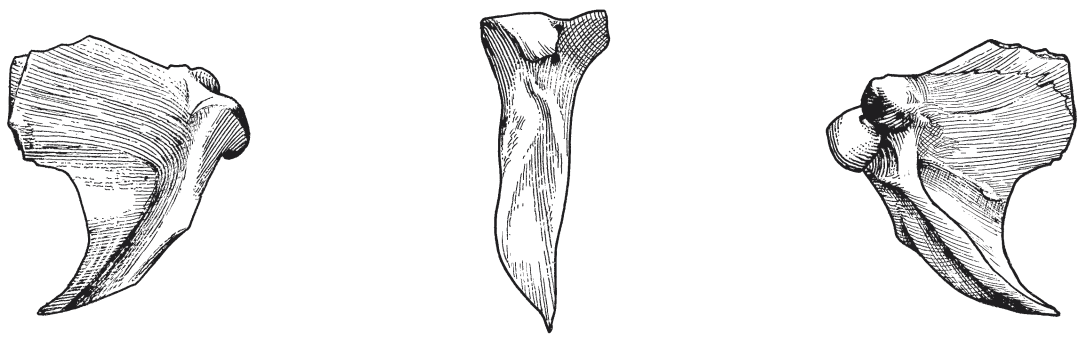
Lateral aspect **Medial aspect**



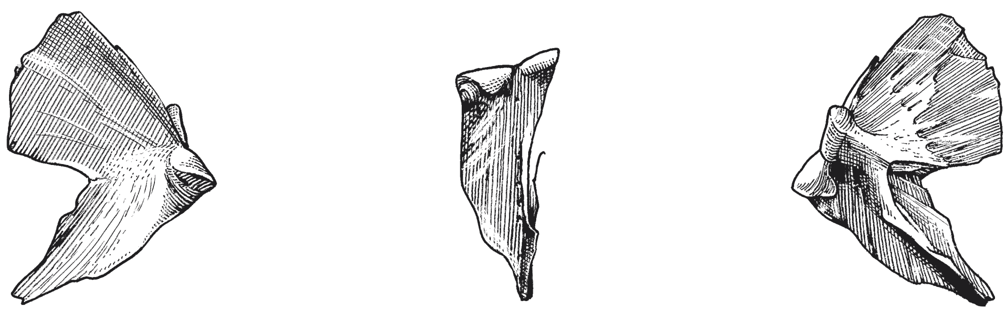
Scorpaena papillosus - Red scorpionfish



Helicolenus barathri - Sea perch



Parapercis colias - Blue cod

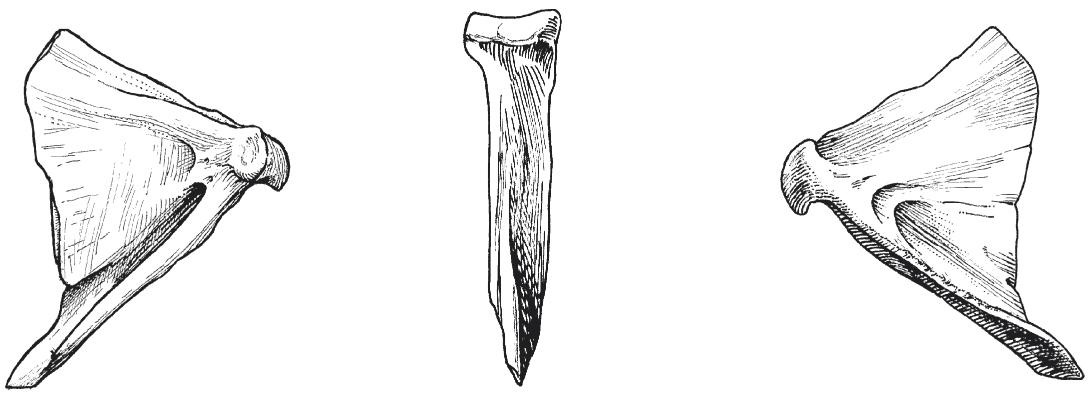


Notothenia angustata - Maori chief

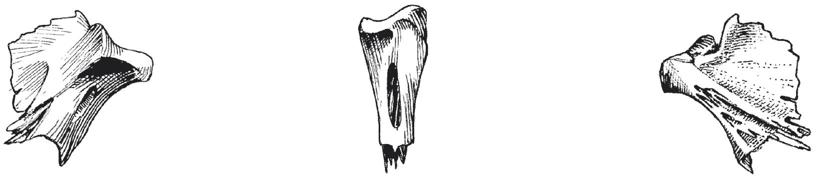
The Left Quadrate 8

Medial aspect **Lateral aspect**

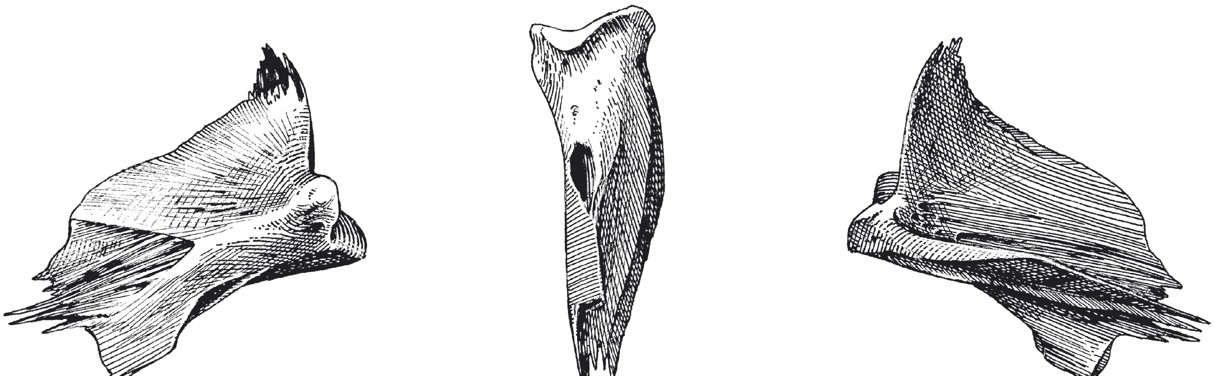
Polyprion oxygeneios - Hapuku, Groper



