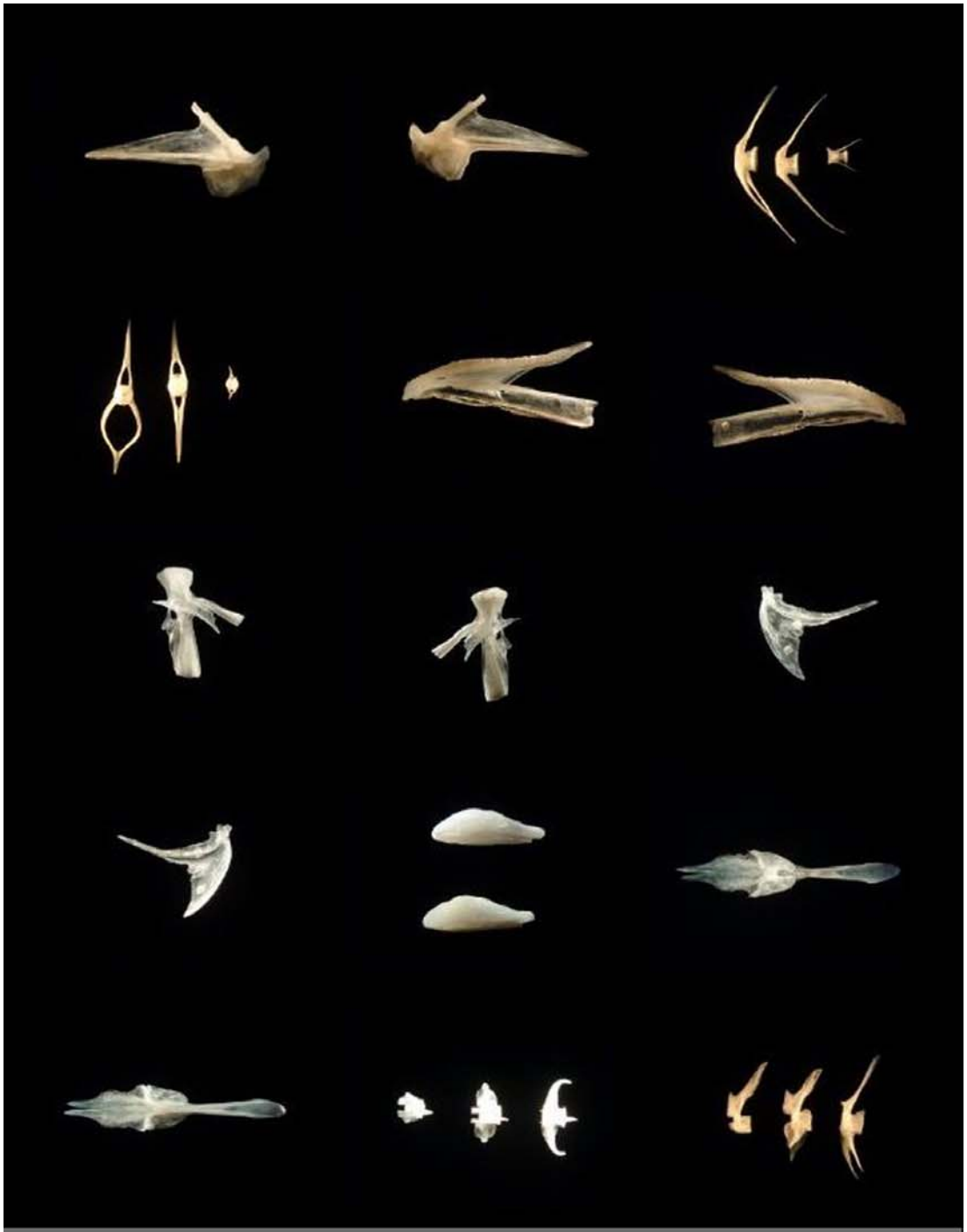

Virtual Comparative Collection of Diagnostic Fish Structures

Hawaii Biological Survey

Version 1.0 Beta April 2004

VIRTUAL COMPARATIVE COLLECTION OF DIAGNOSTIC FISH STRUCTURES

Version 1.0 Beta

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TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Past dietary studies provide a general picture of resource use by the endangered Hawaiian monk seal, *Monachus schauinslandi* (DeLong et al., 1984; Goodman-Lowe, 1998). However, increasing taxonomic resolution in dietary studies can vastly enhance management efforts. Upon identifying the prey species eaten, known depth and habitat use by prey can be used to more accurately infer where monk seals forage. Likewise, species-level dietary analysis can help to more accurately identify critical food resources and track dietary shifts with ontogeny, season or prey availability.

