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COMPARATIVE MORPHOLOGY OF THE CRANIAL MUSCLES IN SOME SPECIES OF THE GENUS *ARIUS*, WITH A NOTE ON THEIR UTILITY IN TAXONOMY (ARIIDAE : SILURIFORMES)

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ABSTRACT

The cranial musculature of three species of the genus *Arius* (*A. arius*, *A. caelatus* and *A. thalassinus*) was studied. The mandibular and hyoid muscle complexes and the constituent muscular elements in each one of these have been described.

A comparison of the three species based on their myological attributes indicates that they exhibit a common pattern in respect of the orign, insertion, disposition and the morphology of nine muscles of the total 18 muscles studied. Moreover, the magnitude of interspecific differences in the rest nine muscles are also slight which has been discussed in relation to the habitat and the systematic status of each species.

The nomenclature of some muscles confused by earlier workers has also been clarified.

Introduction

One of the recent trends in Ichthyotaxonomy has been the increasing awareness of utilising body structure and associated parts for classification and derivation of phylogenetic relationships. Winterbottom (1974) has demonstrated that there is a good deal of interrelationships and diversity among the fishes belonging to the order Tetraodontiformes based on their myology. Fishes in general are well known for their adaptive radiations since they inhabit diverse aquatic ecosystems and are consequently put under different ecological stresses.

The Siluroid fishes are also no exception to this phenomenon though most are generally confined to fresh water ecosystem only. However, the family Ariidae is known from all the three kinds of aquatic habitats viz. fresh water, estuarine and marine. Considering that these diverse habitats may have some modifications in the basic structural patterns, the cranial myology of three species (*A. arius*, *A. caelatus*, and *A. thalassinus*) of the genus *Arius* has been carried out.

The cranial and more particularly, the jaw muscles of teleosts attracted the attention of several authors in the past. The pioneer workers in this field are Vetter (1878), Alis (1897, 1903) and Juge (1899). Among those who have studied cranial muscles of siluroid fishes include : Mc Murrich (1884), Takahasi (1925), Edgeworth (1935), Dubale (1952), Nawar (1955), Munshi (1960), Dubale and Vidyasagar (1960), Dubale and Saha (1962), Singh and Munshi (1969), Mahajan (1971) and Liem (1979).

The knowledge of teleostean myology is still fragmentary. Romer (1962), Klaauw (1963) and Winterbottom (1974a) were aware of this "incompleteness". Winterbottom (*op. cit.*) made a logic comment that lack of reliable published information on the myology of the majority of fish groups prevents any statement pertaining to phylogeny. In recent years investigations of the functional morphology of the skeletal muscles of teleostean fishes have become a facinating study. A large number of workers (Klaauw, 1950, 1963 ; Günther and Deckert, 1953, 1955, 1959, 1960 ; Alexander, 1966, 1967a, b ; Field, 1966 ; Millard, 1966 ; Branch, 1966 ; Karrer, 1967 ; Dutta, 1968 ; Osse, 1969) studied the functional morphology of the cranial muscles of various groups of teleostean fishes. While Greenwood *et al.* (1966), Rosen (1962, 1964), Nelson (1967a, b), Rosen and Patterson (1969) and Winterbottom (1974a, b), studied the myology of the teleosts from morphological stand point and its utility in phylogenetic as well as taxonomic interpretations.

From the aforecited review of the literature, it is clear that no attempt has been made so far to study the muscles of the fishes belonging to the family Ariidae, in any respect. In order to correlate the myology exhibited by the three species inhabiting different ecological niche, with their interspecific relationship, this investigation was undertaken.

Material and Methods

The study is based on the dissection of freshly collected specimens preserved in 10% formalin solution. 20 specimens of each species : *A. arius* from Chilka Lake, *A. caelatus* from Hooghly estuary and Orissa Coast, *A. thalassinus* from the seas near Cochin and Mandapam, were dissected. After thoroughly washing the formalin preserved specimens, the skin was carefully removed without injuring and disturbing the natural disposition of muscular pattern. Dissection of different muscles except the branchial and eye muscles of the cranium were made under the sterioscopic binocular microscope. The structure and the nature of origin, insertion and the course of the muscle fibres were noted with utmost care. Free hand drawings of the outer sketch of the cranium were drawn and then individual muscle components as seen under the sterioscopic Binocular microscope in the dissected specimens have been produced.

The nomenclature adopted by various workers for different cranial muscles is not uniform. Single muscle has been described under an incredible variety of names in the published literature. Winterbottom (1974a) published a descriptive synonymy of the striated muscles of the teleostei which have been followed here.

Observations

The cranial muscles, as the name itself implies, are very much associated, morphologically, functionally, and embryologically, with the cranium. They are also known as branchiomeric muscles from embryological stand point and develop from the embryonic hypomere. They are quite distinct from the body muscles which develop from the myomeres (Eaton, 1951).

For the purpose of this study two complexes have been investigated : (1) Mandibular muscle complex, (2) Hyoid muscle complex. Further division and subdivision

of these complexes, primarily based on the disposition, origin, insertion and function of each muscle are as follows.

