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Length–weight relations of 14 endemic and indigenous freshwater fish species (Actinopterygii) from the Aral Sea basin, Uzbekistan

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Abstract

Length–weight relations (LWR) were estimated for 14 endemic and indigenous fish species from the Aral Sea basin: *Alburnoides holciki* Coad et Bogutskaya, 2012; *Capoetobrama kuschakewitschi* (Kessler, 1872); *Cottus spinulosus* Kessler, 1872; *Glyptosternon oschanini* (Herzenstein, 1889); *Gobio lepidolaemus* Kessler, 1872; *Gobio nigrescens* (Keyserling, 1861); *Iskandaria kuschakewitschi* (Herzenstein, 1890); *Iskandaria pardalis* (Turdakov, 1941); *Paracobitis longicauda* (Kessler, 1872); *Sabanejewia aralensis* (Kessler, 1877); *Schizothorax fedtschenkoi* Kessler, 1872; *Triplophysa daryoae* Sheraliev, Kayumova et Peng, 2022; *Triplophysa ferganaensis* Sheraliev et Peng, 2021; and *Triplophysa uranoscopus* (Kessler, 1872). Measurements were taken for total length (0.1 cm precision) and total weight (0.1 g precision). The LWR parameters were determined using a linear logarithmic regression model of weight against length in which values for the slope of the regression, *b*, that are higher and lower than 3 indicate positive and negative allometric growth, respectively. The estimated values of parameter *b* ranged from 2.703 (*Iskandaria kuschakewitschi*) to 3.162 (*Gobio nigrescens*). The correlation coefficient (r^2) values varied from 0.951 to 0.993, indicating a strong positive relation between length and weight. The maximum total lengths of four of the species (*Glyptosternon oschanini*, *Iskandaria kuschakewitschi*, *Triplophysa daryoae*, and *Triplophysa uranoscopus*) constitute new records, and the LWRs of twelve fish species have hitherto not been available in FishBase.

Keywords

Amu Darya, endemic species, freshwater fish, length–weight relation, Syr Darya, Uzbekistan

Introduction

In Uzbekistan, all river basins are endorheic; therefore, fish diversity is poorer than in other regions. One-quarter of the fish species in the country are endemic (Mirabdullaev and Mullabaev 2020). The recent discovery of two species of *Triplophysa* Rendahl, 1933 from the upper reaches of the Syr Darya also confirms this statement (Sheraliev and Peng 2021; Sheraliev et al. 2022). The majority of endemic and indigenous fish species from the inland waters of Uzbekistan do not have commercial value but are important for aquatic ecosys-

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tems (Mirabdullaev and Mullabaev 2020; Sheraliev and Peng 2021; Sideleva 2021).

A prerequisite in assessing the population characteristics of any fish species is to investigate its length–weight relation (LWR) (Le Cren 1951). LWRs provide basic knowledge for fisheries research, which is important for fish management and conservation (Çiçek et al. 2022). A few commercially important fish species in Uzbekistan have available LWR data (Kurbanov and Kamilov 2015; Kamilov et al. 2017; Sheraliev et al. 2019); however, no such studies on non-commercial endemic fish species have been undertaken. Because of this scarcity of information, the presently reported study was carried out to determine the LWR parameters of 12 endemic and two native fish species inhabiting the Aral Sea basin in Uzbekistan.

Materials and methods

A total of 676 individuals representing 14 endemic and native fish species were collected between March 2020 and June 2022 from the Syr Darya, Amu Darya, and Zeravshan rivers and their various tributaries using hand nets (Table 1). The following species were collected: Holcik's riffle minnow, *Alburnoides holciki* Coad et Bogutskaya, 2012; sharpray, *Capoetobrama kuschakewitschi* (Kessler, 1872); Turkestan sculpin, *Cottus spinulosus* Kessler, 1872; Oshanin's catfish, *Glyptosternon oschanini* (Herzenstein, 1889); Turkestan gudgeon, *Gobio lepidolaemus* Kessler, 1872; Hari gudgeon, *Gobio nigrescens* (Keyserling, 1861); Kuschakewitsch loach, *Iskandaria kuschakewitschi* (Herzenstein, 1890); Tajik loach, *Iskandaria pardalis* (Turdakov, 1941); eastern crested loach, *Paracobitis longicauda* (Kessler, 1872); Aral spined loach, *Sabanejewia aralensis* (Kessler, 1877); Zeravshan marinka, *Schizothorax fedtschenkoi* Kessler, 1872; Sokh stone loach, *Triplophysa daryoae* Sheraliev, Kayumova et Peng, 2022; Fergana stone loach, *Triplophysa ferganaensis* Sheraliev et Peng, 2021; and Zeravshan stone loach, *Triplophysa uranoscopus* (Kessler, 1872). The specimens collected were identified with the aid of Berg (1949), Turdakov (1963), Amanov (1985), Thoni et al. (2017), and Sheraliev and Peng (2021) as representing three orders, seven families, and ten genera (Fig. 1). The fishes were measured to the nearest 0.1 cm total length (TL) using a digital caliper and weighed to the nearest 0.01 g total weight (W). LWRs were calculated using the following equation