Currently, species-level identification of prey fish requires access to a large comparative collection of fish bones and an intimate knowledge of its contents. Unfortunately, there are few comparative collections, their creation and maintenance is time-consuming and costly, they require housing, and obtaining access can be difficult. Further, few foraging ecologists have the necessary familiarity with comparative fish osteology to realize the full potential of a comparative osteological collection. However, imaging technology presents the opportunity to give many researchers unlimited, virtual access to bone collections and to efficiently guide these researchers through the process of identifying fish remains to species.

Toward this end, the Hawaiian Monk Seal Research Program of the National Marine Fisheries Service (NMFS) has commissioned the creation of a digital image database incorporating a key to fish bone identification as a research tool for its foraging ecologists. This document plus the accompanying compact disc represent a prototype of the database. The organization of the prototype can be envisioned as an incomplete, two-dimensional matrix, where structures (bones, otoliths, scales) are the categories of one axis and fish species are the categories of the second axis. The prototype includes:

1. Images of a complete series of diagnostic structures (see Methods) from two fish species (a congrid eel, *Bathycongrus aequoreus*, and a morid cod, *Laemonema rhodochir*).

2. Images of the jaw bones (premaxilla, maxilla, dentary, angular) of 10 labrid (wrasse) species.
3. A key to the dentary bone of labrids.
4. A glossary of osteological terms.
5. A pictorial guide to fish bones and their features.

METHODS

Comparative bone collection at Bishop Museum and its history

Images of diagnostic structures from fishes were taken from a growing osteological collection housed at Bishop Museum. The collection houses approximately 200 species and its growth has occurred in four stages:

1. A collection of animal structures, including fish skeletons, was created by archaeologists at Bishop Museum. The information accompanying fish bones in the collection is sometimes limited to higher level or folk taxonomy. Some identifications are suspect. Method of preparation and individuals making determinations are not indicated.

2. Dr. Leslie Hartzell, Bishop Museum zooarchaeologist at the time, in cooperation with and funded by NMFS, expanded the fish bone collection. The expansion appears to have focused on shallow-water reef fishes. Skeletons were prepared by maceration (low-temperature cooking in water and detergent). Bishop Museum ichthyology collections manager Arnold Suzumoto identified some specimens, but in many cases the determiner is unknown.

3. The estate of the late Dr. Alan Zeigler donated his reference collection to Bishop Museum. All specimens were identified by Zeigler, but the method of preparation is unknown.

4. Dr. Ken Longenecker, guided by Arnold Suzumoto, and in cooperation with and funded by NMFS, is continuing the work of Hartzell. Targeted additions are

based upon analysis of monk seal spews performed by Longenecker and upon obtaining specimens of all species in fish families known to be important in monk seal diets. Skeletons are prepared by exposing specimens to dermestid beetles. Scales and otoliths are included with the final preparation. All specimens are identified by Longenecker, frequently aided by Suzumoto.

Photographic techniques

Specimens selected for imaging are those from families known to be important in the diet of Hawaiian monk seals. If a structure is paired, the left member [per the standard ichthyological taxonomic methodology of Hubbs & Lagler (1947)] was photographed. All structures were photographed from at least two aspects. The aspect of each image is indicated in its file name. Structures were photographed with a Fujifilm FinePix 3800 digital camera programmed for incandescent lighting and macrophotography with an aperture setting of f/8.2. Structures were mounted on insect pins above a background of black velvet and illuminated with a fiberoptic light source. Lighting was arranged to best highlight surface structure on the subject. This lighting technique departs from the recommended archival photographic techniques of Dorrell (1989) (illumination from the top of an object as seen in a frame), but approximates the arrangement typically used with dissecting microscopes (illumination from both sides). Photographs were taken directly, or through a dissecting microscope fitted with a polarizing filter, at the highest magnification that included the whole structure in the field of view. Images and a key were incorporated into the management program SuperJPG. A guide to using SuperJPG as a photo identification program for monk seal work was prepared by Harding (2003). The user is directed to that guide and SuperJPG documentation for instructions on using the program.

