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OSTEOLOGICAL STUDIES ON THREE SPECIES OF CARANGOIDES (FAMILY: CARANGIDAE)

V. K. VENKATARAMANI*, N. RAMANATHAN* AND R. NATARAJAN

Centre of Advanced Study in Marine Biology Porto Novo 608 502, Tamil Nadu, India

ABSTRACT

The systematic status of three closely related carangid fishes namely *Carangoides malabaricus* (Bl. & Schn.), *Carangoides talamparoides* Blkr. and *Carangoides chrysophrys* (Cuv. & Val.) was clarified by employing osteological studies. All the three species were identified as *Carangoides malabaricus* by earlier authors. The taxonomic status of *Carangoides talamparoides* often synonymised with *Carangoides malabaricus* by earlier authors was assessed through the use of detailed osteological characters. In the present study distinct generic and specific osteological characters were made out for all the three closely related species. Thirteen osteological morphomatrics were also taken from large number of specimens covering different length groups. Of all these, the length of the supraoccipital crest was found to be much useful in separating *Carangoides malabaricus* from *Carangoides chrysophrys*. The otolith sagitta was also studied and species specific sculptural patterns of sagitta were also observed in all the studied species. The sagittae of *Carangoides malabaricus* and *Carangoides talamparoides* were broad and oval in shape and that of *Carangoides chrysophrys* was much elongated. In *Carangoides malabaricus* and *Carangoides chrysophrys* the inner view of sagitta showed a central groove extending to full length and touched one side of the sagitta, but in *Carangoides talamparoides* the central groove ended blindly without touching the side of the sagitta.

INTRODUCTION

THE IMPORTANCE of osteological studies in ichthyotaxonomy has been well stressed by many workers. Osteological characters have been found to be most helpful for separating family, genera and species (Hollister, 1941; Matsubara, 1955; Hotta, 1958; Suzuki, 1962 and Collette and Chao, 1975).

Though there are many works in carangid osteology (Starks, 1911, 1926; Gregory, 1933; Hollister, 1941; Marriman, 1943; Matsubara, 1955; Suzuki, 1962; Berry, 1969; Vergara, 1972 and Smith-vaniz and Staiger, 1973) no information is available from Indian waters.

When extensive studies have been made on the otolith (sagitta) of temperate fishes in the determination of age, but their usefulness towards understanding relationships of closely related species has been studied only by very few workers (Fitch and Craig, 1964; Collette and Chao, 1975; Ramaiyan, 1977; Ramanathan, 1977; Reddy, 1977). In carangids such studies have not been undertaken so far. In the present study an attempt has been made to establish species validity using the osteology of three closely related species of the genus *Carangoides*, as the species coming under this genus are much similar in most of the morphological, morphometric and meristic characters.

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* *Present Address:* Fisheries College, Tamil Nadu Agricultural University, Tuticorin 628 008, India.

Material and Methods

The materials for the present study have been collected from trawler catches off Porto Novo. The species that have been studied are *Carangoides malabaricus*, *C. talamparoides* and *C. chrysophrys*.

Fresh specimens were boiled in water to make the tissues soft and the bones of the skull and the entire skeleton of all the above mentioned species were disarticulated for the study. Alizarin stained materials were used to study the skeleton *in situ*. Alizarin staining technique employed by Hollister (1934) as modified by Clothier (1950) was used in the present study. Large number of specimens covering different length groups were critically studied.

Osteological terminology following Suzuki (1962) has been used. Only those bones in the cranium showing differences between species have been illustrated. To find out the morphometric variation in the skull and other parts, following measurements were taken using the method of Suzuki (1962): (1) Cranial length, (2) Rostral length, (3) Diameter of orbit, (4) Postorbital length, (5) Depth, (6) Width, (7) Height of the crest in the center, (8) Length of the crest, (9) Length of hyomandibular bone, (10) Length of metapterygoid, (11) Length of mesopterygoid, (12) Length of opercle, and (13) Length and maximum width of preopercle. All the morphometric measurements in skull bones are expressed as percentage of cranial length in mm, and only those characters which are not found to be overlapping between the species are mentioned. Four groups of osteological characters are considered which exhibited variations. They are neurocranial bones, otolith sagitta, branchio cranial bones and vertebral column.

Observations and Discussion

A. *Orbital bones* (Fig. 2 c-i)

The preorbital bone in all the *Carangoides* species studied presently is flat, broad and thin with a sensory canal on its dorsal surface. The nodule present on its dorsal side gets connected with the ectethmoid.