Seriola lalandi - Kingfish, Yellowtail kingfish



Anguilla dieffenbachii - Long-finned eel

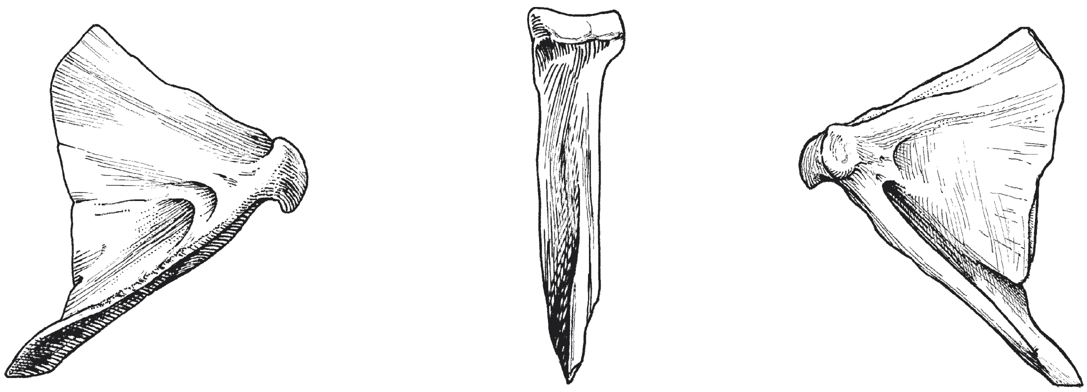


Conger verreauxi - Conger eel

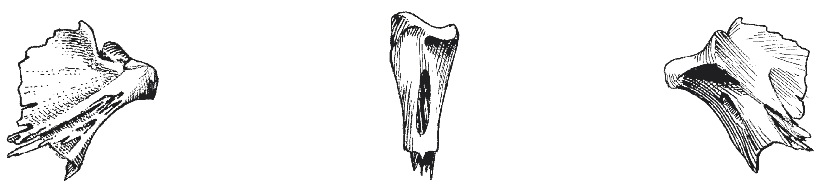
The Right Quadrate 8

Lateral aspect **Medial aspect**

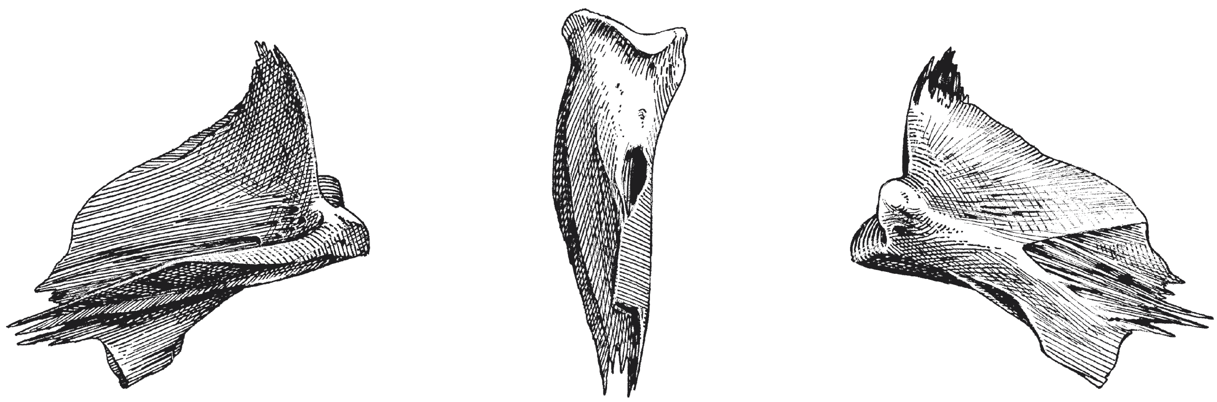
Polyprion oxygeneios - Hapuku, Groper



Seriola lalandi - Kingfish, Yellowtail kingfish



Anguilla dieffenbachii - Long-finned eel



Conger verreauxi - Conger eel