An image of a whole specimen of each species in the database is also included. Annotations were added to all images. Whole specimens are annotated with their binomial and author, source used for identification, photographer (if other than Longenecker), collection locality and depth, length of specimen, and Bishop Museum

catalog number of the structures photographed. Individual structures are annotated with collection number, magnification and determiner.

Diagnostic structure series

Images from two specimens (*Bathycongrus aequoreus* and *Laemonema rhodochir*) prepared by Longenecker illustrate the structures commonly found in seal spews (personal observation) and described as useful taxonomic indicators by Wheeler & Jones (1989). These structures are the: saggital otoliths, premaxilla, maxilla, dentary, articular, quadrate, hyomandibular, vomer, parasphenoid, basioccipital, supraoccipital, pterotic, frontal, opercular, preopercular, 3 precaudal vertebrae, 3 caudal vertebrae, and 6 scales. The three vertebrae selected for the precaudal and caudal series represent the range of conditions for each vertebral type. The six scales are taken from standardized locations (Casteel, 1974):

1. The nape, or anterior to the dorsal fin.
2. High on the flank, or dorsolaterally.
3. Low on the flank, or ventrolaterally.
4. The dorsal surface of the caudal peduncle, or posterior to the dorsal fin.
5. High, or dorsolaterally, on the caudal peduncle.
6. Low, or ventrolaterally, on the caudal peduncle.

A slide with the word “absent” in the database indicates that a species anatomically lacks the structure. If a specimen was damaged and the structure was lost, a slide with the phrase “missing from specimen” is included in the database.

Because the neurocranium of fishes is often found relatively intact in seal spews, an image is included for each species. Like the neurocranium, some bones are often found in an articulated state (the dentary and angular of eels). For these cases, the articulated bones were photographed from at least two aspects and keyed to appear with images of the component structures.

Specialized structures are common in some fish groups. For instance the Anguilliformes (eels) have a premaxillo-ethmo-vomer. This bone is the fusion of the premaxilla, vomer, ethmoid and lateral ethmoid. It is keyed to appear whenever one of its constituent bones is selected in SuperJPG.

Comparative structure series

Images of the premaxilla, maxilla, dentary and angular from each of 10 labrid species (*Anampses cuvier*, *Bodianus bilunulatus*, *Cheilio inermis*, *Coris flavovittata*, *Iniistius pavo*, *Oxycheilinus unifasciatus*, *Stethojulis balteata*, *Thalassoma ballieui*, *Thalassoma duperrey*, *Thalassoma purpureum* and *Thalassoma trilobatum*) demonstrate the comparative potential for the database. Labrids were selected because they are important in the diet of monk seals (Goodman-Lowe, 1998; personal observation) and the wrasses are the best represented of any fish family in Bishop Museum's osteological collection.

Identification key

Images of labrid dentaries were assigned to keys to demonstrate how the database can efficiently guide researchers toward species-level identification of fish remains. Adding key functions to other bones would be premature at this point: Because the characters that would reduce choices most efficiently will change as more images are added to the database, extensive keying at this time would not be an economical use of funds or time.

Glossary and pictorial guide

A glossary of osteological terms based on Rojo (1991) was constructed to assist users of the database. The glossary is accompanied by a pictorial guide to structures and their features.

RESULTS

203 images representing up to 18 diagnostic structures from 12 species are included in the prototype on the accompanying compact disc. Images of labrid dentaries are assigned to keys which can be used to quickly reduce the number of possible matches for a bone

found in monk seal scats or spews. A glossary of 53 osteological terms applicable to the database and an accompanying pictorial guide are located in Appendix I.

DISCUSSION

Images from a comparative collection of fish remains can greatly enhance understanding of Hawaiian monk seal biology by aiding in the species-level identification of gut contents. These images give remote, unlimited access to an unlimited number of researchers while eliminating the cost, effort and space required for individual researchers to build a reference collection. However, any comparative collection used for dietary analysis must include the complete range of possible prey organisms to guarantee high confidence in species-level analysis.

The comparative collection of fish remains at Bishop Museum is large, but not exhaustive. Further, past efforts at expanding the collection did not focus on fish families known to be important in the diet of monk seals. Consequently, none of the families included in the collection are represented by all of the species known to occur in Hawai‘i. For example, the Labridae are the best represented family in the comparative collection yet only 25% of the wrasses known to occur in Hawai‘i are present in the collection.