The first suborbital bone is much broader and triangular. The suborbital shelf is more flattened in the genus *Carangoides*, the shelf is more reduced in other carangid genera such as *Alepes*, *Atule* and *Decapterus* (Suzuki, 1962 and Venkataramani, 1979).

B. *Preorbital Region*

Vomer (Fig. 2 j — o)

This bone is anteroventrally located, unpaired and triangular or spear shaped. It is articulated posterodorsally to mesethmoid and to ectethmoid and ventrally to parasphenoid. On the dorsal surface, a keel is seen, which is continued to mesethmoid, forming mesethmoid vomarine keel (Suzuki, 1962). Ventrally the bone is divisible into two parts namely the head portion and the median shaft. On its ventral surface the vomer has teeth. The teeth pattern in the head region is more or less rhomboidal in *C. malabaricus*. In *C. talamparoides* it is triangular anteriorly and oval at its posterior end. In *C. chrysophrys* it is triangular anteriorly and oval at the posterior end with a small notch in the center. In all, the median shaft is without teeth and posteriorly keeled. Dorsally, the head region of the vomer is relatively broader in *C. talamparoides*. The median shaft is much elongated posteriorly in *C. chrysophrys* and *C. malabaricus* compared to *C. talamparoides*.

Olfactory cavity (Fig. 1 a - d; 2 a, b)

This is present in between the ectethmoid and mesethmoid on both sides. Both these bones share in the formation of this cavity which is much elongated in *C. talamparoides*. In *C. malabaricus* it is depressed confined to the anterior part and is oval in shape. A small foramen is visible inside this cavity for the penetration of olfactory nerve.