1. *Mandibular muscle complex* :

The mandibular muscle complex is enormously developed in case of all the three species of the genus *Arius* studied and it is composed of three groups namely : (1) Adductor mandibulae, (2) Constrictor dorsalis and (3) Intermandibularis.

1.1. *Adductor mandibulae group* :

This group of cranial muscles is massive and complex, having several components which connect the lower jaw with the palato-pterygoid arch and also with the neurocranium. Based on the location, origin and insertion of its various components, in relation to the respective bones, the Adductor mandibulae group, in ariid fishes can be devided into two components : (1) Mandibularis and (2) Intramandibularis. Whereas in case of other teleosts, this group of muscles is supposed to have another component called : Maxillaries, in addition to the above mentioned two components.

1.1.1. *Adductor mandibularis* :

In *Arius arius* this component is enormously developed and comprises six elements viz. *Adductor mandibularis* $_{1,2,3,4,5,6}$. Whereas in *A. caelatus* only five elements are observed but *A. thalassinus* resembles with *A. arius* in having six elements. The gross function of this component is to move the lower jaw upwards resulting the closing of the mouth.

1.1.1.1. *Adductor mandibularis*$_1$ (*Add. mand*$_1$) :

It is a thick, elongated, prominent muscular element covering underneath itself the other elements of *Add. mand.* In all the three species, this muscle originates musculously as well as aponeorotically from the preopercular, hyomandibular and the quadrate. The muscle fibres are arranged in two layers. The first superficial one is thick, long and runs downwards and forwards in a convergent manner which finally inserts musculously on the anterodorsal surface of the angular. Along the upper free margin of th is muscular layer a thin somewhat broad aponeurosis provides attachment to some of the fibres which ultimately are attached to the angular below the musculous insertion. This aponeurosis is very prominent in *A. arius* and *A. thalassinus* while indistinct in *A. caelatus*.

The second, deeper layer of this muscle originates from the lower surface of the hyomandibular and the quadrate and runs antero-downwards to get inserted musculously on the lower surface of the angular. Unlike that of superficial layer, it is overlapped partially by the *Add. mand.*$_2$ in *A. arius* and *A. thalassinus* while in *A. caelatus* this element is overlapped by the *Add. mand.*$_3$ (Fig. 1 : Ia, Ib, Ic)

1.1.1.2. *Adductor mandibularis*$_2$ (*Add. mand.*$_2$) :

It is a narrow and elongated moderately developed muscle, originating from the pre-percular and hyomandibular. The origin of most of the fibres is musculous in all the three species with some exception in case of *A. caelatus* where sometime a few fibres are attached aponeurotically. The muscle runs in forward direction in a convergent fashion and finally gets inserted on the ventral ridged surface of the angular through an elongated