Ongoing expansion efforts are based upon concurrent dietary analysis using monk seal spews. Families known to be important in seal diets are targeted for field collection, with the goal of obtaining specimens of all species in the family. This approach will result in a database that will be useful as it is being constructed. I recommend continued expansion efforts in this manner to increase the utility of the digital reference collection.

REFERENCES CITED

Casteel, R.W. 1974. On the remains of fish scales from archaeological sites. American Antiquity. 39:557-581.

DeLong, R.L., G.L. Kooyman, W.G. Gilmartin & T.R. Loughlin. 1984. Hawaiian monk seal diving behavior. Acta Zool. Fennica. 172:129-131.

Dorrell, P.G. 1989. Photography in Archaeology and Conservation. Cambridge University Press. Cambridge, England. 262 pp.

Gilbert, C.H. 1905. The deep-sea fishes of the Hawaiian Islands. In: The aquatic resources of the Hawaiian Islands. Bulletin of the United States Fishery Commision. 577-713.

Goodman-Lowe, G.D. 1998. Diet of the Hawaiian monk seal (*Monachus schauinslandi*) from the Northwestern Hawaiian islands during 1991 to 1994. Marine Biology. 132:535-546.

Harding, A. 2003. System for managing monk seal digital imaging. Harting Biological Consulting. Bozeman, Montana. 34 pp.

Hardy, G.S. 1983. The status of *Torquigener hypselogeneion* (Bleeker) (Tetraodontiformes: Tetraodontidae) and some related species, including a new species from Hawaii. Pacific Science 37(1):65-74.

Hubbs, C.L. & K.F. Lagler. 1947. Fishes of the Great Lakes Region. Cranbook Inst. Sci. Bull. 26:1-186.

Randall, J.E. 1996. Shore Fishes of Hawaii. Natural World Press. Vida, Oregon. 216 pp.

Rojo, A.L. 1991. Dictionary of Evolutionary Fish Osteology. CRC Press. Boca Raton, Florida. 273 pp.

Waples, R.S., & J.E. Randall. 1989. A revision of the Hawaiian lizardfishes of the genus Synodus, with descriptions of four new species. Pacific Science 42:177-213.

Wheeler, A. & K.G. Jones. 1989. Fishes. Cambridge University Press. New York, New York. 210 pp.

Appendix A: Glossary of Osteological Terms

Acrodont – A term applied to teeth fixed to the biting surfaces of bone by connective tissue. Most fish teeth are acrodont.

Angular – A paired bone forming the posterior section of the lower jaw and the articulation with the quadrate. In teleosts, it is typically triangular with the anterior angle fitting into the posterior bifurcation of the dentary (see Figure 1). *Synonym*: articular.

Ankylose – To join or consolidate; fuse.

Ankylosis – The consolidation of fusion of bones to form a single unit.

Apophysis – A narrow extension from the body of a bone.

Articular – See Angular.

Articular process – An extension from the dorsal edge of the premaxilla, posterior to the ascending process. This process is found in most derived actinopterygians and acts as a fulcrum for the maxillary when the mouth opens (see Figure 2).

Articulation – The area of contact between two bones.

Ascending process – A vertical extension from the anterior part of the premaxillary. This process is found in most teleosts (see Figure 2).

Caniniform – A term applied to teeth that are conical or elongated and have a sharp end. They may be straight or curved. These teeth are typical of predaceous fishes.

Cardiform – A term applied to teeth that are numerous, short, fine and pointed. The term refers to the fine-toothed card used to prepare wool. These teeth are found in many members of the Serranidae.

Caudal process – A posterior extension from the premaxilla (see Figure 2).

Chevron – "V"-shaped. The term also applies to the ventral "V"-shaped scales of some members of the Clupeidae.

Condyle – A rounded protuberance at the end of a long bone. A condyle typically forms part of an articulation.

Coronoid process – The dorsal, posterior branch of the dentary (see Figure 3); ***also***, a dorsal extension from the angular (see Figure 1).

Crest – A long, narrow protrusion from the surface of a bone.

Cuneiform - A term applied to teeth shaped like a wedge or arrowhead.

Deciduous – A structure likely to be lost (as in weakly attached teeth or scales).

Dentary – A paired bone forming the anterior section of the lower jaw. Anteriorly, both dentaries meet at the mandibular symphysis. Typically there are two posterior processes, the dorsal, coronoid process and a ventral process (see Figure 3).