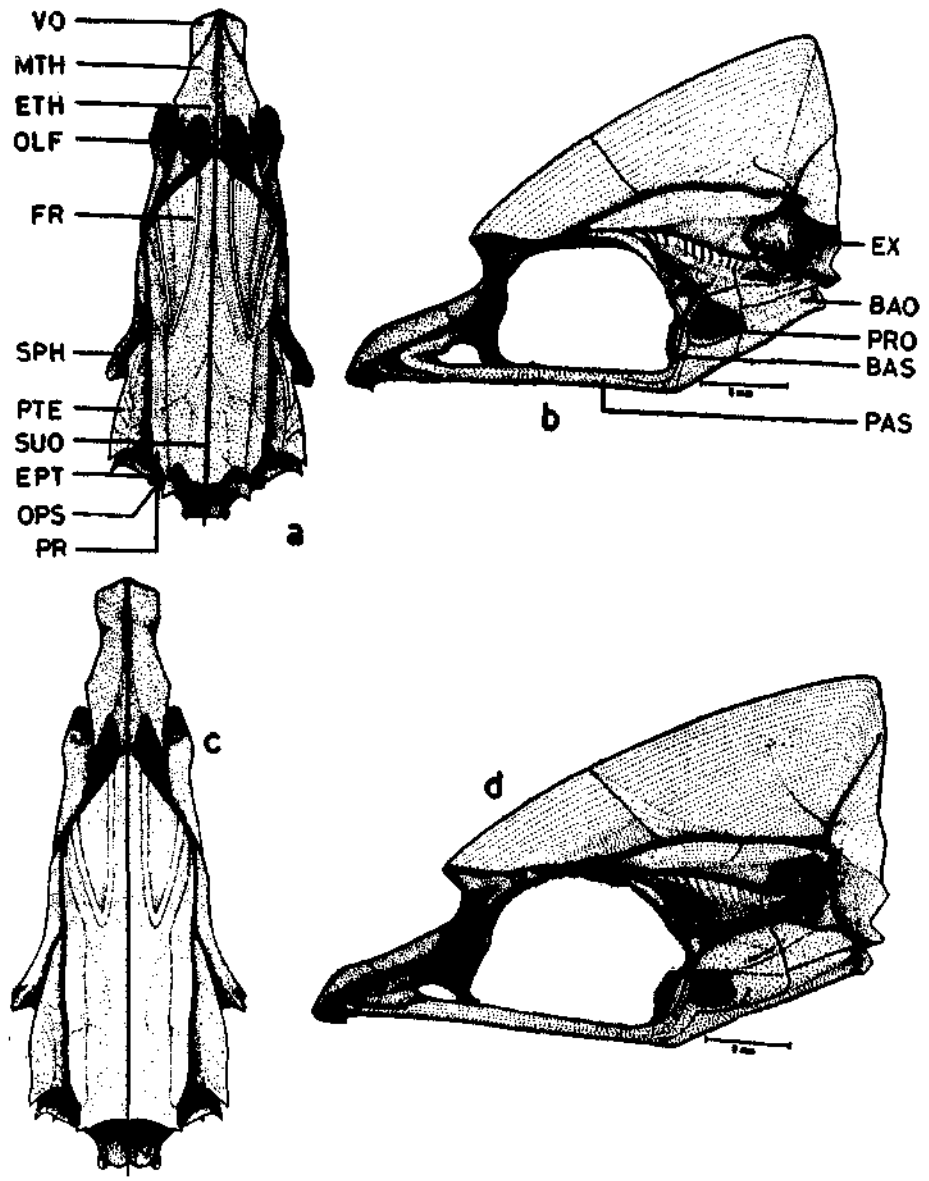

Fig. 1. Neurocranium of a. *Carangoides malabaricus* (dorsal view), b. *C. malabaricus* (lateral view), c. *C. talamparoides* (dorsal view) and d. *C. talamparoides* (lateral view).

ar — Articular, an — Angular, hp — Hypohyal, cw —Ceratohyal window, ce — Ceratohyal, ep — Epihyal, in — Interhyal, u — Urohyal, l — Lamina, p — Suborbital process). (vo — Vomer, MTH — Mesethmoid, OLF — Olfactory cavity, ETH — Ectethmoid, FR — Frontal, SPH — Sphenotic, PTE — Pterotic, SUO — Supraoccipital crest, PR — Parietal, EPT — Epiotic, OPS — Episthotic, EX — Exoccipital, PAS — Parasphenoid, BAS — Basisphenoid, PRO — Prootic, BAO — Basioccipital.