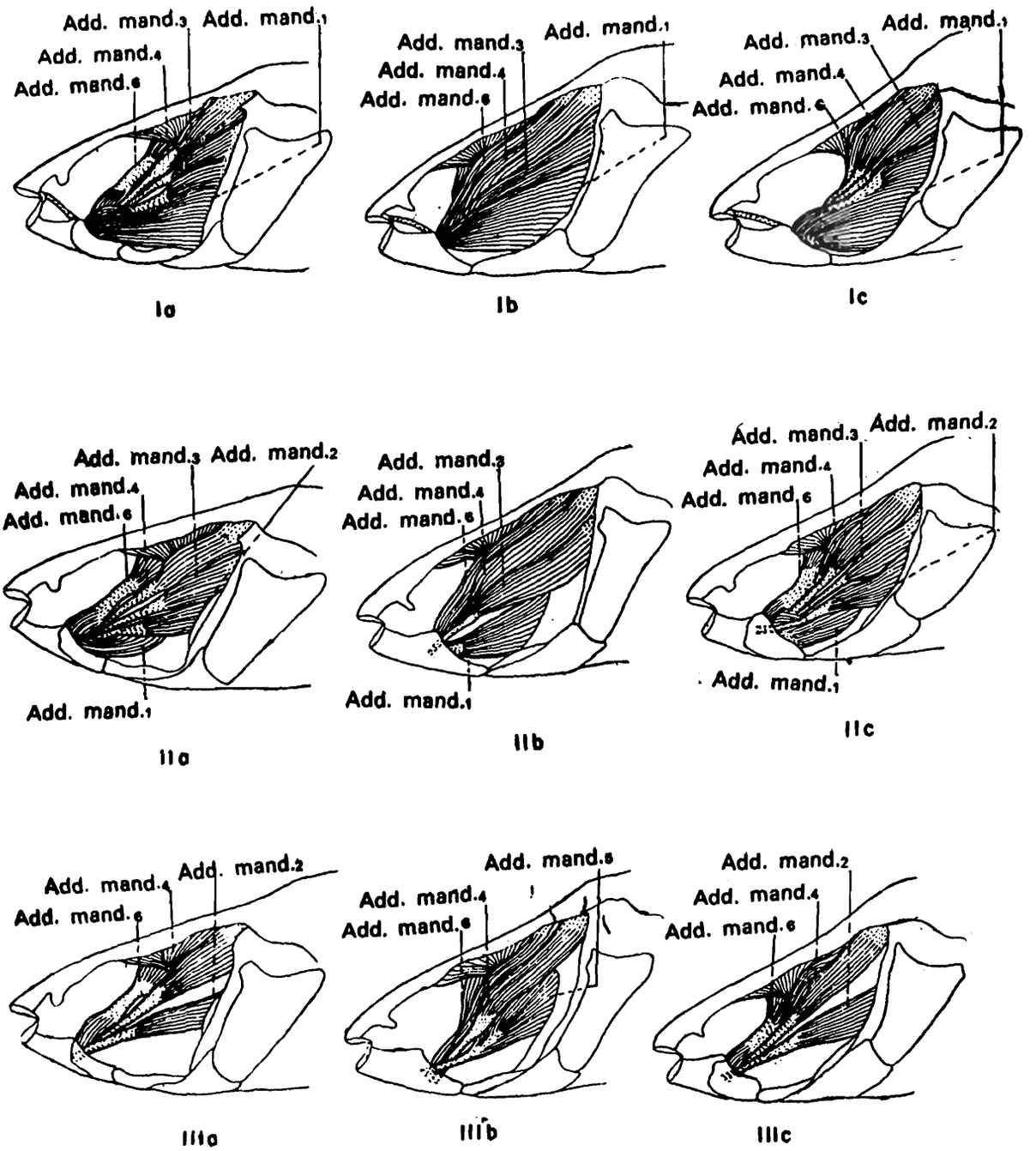

Fig. 1. I. Left lateral view of the head region showing the disposition of *Adductor mandibularis* components. a- *Arius arius*, b- *A. caelatus*, c- *A. thalassinus*. II. Left lateral view of the head region showing the disposition of *Adductor mandibularis* components after removing the superficial layer of *Adductor mandibularis*$_1$. III. Left lateral view of the head region showing the disposition of *Adductor mandibularis* components after removing the muscle *Add. mand.* $_{1, 3}$.

aponeurosis. It is overlapped partially by *Add. mand.*$_1$ and *Add. mand.*$_3$.

In case of *A. arius* and *A. thalassinus* the muscle is distinctly separated from *Add. mand.*$_3$ and its aponeurosis provides attachment to some of the fibres of *Intramandibularis* in the latter species. Whereas in *A. caelatus* this muscle has blended with the fibres of *Add. mandibularis*$_3$; (Fig. 1 : IIa, IIc ; IIIa, IIIc).

1.1.1.3. *Adductor mandibularis*$_3$ (*Add. mand.*$_3$) :

It is comparatively a less developed element of the *Add. mand.* component. In all the three species the muscle originates musculously and partly aponeurotically from the upper portion of the preopercular and the hyomandibular. The muscle fibres run forwards and downwards in a convergent manner through an elongated aponeurosis which finally insert on the inner ventral surface of the angular. In *A. arius* and *A. thalassinus*, the muscle covers the *Add. mand.*$_2$ partially and itself is overlapped by the *Add. mand.*$_1$ as well as *Add. mand.*$_4$ in all the three species (Fig. 1 : Ia, Ib, Ic ; IIa, IIb, IIc).

1.1.1.4. *Adductor mandibularis*$_4$ (*Add. mand.*$_4$) :

This muscle is quite massive and well developed as compared to *Add. mand.*$_3$. In *A. arius*, it originates aponeurotically as well as musculously from the dorsal surface of the preopercular, and lateral surface of the sphenotic and pterotic. While in *A. thalassinus*, the origin is completely tendinous, though the place of attachment is same as in *A. arius*. In *A. caelatus* the muscle originates from the dorsal surface of the hyomandibular, lateral surface of the sphenotic and pterotic. The nature of origin is more or less similar to that of *A. arius*.

In all the three species, the muscle lies along the dorsal aspect of *Add. mand.*$_3$. The fibres of this muscle run obliquely downwards, converging at the fairly long proximal end of an aponeurosis which provides attachment to the *Intramandibularis* and finally gets inserted on the inner ventral ridged surface of the angular just below the insertion of the *Add. mand.*$_3$. Partially, it overlaps the *Add. mand.*$_4$ and *Add. mand.*$_5$ (Fig. 1 : IIa, IIIb, IIIc).

1.1.1.5. *Adductor mandibularis*$_5$ (*Add. mand.*$_5$) :

A well developed muscle which can be viewed after removing the *Add. mand.*$_{1-4}$. In all the three species, it originates musculously from the ventral grooved surface of the hyomandibular and slightly from the junction of the quadrate and hyomandibular. The lower fibres are longer than the upper and run obliquely in a convergent fashion to the proximal end of an elongated aponeurosis which finally insert on the inner ventral grooved surface of the angular. The aponeurosis of this muscle overlaps the aponeurosis of the *Add. mand.*$_{2-4}$ in case of *A. arius* and *A. thalassinus*, whereas *Add. mand.*$_{3-4}$ in *A. caelatus* (Fig. 1 : IIIb ; Fig. 2 : IIa, IIc).

1.1.1.6. *Adductor mandibularis*$_6$ (*Add. mand.*$_6$) :

This muscle is the largest and deepest among the other elements of the mandibularis group. In *A. arius* the whole muscle originates musculously from the entire anterodorsal and anteroventral surface of the hyomandibular. While in *A. caelatus* and *A. thalassinus* the muscle is cleft into two layers.