$$W = a\mathrm{TL}^b$$

and logarithmically transformed (Froese 2006) into

$$Log(W) = \log(a) + b \cdot \log(\mathrm{TL})$$

where W is the total body weight [g], TL is the total body length [cm], a is the intercept, and b is the slope. The 95% confidence limits of a and b, and the coefficient of determination (r^2) were calculated using the equations of Sparre and Venema (1998). All statistical analyses were performed using MS Excel 2019 software.

Table 1. Sampling locations of 14 endemic and indigenous freshwater fish species used in this study.

Order/Family/Species	Drainage (Basin)	Coordinates
Cypriniformes/Cobitidae		
Sabanejewia aralensis (Kessler, 1877)	Zeravshan River (Amu Darya basin)	39.677730°N, 67.078299°E
	Karatag River (Amu Darya basin)	38.345899°N, 68.057145°E
	Sherabad River (Amu Darya basin)	37.725809°N, 66.998718°E
Cypriniformes/Cyprinidae		
Schizothorax fedtschenkoi Kessler, 1872	Zeravshan River (Amu Darya basin)	39.677730°N, 67.078299°E
Cypriniformes/Gobionidae		
Gobio lepidolaemus Kessler, 1872	Kara Darya River (Syr Darya basin)	40.785837°N, 72.999462°E
Gobio nigrescens (Keyserling, 1861)	Zeravshan River (Amu Darya basin)	39.677730°N, 67.078299°E
Cypriniformes/Leuciscidae		
Alburnoides holciki Coad et Bogutskaya, 2012	Zeravshan River (Amu Darya basin)	39.677730°N, 67.078299°E
	Tupalang River (Amu Darya basin)	38.343337°N, 67.992137°E
	Surkhan Darya River (Amu Darya basin)	37.340607°N, 67.398966°E
Capoetobrama kuschakewitschi (Kessler, 1872)	Amu Darya River (Amu Darya basin)	37.235241°N, 67.677525°E
Cypriniformes/Nemacheilidae		
Iskandaria kuschakewitschi (Herzenstein, 1890)	Great Fergana Canal (Syr Darya basin)	40.479526°N, 70.888375°E
Iskandaria pardalis (Turdakov, 1941)	Tupalang River (Amu Darya basin)	38.343337°N, 67.992137°E
	Sherabad River (Amu Darya basin)	37.725809°N, 66.998718°E
Paracobitis longicauda (Kessler, 1872)	Zeravshan River (Amu Darya basin)	39.677730°N, 67.078299°E
	Tupalang River (Amu Darya basin)	38.343337°N, 67.992137°E
	Karatag River (Amu Darya basin)	38.385116°N, 68.081272°E
Triplophysa daryoae Sheraliev, Kayumova et Peng, 2022	Sokh River (Syr Darya basin)	40.049308°N, 71.100995°E
Triplophysa ferganaensis Sheraliev et Peng, 2021	Shohimardonsoy River (Syr Darya basin)	39.963237°N, 71.759454°E
Triplophysa uranoscopus (Kessler, 1872)	Zeravshan River (Amu Darya basin)	39.741008°N, 66.889978°E
Perciformes/Cottidae		
Cottus spinulosus Kessler, 1872	Sokh River (Syr Darya basin)	39.940108°N, 71.157773°E
Siluriformes/Sisoridae		
Glyptosternon oschanini (Herzenstein, 1889)	Margilansay River (Syr Darya basin)	40.355162°N, 71.803980°E