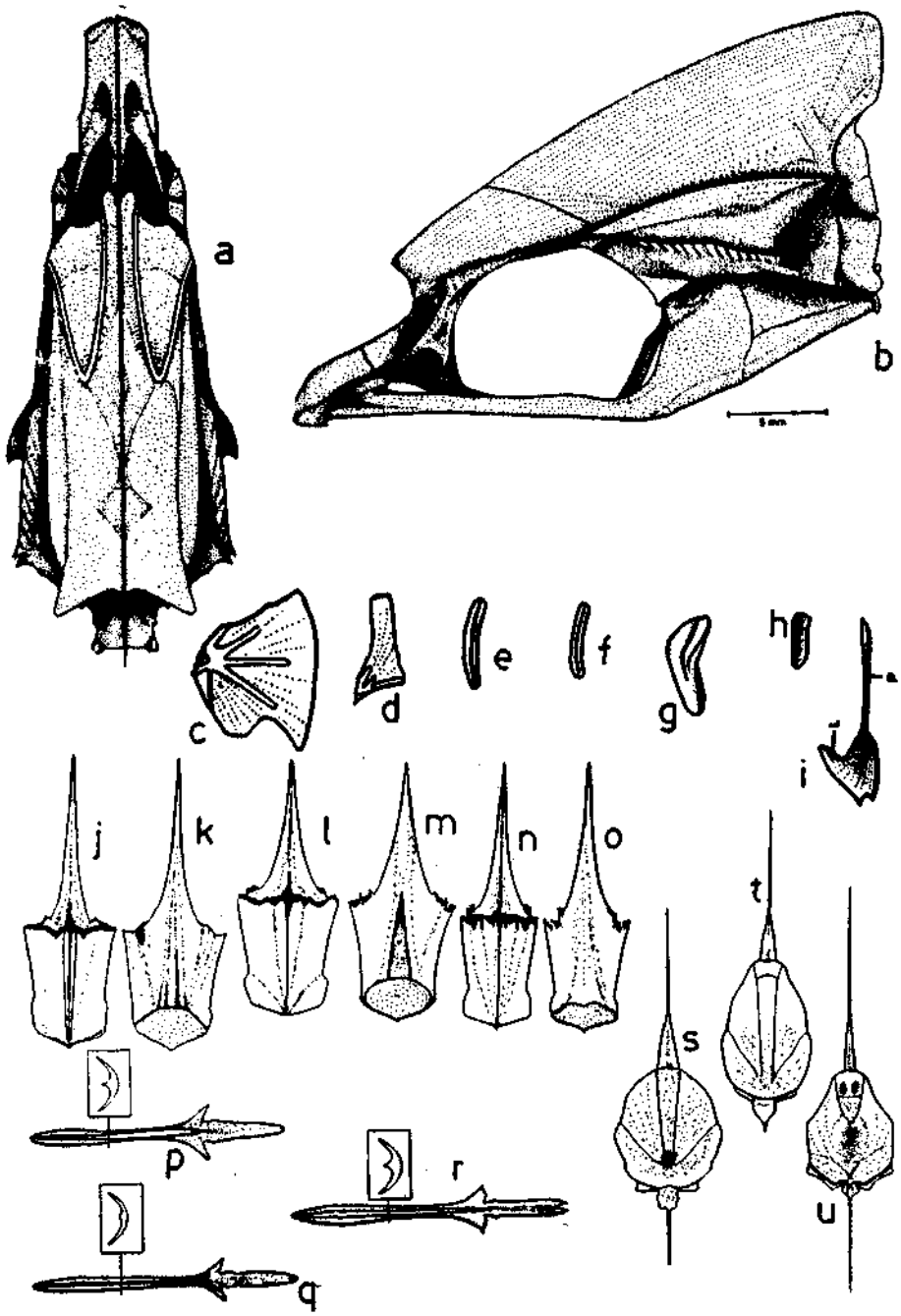

Fig. 2 a. Neurocranium of *C. Chrysophrys* (dosral view). b. Neurocranium of *C. chrysophrys* (lateral view), c. Preorbital bone, d. Ist suborbital bone, e. IInd suborbital bone, f. IIIrd suborbital bone, g. IVth suborbital bone, h. Vth suborbital bone, i. Suborbital shelf. Vomer of : j. *C. malabaricus* (dorsal view), k. *C. malabaricus* (ventral view), l. *C. talamparoides* (dorsal view), m. *C. talamparoides* (ventral view), n. *C. chrysophrys* (dorsal view), o. *C. chrysophrys* (ventral veiw), p. parasphenoid of *C. malabaricus* (inner view) q. *C. talamparoides* (inner view) r. *C. chrysophrys* (inner view); Supraoccipital of : s. *C. malabaricus* (inner viwe), t. *C. talamparoides* (inner view) and u. *C. chrysophrys* (inner view).

Parasphenoid (Fig. 2 p - r)

It is an unpaired elongate bone with a pair of ascending lateral wings posteriorly. It is articulated dorsally with ectethmoid. The anterior end is bifurcated on its ventral surface to receive the spear shaped posterior part of the vomer. Posteriorly it connects the prootic, basioccipital and basisphenoid. Just in front of the prootic it is extended laterally. The inner surface of the parasphenoid at its anterior end is keeled in *C. malabaricus* and *C. chrysophrys* but not so in *C. talamparoides*.

Frontals (Fig. 3 a -c)

The frontals form the roof for the cranium and are the longest among the skull bones. The bone is united anteriorly with mesethmoid and ectethmoid, laterally with the sphenotic, ventrally with the alisphenoids and posteriorly they are bound by supraoccipital and parietals. Anteriorly they taper but are broad posteriorly. Many growth lines are seen in them near the central region. Ventrally each frontal bears a sheet of orbit lamella which is close to the sphenotic posteriorly, to the ectethmoid process anteriorly and to the alisphenoid medially. On their dorsal side, two horizontal and one vertical sensory tubes are seen. The frontal bears a well developed ridge in the middle which is continued posteriorly as a strong supra-occipital crest. In each frontal there are two crests, the temporal and pterotic. The temporal crest is formed of epiotic, parietal and frontal. The pterotic crest is present near the lateral border of the cranium. In *Carangoides* spp. the temporal crest ends in the middle of the orbital cavity. In *C. chrysophrys* and *C. talamparoides* the pterotic crest is very close to temporal crest and gets partially united near its extreme anterior end. In *C. malabaricus* and *C. talamparoides* the supraoccipital crest is more elevated compared to that of *C. chrysophrys*, as a result of which the depth is more between the crests on either side.

C. *Postorbital region*

Supraoccipital (Fig. 2 s - u)

This bone which forms the dorsomedial portion of the posterior end of the neurocranium, is articulated anteriorly with the frontals and laterally with the epiotics and parietals. In the midline it is keeled and bears a well developed ridge which continues anteriorly to the frontals and posteriorly as a strong supraoccipital crest extending down without being interposed between the two exoccipitals. The crest in *C. chrysophrys* is elongated and much produced posteriorly beyond the cranium unlike in *C. malabaricus* and *C. talamparoides*. The length of the supraoccipital crest was found to be 85.88-87.51 (M: 85.76) in *C. malabaricus*, 88.26 - 93.32 (M: 91.63) in *C. chrysophrys* and 81.81 - 84.84 (M: 82.40) in *C. talamparoides*. In all *Carangoides* spp. the height of the crest in the middle region is more than half the height of the entire cranium. In *C. malabaricus* and *C. talamparoides* this bone is oval and posteriorly blunt. In *C. chrysophrys* the posterior region is more triangular and its tip is blunt.

