



A comparative analysis of osteocranium morphology in *Lutjanus johnii* (Bloch, 1792) and *Lutjanus gibbus* (Forsskal, 1775) inhabiting different habitats

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ABSTRACT

The snapper species *Lutjanus gibbus* (*L. gibbus*) is commonly found in coastal areas characterized by coral reefs and clear water, while *Lutjanus johnii* (*L. johnii*) resides in mangrove waters with murky conditions and strong currents. The habitat plays a crucial role in influencing body shape and ossification patterns in fish. Therefore, this study aimed to examine the differences in the cranial bone morphology between the two *Lutjanus* fish species that resided in contrasting habitats. The fish samples were collected from local fishermen operating in the waters of Pulo Aceh, Aceh Besar, Indonesia. Following capture, the fish were transported and landed at Lampulo Fishing Port in Banda Aceh for further analysis. For each species, a total of 5 fish samples were randomly selected, and thorough cleaning of scales and muscles was performed before the drying of the bones. These dried cranial bones were then photographed, edited, and subjected to detailed analysis. The study showed that, of the 23 observed skull bone characters, 15 characters showed the differences in the cranial bones of the two snapper species, including the pre-ethmoidal, ethmoidal lateralis, prefrontal, supraorbital, nasal, ethmoidal, sphenoticum, crista occipital, lacrimal, inter-opercular, opercular, preopercular premaxilla, endopterygoideum, and hyomandibular. Significant differences were observed in the bones composing the eyes, nose, jaws, and ventral region of the head. In the mangrove snapper (*L. johnii*), the bones associated with the eyes (orbitosphenoidal, supraorbital, and prefrontal) were less developed, while those related to the nose (nasal, ethmoidal, ethmoidal lateralis, pre-ethmoidal) showed well-developed characteristics. The coral snapper *L. gibbus* displayed a relatively small but thicker premaxilla bone in the jaw region, along with smaller bones in the ventral head area.

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Introduction

The Lutjanidae family is composed of 6 genera, including Haplopagrus, Macolor, Ocyurus, Pinjalo, Rhomboplites, and *Lutjanus* (Allen, 1985; Vineesh et al., 2014; Velamala et al., 2017; Veneza et al., 2019; Franklin, 2021; Nair, 2022), with *Lutjanus* being the most dominant genus in terms of species diversity. Currently, there are 65 recognized species of *Lutjanus* distributed across global waters (Allen, 1985; Latumeten et al., 2018). This particular Lutjanidae family is predominantly found in tropical and sub-tropical waters (Habibi et al., 2011; Prihatiningsih et al., 2017). Geographically, Allen (1985) categorized the distribution of *Lutjanus* into 4

four regions, including the Eastern Pacific, Indo-West Pacific, East Atlantic, and West Atlantic. Within the West Indo-Pacific region, there are approximately 43 *Lutjanus* species, consisting of 33 species inhabiting Indonesian waters, with 25 species reported in the Malacca Strait (Allen, 1985). The Malacca Strait supports two primary *Lutjanus* habitats, including coral reefs, where *L. gibbus* predominantly resides, and coastal areas characterized by mangrove forests, which are occupied by *L. johnii* (Rome and Newman, 2010).

Several scientific reviews explored the relationship between fish morphology and their respective habitats, including the relationship between

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osteology and various environmental factors such as depth (Gerringer *et al.*, 2021; McGonagle *et al.*, 2023; Muir *et al.*, 2014), water turbidity (Jalili and Eagderi, 2014), water currents (Cao *et al.*, 2021; Souza and Pompeu, 2020; Lauder and Drucker, 2003), and feeding habits (Friedman *et al.*, 2016; Wainwright, 2002; Winemiller *et al.*, 1995; Muir *et al.*, 2014). The cranium bones (Osteocranium) plays an important role in protecting the brain and nerves such as vision (sensory) and smell (olfactory). Specific studies examined the correlation between the bone shape and water depth in marine fish, such as investigations on snailfishes of the Liparidae family conducted by Gerringer (2021). These reviews consistently concluded that noticeable differences existed in the facial bones, particularly the opercular, hyoid, dentary, and angular bones. In species inhabiting deep waters, these bones tend to exhibit reduced size, along with a softer and thinner bone structure.

Previous studies also examined the habitat-related differences observed in cave-dwelling fish species such as *Iranocypris typhlops* and *Garra lorestanensis*. Significantly, it was observed that the lacrimal bones, contributing to the development of the eyes, were poorly developed in these fish (Jalili and Eagderi, 2014; Sabet and Eagderi, 2016). Several reviews have investigated the relationship between feeding habits and jawbone morphology, concluding that carnivorous fish generally exhibited well-developed dentary and angular bones compared to herbivorous fish and vice versa (Friedman *et al.*, 2016; Wainwright, 2002; Gidmark *et al.*, 2012); Wainwright and Richard, 1995). Cao *et al.* (2021) and Langerhans *et al.* (2004) indicated that water currents could influence the shape of the osteocranium in fish, with species inhabiting fast-flowing waters often possessing a low hump in the occipital region to reduce resistance while swimming against the current. Despite these previous investigations, studies examining the osteology of snapper species, particularly focusing on the head (osteocranium) based on their habitats, remain scarce. Therefore, this study aims to examine the differences in the osteocranium (head bone) between two *Lutjanus* species that occupy distinct habitats. These species include *L. johnii* (Bloch, 1792), inhabiting mangrove waters characterized by high turbidity and swift currents, and *L. gibbus* (Forsskal, 1775), dwelling in coral reefs with clear water and slow currents (Rome and Newman, 2010). Therefore, information on the osteocranium of these two species of snapper is crucial to differentiate these species based on the cranium bones due to adaptation to different environments and contributes

to the ichthyological science as an alternative tool in fish taxonomy.

