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Descriptive and comparative osteology of five cyprinid fishes from Southern Iraq

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Abstract - Descriptive and comparison osteology was conducted in the present research for five species of cyprinid fishes during the period from June to September 2016 of some paired head bones for premaxilla, maxilla, lower Jaw and opercular. A total of 111 specimens were collected by electrofishing from Huwaza and Chybiyesh marshes Southern Iraq include: *Carasobarbus luteus, Carassius gibelio, Cyprinus carpio, Leuciscus vorax* and *Mesopotamichthys sharpeyi*. Results showed the significant differences ($P<0.05$) among bones of species which were described and compared in both intergeneric and interspecific. Statistical analysis was done for all bones. Coefficient of determination (r^2) showed a strength correlation of the linear association between standard length and length of premaxilla, maxilla, dentary, angloluarticular and opercular of *L. vorax* (0.973, 0.89, 0.976, 0.95 and 0.986) respectively. The present study revealed new information about the phylogeny of cyprinids by evident the differences among species in the shape and design of bones, which was rise to isolate it in different genera, but there was convergence in general shape to join it in one family.

Key words: Osteology, Five cyprinid species, Premaxilla, Maxilla and Opercualr.

Introduction

Cyprinidae is the largest families of freshwater fishes, their species widespread during the world (Durand *et al*., 2002; Gul *et al*., 2004). Cyprinid fishes are widely distributed in Europe, Asia, Africa and North America, this family have a great diversity in Iraqi inland waters (Al-Noor and Abdullah, 2015). Most previous studies in Iraq were focused on morphometric and meristic characteristics which are affected by external ambient; however the osteological traits enhance the other characters, since these features are useful to make identification keys for their distinction (Nasri *et al*., 2013; Mafakheri *et al*., 2014). The jaw bones are considered to be important characteristics to separate the groups of symmetric species in teleostean fishes. Although, they are remarkably variable in shape correlated to the feeding behavior (Taniguchi, 1970). Bones of head are particularly useful for identifying the size and composition of prey species from the food remains of predators, as they withstand digestion and are taxonomically valuable (Copp and Kovac, 2003). Osteological studies provide additional information for a better understanding of the phylogeny of cyprinid fishes (Alkahem *et al*., 1990).

Several studies were focused on fish taxonomy based on fish bones such as Takahashi (1962), which identification species using vertebral column, Qasim (1973) investigated the osteology of *Luciobarbus xanthopterus* and *M. sharpeyi* with special reference to their lateral-line system. Nasri *et al.* (2013) Comparative osteology of Lotaks, *Cyprinion kais* and *Cyprinion macrostomum* from West Iran. Jalili *et al.* (2015) Address the osteological description of the southern king fish, *Alburnus mossulensis* from Iranian part of the Tigris River drainage.

The aim of the present study was to describe some of head bones and analysis both intergeneric and interspecific differences in premaxilla, maxilla, dentary, anguloarticular and opercula to append useful information which will support the studies about the taxonomy of this species.

Materials and Methods

A total of 111 specimens of *M. sharpeyi*, *C. luteus*, *C. carpio*, *C. gibelo* and *L. vorax*, were collected from Southern Iraqi marshes (Huwaza N 31° 10′ 30″; E 47° 34′ 12″ and Chybiyesh N 31° 01′ 12″; E 47° 01′ 48″) during the period from June to September 2016 (Fig. 1). The specimens were weighed (Wt, to nearest 0.01 g) and measured the standard length (SL in mm). The species were classified according to Coad (2015). Specimens were boiled in water until flesh was easily removed and the bones were left to dry. In each species, measurements of bone dimensions for premaxilla, maxilla, dentaries, anguloarticular and opercular were taken (Hansel *et al*, 1988; Prenda and Granado-Lorencio, 1992). The premaxilla (length mm) were measured from the symphysis to end of the posterior process, the maxilla (length mm) from the anterior edge to the posterior process, the anguloarticular (length mm) from the pointed anterior part, which being inserted into the hollow of dentary to the end of the angular, the dentary (length mm) from the mandibular symphysis to the posterior ventral tip, the opercular (articular axis height) from the articulation tip to the anterior angle (Hansel *et al.*, 1988). The bones were photographed using digital camera (Sony 1080 Steadyshot).