Alisphenoids (Fig. 3 d - f)

The alisphenoids form the posterodorsal region of the orbit. They form the anterior wall of the brain case. They abut the prootica posteriorly, the basisphenoid ventroposteriorly, the sphenotics laterally and the frontals dorsally. In all the species studied here, the alisphenoids are widely separated by the brain case. In the genus *Carangoides*, the ridges reach the the ectethmoid and do not come into contact with each other along their entire length in the midline but run closely to each other. The part of the alisphenoid which is in contact with the brain chamber in *C. chrysophrys* and *C. talamparoides* has a small notch in the center and is curved on its sides. This side is even, with no notch in the middle in *C. malabaricus*.

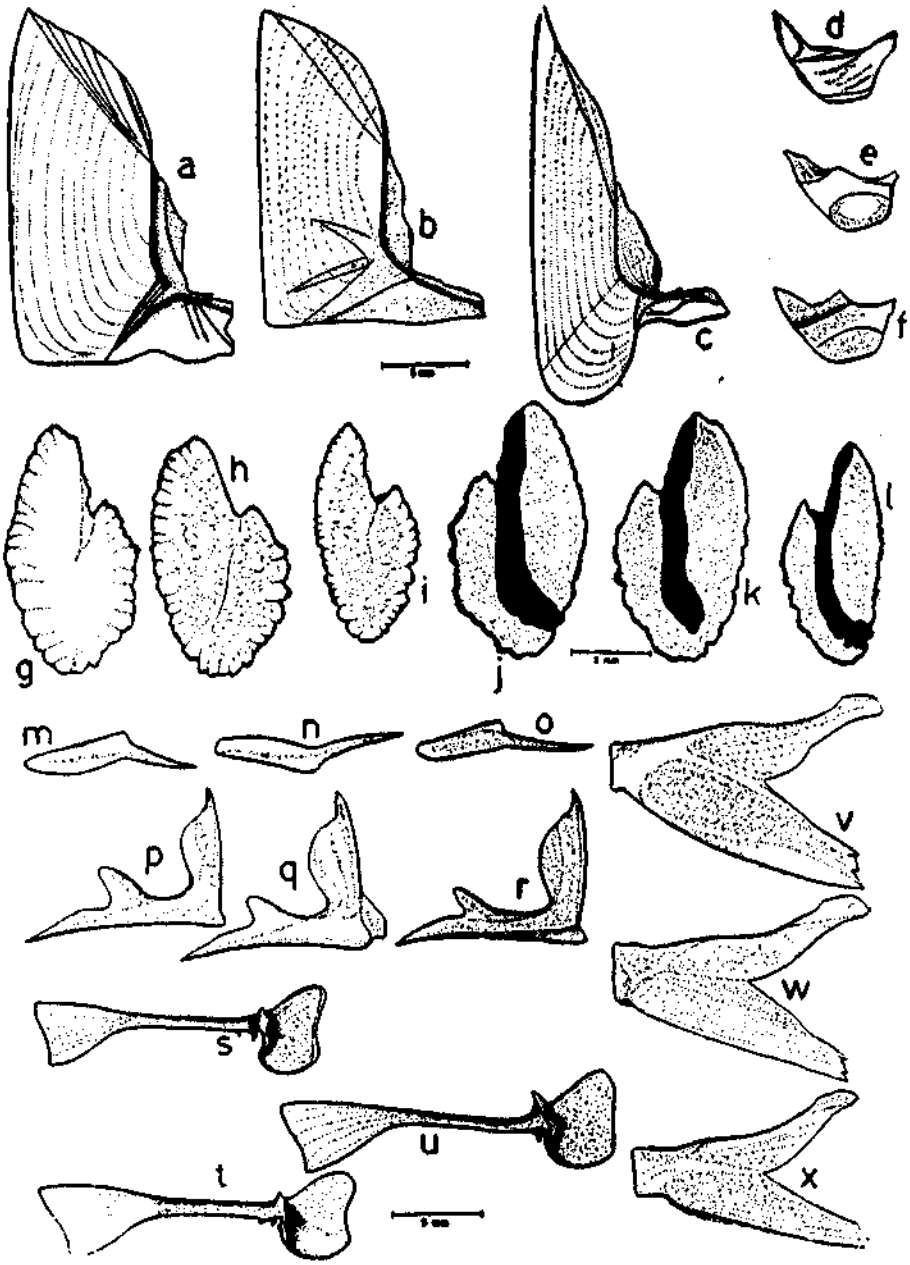

Fig. 3. Supraoccipital crest of a. *C. malabaricus* lateral view), b. *C. talamparoides* (lateral view), c. *C. chrysophrys* (lateral view); Alisphenoid of: d. *C. malabaricus* (dorsal view), e. *C. talamparoides* (dorsal view), f. *C. chrysophrys* (dorsal view); Otolith of: g. *C. malabaricus* (outer view), h. *C. talam. paroides* (outer view), i. *C. chrysophrys* (outer view), j. *C. malabaricus* (inner view), k. *C. talamparoides* (inner view), l. *C. chrysophrys* (inner view); Supramaxilla of: m. *C. malabaricus*, n. *C. talamparoides*, o. *C. chrysophrys*, Premaxilla of: p. *C. malaabricus*, q. *C. talamparoides*, r. *C. chrysophrys*; Maxilla of: s. *C. malabaricus*, t. *C. talamparoides*, u. *C. chrysophrys*; Dentary of: v. *C. malabaricus*, w. *C. talamparoides* and x. *C. chrysophrys*.

Exoccipitals:

They enclose the foramen magnum and lie laterally above the basioccipital. They are articulated ventrally with the basioccipital, anteriorly with the prootic and dorsally with the pterotic, opisthotic, epiotic and supra-occipital. The zygapophyses of the exoccipitals are joined together in all the species of *Carangoides*.

D. *Otolith* (Fig. 3 g – l)

