Short communication

Caudal skeleton variations in *Alburnoides* spp.

ABSTRACT

The species in the genus *Alburnoides* is distinguished based on having a combination of some morphological characters and different fin ray counts. Most descriptions are based on morphological characters and molecular approaches. The species are widely distributed in the Iranian basins. The caudal shape comparison of *Alburnoides* species from the Inland water of Iran revealed some differences between them including the shape of the epural and rudimentary neural arch. However, ten species of *Alburnoides*, reported from Iran were not distinguishable based on these osteological characters.

Keywords: Inland water Fishes of Iran, Osteology, *Alburnoides*, Ichthyology, Biodiversity.

INTRODUCTION

The genus *Alburnoides* is widely distributed from Europe to Asia Minor and Central Asia (Bogutskaya and Coad 2009; Coad and Bogutskaya 2009, 2012, Turan et al. 2014; Mousavi-Sabet et al. 2015 a,b; Schönhuth et al. 2018). Recently, twelve species were considered to occur in Iranian Inland waters. *Alburnoides eichwaldii* (De Filippi, 1863) from Kura River basin was re-introduced (Bogutskaya and Coad 2009) and 11 other species were described: *A. namaki* Bogutskaya & Coad, 2009 from a qanat at Taveh, Namak Lake Basin, *A. nicolausi* Bogutskaya & Coad, 2009 from the Tigris River drainage, *A. qanati* Coad & Bogutskaya, 2009 from the Pulvar River drainage, Kor River Basin, *A. idignensis* Bogutskaya & Coad, 2009 from the BideSorkh River, Gamasiab River system, Tigris River drainage, *A. petrubanarescui* Coad & Bogutskaya, 2009 from the QasemlouChay, Urmia Basin, *A. holciki* Coad & Bogutskaya, 2012 from the Harirud River, *A. tabarestanensis* Mousavi-Sabet et al. 2015a from Tajan River in the southern Caspian Sea Basin, *A. parhami* from BabaAman Stream, Atrak River drainage, *A. coadi* from Namrud River, Hablerud River, Kavir Basin and *A. samiii* from Guilan Province, upper Sefidrud River basin, Tutkabon Stream (Mousavi-Sabet et al. 2015b), *A. damghani* Jouladeh Roudbar et al. 2016a from Cheshmeh Ali, Damghan River system. Recently, *Alburnoides* cf. *taeniatus* (Kessler, 1874) was reported from Harirud (Tedzhen) River (Jouladeh-Roudbar et al. 2016b), but revision is needed to illuminate status of some recent described species (Esmaeili et al. 2017). Recently, Eagderi et al. (2019) showed that *A. parhami*, *A. coadi* and *A. idignensis* were invalid species. They proposed *A. parhami* as a synonym of *A. holciki*, *A. coadi* as synonym of *A. namaki* and *A. idignensis* as synonym of *A. nicolausi* (Eagderi et al. 2019).

Although there are many benefits to morphological descriptions, there are also some disadvantages in morphological characters as they are sensitive to environmental changes. Also, molecular approaches are expensive and time consuming. So using different approaches are needed to distinguish *Alburnoides* spp. (described and undescribed) from Iranian inland waters. Osteological characters are important and valid for identification and classification of fish species, and understanding biological features of fishes such as swimming, feeding and respiration (Helfman et al. 2009; Keivany 2014a,b,c,d). In addition, the skeletal structures contains more biological information that researchers use to distinguish environmental conditions of fish habitats (Helfman et al. 2009). Osteological characters can be utilized in ichthyology studies, especially fish systematics and potentially can resolve some complexities in this context.

Since identification of *Alburnoides* species is based on the morphological features that show many overlap with other members of this genus and due to high diversity and morphological similarity of the members of *Alburnoides*, using osteological data, may help to better understand their taxonomic relationships. Moreover, due to lack of more studies about osteological features of the genus *Alburnoides* in Iran (Mohammadi-Sarpiri et al, 2021), this study was conducted to give some basic results for further comparative osteology and phylogenetic studies of these fishes to draw a clear distinction among the different species based on osteological character.