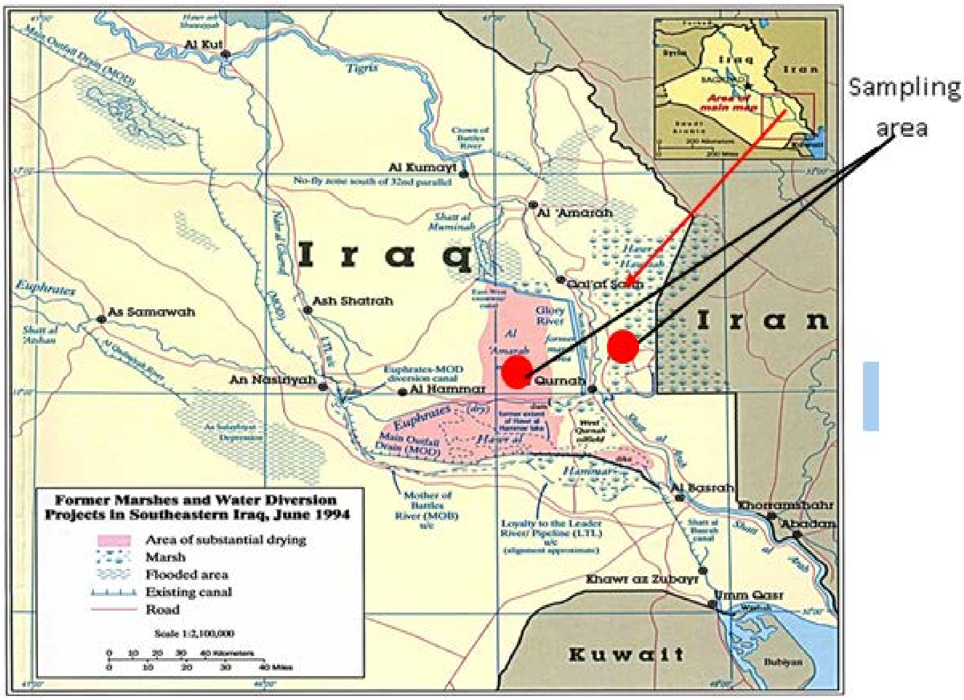

Figure 1. Map of sampling area.

The nomenclature to describe the bones following to Howes (1982); Rosello (1989) Miranda and Escala (2005). Measured of bones dimensions (BL, mm) were regressed against standard length and weight as proposed by Copp and Kovac (2003). Linear and non-linear regressions of the relationships between BL and SL was as BL=bSL±a and $BL=aWt^b$ in the weight relationships, where (a) is the intercept of the regression curve and b the regression coefficient. To comparative left side of paired bones were regressed against SL and Wt. ANOVA was used to compare the bones size among five species. Statistical analysis were performed by using SPSS ver. 17software Inc.

Results

Upper Jaw:

The variations in the premaxilla among five examined species of cyprinids were differed in shape and size, its generally convex paired bones, and all present species possess a developed ascending process (Fig. 2). In the *C. luteus* the bone was thin, the posterior process gently sloped, the ascending process columnar and longer than of *M. sharpeyi*. The premaxilla of *C. gibelo* was a broad with a well-developed anteriorly ascending process. In *C. carpio* irregular with slowly sloped toward posterior end, anterior ascending process has wide basal and mid elevated moderately in *L. vorax* anterior ascending process is thick and tapering in its tip, mid of posterior portion is elongated, with ending in pointed shape. In *M. sharpeyi* premaxilla it was thin and tapering posteriorly. The ascending process has a wide anterobasal portion with sloped end.

Maxilla:

The maxilla of all represented species was convex dorsally and small in size. The five cyprinids possess one anterior ascending process in maxilla (Fig. 3). The posterior process were developed and expanded in all examined species except *L. vorax* which was short. The posterior process of *M. sharpeyi* finger-like shape, whereas *C. luteus* is longer and it was observed rectangular-like shape and plate-like with expanded in both *C. carpio* and *C. gibelo*, whereas trapezoidal shape in *L. vorax*. The crest plate-like form with slightly bended for *M. sharpeyi*, *C. carpio* and *C. gibelo*, but well defined in *C. luteus* while small in *L. vorax*.