The fibres of upper layer originate aponeurotically from the sphenotic and overlap the *Lev. arc. pal.* The lower layer of the muscle originates musculously from the hyomandibular and ventral surface of sphenotic and itself is overlapped by the *Lev. arc. pal.* and the *Dil. op.* It runs anterodown-wardly in a convergent manner to get inserted on the inner ventral surface of the angular by an elongated and strong aponeurosis which provides attachment to some fibres of the *Intramandibularis*. In *A. arius* and *A. thalassinus*, the aponeurosis is very prominent and the fibres of *Intramandibularis* muscle are attached along its distal anterior margin, while in *A. caelatus* the aforesaid aponeurosis is poorly developed and the *Intramandibularis* muscle fibres are attached along the distal posterior margin of it (Fig. 2 : Ia, Ib, Ic ; IIa, IIb, IIc).

1.1.2. *Intramandibularis* (*Int. mand.*) :

The magnitude of development of this muscle varies from species to species, in the sequence of well, moderately, and poorly developed in *A. arius*, *A. thalassinus* and *A. caelatus* respectively. It arises from the aponeurosis of *Add. mand.*$_2$ *Add. mand.*$_6$ in case of *A. arius* and *A. thalassinus*, while only the *Add. mand.*$_6$ in *A. caelatus*. The muscle fibres run in a divergent fashion and directly attached on the inner surface of the dentary and angular in all the three species (Fig. 2 : IIa, IIb, IIc, IIa, IIIa).

1.2. *Constrictor dorsalis group* :

This group of muscles provides suspensary support to the hyomandibular and the opercular from the cranium. In the present species it comprises two components : (1) Levator arcus palatini, (2) Dilator operculi.

1.2.1. *Levator arcus palatini* (*Lev. arc. pal.*) :

In all the three species, this muscle is well developed which can be viewed after removing the *Add. mand.* muscle complex. It originates from the ventral surface of the sphenotic and frontal. The origin of the fibres from the frontal is musculous, while from the sphenotic partly musculous and partly aponeurotic. The anterior fibres run downwards at right angle to the median longitudinal axis while the posterior fibres run slightly backwards and downwards finally all the fibres get inserted on the mesial ridged surface of the hyomandibular. It overlaps the *Add. mand.*$_6$ and *Dil. op.* partially. The contraction of this muscle moves the hyomandibular upwards and thus increasing the capacity of pharyngeal cavity (Fig. 2 : Ib, IIa, IIc).

1.2.2. *Dilator operculi* (*Dil. op.*) :

This component of constrictor dorsalis group is well developed, lying underneath the *Add. mand.* complex and the *Lev. arc. pal.* It connects the opercular to the neurocranium. The whole muscle is divisible into two distinct parts based on the nature of origin and insertion of the fibres : 1) *Dilator operculi superioris* and 2) *Dilator operculi inferioris*.

1.2.2.1. *Dilator operculi superioris* (*Dil. op. sup.*) :

In all the three species, this muscle is somewhat conical in shape and lies underneath the *Lev. arc. pal.* It originates directly from the ventral surface of the sphenotic and the frontal. From the place of origin the muscle fibres run downwards and backwards