Dentigerous – Bearing teeth.

Diastema – A space between teeth in the jaw.

Edentulous – Without teeth

Ethmoid – A median bone formed in the nasal septum between the two nasal capsules. In the Anguilliformes, the premaxilla is ankylosed to the ethmoid, lateral ethmoid and vomer.

Face – A term applied to the surface of any bone.

Facet – A flat to slightly curved surface on a bone. A facet is typically part of an articulation.

Fissure – Any naturally-occurring furrow or groove on the surface of a bone.

Foramen – Any hole in a bone through which nerves or blood vessels pass.

Fossa – A cavity, forming the articulating surface of a bone, receiving the process of another bone.

Head – A round process on a bone.

Heterodont – A term applied to teeth that vary in shape and size within the same individual.

Homodont – A term applied to teeth that are all the same shape and size within an individual.

Incisiform – A term applied to teeth used for cutting and similar in appearance to mammalian incisors

Incisure – Any naturally-occurring notch or cleft in a bone.

Lateral ethmoid – A paired bone present in teleosts. In the Anguilliformes, the premaxilla is ankylosed to the lateral ethmoid, ethmoid and vomer.

Mandibular symphysis – The articulation between the dentaries.

Maxilla – A paired bone of the upper jaw located posterior to the premaxilla. *Synonym*: Maxillary (see Figure 4).

Maxillary – See Maxilla.

Maxillar symphysis – The articulation between the premaxillae.

Molariform – A term applied to teeth with flat surfaces used for crushing or grinding. These teeth are similar in appearance to mammalian molars.

Mosaic – See Pavement.

Pavement – A term applied rows of teeth packed into large Figures. *Synonym*: Mosaic.

Pleurodont – A term applied to teeth implanted in the lateral surface of a bone. These teeth are found in some members of the Balistidae and Scaridae.

Postmaxillary process – An extension from the posterior half of the dorsal surface of the premaxilla. The postmaxillary process prevents the lateral dislocation of the premaxilla when the mouth opens (see Figure 2).

Premaxilla – A paired bone forming the anterior part of the upper jaw (see Figure 2). *Synonym*: Premaxillary.

Premaxillary – See Premaxilla.

Prevomer – See Vomer.

Process – Any extension from the body of a bone. Processes are named according to size and shape (*e.g.*, apophysis, condyle, head, tuberosity).

Quadrate – A paired bone which, in most teleosts, has a triangular shape. The anteroventral angle of the quadrate articulates with the angular, acting as a pivot for the lower jaw.

Retroarticular – A bone attached to the posterioventral portion of the angular. It does not form part of the mandibular articulation. (see Figure 1)

Suture – A joint composed of thin connective tissue, such that there is no movement between the two bones.

Symphysis – A joint in which the two bony surfaces are firmly united by cartilaginous tissue.

Villiform – A term applied to long, thin teeth.

Vomer – A paired bone, frequently dentigerous, forming the anterior roof of the palate. In derived actinopterygians, the pair is ankylosed to form a single bone. In the Angulliformes, the premaxilla is ankylosed with the vomer, ethmoid and lateral ethmoid. *Synonym*: Prevomer.