Lower Jaw:

Dentary was usually toothless bone as other cyprinids fishes which was curved anteriorly from a symphysis, the lower jaw consists of four bones, dentry, angular and retroarticular, addational to have series of sensory pores forming anterior part of the lateral line system along the entire length of the ventral surface (Fig. 4). The dentary make a thick edge that attachment with bone of the other side of the lower jaw. The coronoid process has a sagittal shape in *C. gibelo*, while rectangular shape in *C. luteus* and *M. sharpeyi*, whereas a trapezoidal-shape in *C. carpio* and *L. vorax*. Dentary has a medium size in all examined species except, in *L. vorax*, it was being elongated. All species have a series of sensory pores in the ventrolateral surface. The anguloarticular was anteriorly pointed, being inserted into the hollow of the dentary, it was contact with the dentary by meckelian cartilage from the middle part. The posterodorsal part of the anguloarticular which was sturdy and thick, forming a fulcrum for articulation with the quadrate. The angular of *M. sharpeyi* and *C. gibelo* are large, but in *C. luteus* is small, in specimens that have the same standard length, the posterodorsal portion of *C. gibelo* bears large rounded foramen, the bone was thick and elongated in *L. vorax*. The retroarticular is a small bone fused to the posteroventral portion of the anguloarticular, provides an attachment site for the ligament connecting with lower jaw and attached the angular dorsally. The retroarticular was differing in shapes; its small in all represented species except *L. vorax* was being large and thick.

Opercular:

The analysis of morphological of opercular in the five investigated species as follows:

In *C. luteus* the upper edge was concave, the posterior angle was rounded with an elevated position, the articular process and opercular arm process were short and narrow. The auricular process was well developed (Fig. 5). In *C. gibelo* the articular process and opercular arm were strudy, with a fovea around the lower margin of the opercular arm, the auricular process was well developed. In *C. carpio* the upper edge was straight, the posterior angle in an elevated position. The articular process and opercular arm process were short and wide, the auricular process was well defined. In *L. vorax*, the opercal was display a rhombus-shaped. The posterior angle was acute and low positioned, the articular process was short and wide, the opercular arm process was elongated and narrow, the auricular process was absent (Fig. 5). In *M. sharpeyi* the upper edge was slightly concave and posterior angle in low positioned (Fig. 5). The articular process and opercular arm process were short and wide with a small concavities around the opercular arm, the auricular process was present.

Bones of haed measurment reveald significant differences ANOVA ($P<0.05$) in premaxilla, maxilla, dentary and anguloarticular between *L. vorax* and other four species, also significant differences ($P<0.05$) in maxilla and dentary between *M. sharpeyi*, *C. luteus* and *C. gibelo*, but in opercular there was a great similarity in the overall shapes among of *M. sharpeyi* and *C. luteus with* variations in articular process and opercular arm, as well as have a highly significant differences ($P<0.05$) among *Cyprinus*, *Carassus*, and *Leuciscus*.

The biometric relationship between bones (BI) with standard length (SL) were statistically significant except maxilla in *C. luteus* and opercular in all five representatives species, wherever the relationship between bones size and body weight (Wt) were significant ($P<0.05$) except in opercular of four species. Coefficient of determination (r^2) with standard length (0.073) in maxilla of *C. luteus* and 0.976 in dentary of *L. vorax*. The coefficient of determination with body weight were 0.937 with the dentary and 0.239 in opercular of *M. sharpeyi*, but in opercular of genera Mesopotamichthys and *Carasobarbus* were highly significant differences of other three genera (Table 1).