Species specific sculptural patterns of otolith could be observed in all the three species. The otolith shows differences in all the three closely related *Carangoides* spp. The otolith of *C. malabaricus* and *C. talamparoides* are broad and oval in shape. In *C. malabaricus* and *C. chrysophrys* the inner view of otolith shows a central groove extending to full length and touches one side of the otolith. In *C. talamparoides* it ends blindly without touching the side. The otolith of *C. chrysophrys* is more elongate than broad and tapers at one end unlike in *C. malabaricus* and *C. talamparoides*.

E. *Jaws*

Upper jaw

The upper jaw in carangids is composed of three bones supramaxilla, premaxilla and maxilla.

Supramaxilla (Fig. 3 m – o)

Small flat bone, present on the posterior half of the dorsal edge of maxilla showing similarity in all the species.

Premaxilla (Fig. 3 p – r)

Consists of anterior ascending process and posterior elongate process with teeth. The premaxillary process is well developed and elongated. The premaxillary process is much broader in *C. malabaricus* than in *C. talamparoides* and *C. chrysophrys*. In *Carangoides* spp. this process has a blunt tip.

Maxilla (Fig. 3 s – u)

Transparent, slender, long curved bone surmounting the premaxilla dorsolaterally. It is broader at the posterior end and spatulate in shape. The anterior end is forked to which the rostral cartilage of premaxilla is connected. Behind the forked end is a small pointed projection. The edges are even. Differences in shape could be noticed in all the species of the genus *Carangoides*.

Lower jaw

The lower jaw is composed of three bones, dentary, articular and angular.

Dentary (Fig. 3 v – x)

This massive bone, forked posteriorly into two arms, forms the major part of the lower jaw. Anteriorly it meets its opposite fellow at a median symphysis. In *C. malabaricus* the lower arm is much broader than in *C. talamparoides* and *C. chrysophrys*.

Articular and angular (Fig. 4 a – c)

The anterior part of the large and stout articular is triangular and pointed. It is inserted into the 'V' shaped sinus of the dentary. The bone has two processes. The posterior process is short and stout and similar in all the species studied presently. This bone is much elongated in *C. malabaricus*. Angular bone is small and almost alike in all the species.