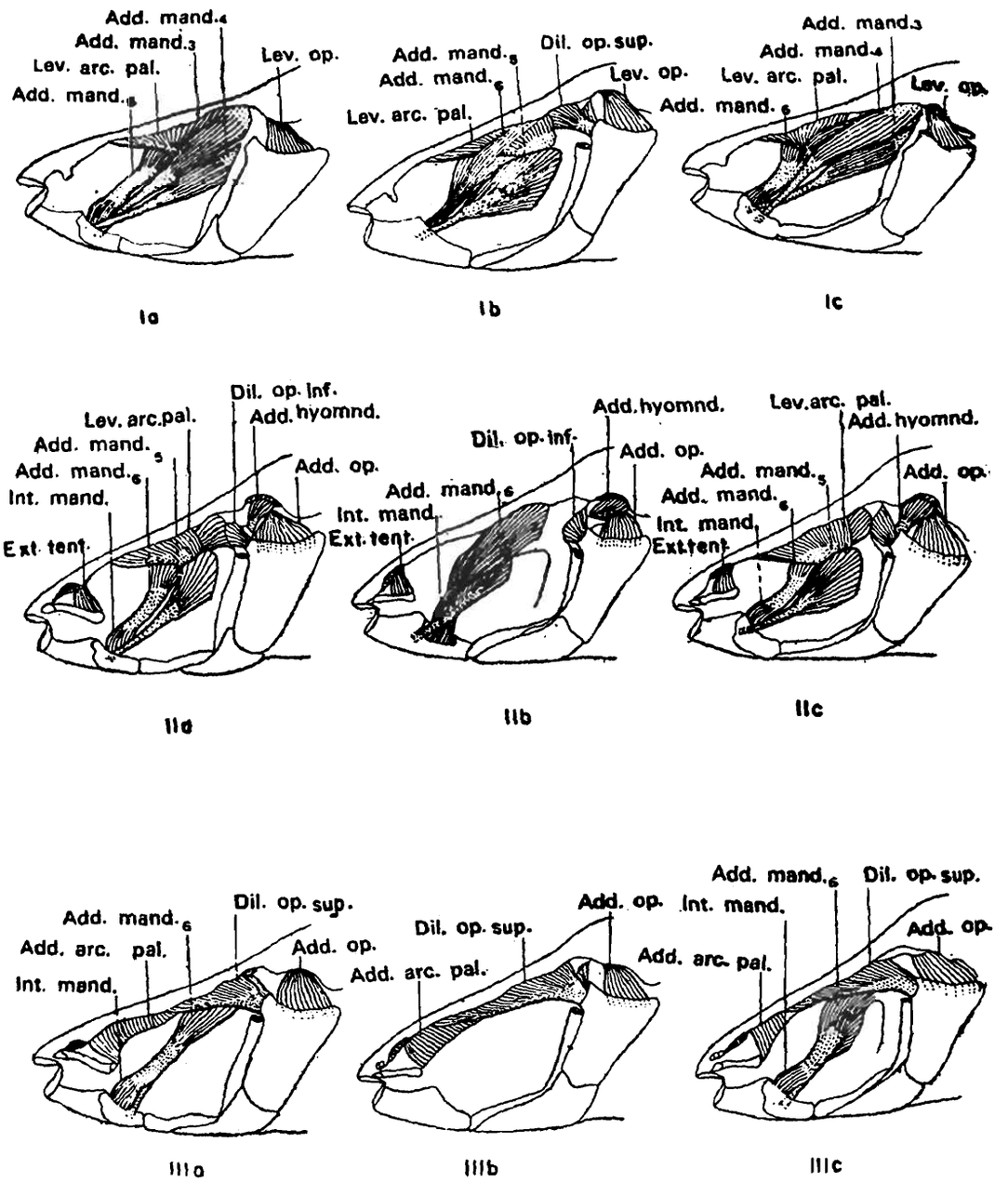

Fig. 2. I. Left lateral view of the head region showing the disposition of some *Add. mand.* components and *Levator arcus palatini*, *Levator operculi* and *Dilator operculi*. a- *Arius arius*, b- *A. caelatus*, c- *A. thalassinus*. II. Left lateral view of the head region showing the disposition of *Extensor tentaculi*, *Levator arcus palatini*, *Dilator operculi inferioris*, *Adductor operculi*, *Adductor hyomandibulae* and *Intramandibularis*. III. Left lateral view of the head region showing the disposition of the *Adductor arcus palatini*, *Dilator operculi superioris* and *Adductor operculi*.

in a convergent manner to get inserted through an aponeurosis on the dorsolateral cornu of the opercular. The muscle overlaps the anterior fibres of the *Dil. op. inf.* (Fig. 2 : IIIa, IIIb, IIIc).

1.2.2.2. *Dilator operculi inferioris* (*Dil. op. inf.*) :

It is a small poorly developed element situated just behind and slightly underneath the *Dil. op. sup.* The fibres of this muscle originate from the dorso-posterior surface of the hyomandibular and the ventral surface of the pterotic in *A. arius* and *A. thalassinus* while only from hyomandibular in *A. caelatus*. From the place of origin the muscle fibres run downwards at right angle to the longitudinal axis to get inserted on the opercular just below the insertion of *Dil. op. sup.* (Fig. 2 : IIa, IIb, IIc).

1.3. *Intermandibularis* (*In. mand.*) :

In the present three species of the genus *Arius*, the muscle is moderately developed and stretched transversely between the dentaries of either side just behind the symphysis. The attachment of the fibres is mainly musculous but for some of the posterior fibres which are aponeurotically attached. The whole muscle is sandwitched between the two silvers of the *Protractor hyoidei* (Fig. 3 : IIa, IIb, IIc).

2. *Hyoid muscle complex* :

The muscles of this complex can be grouped into two main divisions : (1) Constrictor hyoideus dorsalis and (2) Constrictor hyoideus ventralis (Edgeworth, 1935).

2.1. *Constrictor hyoideus dorsalis* :

This dorsal group of the hyoid muscle complex suspend the hyomandibular and the palato-pterygoid arch from the cranium. It comprises 5 components : (1) *Adductor arcus palatini*, (2) *Extensor tentaculi*, (3) *Levator operculi*, (4) *Adductor operculi* and (5) *Adductor hyomandibulae*.

2.1.1. *Adductor crcus palatini* (*Add. arc. pal.*) :

It is a massively developed muscle filling the entire space present between the neurocranium and pterygo-hyomandibular arches. The muscle lies directly underneath the membrane in the roof of the mouth and the anterior part of the pharyngeal cavity on either side of the parasphenoid. The muscle fibres originate from the lateral surface of the parasphenoid in case of *A. arius* and *A. thalassinus* while in *A. caelatus* the origin of some of the fibres extend anteriorly upto the orbitosphenoid. From the site of origin the fibres run horizontally at a right angle to the longitudinal axis of the head in a divergent fashion and finally get inserted on the hyomandibular and the metapterygoid. The origin and insertion of the fibres are mainly musculous but in some specimens the fibres are also seen attached through tendon. Anteriorly the muscle overlaps the *Extensor tentaculi* partially, in all the three species (Fig. 3 : IIIa, IIIb, IIIc).