Number of *C. luteus, C. gibelo, C. carpio, L. vorax* and *M. sharpeyi* (n), coefficient of determination (r^2), intercept (a) and regression slope (b) for linear and non-linear of bone sizes (Bl, in mm) regressed against total length ($BL=b\text{SL} \pm a$) and body weight ($W_t=a\ BL^b$) for the left side of five studied species. *C. luteus* (mean SL=169.08 mm, SE=0.294, min.=143 mm, max.=197 mm). *C. gibelo.* (mean SL=195.58 mm, SE=0.572, min=158 mm, max=249 mm). *C. carpio* (mean SL=172.8 mm, SE=0.59, min=152 mm, max=234 mm). *L. vorax* (mean SL=263.11 mm, SE=1.610, min=195 mm, max= 324 mm). *M. sharpeyi* (mean SL = 206.41 mm, SE =0.711, min=154 mm, max = 306 mm).

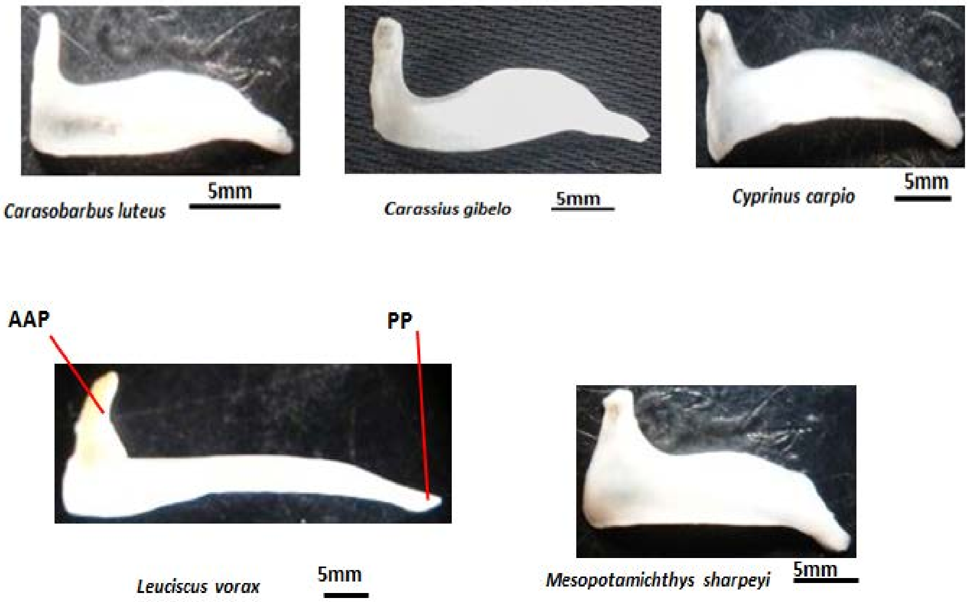

Figure 2. Lateral view of premaxilla, left side of representative species. AAP: Ascending anterior process, PP: Posterior process.

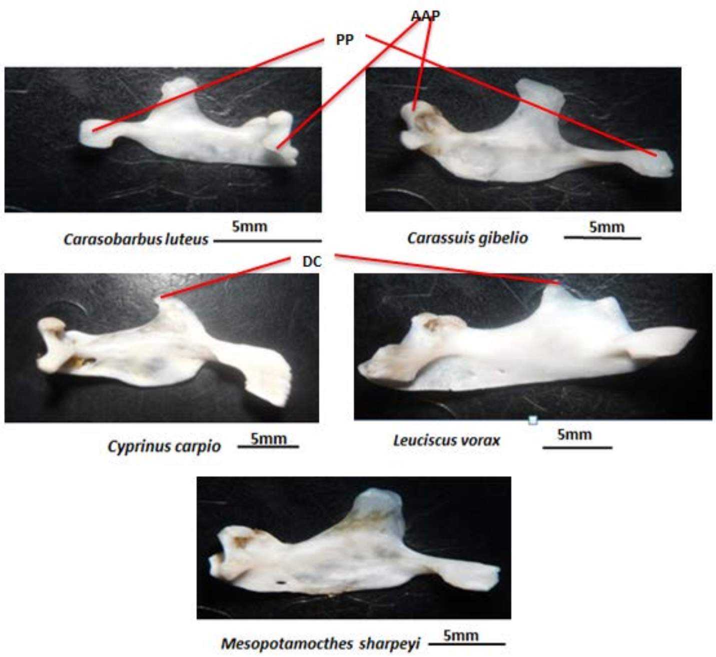

Figure 3. Dorsal view of maxilla, of studied species. AAP: Anterior ascending process, PP: Posterior process, DC: Dorsal crest.