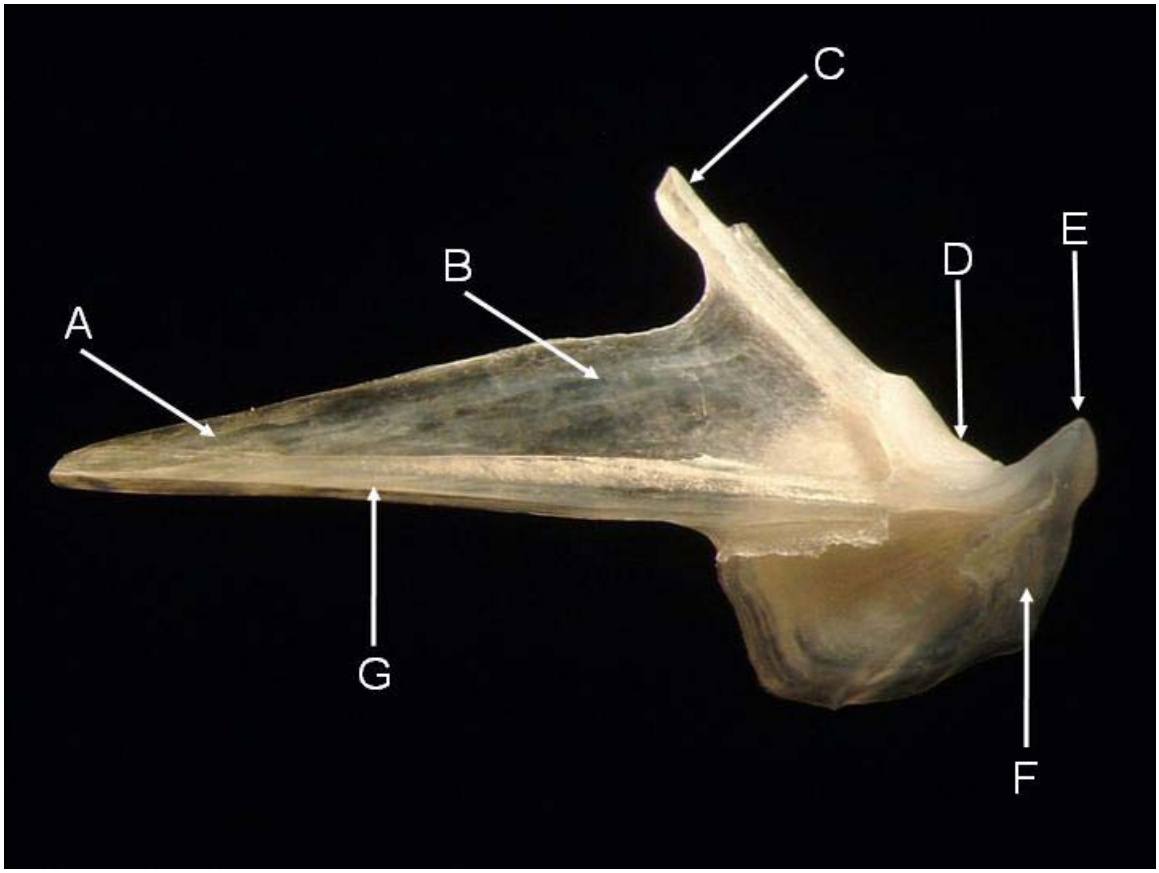

Figure 1. Features of the angular (from *Laemonema rhodochir*). A = anterior process, B = prearticular fossa, C = coronoid process, D = quadrate facet, E = postarticular process, F = retroarticular, G = inferior crest.