MATERIALS AND METHODS

Three specimens of ten species of *Alburnoides* were collected using electrofishing from Iranian Basins (Fig.1), then fixed in 10% buffered formalin after anesthetizing in 1% clove oil solution and transferred to laboratory for further examinations (Table.1). The specimens were cleared and stained with Alcian blue and Alizarin red S according to the protocols of Taylor and van Dyke (1985) and Sone and Parenti (1995) with minor modifications. The cleared and stained specimens were studied using a stereomicroscope (SMP-120 model) and their skeletal elements were dissected and photographed by a digital camera. Drawing of the specimens were performed using CorelDraw X7 software. The terminology of skeletal elements was based on Rojo (1991) and Helfman et al. (2009).

RESULTS

The caudal skeleton of *Alburnoides* consists of six hypural, one parhypural and epural, and one uroneurals. The haemal spines of preurals 1 and 2 were wide. These characteristics were similar in all studied specimens. Caudal fin was just different in the shape of epural and rudimentary neural arch. We found eight different structures in the caudal fin of *Alburnoides* species. The epural has three shapes including triangular in the *A. namaki* and *A. damghani* (Fig. 2-A) irregular form *A. nicolausi* and *A. idignensis* (Fig. 2-H), bar-like (the other shape in Fig. 2). Moreover, the rudimentary neural arch has a more different shape such as single or two-branched, having neural foramen, without neural foramen (Fig. 2). In the caudal fin structure of our samples, we found different states of epural and rudimentary neural arch together in Fig. 2. Also, we found same structure in the *A. namaki* and *A. damghani* (Fig. 2A), *A. namaki* and *A. petrubanarescui* (Fig. 2C), and two different types in the *A. holciki* (Fig. 2B) and *A. qanati* samples (Fig. 2D). Moreover, we found more different structures in the *A. qanati, A. tabarestanensis and A. idignensis* and *A. holciki* (Fig. 2E), *A. namaki* and *A. tabarestanensis* (Fig. 2F), *A. eichwaldii* and *A. samiii* (Fig. 2G) and *A. nicolausi* and *A. idignensis* specimen (Fig. 2H).

DISCUSSION

Morphological and mitochondrial genetic data reveal that *Alburnoides* has twelve species in Iranian Basins. The caudal skeleton of fishes has been used for taxonomic studies by workers since more than 100 years ago (Kölliker, 1860; Lotz, 1864; Cope, 1890; Whitehouse, 1910; Regan, 1910; Hollister, 1936 and Fujita, 1990). Osteology still is an important instrument in the systematic study of fishes (Keivany 1996, 2000, 2014a,b,c,d, 2017a; Keivany and Nelson 1997, 1998, 2004, 2006; Nasri et al. 2013, 2016; Jalili et al. 2015, Keivany 2017b; Moezzi et al. 2019; Zamani-Faradonbe and Keivany, 2021). The main role of the caudal peduncle in the best performance in swimming, such as increasing the acceleration and speed of swimming at the beginning of swimming. Morphological differences in the caudal peduncle lead to more efficiency of swimming (lowering the cost of metabolism) and increasing the power of moving forward along the river. This diversity also occurs in the bony structures of the caudal fin (Hawkins and Guinn 1996). In the present study, high diversity was observed in the caudal fin skeleton and it seems to be due to the adaptation of these fish to different environmental conditions. In our study, not only *Alburnoides* species had structurally different caudal fin in different basins but also had different structures among populations. However, the observed differences are not due to the different ages of the samples. Because in Cyprinid fish, the caudal fin becomes fully bony at 14 weeks after hatching (Hasanpour et al. 2015).

CONCLUSIONS

According to our results, it seems there was no special structure in the caudal fin of the *Alburnoides* species as species identification traits. Also, we can not use this osteological structure for the identification of members of this genus in the Iranian Basins.

Table1. List of samples.

N	Species name	Basin	N	Species name	Basin
1	*A. holciki*	Hari River	6	*A. eichwaldii*	Caspian Sea
2	*A. damghani*	Kavir	7	*A. samiii*	Caspian Sea
3	*A. qanati*	Fars	8	*A. petrubanarescui*	Urmia
4	*A. namaki*	Namak	9	*A. idignensis*	Tigris
5	*A. tabarestanensis*	Caspian Sea	10	*A. nicolausi*	Tigris

Fig1. Iranian Basins (Keivany et al., 2016).