2.1.2. *Extensor tentaculi* (*Ext. tent.*) :

The development of this muscle varies significantly among the three species, that is poorly, moderately and well developed in *A. arius*, *A. thalassinus* and *A. caelatus* respectively. Otherwise there is no difference in respect of origin and insertion. In all the three species the muscle originate from the ventral aspect of the lateral ethmoid and

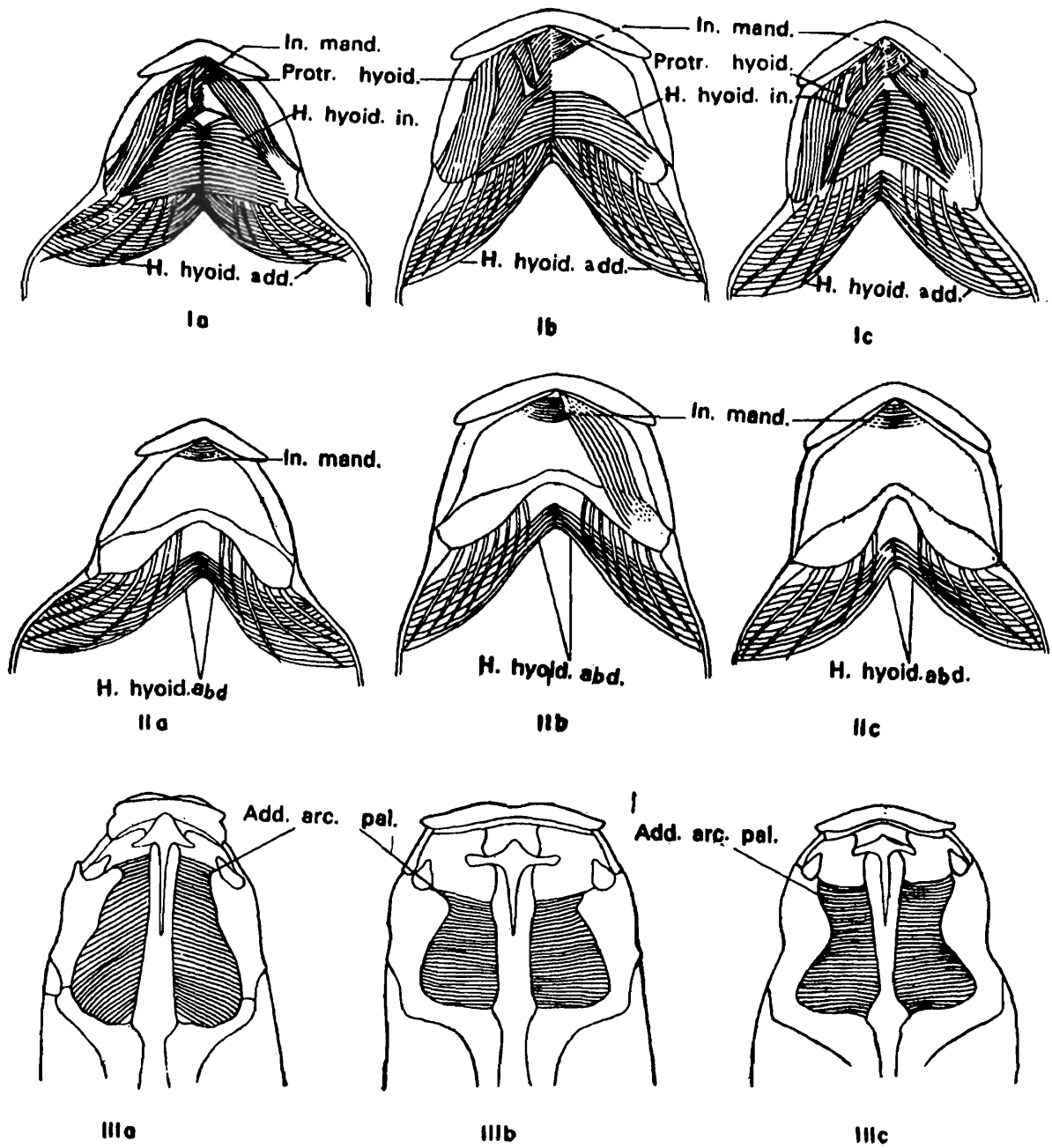

Fig. 3. I. Ventral view of the head region showing the disposition of *Protractor hyoidei*, *Hyohyoides inferioris* and *Hyohyoidei adductores*. a- *Arius arius*, b- *A. caelatus*, c- *A. thalassinus*. II. Ventral view of the head region showing the disposition of *Intermandibularis* and *Hyohyoidei abductores*. III. Ventral view of the head region showing the disposition of *Adductor arcus palatini*.

orbitosphenoid. The insertion is mainly musculous except some posterior fibres which are attached through aponeurosis on the distal end of the autopalatine and the endopterygoid. This muscle helps in the movement of the maxillary barbel (Fig. 2 : IIa, IIb, IIc).

