Comparative anatomy of the caudal fin (*pinna caudalis*) *Tor douronensis* (Valenciennes, 1842) and *Tor soro* (Valenciennes, 1842)

Yusrizal Akmal[1], *Ilham* Zulfahmi[2,*], *Muliari* Muliari[1], *Andi* Iqbal Burhanuddin[3], *Budimawan* Budimawan[3], *Yeni* Dhamayanti[4], *Rindhira* Humairani[1], *Irfannur* Irfannur[1], *Rinaldi* Rinaldi[1]

[1]Department of Aquaculture, Faculty of Agriculture, Universitas Almuslim, Bireuen, Indonesia
[2]Department of Fisheries Resources Utilization, Faculty of Marine and Fisheries, Universitas Syiah Kuala, Banda Aceh, Indonesia
[3]Faculty of Marine Science and Fisheries, Hasanuddin University, Sulawesi Selatan, Indonesia
[4]Department of Veterinary Anatomy, Faculty of Veterinary Medicine, Universitas Airlangga, Indonesia

Abstract. *Tor douronensis* and *Tor soro* were two of the four species of the Tor genus that live in Indonesian waters. However, studies related to the skeleton of these two fish are still rarely disclosed. The aim of this study compared the morphology of the caudal-fin (*pinna caudalis*) *T. douronensis* and *T. soro*. The research stages include sample preparation, making skeleton preparations, image analysis, and identification of skeleton terminology. *T. douronensis* fish were collected from the waters of the Pagar Alam area, Lahat Regency, South Sumatra, while *T. soro* was collected from the waters of Bukit Lawang, Bohorok District, Langkat Regency, North Sumatra Province. The caudal-fin (*pinna caudalis*) is part of the ossa urostylus which produces optimal hydrodynamic propulsion. The caudal-fin (*pinna caudalis*) Genus Tor is part of the *ossa urostylus* which is composed of 31 caudal-fin rays (*pinnae*), six *hypural* bones, *parhypural*, *pleurostylus*, *epural*, and *uroneuralis*. The ventral part of *T. douronensis* and *T. soro* is composed of the *parhypural,* and the 1st and 2nd *hypural* bones. *T. douronensis* had a *parhypural* bone that was more prominent and separates from the *spina hemalis* compared to *T. soro*. The dorsal part was composed of the 3rd *hypural* bones to 6th *hypural*, in *T. soro* the *hypural* bone was fused with cartilage. *Os pleurostylus T. douronensis* had a more prominent shape than *T. soro* and there was enlargement in the posterior part. The 3rd and 4th *hypural* bones on *T. soro* had the largest size. The *T. soro* had three *spina neuralis* and three *spina hemalis* to support the rays of the tail. The bones that composed the caudal-fin of *T. douronensis* and *T. soro* were relatively similar to those of some fish from the family Cyprinidae. The results of this study could be used as an alternative to identify *T. douronensis* and *T. soro* from the skeleton.

1 Introduction

Although many studies of the fish skeleton morphology had been carried out, the nomenclature of the bones that make up the skeleton, especially the head, still shows a high level of inconsistency so that it had an impact on the bias of the bone constituent data for different fish species (Bogutskaya et al. 2008) [1]. Fish of the same genus generally have almost similar external morphological characteristics so that it was sometimes difficult to distinguish, therefore additional analysis was needed to be able to identify differences between these species, including through skeleton comparisons. Several studies on skeleton comparisons of several fish families had been carried out previously, including fish from the Nemacheilidae family [2], Characidae family [1], Cichlidae family [3], and Zoarcoidei family [4].

The limb bones of fish were composed of fins supported by skeletal and controlled by muscles [5]. According to Standen, fish depend 20% of their movement and propulsion on their fins [6]. Generally, fish have two paired fins and three single fins. Paired fins consist of pectoral (*pinna pectoralis*) and pelvic fins (*pinna pelvis*), while single fins consist of dorsal (*pinna dorsalis*), anal (*pinna analis*), and caudal fin (*pinna caudalis*) [7][8]. The caudal-fin had optimal hydrodynamic propulsion and the shape could also indicate the swimming habits of fish [9]. In some fish species, the shape of the fins and the rays of the fins are modified from the general form and had several other additional functions, such as sperm distribution and attachment tools [9].