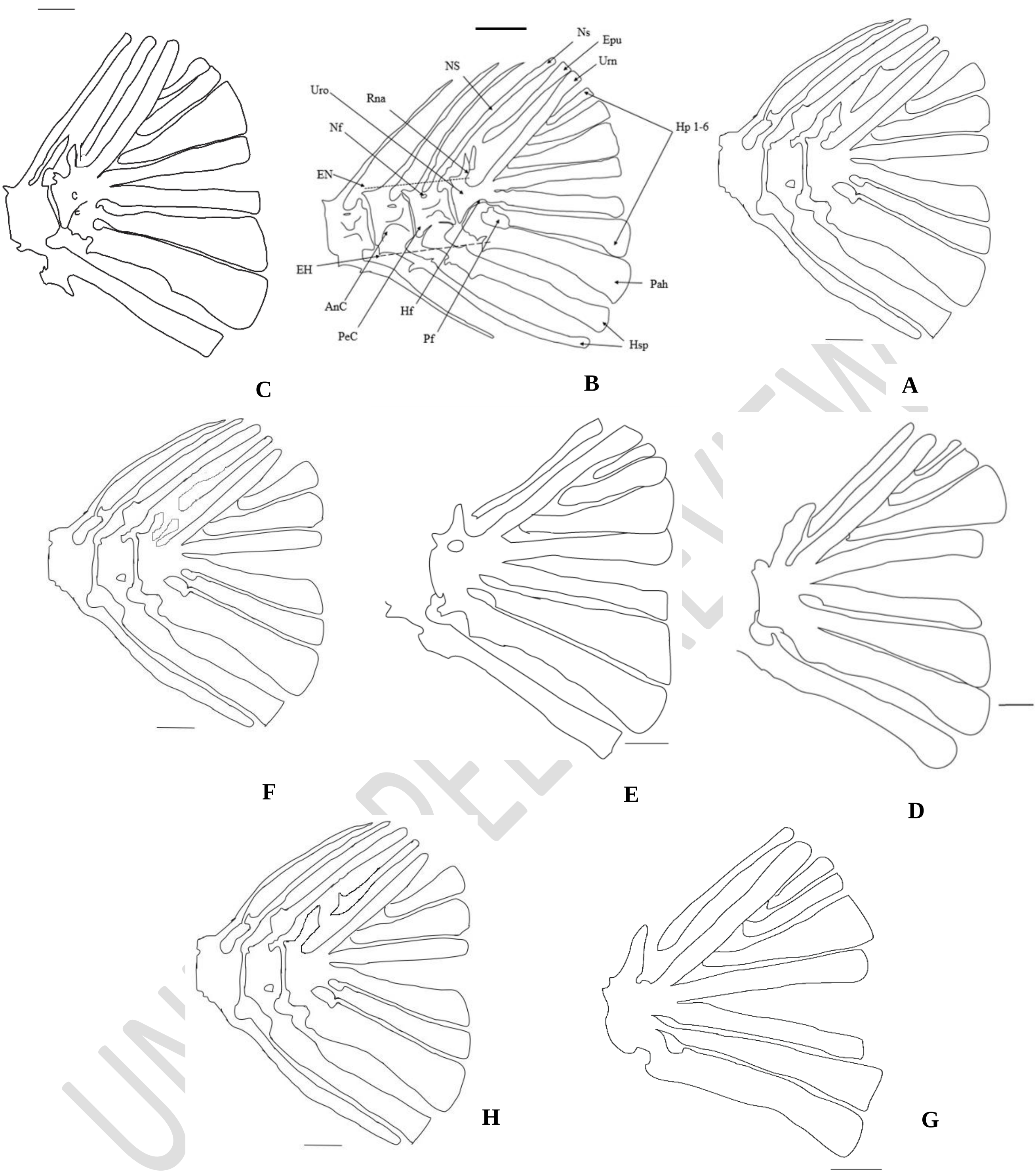

Fig2. Lateral view of caudal fin skeleton in *A. holciki* (AnC: Antepenultimate Centrum; EH: Epihemal; EN: Epineural; Epu: Epural; Hp 1-6: Hypural Plates 1-6; Hsp: Hemal Spine; NS: Neural Spine; Pah: Parhypural; PeC: Antepenultimate Centrum; Rna: Rudimentary Neural Arch; Urn: Uroneural; Uro: Urostyle).

Availability of data and materials: Voucher specimens are available (the museum of the University of Technology, Isfahan, Iran) as described in the text.

Consent for publication: Not applicable.

Ethics approval consent to participate: the authors followed the ethical standards of the responsible committee on laboratory animal experimentation.

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