Materials and Methods

Time and site

This research was conducted from March to May 2022. Fish samples were caught by fishermen in the waters of Pulo Aceh Aceh Province, Indonesia, and landed at the Lampulo Fishing Port, Banda Aceh City, Aceh Province. The collected samples were analyzed at the Physiology Laboratory, Faculty of Mathematics and Natural Sciences, Syiah Kuala University, Banda Aceh. The object species in this study were *L. gibbus* and *L. johnii*. According to Rome and Newman (2010), these two fish live in two different habitats, namely *L. gibbus* in coral reefs, while *L. johnii* in mangrove ecosystems. This information was confirmed and validated by the fishermen who caught the fish sample.

Fish sample preparation and data analysis

A total of 5 fish samples per species, weighing between 1500 g to 2000 g, and total length of 30 – 35 cm were randomly selected for the study. The samples were immediately placed in a styrofoam box and kept at a temperature of 4°C to maintain their freshness during transportation to the laboratory. Upon arrival, the fish was carefully rinsed with fresh water to remove any external debris. Each fish sample was photographed using a Canon 1200D digital camera (Japan), with an example shown in Figure 1. Furthermore, hot water at 100°C was poured over the entire body of each fish sample to facilitate the removal of scales and skin, which were delicately peeled off using a scalpel. The muscles were filleted from the dorsal to the median part on both sides of the body. Moreover, the head was separated from the body by cutting the neck bone, and any remaining muscles were extracted using tweezers.

All the remaining meat and fat were soaked in 70% alcohol for two days to clean the cranium. Following this process, the cranium bones underwent sun-drying for one day until achieving a white appearance. Any dislocated bones were reconstructed in their original positions using adhesive. Once the cranium was reconstructed, it was photographed and edited using Photoshop CS6 software. The identification of the different parts of the cranium was based on the references provided by Zulfahmi *et al.* (2022) and Rojo (2013). These references were consulted to ensure accurate identification and naming of the cranium parts. The data obtained from the analysis were presented in the form of images and analyzed descriptively. A

comparison was made with relevant reports and references to ensure accuracy and provide a comprehensive description of the results.

Data analysis

Data were presented in the tables and figures and then analyzed descriptively by comparing the findings with previous studies or reports, and other relevant theories.

Results

The cranium of *Lutjanus* species is comprised of 23 bones, including the premaxilla, maxilla, palatinum, nasal, lacrimal, frontal, paraspheniodal, endopterygoid, basisphenoidal, parietal, crista occipital, posttemporal, hyomandibular, opercular, preopercular, subopercular, inter-opercular, metapterygoid, symplectic, quadratum, angular, ectopterygoid, and dentary (Figure 2). Among these, 15 bones involving pre-ethmoidal, ethmoidal lateralis, prefrontal, supraorbital, nasal, ethmoidal, sphenotic, crista occipital, lacrimal, inter-opercular, opercular, preopercular, premaxilla, endopterygoid, and hyomandibular differ significantly between the two species. The description of the bone differences were summarized in the Table 1.

Table 1. Comparative osteocranium descriptions of *Lutjanus johnii* and *Lutjanus gibbus*

Bones	<i>L. johnii</i>	<i>L. gibbus</i>
Pre-ethmoidal	Widen laterally	Narrows anteriorly
Ethmoidal lateralis	A wide axis with a narrow end	A small axis with a short end
Prefrontal	The prefrontal is wavy and narrow angles	Straight and wide angle
Supraorbital	The posterior angle is concave	The anterior angle is concave
Nasal	The nasal bone is small and narrow laterally and long posteriorly	The nasal bone is large and wide laterally with a short posterior part
Ethmoidal	The ethmoidal is slender and long	The ethmoidal is wider and short
Sphenotic	The sphenotic with a slight indentation	Concave dorsal to ventral
Crista occipital	The crista occipital has a low angle and is directed posterior-ventrally	The crista occipital has a high angle
Lacrimal	The lacrimal has a wide site of	The lacrimal has a small

	articulation, with a blunt posterior angle that forms a small anteriorly	articulation site, with the posterior, ventral and dorsal angles that tapers anteriorly.
Inter-opercular	The posterior of the inter-opercular is blunt and lacks elevation	The inter-opercular has a sharp posterior with high anterior bony elevation
Opercular	The opercular is thick and shallow	The opercular is thinner, and its dorsal part is concave
Preopercular	The posterior-dorsal of the preopercular has a straight angle	The posterior-dorsal of the preopercular angle is curved
Premaxilla	The premaxilla is small and it has kinetmoid and long lateral maxillae	Wide premaxilla, but the kinetmoid and lateral premaxilla are shorter
Endopterygoid	The posterior part of the endopterygoid is straight with a bony prominence on the ventral side	The posterior is blunt without bony prominences
Hyomandibular	The dorsal side of the Hyomandibular is widened	The dorsal side of the Hyomandibular is narrow

Description of pre-ethmoidal, ethmoidal lateralis, prefrontal, supraorbital, nasal, ethmoidal, sphenotic, and crista occipital bones

The pre-ethmoidal bones displayed lateral widening in *L. johnii* and anterior narrowing in *L. gibbus*. In *L. johnii*, the ethmoidal lateralis had a wide axis with a narrow end, whereas *L. gibbus* exhibited a small axis with a short end. The prefrontal in *L. johnii* exhibited a wavy and narrow-angle, contrasting with the straight and wider angle observed in *L. gibbus*. In *L. johnii*, the supraorbital had a concave posterior angle, whereas in *L. gibbus*, it had an anterior concave angle (Figure 3 and Table 2). The nasal foramen in *L. johnii* was small and narrow laterally with a long posterior, while in *L. gibbus*, it was large and wide laterally with a short posterior (Figure 4 and Table 2).