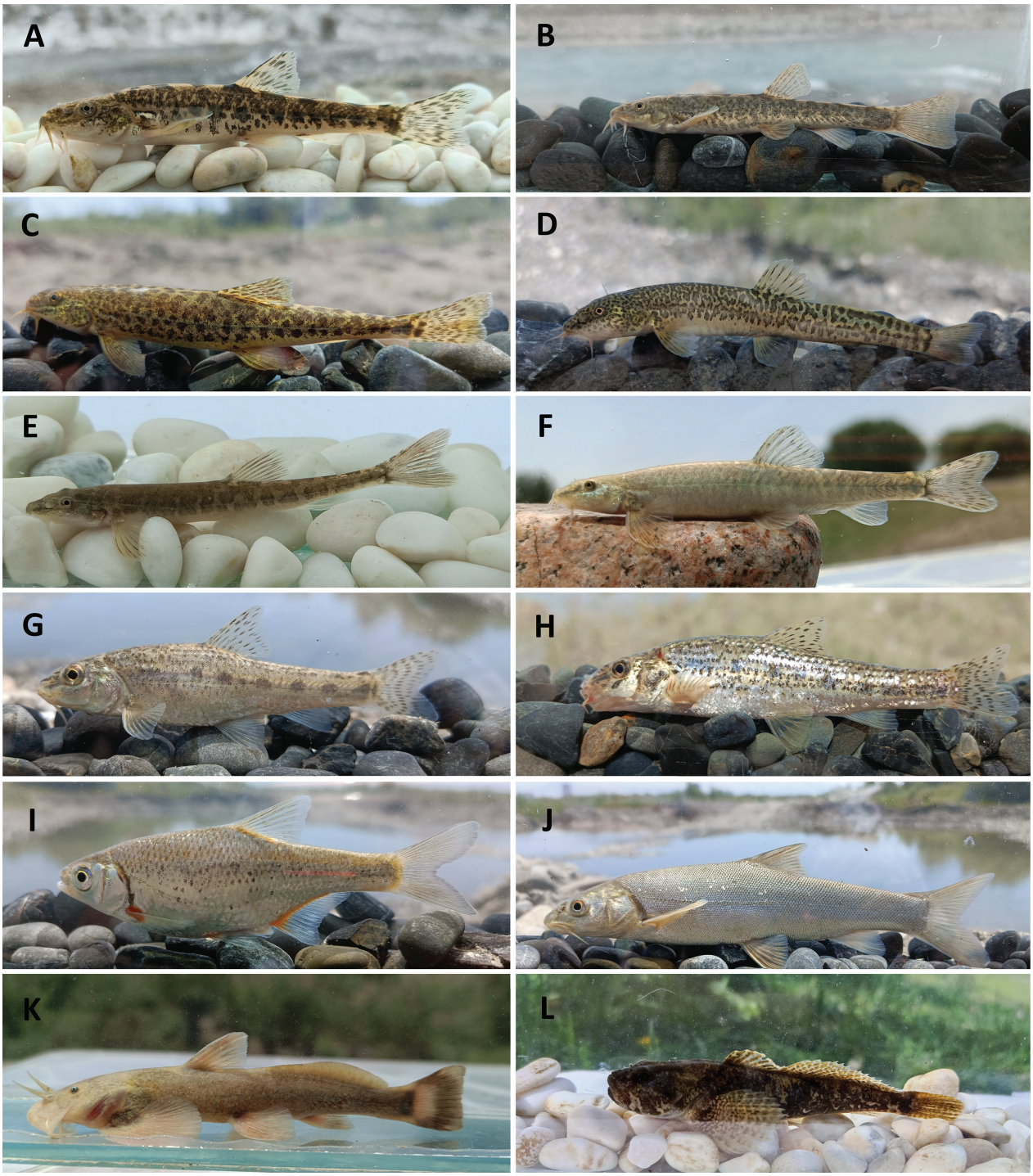

Figure 1. Twelve out of 14 fish species covered by the presently reported study: (**A**) *Triplophysa ferganaensis* (8.2 cm TL) from the Shakhimardan River; (**B**) *Triplophysa daryoae* (9.5 TL) from the Sokh River; (**C**) *Triplophysa uranoscopus* (9.8 cm TL) from the Zeravshan River; (**D**) *Paracobitis longicauda* (7.9 cm TL) from the Zeravshan River; (**E**) *Iskandaria kuschakewitschi* (5.2 cm TL) from the Great Fergana Canal; (**F**) *Iskandaria pardalis* (6.9 cm TL) from the Tupalang River; (**G**) *Gobio nigrescens* (6.1 cm TL) from the Zeravshan River; (**H**) *Gobio lepidolaemus* (7.4 cm TL) from the Kara Darya River; (**I**) *Alburnoides holciki* (7.1 cm TL) from the Zeravshan River; (**J**) *Schizothorax fedtschenkoi* (12.7 cm TL) from the Zeravshan River; (**K**) *Glyptosternon oschanini* (10.2 cm TL) from the Margilansay River; (**L**) *Cottus spinulosus* (6.3 cm TL) from the Sokh River.