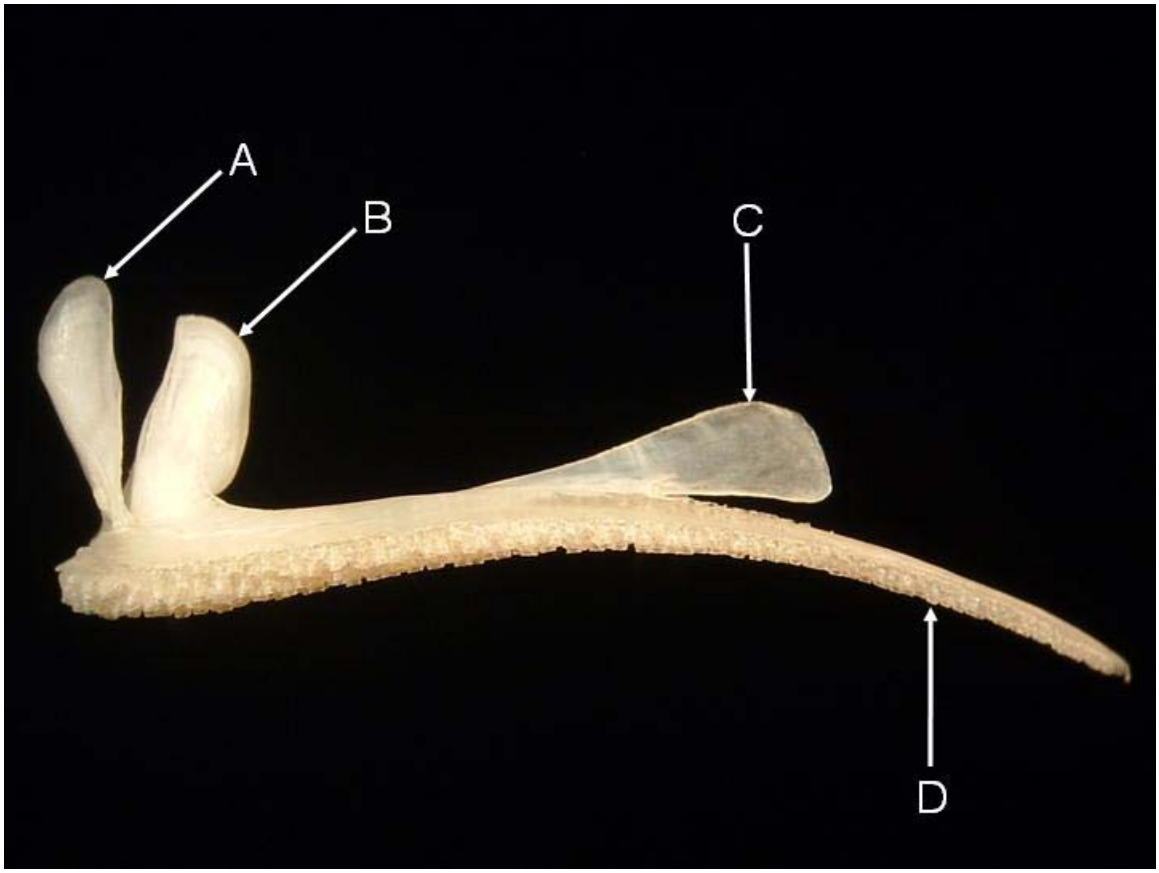

Figure 2. Features of the premaxilla (from *Laemonema rhodochir*). A = ascending process, B = articular process, C = postmaxillary process, D = caudal process