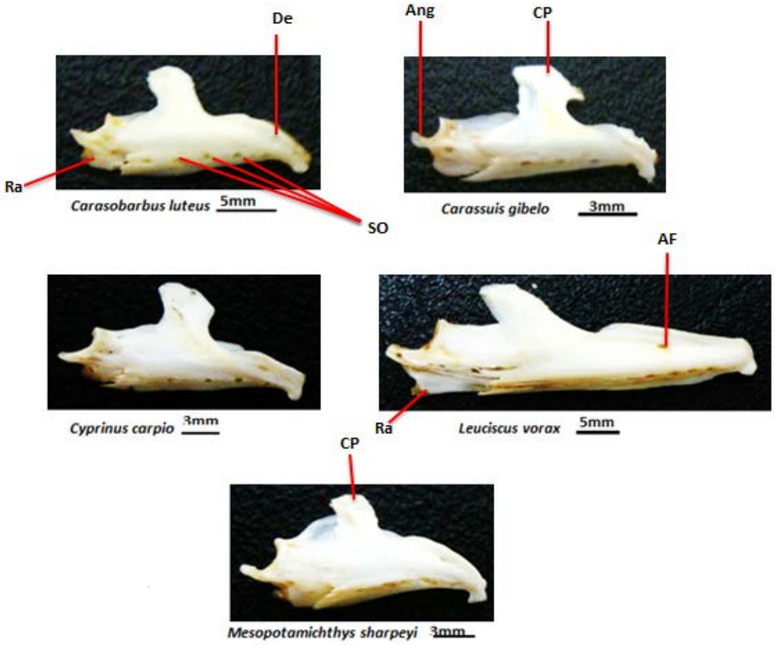

Figure 4. Lateral view of the lower jaw of cyprinid five species (left side). Ang: Angular, Cp: Coronoid process, De: Dentary, Ra: Retroarticular, SO: Sensory pores, AF: Anterior-lateral foramen.

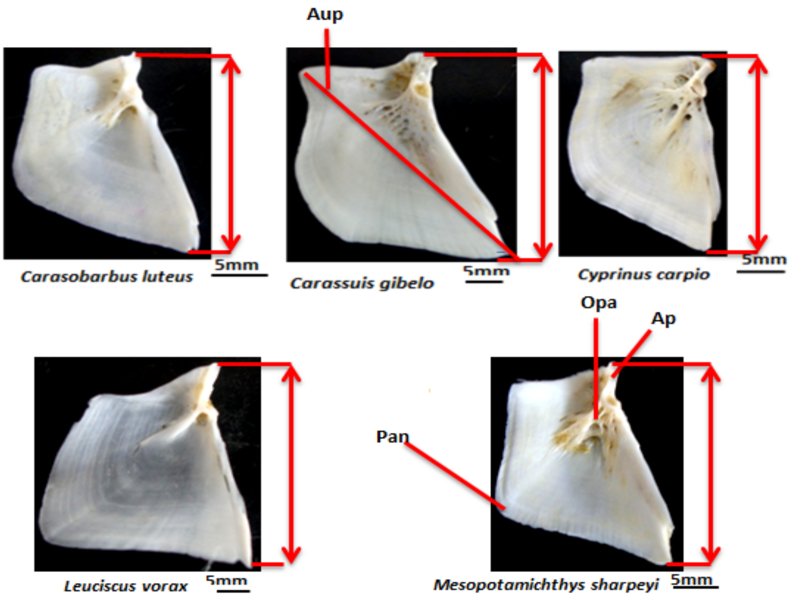

Figure 5. Internal view of the left side opercular of the five cyprinid species. Ap: articular process, Opa: opercular arm, Pan: Posterior angle, Aup: auricular process.

Table 1. The statistical analysis of head bones measurement of five cyprinid species from Southern Iraq.