F. Suspensorium

Hyomandibular (Fig. 4 d – f)

Stout cross shaped bone, which supports the opercular apparatus and suspends the mandibular from the neurocranium. Dorsally it has a broad head and ventrally it tapers to reach the symplectic bone. The head portion is provided with three condyles. The neurocranium accepts the first two condyles, one on the posteroventral face of sphenotic while

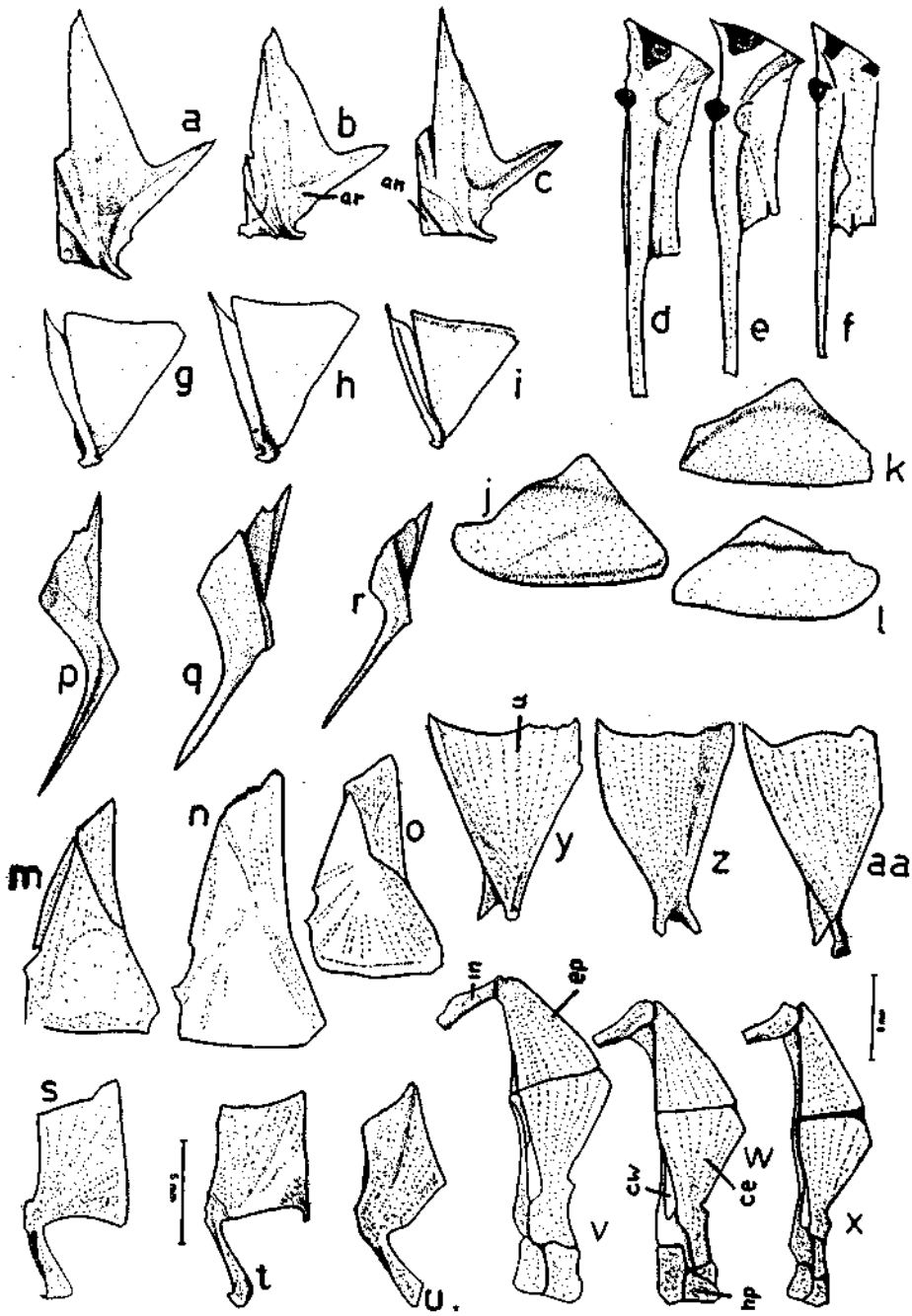

Fig. 4. Articular and angular of: a. *C. malabaricus*. b. *C. talamparoides* c. *C. chrysophrys*; d. Hyomandibular of *C. malabaricus*. e. Hyomandibular of *C. talamparoides*, f. Hyomandibular of *C. chrysophrys*; Quadrate of: g. *C. malabaricus*, h. *C. talamparoides*, i. *C. chrysophrys* Mesopterygoid of: j. *C. malabaricus*, k. *C. talamparoides*, l. *C. chrysophrys*; Metapterygoid of: m. *C. malabaricus*, n. *C. talamparoides*, o. *C. chrysophrys*; Pterygoid of: p. *C. malabaricus*, q. *C. talamparoides*, r. *C. chrysophrys*; Palate of: s. *C. malabaricus*, t. *C. talamparoides*, u. *C. chrysophrys*; Hyoid apparatus of: v. *C. malabaricus*, w. *C. talamparoides*, x. *C. chrysophrys*; Urohyal of: y. *C. malabaricus*, z. *C. talamparoides* and aa. *C. chrysophrys*.

the other fits into the pterotic. The third, which articulates with the opercular apparatus, is distinctly separated from the first two. This bone is much broader in all *Carangoides* spp.