Results

For all collected species, the coefficient of determination (r^2) ranged from 0.951 to 0.993, the *a* value ranged from 0.0046 to 0.0132, and the *b* values ranged from 2.703 to 3.234. Sample sizes, total length and total weight ranges, regression parameters, 95% confidence limits of *a* and *b* values, and coefficients of regression are given in Table 2. In LWRs, *b* values higher and lower than 3 indicate positive and negative allometric growth, respec-

Table 2. Descriptive statistics and estimated parameters of length–weight relations for 12 endemic and two native fish species caught from the Aral Sea basin, Uzbekistan.

Species	E	*N*	Total length [cm]		Weight [g]		Length–weight relation parameters					
			Min	Max	Min	Max	*a*	95%CL of *a*	*b*	95%CL of *b*	GT	r^2
*Alburnoides holci*ki		155	4.3	12.1	0.8	19.8	0.0087	0.0076–0.0099	3.156	3.085–3.226	+A	0.971
Capoetobrama kuschakewitschi[a]	+	17	4.7	13.7	0.7	16.3	0.0055	0.0037–0.0081	3.108	2.932–3.283	I	0.960
Cottus spinulosus[a]	+	39	3.9	10.2	0.7	12.6	0.0098	0.0064–0.0151	3.093	2.872–3.315	I	0.963
Glyptosternon oschanini[a]	+	12	9.1	**17.6**	9.4	69.3	0.0132	0.0093–0.0189	2.954	2.814–3.094	I	0.989
Gobio lepidolaemus[a]	+	16	4.4	10.9	0.9	18.8	0.0068	0.0042–0.0112	3.234	3.003–3.464	+A	0.951
Gobio nigrescens[a]		17	4.7	8.3	1.2	7.8	0.0090	0.0061–0.0134	3.162	2.955–3.369	+A	0.977
Iskandaria kuschakewitschi[a]	+	27	9.0	**14.6**	3.4	14.2	0.0102	0.0043–0.0244	2.703	2.502–2.887	–A	0.955
Iskandaria pardalis[a]	+	54	3.2	8.3	0.2	4.8	0.0069	0.0053–0.0089	2.946	2.790–3.102	I	0.982
Paracobitis longicauda	+	61	5.2	17.1	0.9	23.8	0.0121	0.0093–0.0157	2.710	2.599–2.820	–A	0.971
Sabanejewia aralensis[a]	+	134	3.3	7.1	0.2	2.2	0.0050	0.0044–0.0058	3.045	2.962–3.127	I	0.961
Schizothorax fedtschenkoi[a]	+	30	5.8	19.9	2.1	87.0	0.0116	0.0093–0.0146	2.949	2.848–3.050	I	0.989
Triplophysa daryoae[a]	+	59	4.6	**11.3**	0.8	9.1	0.0106	0.0084–0.0133	2.781	2.672–2.890	–A	0.964
Triplophysa ferganaensis[a]	+	37	2.6	10.3	0.1	6.7	0.0049	0.0041–0.0060	3.147	3.043–3.252	+A	0.982
Triplophysa uranoscopus[a]	+	18	3.4	**11.5**	0.3	11.6	0.0072	0.0037–0.0081	3.012	2.927–3.097	I	0.993

E = endemic fish species to the Aral Sea basin (plus signs); *N* = number of individuals; Min = minimum; Max = maximum; *a* = intercept; *b* = slope; CL = confidence limits; GT = growth type, I = isometric growth; –A = negative allometric growth; +A = positive allometric growth; r^2 = correlation coefficient.
[a]Data represent first reported LWR value; **bold** font indicates new maximum total length record for the species.

tively. According to their *b* values, *Iskandaria pardalis*, *Schizothorax fedtschenkoi*, *Glyptosternon oschanini*, *Triplophysa uranoscopus*, *Sabanejewia aralensis*, *Cottus spinulosus*, and *Capoetobrama kuschakewitschi* are isometric; *Iskandaria kuschakewitschi*, *Paracobitis longicauda*, and *Triplophysa daryoae* have negative allometry; and *Alburnoides holciki*, *Gobio lepidolaemus*, *Gobio nigrescens*, and *Triplophysa ferganaensis* have positive allometry (Table 2). The new maximum total lengths of *Glyptosternon oschanini*, *Iskandaria kuschakewitschi*, *Triplophysa daryoae*, and *Triplophysa uranoscopus* were updated.