Tor douronensis and *Tor soro* were two of the four species of the Tor genus that live in Indonesian waters. However, the study related to the osteology of these two fish are still rarely disclosed. The caudal-fin was one of the body parts of the fish with striking differences between species in the same genus in addition to weber bones [10]. The aims of this study was to compare the caudal-fin (*pinna caudalis*) of *T. douronensis* and *T. soro*.

Corresponding author: Ilham.Zulfahmi@unsyiah.ac.id

2 Materials and Methods

2.1 Location and Sample Preparation

The research stages include sample preparation, making skeleton preparations, image analysis, and identification of the skeleton terminology. Making skeleton preparations at the Aquaculture Laboratory, Aquaculture Study Program, Faculty of Agriculture, Almuslim University. The fish was used in this study were obtained by direct capture from fish collectors. Sample of the fish have a minimum weight, at least 2 kg with a length 30-50 cm. *T. douronensis* were collected from the waters of the Pagar Alam area, Lahat Regency, South Sumatra, while *T. soro* was collected from the waters of Bukit Lawang, Bohorok District, Langkat Regency, North Sumatra Province. 10 sample for each type of the fish were collected. The fish are then preserved using ice and transported to the laboratory.

2.2 Caudal fin preparation

The procedure of the preparation tail was based on Zulfahmi et al. 2020[11]. Tail's fish was cutting located at the posterior aspect of the last centrum of the *ossa vertebrae caudales.* The separated fish fins are then soaked in hot water at a temperature range of 80–90ºC until the muscle and connective tissue are blistered and white. Soaking in hot water was done carefully so that the bones did not become brittle. Preparation of fish skeleton preparations was done physically and chemically. Physically, fish scales are removed using a knife or tweezers and then doused with hot water until the muscles scald and turn white. The chemical stage begins with immersing the skeleton sample into formalin 10%. Specimens were transferred to 70% ethanol solution to remove stains on the skeleton [12].

2.3 Image editing and Identification of Skeleton Terminology

The digital image of the fish was taken from the lateral direction with *Canon EOS 750D.* After that, it was analyzed with the *Adobe Photoshop CS6* software and then presented with a table and image.

3 Results and Discussion

The cauda fin (*pinna caudalis*) of the Tor's Genus was part of the urostylus bones. These bones had 31 of the cauda fin (*pinnae*), six of the hypural bones, pleurostylus, epural, and uroneuralis bone. The ventral side of the *T. douronensis* and *T. soro* is composed of parhypural bone, and 1st – 2nd hypural bones. The parhypural bone of the *T. douronensis* more prominent than T. *soro*. The parhypural bone of the *T. soro* fused with cartilage bone and enlargement at the posterior part.

The dorsal part was composed of the 3rd to 6th hypural bones, and in *T. soro* the hypural bone was fused with cartilage. Os pleurostylus *T. douronensis* was a more prominent shape than *T. soro*, and there was an enlargement in the posterior part. The 1st, 3rd, and 4th hypural bones of the *T. soro* had the largest size, while the 5th and 6th hypural was the smallest size. The 2nd hypural *bone of T. douronensis* was the largest one, while the 6th hypural was the smallest size. *T. soro* had three neural spines and three haemal spines to support the rays of the caudal fin (Figure 1.)
The bones that make up the fins of the tail of *T. douronensis* and *T. soro* are relatively the same as some fish from other Cyprinidae families, such as *Ischikauia steenackeri*, *Alburnus amirkabiri*, *Cyprinion milesi*, and *Barbus cyri* [14][15][16][17]. However, the Barbus cyri fish had a larger hypural bone size than the parhypural bone, compared to that T. *soro* fish.