2.1.3. *Levator operculi* (*Lev. op.*) :

This muscle is moderately developed just lying underneath the skin behind the *Dialator operculi*. It originates directly from the ventrolateral surface of the pterotic and the post temporal in *A. arius* and *A. caelatus*, while in *A. thalassinus* some of the fibres are also attached through tendon. The muscle fibres run downwards to get inserted on the dorsomesial surface of the opercular. It partially overlaps the *Add. hyomand.* and *Add. op.* (Fig. 2 : Ia, Ib, Ic).

2.1.4. *Adductor operculi* (*Add. op.*) :

It lies beneath the *Lev. op.* clearly separated by a connective membrane from the latter. In all the three species the muscle originates from the ventro-lateral surface of the pterotic and runs downwards in a divergent manner, to get its insertion on the inner-dorsal surface of the opercular. The origin and insertion is mainly musculous but in case of *A. thalassinus* some of the fibres are attached aponeurotically on the pterotic (Fig. 2 : IIIa, IIIb, IIIc).

2.1.5. *Adductor hyomandibulae* (*Add. hyomnd.*) :

It is a moderately developed muscle, situated underneath the Lev. op. In all the three species, the muscle originates from the ventral surface of the pterotic, and runs forwardly directing downwards to get its insertion on the posterodorsal projection of the hyomandibular. The insertion is partly aponeurotic and partly musculous. It partially overlaps the *Add. op.* and itself overlapped by the *Lev. op.* (Fig. 2 : IIa, IIb, IIc).

2.2. *Constrictor hyoideus ventralis group* :

This group of muscle consists of 5 distinct muscular components which are responsible for the movement of lower jaw in relation to the hyoid arch. These are as follows :

1. Protractor hyoidei, 2. Hyohyoides inferioris, 3. Hyohyoidei abductores, 4. Hyohyoidei adductores.

2.2.1. *Protractor hyoidei* (*Protr. hyoid.*) :

This is an enormously developed compound component formed by the fusion of the *Intermandibularis posterioris* (anteriorly) and the *interhyoideus* (posteriorly) (Edgeworth, 1935 ; Winterbottom, 1974). The antero-lateral segment of the muscle originates from the epihyal and the junction of the ceratohyal and epihyal musculously in case of *A. caelatus*, partly musculously and aponeurotically in *A. arius* and *A. thalassinus*. Finally the fibres of this segment get inserted on the mesial surface of the dentary through an aponeurosis as well as directly. The posteroinner portion of this muscle is quite massive and broad covering almost entire, anterior-ventral surface of the head. The fibres of this muscle originate directly from the ceratohyal in *A. arius* and *A. thalassinus* but in *A. caelatus* some of the fibres are also originating tendinously from the junction of the epihyal and the ceratohyal. The muscle fibres run forwards and inwards in a divergent fashion to get fused with its fellow of the other side along the mid ventral line. Anteriorly the muscle bifurcates into two slips (superior and inferior), which finally get inserted on the

mesial surface of the dentary near the symphysis. The lower (inferior) slip runs below the *intermandibularis*, while the upper (superior) one overlaps the *intermandibularis*. This muscle provides support to the mandibular barbels. The insertion on the dentary is partly musculous and partly aponeurotic. The muscle overlaps the *H. hyoid. inf.* (Fig. 3 : Ia, Ib, Ic).

2.2.2. *Hyohyoides inferioris* (*H. hyoid. inf.*) :

It is a massive and enormously developed muscle situated behind and slightly underneath the *Protractor hpoidei*. The muscle fibres arise from the ceratohyal and hypohyal in all the three species, besides from the fourth branchiostegal ray in *A. thalassinus*, the fifth ray in *A. arius* and the sixth ray in *A. caelatus*. After the musculous origin the fibres run transversly at right angle to the median longitudinal axis which finally get fused with its fellow of the other side along the mid ventral line. The muscle partly overlaps the *Abd. hyoid.* and the *Add. hyoid* (Fig. 3 : Ia, Ib, Ic).

2.2.3. *Hyohyoidei abductores* (*H. hyoid. abd.*) :

It is also a well developed muscle, lying underneath and behind the *H. hyoid. inf.* In all the three species the muscle fibres from either side get fused with each other through a raphae along the mid ventral line above the urohyal. The fibres are stretched in a divergent fashion transversely, which finally get attached on the entire first branchiostegal ray in all the species in addition to the distal end of the other branchiostegals (Fig. 3 : IIa, IIb, IIc).

2.2.4. *Hyohyoidei adductores* (*H. hyoid. add.*) :

This muscle is stretched in between the branchiostegal rays and the opercular in various bands. The number of muscle bands vary specifically in the three species. There are 6 bands in *A. arius*, 6-7 in *A. caelatus*, and 5 in *A. thalassinus*. In the distal portion of all the branchiostegals the muscle fibres are well developed but gradually get thinner towards the proximal portion and finally vanish at the end (Fig. 3 : Ia, Ib, Ic).