Discussion

Overall, the expected range of *b* values for LWRs is 2.5–3.5 (Froese 2006) although the ideal value of *b* is 3.0 (Le Cren 1951). The results of the presently reported study are concordant with the expected range. It has been shown that when *b* is greater than three, fish grow faster in weight than in length (Islam et al. 2017; Yang et al. 2021). In addition, a *b* value lower than 3.0 signifies that fish expend more energy on axial growth than to accumulate mass, which could help them seek food and avoid predators (Yang et al. 2021). The calculations performed in this study indicate that, in *Iskandaria kuschakewitschi*, *Paracobitis longicauda*, and *Triplophysa daryoae*, parameter *b* was lower than 3.0, which may be due to cold water, severe environment, low availability of food resources, the large abundance of predators and food competitors, and other unpredictable reasons (Le Cren 1951; Rypel and Richter 2008; Wang et al. 2016). On the other hand, several scientific results indicate that the *b* value of the same species can vary depending on several factors, including environmental factors such as habitat type, seasonality, and geographic location; biotic factors such as sex, gonadal maturity, health, degree of stomach fullness, food competition, and trophic potential of rivers or ponds; and anthropogenic factors such as gear selectivity, number of examined specimens, and a length range of observed individuals (Hossain et al. 2006; Siddik et al. 2016; Islam et al. 2017; Sheraliev et al. 2019). In previous studies, the maximum lengths of *Glyptosternon oschanini*, *Iskandaria kuschakewitschi*, *Triplophysa daryoae*, and *Triplophysa uranoscopus* were given as 10.4, 11.0, 11.2, and 9.0 cm, respectively (Thoni et al. 2017; Froese and Pauly 2022; Sheraliev et al. 2022). By examining a different subsample in the presently reported study, these records were revised to 17.6, 14.6, 11.3, and 11.5 cm, respectively.

In conclusion, our study provides partial information on the 14 endemic and native fish species from the Aral Sea basin as a contribution to the online FishBase, which could help to understand better the fishes of the region and contribute to the management and conservation of fishes in central Asia.

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PENSOFT

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First specimen-based Indonesian record of a rare scorpionfish, *Scorpaenopsis obtusa* (Actinopterygii: Perciformes: Scorpaenidae), from Alor Island

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Abstract

A single specimen of the shortsnout scorpionfish, *Scorpaenopsis obtusa* Randall et Eschmeyer, 2002 (Scorpaenidae), collected from the south coast of Ampera, Alor Barat Laut, Alor Island, Indonesia, at 5 m depth, represents the first voucher specimen-supported record of the species from Indonesian waters (previous records from Nusa Penida and northern Sulawesi having being based on underwater photographs). At 91.1 mm in standard length, the Alor specimen is the largest recorded individual of the species to date.

Keywords

distribution, largest specimen, ontogenetic change, variation, voucher specimen

Introduction

The scorpionfish genus *Scorpaenopsis* Heckel, 1837 (Scorpaenidae), characterized by 12 dorsal-fin spines, three or more suborbital spines, the absence of palatine teeth and black pigment between the first and third dorsal-fin spines, and a compressed head (Randall and Eschmeyer 2001; Motomura et al. 2011), comprises 28 valid species (Fricke et al. 2013), 10 of which have been recorded in Indonesian waters to date, viz., *Scorpaenopsis diabolus* (Cuvier, 1829); *Scorpaenopsis macrochir* Ogilby, 1910; *Scorpaenopsis neglecta* Heckel, 1837; *Scorpaenopsis obtusa* Randall et Eschmeyer, 2002; *Scorpaenopsis oxycephalus* (Bleeker, 1849); *Scorpaenopsis papuensis* (Cuvier, 1829); *Scorpaenopsis possi* Randall et Eschmeyer, 2002; *Scorpaenopsis ramaraoi* Randall et Eschmeyer, 2002; *Scorpaenopsis venosa* (Cuvier, 1829); and *Scorpaenopsis vittapinna* Randall et Eschmeyer, 2002 (Randall and Eschmeyer 2001; Allen and Adrim 2003; Allen and Erdmann 2012).

A single specimen of *Scorpaenopsis*, collected from Alor Island during a marine rapid assessment project for protected marine areas in Nusa Tenggara Timur and Maluku Provinces, Indonesia, conducted by the Pattimura University, Ambon and the Yayasan Konservasi Cakrawala Indonesia (YKCI), was subsequently identified as the western Pacific scorpionfish *S. obtusa*, a species previously known from only eight collected specimens from Japan, the Philippines, Taiwan, Papua New Guinea, and Australia (Randall and Eschmeyer 2001; Motomura and

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Shinohara 2005; Motomura et al. 2011; Allen and Erdmann 2012). In Indonesian waters, *S. obtusa* has previously been photographed underwater (specimens not collected) off Nusa Penida and northern Sulawesi (Allen and Erdmann 2012: 234). The specimen of *S. obtusa* described in the presently reported study represents the first confirmed Indonesian record of the species.