Quadrate, Mesopterygoid. Pterygoid and Metapterygoid (Fig. 4 g – r)

Species specific differences could be noted in the shape of these bones between *Carangoides* spp. The metapterygoid is much broader and elongated in *C. talamparoides* than in *C. malabaricus* and *C. chrysophrys*. The lamina is well developed in *C. talamparoides*. The bone is more than half in length compared to the hyomandibular in all the species.

Palate (Fig. 4 s – u)

Posteriorly it articulates with pterygoid and dorsally to metapterygoid. Anteriorly it is produced into prepalatine process and its anterior end articulates with a facet on the maxilla. Palate is much broader and more or less expanded in all the species of *Carangoides* studied presently.

G. *Hyoid apparatus* (Fig. 4 v – aa)

The hyoid arch consists of ceratohyal, epihyal, glossohyal, hypohyal, interhyal and urohyal. The hypohyal, ceratohyal and epihyal are closely articulated with each other and form single functional unit. Structural differences could be noticed in all the bones of the species of *Carangoides*.

H. *Vertebral column*

The vertebral column exhibits similar pattern in all the species of the genus *Carangoides*. The infracentral grooves, ribs, fin elements and the caudal skeleton of the species examined presently did not show any appreciable difference. However, differences are seen in the pattern of occurrence of neural and haemal zygapophyses.

Neural and haemal zygapophyses

The pre and postneural zygapophyses make their appearance as blunt projections from 3rd vertebra onwards in all *Carangoides* species. In all *Carangoides* spp. examined presently, the prehaemal zygapophyses make their appearance as small protruberances from the second caudal vertebra. The posthaemal zygapophyses make their appearance as small knobs in *C. talamparoides* and in *C. malabaricus* from third caudal vertebra onwards and in *C. chrysophrys* from the fourth onwards.

General Remarks

In the present study, the osteology of three carangid species of *Carangoides* has been studied. Of these species, *C. talamparoides* has been recently separated from *C. malabaricus* group based on morphological and meristic characters such as naked area of the breast and gillraker counts (Williams and Venkataramani, 1978) and osteological characters such as teeth-pattern in the head region of vomer, nature of olfactory cavity, inner surface of the parasphenoid, central groove pattern in otolith, the premaxillary process and metapterygoid lamina. Apart from these, the shape and structure of certain bones have also been employed in identifying one from the other.

C. chrysophrys another close relative of *C. malabaricus* was separated by earlier workers taking into account the differences in gillraker, dorsal and anal fin counts. Osteologically this species differs considerably from the other aforesaid two species. *C. malabaricus* overlaps with *C. talamparoides* in all the 13 morphometric characters. But in the length of the supra-occipital crest *C. chrysophrys* stands apart from *C. malabaricus* and *C. talamparoides*.

Electrophoretical studies also corroborate the evidence derived from osteological studies. The similarity in protein fraction of eyelens protein and muscle myogen in *C. malabaricus*

and *C. talamparoides* is worth mentioning here. Compared to *C. malabaricus* and *C. talamparoides, C. chrysophrys* showed a difference electrophoretic pattern (Venkataramani, 1979).

The cranium of all the above mentioned three species falls in the fourth stage of the cranial classification of Suzuki (1962). The zygopophyses of exoccipitals are fused, olfactory cavity well developed, fronto supra occipital crest being high and the mesethmoidvomarine keel is very narrow and deep. These so called specialized characters belong to the genus *Carangoides* and not for the genera *Atule, Alepes* and *Decapterus* (Suzuki, 1962; Venkataramani, 1979).

The pterygoid bone is widely enlarged and is produced at the dorso-anterior corner into an elongated process. The height of the suspensorial and opercular apparatus are larger compared to their length in all the three species of *Carangoides* and are not well developed in *Atule, Alepes, Trachinotus* and *Elagatis* (Suzuki, 1962; Venkataramani, 1979). Further the height of the suspensorial and operculai apparatus is lesser compared to their length in these genera. The metapterygoid lamina and its development is an advanced character (Suzuki, 1962) which is also well developed in all the species of *Carangoides* studied and the same is poorly developed in other carangid genera viz, *Atule* and *Alepes* (Venkataramani, 1979).

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