Table 2. The measurement of cranial bone of snappers *L. johnii* and *L. gibbus*

Bones	<i>L. johnii</i>	<i>L. gibbus</i>
Lacrimal articulation site width (cm)	1.42	1.88
Lateral maxilla length (cm)	3.29	2.20
Hyomandibular width (cm)	2.26	1.67
Kinethmoid length (cm)	2.01	1.06
Premaxilla width (cm)	1.75	1.15
Ethmoidal lateralis axis width (cm)	0.77	0.49
Pre frontal angle length (cm)	0.82	1.71
Lateral nasal width (cm)	0.57	0.73
Posterior nasal length (cm)	1.86	1.31
Ethmoidal length (cm)	2.82	1.92

Regarding the ethmoidal bone, *L. johnii* exhibited a slender and long shape, while *L. gibbus* had a wide and short shape. The sphenotic bone in *L. johnii* showed slight indentation, whereas *L. gibbus* displayed a dorsal to a ventral concave shape. The crista occipital in *L. johnii* had a low angle directed posterior-ventrally, in contrast to the high angle dorsally observed in *L. gibbus* (Figure 5 and Table 2).

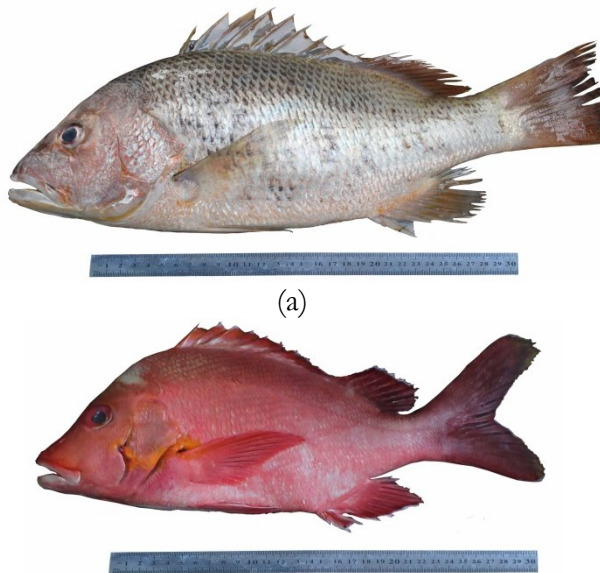


Figure 1. The sample of snappers used in this study.
(a) *L. johnii* dan (b) *L. Gibbus*

Lacrimal, inter-opercular, and opercular bones

The lacrimal bones in *L. johnii* exhibited a wide articulation site, with a blunt posterior that formed a small angle anteriorly. Meanwhile, the lacrimal in *L. gibbus* had a small articulation site, with a tapered ventral posterior and dorsal and ventral angles in the

anterior (Figure 6 and Table 2). The inter-opercular bones in *L. johnii* had a blunt posterior and lacked anterior bony elevation, while it had a sharp posterior with anterior bony elevation in *L. gibbus* (Figure 7). In *L. johnii*, the opercular tended to be shallow, whereas in *L. gibbus*, it was thinner, and the dorsal notch was highly concave (Figure 8).

Preopercular, premaxilla, endopterygoid, and hyomandibular bones

The preopercular bone in *L. johnii* had a straight angle in the posterior-dorsal portion, while in *L. gibbus*, it displayed a curved shape (Figure 9). The premaxilla in *L. johnii* had a longer kinetmoid and lateral maxilla, but a smaller premaxilla. Meanwhile, it had a shorter kinetmoid and lateral premaxilla, but a wider premaxilla in *L. gibbus* (Figure 10 and Table 2). The endopterygoid bones in *L. johnii* exhibited a straight posterior with bony prominences on the ventral side, whereas, in *L. gibbus*, the posterior was blunt without bony prominences (Figure 11). In *L. johnii*, the hyomandibular bone had a wider dorsal side, while in *L. gibbus*, the dorsal part was small (Figure 12 Table 2).

Discussions

This study identified five significant differences in the cranial bone morphology between two Lutjanus fish species. These differences primarily involved the nasal bones (pre-ethmoidal, lateral ethmoidal, nasal, ethmoidal), eye bones (prefrontal, supraorbital, lacrimal), hump bones (occipital crista), ventral head (inter-opercular, opercular, preopercular, endopterygoid, and hyomandibular), and masticatory or jaw bones (premaxilla).

In the case of *L. johnii*, the mangrove snapper, the orbit sphenoidal (eye holes) have appeared degraded, smaller, and oval-shaped, extending towards the posterior head. However, in *L. gibbus*, the orbit sphenoidal was rounded and centrally located on the head. The observation suggests that the eye structure of *L. johnii* may have undergone adaptations due to its habitat in murky waters, where a visual function is less dominant. This speculation finds support in the work of Schadu (2018), who noted that mangrove waters exhibit high turbidity caused by silt and organic materials from the land. Consequently, snapper species inhabiting mangrove waters rely more on their olfactory function, which is indicated by the presence of large nasal bones, as observed in *L. johnii*. Nasri et al. (2016) and Jalili et al. (2015) reported that fish species with reduced reliance on their sense of smell tended to have smaller ethmoidal bones. Additionally, Akmal et al. (2020) emphasized

that ethmoidal bones functioned as chemosensors, housing receptors for olfactory nerves located in the nostrils. These results were consistent with the work of [Eagderi and Adriaens \(2010\)](#), who noted that the

Hoplunnis punctata fish (Nettastomatidae), depending on olfactory for prey detection, possessed long and pointed ethmoidal bones.