Methods

Counts and measurements generally followed Randall and Eschmeyer (2001) and Motomura and Shinohara (2005), except head width (Motomura et al. 2005) and maxillary depth (Motomura et al. 2006). The last two soft rays of the dorsal and anal fins were counted as single rays, each pair being associated with a single pterygiophore. Standard and head lengths are expressed as SL and HL, respectively. Head spine terminology follows Wibowo and Motomura (2021: fig. 1). Descriptive method generally follows Motomura and Shinohara (2005). Descriptive characters are based on the Indonesian specimen, which was deposited in the Museum Zoologicum Bogoriense (MZB), Indonesia.

Results

Family Scorpaenidae Risso, 1827
Scorpaenopsis Heckel, 1837

Scorpaenopsis obtusa Randall et Eschmeyer, 2002

English common name: shortsnout scorpionfish

(Figs. 1–3)

Material examined. MZB.26532, 1 specimen, 91.1 mm SL, Ampera, Alor Barat Laut, Alor Island, Indonesia, 8°16′03.7″S, 124°25′33.1″E, 5 m depth, hand net, K. Wibowo, 26 February 2022.

Description. Counts and proportional measurements [given below as percentages of SL and HL (for head characters; presented in parenthesis)] of presently reported specimen (91.1 mm SL) were as follows: dorsal fin with 12 spines and 9 soft rays; pectoral fin with 1 uppermost unbranched ray, 6 branched rays, 12 lower unbranched rays, total 19 rays; longitudinal scale rows 38; pored lateral-line scales 20; scales above lateral line 5, below 12; gill rakers on upper limb of first gill arch 4, lower limb 9, total 13; body depth 44.5% of SL; body width 30.2; head length 45.6; snout length 11.8 (26.0% of HL); orbit diameter 10.3 (22.7); interorbital width at posterior end of preocular spine bases 11.1 (24.3); caudal-peduncle depth 12.0; caudal-peduncle length 15.7; upper-jaw length 25.9 (57.0); pre-dorsal-fin length 38.5; pre-anal-fin length 71.5; pre-pelvic-fin length 39.3; first dorsal-fin spine length 7.8; second dorsal-fin spine length 11.9; third dorsal-fin spine broken; fourth dorsal-fin spine length 15.8; eleventh dorsal-fin spine length 10.8; twelfth dorsal-fin spine length 12.9; longest dorsal-fin soft ray length 19.2 (third ray); first anal-fin spine length 9.4; second anal-fin spine length 17.5; third anal-fin spine length 15.6; longest anal-fin soft ray length 23.0 (second ray); caudal-fin length 26.9; pectoral-fin length 39.0; pelvic-fin spine length 19.3; longest pelvic-fin soft ray length 29.2 (second ray); head width 21.5 (47.3); postorbital length 27.3 (59.9); maxillary depth 7.6 (16.6).

Body wide anteriorly, progressively compressed posteriorly. Mouth large, oblique, positioned at angle of about 60° to horizontal axis of head and body. Posterior margin of maxilla extending beyond line from posterior margin of orbit to edge of retroarticular. Vomerine plate forming V-shaped patch, with rudimentary teeth. Palatine teeth absent. Nasal spine with 3 spinous points. Ascending process of premaxilla intruding into interorbital space, its posterior margin level with anterior margin of pupil. Median interorbital ridge absent. Interorbital ridges distinct; space between interorbital ridges shallow and broad, its width about half of orbit diameter. Preocular and supraocular spines small, directed upward. Postocular spine large, with 3 points, broadly joined to tympanic spine at base. Tympanic with 2 spinous points, located between postocular spines. Coronal spine absent. Occipital pit deep, its width greater than length. Parietal and nuchal spines about equal size, joined at base. Sphenotic with 2 small spines. Postorbital with 2 small spines. Pterotic spine simple, larger than supraocular spine. Upper posttemporal spine larger than lower spine. Space between parietal, nuchal, pterotic, and lower posttemporal spines with two small spines. Supracleithral spine asymmetric, with 3 and 2 pointed spines on left and right sides, respectively. Cleithral spine flattened, strongly pointed. Anterodorsal lacrimal spine present. Single small spines on middle and posterior end of lacrimal ridge. Anterior lacrimal spine directed anteriorly, its tip reaching dorsal margin of upper lip; two additional small points on posterior margin. Posterior lacrimal spine directed ventrally, larger than anterior spine, its tip not reaching dorsal margin of upper lip; an additional spine present on anterior margin; posterior lacrimal spine associated with short fimbriate flap. Lateral lacrimal spine present, its size approximately equal to anterodorsal lacrimal spine. Suborbital ridge with 3 spines. Suborbital pit present. Preopercle with 5 spines; uppermost spine largest, with supplemental preopercular spine on base; second spine sharp; third to fifth spines blunt. Upper opercular spine with 2 points; lower opercular spine simple, with median ridge.