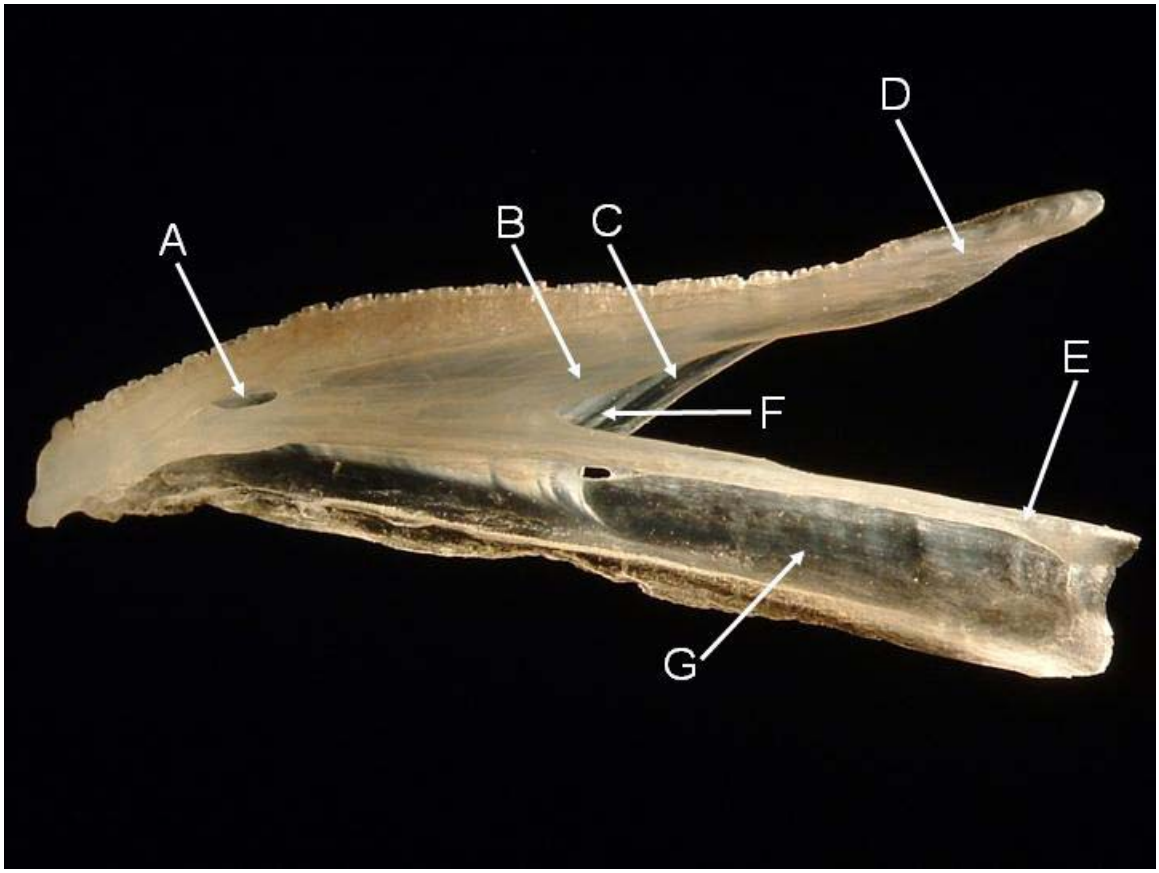

Figure 3. Features of the dentary (from *Laemonema rhodochir*). A = mental foramen, B = external wall, C = internal wall, D = coronoid process, E = sensory canal, F = meckelian fossa, G = ventral process.

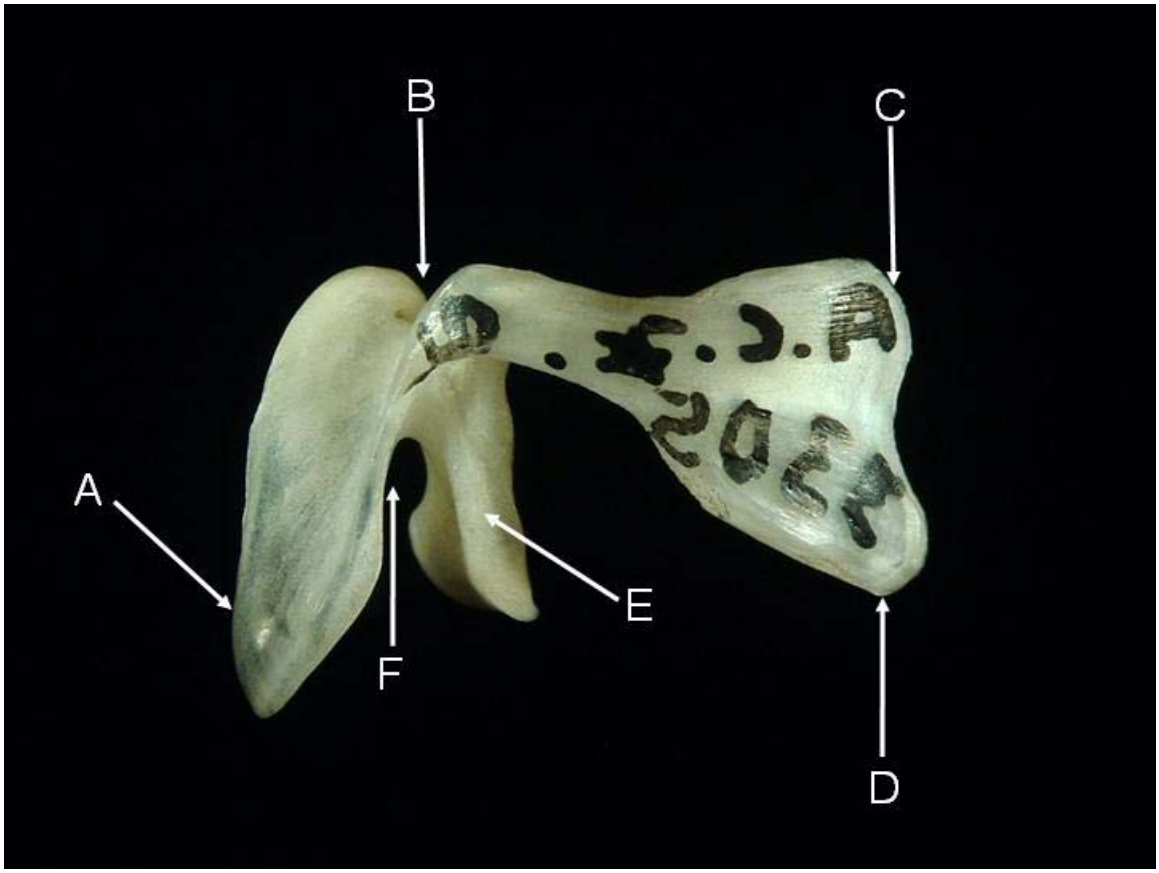

Figure 4. Features of the maxilla (from *Anampses cuvier*). A = external process, B = palatine sulcus, C = maxillary process, D = caudal process, E = internal process, F = premaxillary sulcus.