Discussion

While comparing the various muscular elements of the mandibular and hyoid muscle complexes, it is seen that the three species (*Arius arius*, *A. caelatus* and *A. thalassinus*) exhibit a common pattern in respect of the origin, insertion, disposition and the morphology of the following muscles : *Adductor mandibularis*$_{3,4}$; *Levator arcus palatini*, *Dilator operculi* ; *Intermandibularis* ; *Adductor operculi* ; *Adductor hyomandibulae* and *Hyohyoidei abductores*. However, from table 1 it may be observed that in the gross morphology of the *Adductor mandibular* muscle complex, certain specific differences do exist such as the absence of *Adductor mandibularis*$_2$ in *A. caelatus* unlike that of the other two species where it is present. Similarly the three species also vary in respect of the magnitude of the development of the *Intramandibularis* and the *Extensor tentaculi*.

The *Constrictor dorsalis* and *Intermandibularis* group of the *Mandibular* complex do not differ much in the three species. Moreover the nomenclature of the muscle *Levator arcus palatini* itself (and adopted here) needs some clarification since the earlier workers (Munshi, 1960 ; Singh and Munshi, 1969) reported this muscle under two different names i.e., *Abductor hyomandibularis* and

Protractor hyomandibularis. Winterbottom (1974a) considered these two names as synonymous with the *Levator arcus palatini*, which seems to be apt since there is no cleavage in this muscle at least in the three species studied.

In respect of the *Hyoid* muscle complex, the *Adductor hyomandibulae* originates from the pterotic in all the three species we have studied. Singh and Munshi (1969) on the other hand reported this muscle as originating from the hyomandibur (named by them as *Retractor hyomandibularis*) in *Rita rita*, *Wallago attu* and *Aoriichthys aor*. Jayaram and Singh (1982) have, however, found that this muscle (*Adductor hyomandibulae* = *Retractor hyomandibularis* as per Winterbottom, 1974a) originating from the pterotic only in *Rita*

TABLE. 1. Comparison of various muscles in the three species of the genus *Arius*.

	A. arius	*A. thalassinus*	*A. caelatus*
1. Adductor mandibularis$_1$	This muscle is inserted through a very prominent aponeurosis. The inner part of this muscle is overlapped by *Add. mand.*$_2$.	Similar to that of *A. arius*.	The aponeurosis is indistinct and inner part of this muscle is overlapped by *Add. mand.*$_3$
2. Adductor mandibularis$_2$	Present	Present	Absent
3. Adductor mandibularis$_3$	The aponeurosis of this muscle overlaps the aponeurosis of *Add. mand.*$_{2,4}$.	Similar to that of *A. arius*.	The aponeurosis of this muscle overlaps the aponeurosis of *Add. mand.*$_{3,4}$.
4. Intramandibularis	Well developed, attached on the aponeurosis of *Add. mand.* $_{2,6}$.	Moderately developed, attached on the aponeurosis of *Add. mand.*$_{2,6}$.	Poorly developed, attached on the aponeurosis of *Add. mand.*$_6$ only.
5. Adductor arcus palatini	Originates only from the parasphenoid.	Similar to that of *A. arius*.	The origin also extends up to the orbitosphenoid.
6. Extensor tentaculi	Poorly developed.	Moderately developed.	Well developed.
7. Levator operculi	Originates musculously.	Originates musculously as well as aponeurotically.	Similar to that of *A. arius*.
8. Adductor operculi	Originates musculously.	Originates musculously as well as aponeurotically.	Similar to that of *A. arius*.
9. Protractor hyoidei	Originates musculously from ceratohyal only.	Similar to that of *A. arius*.	Originates musculously and aponeurotically from ceratohyal as well as from the junction of cerato-and epihyal.
10. Hyohyoidei adductores	Present in 6 bands.	5 bands.	6-7 bands.

rita, *Mystus gulio*, *Horabagrus brachysoma* and *Aoriichthys aor*. The *Protractor hyoidei* originates musculously from the ceratohyal in *A. arius* and *A.* thalassinus but in *A. caelatus* it extends to the junction of epihyal as well. The comparative table indicates *A. arius* and *A. thalassinus* to be sharing many common features unlike *A. caelatus*. The origin of *Adductor arcus palatini* extends up to the orbitosphanoid in case of *A. caelatus* while in the other two species it is restricted to the parasphenoid only. The *Hyohyoidei adductores* has greater number (6 or 7 bands) of supporting bands in *A. arius* and *A. caelatus* unlike *A. thalassinus* which has only five bands. *Extensor tentaculi* is also well developed in *A. caelatus* than in the other two species.

It appears from the above structural pattern that amongst the three species, *A. caelatus* is better developed than the other two. However, A. *thalassinus* grows to considerably larger size (1 meter or more) than *A. arius* (400 cm) and *A. caelatus* (not more than 600 cm) and is also more widely distributed and abundant in terms of catches. *A. arius* is the smaller of the three in size wise and is also restricted in its distribution.

A. arius is dominant in the Chilka Lake while *A. caelatus* is an inhabitant of estuaries and sea shores. *A. thalassinus* is a denizen of the open seas. Whether these habitat preferences have any relationship with their structure is hard to postulate at this juncture. It may however be stated that these differences in the muscle pattern are of limited taxonomic utility.

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