Lateral surface of body covered with weak ctenoid scales, becoming cycloid ventrally. Exposed cycloid scales covering pectoral-fin base. Cycloid scales embedded in thin skin covering anteroventral surface of body. Body scales not extending onto fin rays or membranes, except basally on seven uppermost pectoral fin rays. Lateral line complete, first two scales with spine-like projection at end of sensory tube. No scales on head.

Numerous tiny papillae scattered on dorsal and lateral surfaces of head, including snout, interorbital space,

Figure 1. Fresh specimen photograph of *Scorpaenopsis obtusa*, MZB.26532, 91.1 mm SL, collected from Alor Island, Indonesia.

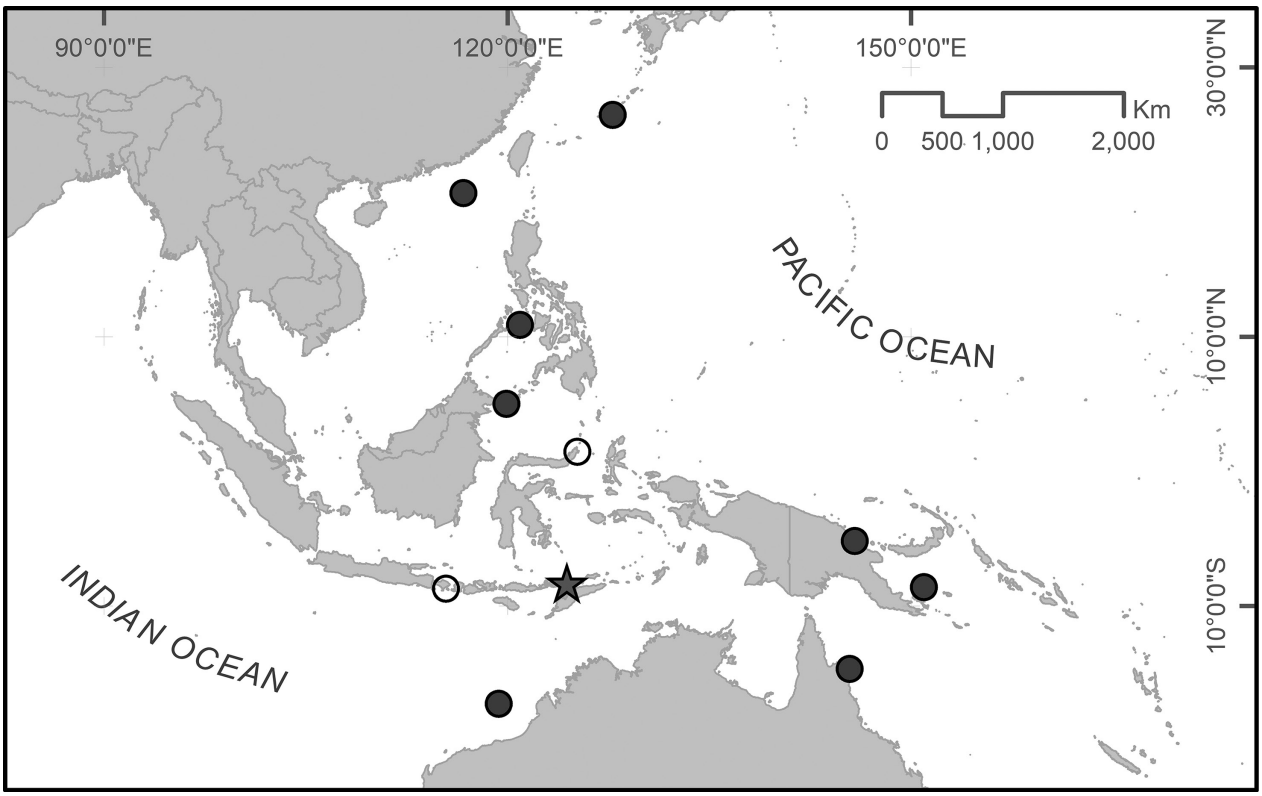

Figure 2. Distributional records of *Scorpaenopsis obtusa*, based on previous studies (circles) and the presently reported study (star). Closed and open symbols indicate specimen- and underwater photograph-based records, respectively.