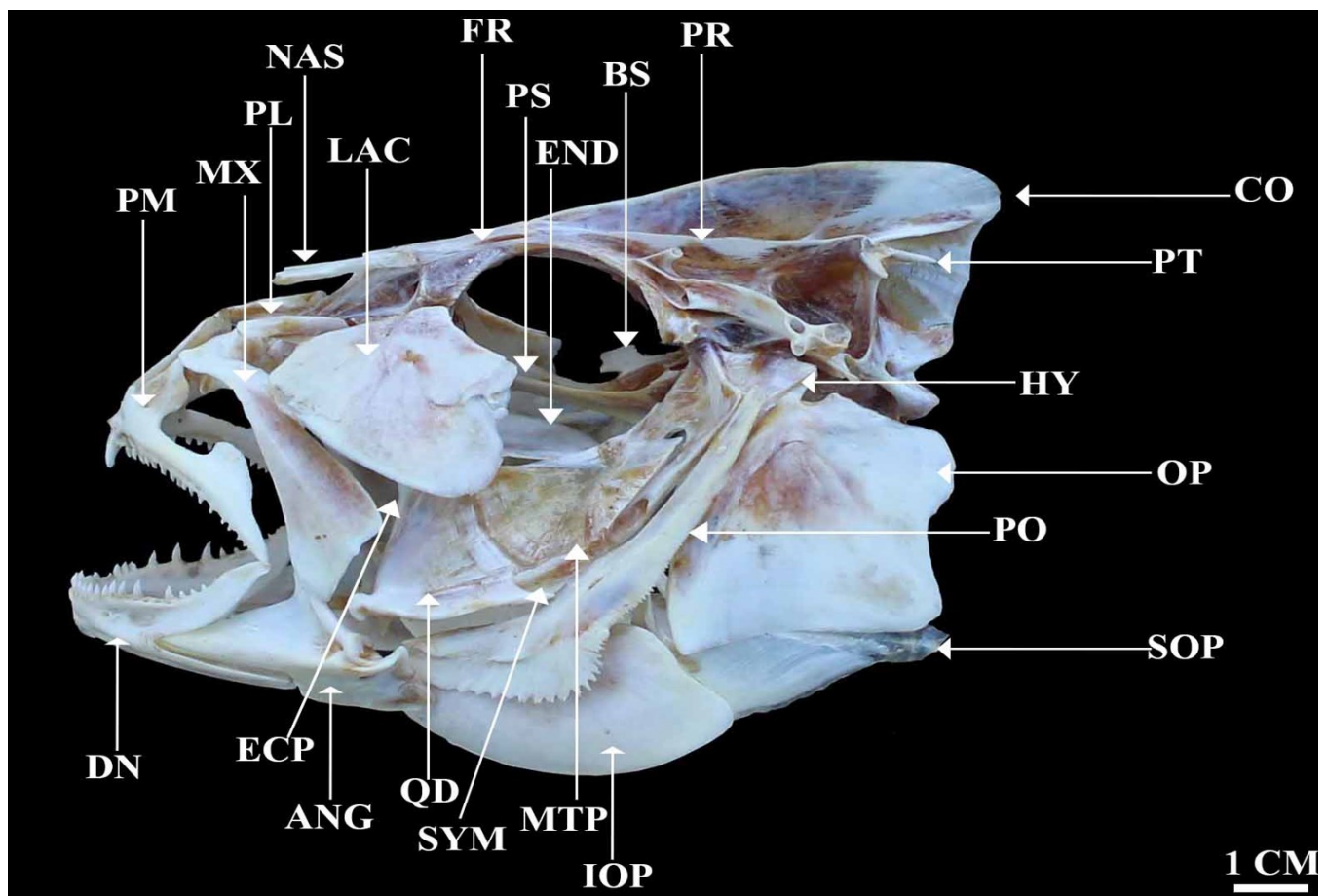


Figure 2. Osteocranium of *Lutjanus johnii* and *Lutjanus gibbus*. PM: premaxilla, MX: maxilla, PL: palatinum, NAS: nasal, LAC: lacrimal, FR: frontal, PS: paraspheniodal, END: endopterygoid, BS: basisphenoid, PR: parietal, CO: crista occipital, PT: posttemporal, HY: hyomandibular, OP: opercular, POP: preopercular, SOP: subopercular, IOP: interopercular, MTP: metapterygoid, SYM: symplectic, QD: quadratum, ANG: angular, ECP: ectopterygoid, DN: dentary.