Species		Standard length (mm)			Body weight (g)		
	N	r^2	a	b	r^2	a	b
C. luteus							
Premaxilla	24	0.724	5.174	0.034	0.68	5.851	0.003
Maxilla	24	0.073	11.86	0.004	0.728	4.966	0.005
Dentary	24	0.598	6.467	0.031	0.656	6.597	0.003
angoluarticular	24	0.718	3.538	0.038	0.78	4.723	0.004
opercular	24	0.668	9.69	0.056	0.488	12.86	0.002
C. gibelo							
premaxilla	26	0.909	2.665	0.05	0.652	8.136	0.001
maxilla	26	0.884	0.166	0.07	0.781	6.879	0.002
dentary	26	0.866	1.074	0.074	0.729	8.445	0.002
angoluarticular	26	0.921	-0.189	0.067	0.732	6.875	0.002
opercular	26	0.329	23.35	0.017	0.614	22.34	0.001
C. carpio							
premaxilla	21	0.913	0.563	0.023	0.809	7.268	0.002
maxilla	21	0.955	0.029	0.074	0.781	9.095	0.001
dentary	21	0.808	3.465	0.06	0.743	10.2	0.001
angoluarticular	21	0.83	2.157	0.057	0.674	8.983	0.001
opercular	21	0.519	15.84	0.037	0.382	19.59	0.014
L. vorax							
premaxilla	23	0.973	0.678	0.084	0.816	9.639	0.002
maxilla	23	0.89	4.171	0.078	0.638	12.98	0.001
dentary	23	0.976	1.148	0.105	0.797	12.84	0.002
angoluarticular	23	0.95	1.004	0.089	0.759	19.99	0.002
opercular	23	0.986	3.507	0.08	0.838	11.56	0.001
M. sharpeyi							
premaxilla	17	0.703	4.395	0.034	0.675	66.059	0.003
maxilla	17	0.91	4.707	0.04	0.924	3.942	0.005
dentary	17	0.916	5.305	0.036	0.937	3.435	0.005
angoluarticular	17	0.911	2.26	0.07	0.928	2.441	0.007
opercular	17	0.42	0.08	0.153	0.239	10.71	0.002

Discussion

Osteological features are useful characters for their identifying, after that can be well interpreted in taxonomy and phylogenetic relationship of fish species even in higher level (Rojo, 1991; Prokofiev, 2010). Results appeared several differences among bones of represented species that reflected specific distinction among five specie, as other cyprinid member which belong to interspecific and intergeneric variance. However, the variation in design and shape of bones is a good taxonomical tool in studies of phylogenetic relationship among groups of fishes (Shukla and Verma, 1972). Premaxilla of present five species demonstrated that some of bones were thin, but others were thick and tapering posteriorly with well - developed ascending process, as well as its elongated in *L. vorax* which has a specialize adaptive traits (mouth opening is wide), however its generally compatible with the previous studies on osteology of cyprinidae (Alkahem *et al.*, 1990; Nasri *et al.*, 2013). One ascending process in maxilla for all investigated species, with more similarities between the ascending process of *M. sharpeyi* and *C. luteus*, then *C. gibelo* and *C. carpio*, but Alkahem *et al.* (1990) found more than one, the reason due to environmental differences, as well as they varies in species and genus. Jalili *et al.* (2015) denoted that the maxilla was long and bears a descending process in its anterior part with broadened of it middle part when they carried out osteological description of the *Alburnus mossulensis* from Iranian part of the Tigris River drainage, the differences belong to feeding method of this species which is in the mid river and mouth design (mouth open upwards). Alkahem *et al.* (1990) showed that the premaxilla is thin and narrow in *Cyprinion mhalensis* but thick and broad in *Cyprinion acinaces* and the posterior process is distally bifurcated in *C. acinaces*, and broad in *C. mhalensis* (Mansson *et al*, 2011). Nasri *et al.* (2013) found that the premaxilla was uniformly thin in the posterior process in *Cyprinion kais* and *Cyprinion macrostomum*. The crest and posterior ascending process was well-define in all species, except the crest of *L. vorax* it appear small size which was compatible with the finding of Alkahem *et al.*, (1990). Bones of head have a specialized adaptive characteristics and are high taxonomic value (Prenda and Granado-Lorencio, 1992). The differences were evident in the dentary among the represented species in coronoid process, that looks a rectangular shape in *M. sharpeyi* and *C. luteus*, but it trapezoidal in *C. carpio* and *L. vorax* and sagittal in *C. gibelo*, so the bones of jaw are an important adjective to distinguish the species (Antovic and Sminovic, 2006). The angular was pointed in *C. luteus*, *C. carpio* and *M. sharpeyi* and sturdy in other two species, the retroarticular varies in size among represented species (Alkahem *et al.*, 1990; Nasri *et al.*, 2013; Jalili *et al.*, 2015). Opercula divergent among present five species in length of articular process, arm process and in present or absent of auricular process, the size or area of opercular related with amount of water passed over the gill area tissues, so species that possess a small opercualr to be less tolerant of low dissolved oxygen water (Coad, 2010), such as the genera of *Mesopotamychthes* and *Carasobarbus*, which are sensitive to change in oxygen concentration in waters. Alkahem *et al.* (1990) studied four species of cyprinid fishes belong to genus *Barbus* (two species), *Cyprinion* and *Garra* from the Arabian Peninsula, they deal with jaw bones (premaxilla, maxilla, lower jaw and vertebral structure), they found enormous differences in head bones and vertebrae, their results agrees with the present research concern of premaxilla, maxilla and lower jaw. However, the current results of opercular corresponded with Masson *et al.* (2011) when they detected a large diverge in opercular of three species of *Carassius* and the forth hybrids (*C. carassus*, *C. auratus*, *C. auratus gibelio* and *C. carassus* × *C. auratus*). Finally the important conclusion of this study gave a tool for identification of species and biometric relationship which enables us to estimation the length and weight by using bones of head that taken as prey during feeding of large piscivorous fauna that withstand the digestive processes (Britton and Shepherd, 2005). In the present work most of head bones have high significant relationship with length especially in status of *L. vorax* and this was consistent with the results of (Mansson *et al.*, 2011).