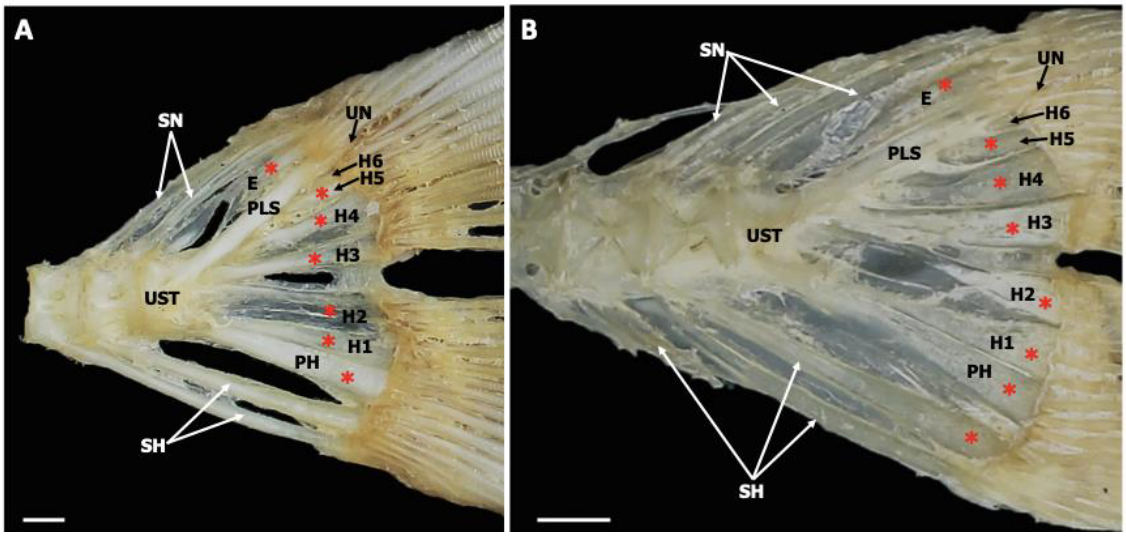

Fig. 1. *Pinna caudalis* lateral view of *T. douronensis* (A) and *T. soro* (B). Description: *arcus neuralis* (AN); *Centrum* (C); *Os epural* (E); *Os hypural* (H); *Os parhypural* (PH); *Os pleurostylus* (PLS); *Os preural urostylus* (PU); *spina haemalis* (SH); *spina neuralis* (SN); *Os uroneuralis* (UN); *Ossa urostylus* (UST). Bar scale: 0.5 cm.

Table 1. Comparative morphology of the caudal fin (*pinna caudalis*) *T. douronensis* and *T. soro*

No	Bone name	view	*T. douronensis*	*T. soro*
1	*Os parhypural*	Lateral	The shape more prominent and slim, separated from *spina hemalis*	The shape thinner, enlargement at the posterior part, and fused to *spina hemalis*
2	*Os hypural 1*	Lateral	Slim and sturdy	Enlargement at the posterior part
3	*Os hypural 2*	Lateral	Slim and thin	Slim and short
4	*Os hypural 3*	Lateral	Slim and sturdy	Wide and enlargement at the posterior part
5	*Os hypural 4*	Leteral	Had a clear boundary with the 5th *hypural* bone	Had the largest size with indistinct boundaries with the 5th hypural O
6	*Os hypural 5*	Leteral	Not wide and short	Wide and long
7	*Os hypural 6*	Lateral	Clearly boundry with the 5th hyoural bone	Indistinct boundry with the 5th hypural bone
8	Neural spines	Lateral	2 spines	3 spines where the last one bigger than others
9	Haemal spines	Lateral	2 spines	3 spines

T. douronensis had more tail fin rays than *Petrocephalus simus* (family Mormyridae) and lower than *Oreochromis lorenzoi* fish (family Cichlidae) [18][19]. The caudal fin rays of *T. douronensis* and *T. soro* fish were divided into two parts, namely the ventral fin rays and the dorsal fin rays with sharp angles. According to Lauder, the function of the ventral caudal fin rays was more dynamic than the dorsal [20]. The shape of the pointed tail fin with long fingers on the *Keureling* fish indicated that the fish was capable of swimming at high speeds [21]. The caudal fin was one of the bones that had a high variation between species compared to the bones that make up other body parts.

4 Conclusion

The caudal fin (*pinna caudalis*) of *T. douronensis* and *T. soro* fish was part of the ossa urostylus. The urostylus bone was composed of 31 caudal-fin rays (*pinnae*), six hypural bones, parhypural, pleurostylus, epural, and uroneuralis bones. The ventral parts of *T. douronensis* and *T. soro* were composed of the parhypural bone and the 1st and 2nd hypural bones. *T. douronensis* had a parhypural bone that was more prominent and separated from the *haemalis spine* than *T. soro*. The dorsal part was composed of the 3rd to 6th hypural bones. The hypural bone of the *T. soro* fused with cartilage. The shape pleurostylus *bone T. douronensis* was more prominent than *T. soro,* and there was an enlargement in the posterior part. The size of the 3rd and 4th hypural bones of the *T. soro* was the largest. The *T. soro* had three neural spines and three haemal spines to support the rays of the caudal fin. The results of this study could be used as an alternative to identify *T. douronensis* and *T. soro* by osteology.

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