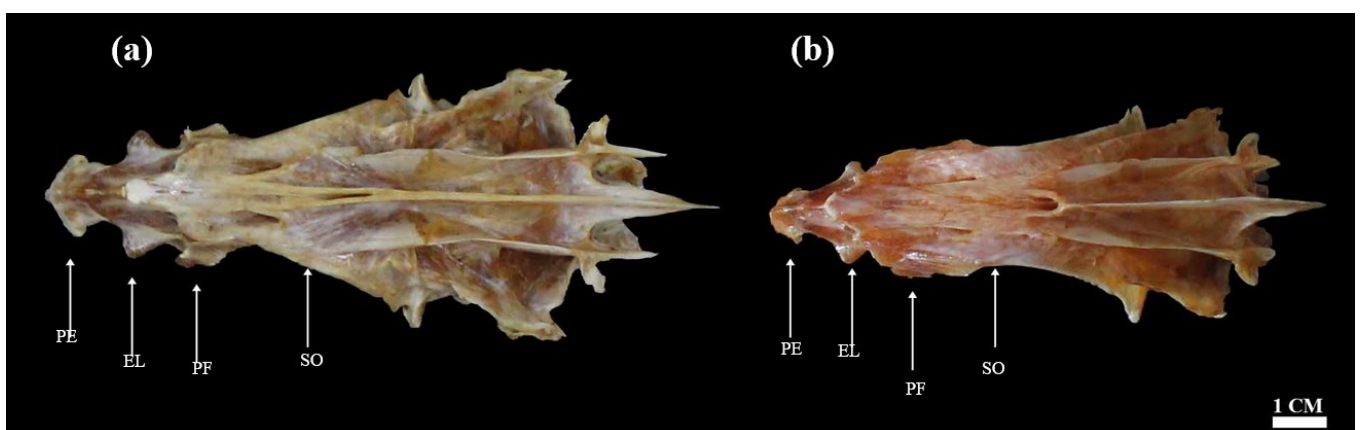


Figure 3. Cranium (dorsal) *L. johnii* (a) dan *L. gibbus* (b). Note: PE: preethmoidal; EL: ethmoidal lateralis; PF: pre frontal; SO: supra orbital.

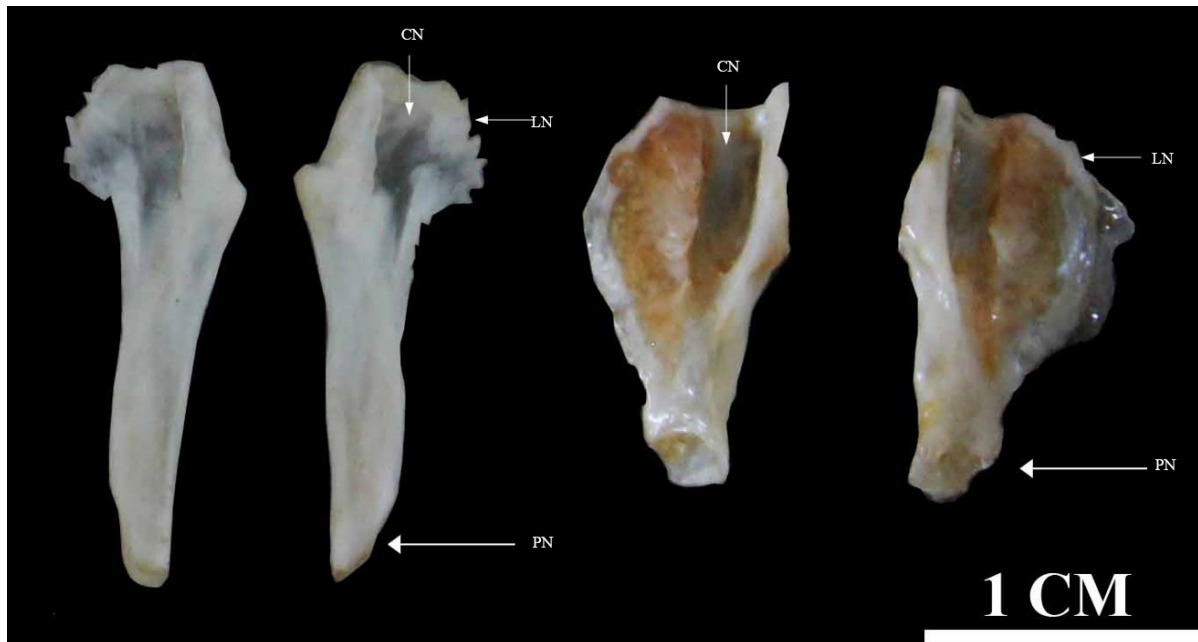


Figure 4. nasal bone of (a) *Lutjanus johnii*, and (b) *Lutjanus gibbus*. CN: canal nasal, LN: lateral nasal; PN: posterior nasal.

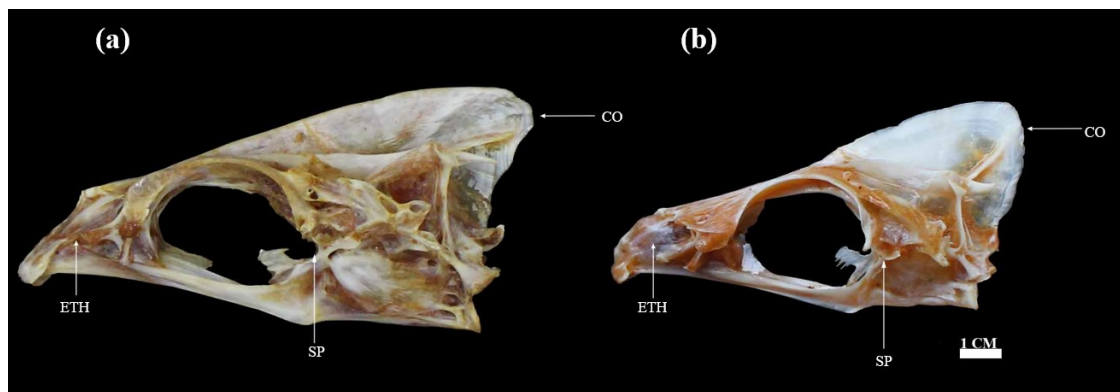


Figure 5. cranium (lateral) (a) *Lutjanus johnii*, and (b) *Lutjanus gibbus*. ETH: ethmoidal; SP: sphenotic; CO: crista occipital.