The survey has been revealed a wide convergence evolution among five species in shapes and design of head bones, so that present study was supported to join these species under one family, but the differences in design details of bone compatible to isolate the species in to five genera, with more similarity between *M. sharpeyi* and *C. luteus* with variations in size of their bones of fish that have the same standard length, with a diverge in status of *L. vorax*.

Conclusions

Bones morphology is a good tool to determine the variance intergeneric and interspecific to investigate the phylogeny traits among species, genera and families and understanding the range of environmental and genetic influences on modification of bones which helpful the fauna to live in their habitat.

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مقارنة وصفية وعظمية لخمسة أنواع من عائلة الشبوطيات من جنوبي العراق

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المستخلص - أُجريت مقارنة وصفية عظمية لخمسة أنواع من عائلة الشبوطيات Cyprinidae للمدة من حزيران إلى أيلول 2016 لبعض عظام الرأس الزوجية، وضمت كل من العظم قبل الفكي والفكي وعظام الفك الأسفل وعظم الغطاء الغلصمي. جمعَ 111 نموذج جمعت بالصيد الكهربائي من هوريَّ الحويزة والجبايش في جنوب العراق شملت: *Carasobarbus luteus* و *Carassius gibelo* و *Cyprinus carpio* و *Leuciscus vorax* و *Mesopotamichthys sharpeyi*. أظهرت النتائج فروقات معنوية ($P<0.05$) بين عظام الأنواع قيد الدراسة، التي وصفت وقُورنت بين الأجناس والأنواع. أُجريَّ التحليل الأحصائي لجميع العظام، وأظهر معامل التحديد (r^2) علاقة ارتباط قوية في العلاقة الخطية بين الطول القياسي وطول العظم قبل الفكي والفكي والسني والعظم الزاوي والمحوري والعظم الغطائي الخيشومي للنوع *Leuciscus vorax* (0.973، 0.89، 0.976، 0.95، 0.986) على التوالي. أظهرت الدراسة الحالية معلومات جديدة حول العلاقات العرقية لعائلة الشبوطيات بأظهار الأختلافات بين عظام الأنواع في الشكل والتصميم، الذي يرتقي لعزلها إلى أجناس مختلفة، لكن هناك تقارب في الشكل العام لضمها في عائلة واحدة.