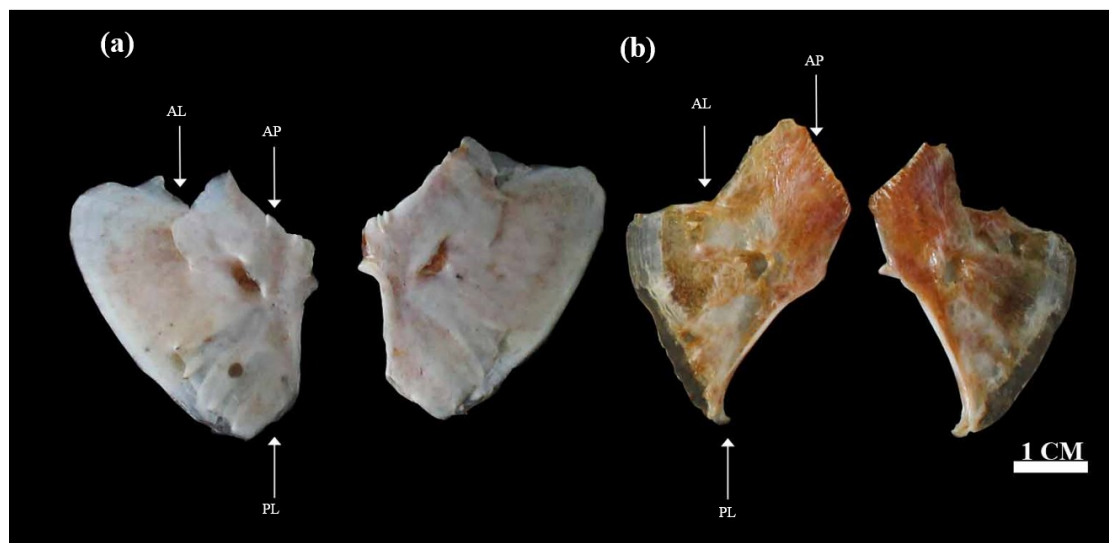


Figure 6. Lacrimal bone of (a) *L. Johnii* (b) *L. L. Gibbs*. Note: PL= posterior lacrimal, AP= articulation part, AL= anterior lacrimal.

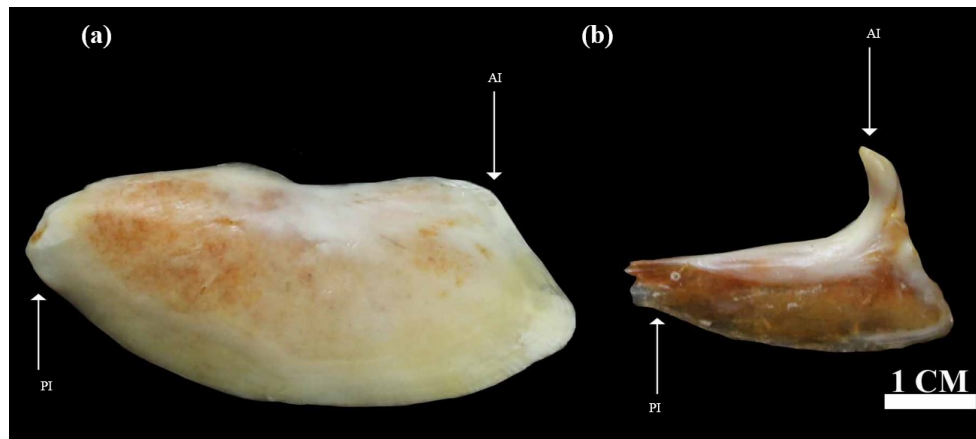


Figure 7. interopercular of (a) *L. johnii* (b) *L. gibbus*. Note: PI= posterior interopercular, AI= anterior interopercular.

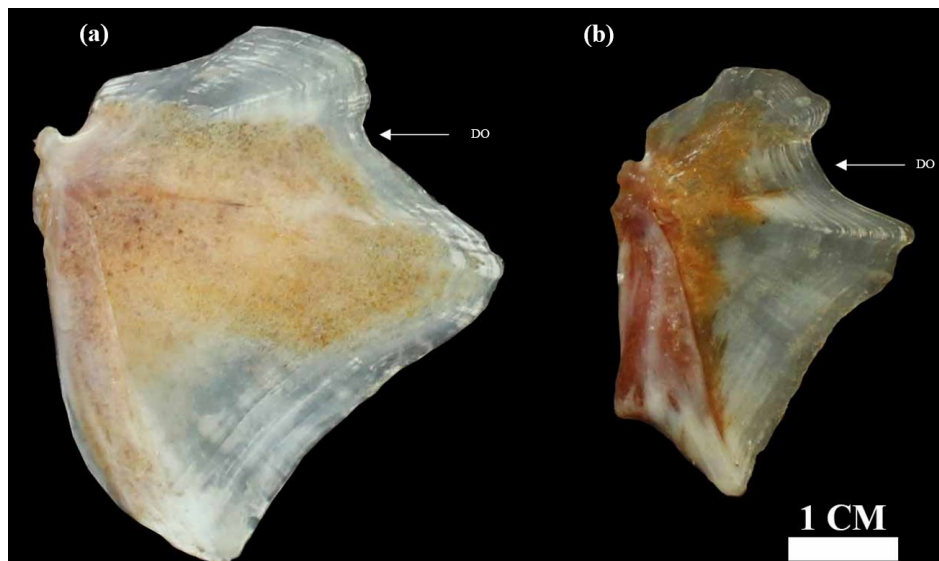


Figure 8. Opercular bone of (a) *L. Johnii* (b) *L. gibbus*. Note; DO= dorsal opercular.

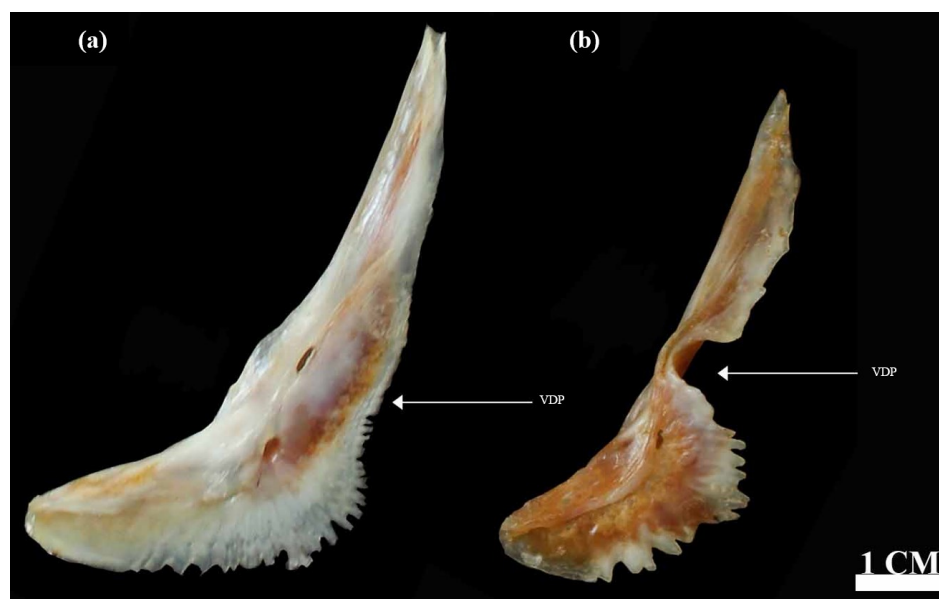


Figure 9. The preopercular bone of (a) *L. johnii*, (b) *L. gibbus*. Note: VDP= ventral-dorsal preopercular

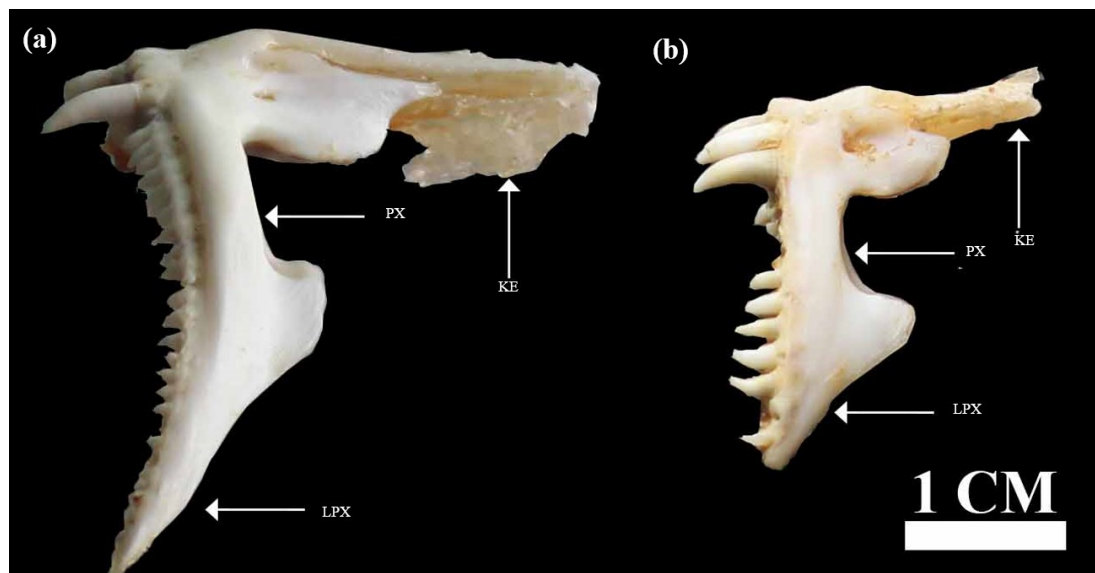


Figure 10. Premaxilla bone of (a) *L. johnii*, (b) *L. gibbus*. Note: KE= kinetmoid, PX= pemaxilla, LPX= lateral Premaxilla.

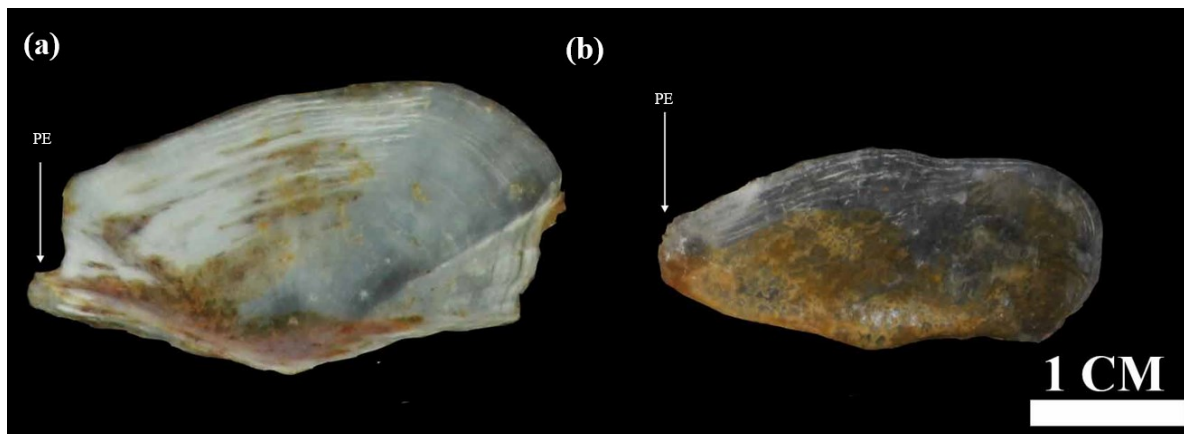


Figure 11. endopterygoid bone of (a) *L. johnii*, (b) *L. gibbus*. Note: PE is posterior of endopterygoid.

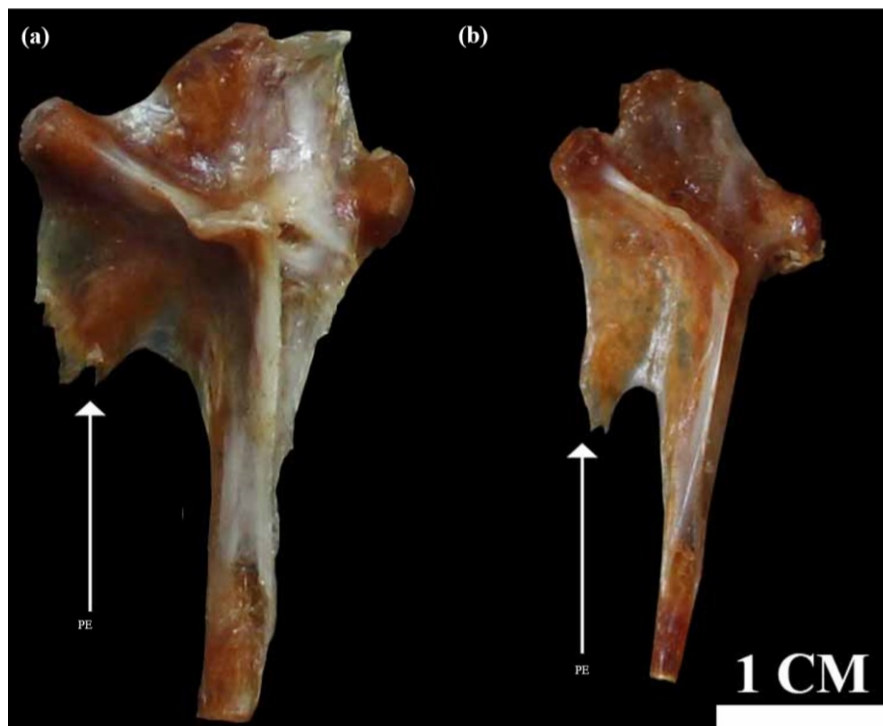


Figure 12. hyomandibular bone of (a) *L. johnii*, (b) *L. gibbus*. Note: DH is dorsal of hyomandibular.

The results of this study showed that the hump bones (occipital), specifically the occipital crista, were not well-developed in the mangrove fish (*L. johnii*). A low hump is typically observed in fast-swimming fish (Cao et al., 2021), suggesting that despite inhabiting murky waters, *L. johnii* is capable of swimming at high speed due to its reduced hump structure. However, several cranium bones in *L. gibbus* appear to be degraded and smaller, such as the inter-opercular, opercular, preopercular, endopterygoid, and hyomandibular bones. The opercular and endopterygoid bones also show signs of thinning. This degradation is likely attributed to the fact that *L. gibbus* inhabits deeper waters compared to *L. johnii*. Previous studies reported that bone shape degradation could be linked to the depth of the water where fish reside (Gerringer et al., 2021; Rendal and Farrell, 1997). According to Rome and Newman (2010), *L. gibbus* can be found at depths of up to 50 m, while *L. johnii* inhabits even deeper waters, reaching depths of up to 80 m.

Further observations on the masticatory bone (premaxilla) in *L. johnii* show a long, thin premaxilla with fewer sharp teeth, whereas in *L. gibbus*, this bone is shorter, thicker, and the teeth are more pointed. Studies by Friedman et al. (2016) and Gidmark et al. (2012) suggested that differences in jaw bone morphology in fish could be influenced by variations in feeding habits. Although both species are carnivorous (Prihatiningsih et al., 2017), there are distinctions in their prey-capture strategies. *L. johnii* tends to adopt a passive approach, hiding and launching sudden high-speed attacks, while *L. gibbus* actively hunts for prey. The presence of a tall tail and a narrow or slender caudal peduncle base in *L. gibbus* supports this hunting behavior (Wainwright and Bellwood, 2002; Gonza'lez et al., 2022; Song et al., 2020).

Conclusions

In conclusion, this study identified distinct differences in the cranium bones of *L. johnii* and *L. gibbus*, specifically in the bones related to the eyes and nose. *L. johnii* exhibited underdeveloped eye bones but well-developed nasal bones compared to *L. gibbus*. However, *L. gibbus* displayed shorter and larger jaw bones, along with smaller ventral bones.

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