outer margin of eye membrane, preopercle, and opercle. No papillae on occipital pit. Tentacle on upper posterior edge of low membranous tube associated with anterior nostril. Fleshy tentacle associated with posterior lacrimal spine. Several short, slender tentacles on lateral surface of maxilla. Broad, skin flap associated with each of third to fifth preopercular spines. Many small, round flaps on ventral surface of head and anteroventral surface of body.

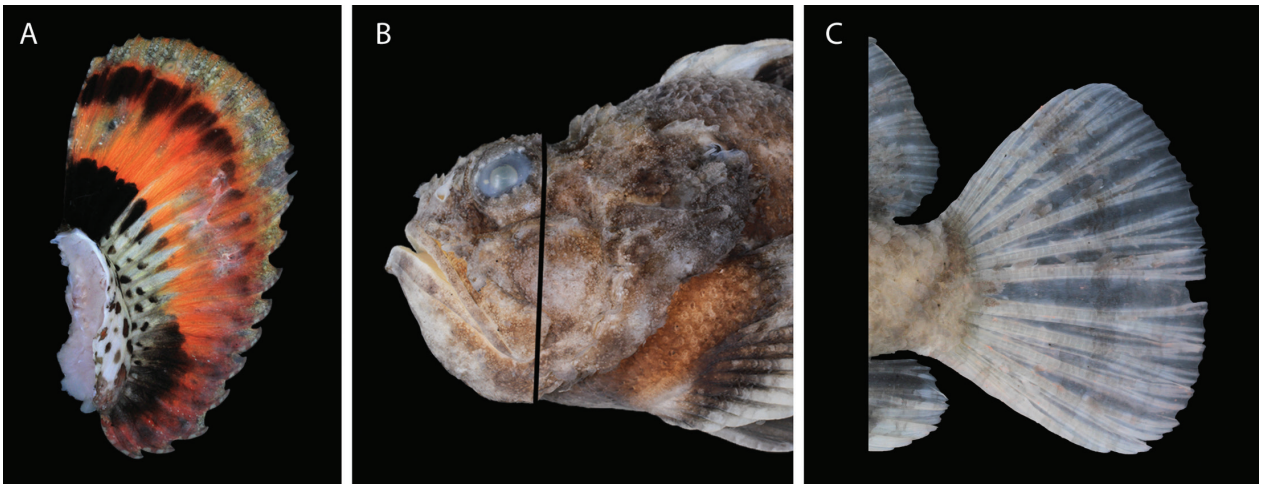

Figure 3. Inner surface of pectoral fin (fresh condition) (**A**), head (showing line from posterior margin of orbit to posteroventral tip of retroarticular) (**B**), and caudal fin (**C**) of *Scorpaenopsis obtusa*, MZB.26532, 91.1 mm SL, collected from Alor Island, Indonesia.

Many slender tentacles associated with posterior margin of opercle, pored lateral scales scattered on lateral and dorsal surfaces of body, and pectoral and caudal fins.

Origin of first dorsal-fin spine above supracleithral spine. Posterior margin of opercular membrane level with posterior margin of third dorsal-fin spine base. Posterior tip of pectoral fin extending beyond third anal-fin spine base. Posterior tip of pelvic fin extending slightly beyond anus when depressed. Origin of last dorsal-fin spine just above origin of first anal-fin spine.

Color when fresh (Figs. 1, 3A). Head and body mottled dark reddish-brown to white. Dorsal fin whitish to reddish-brown, distinct black blotch on base of spinous portion between fourth and eighth spines. Pectoral fin outer surface pinkish-white, blackish basally, with blackish band near tip; inner surface orange, with broad black blotch basally on each of uppermost four and lowermost seven rays, black submarginal band (progressively less distinct on lower unbranched rays), axil and base of membrane of fifth to fourteenth rays white with small black spots. Pelvic fin black, with white distal margin. Anal fin dark reddish with numerous tiny spots and white posterior margin. Caudal fin whitish, with broad pinkish band.

Discussion

The characters of a single specimen of the genus *Scorpaenopsis* from Alor Island, Indonesia (Fig. 1), determined in this study, agreed well with the diagnostic characters of *S. obtusa* given by Randall and Eschmeyer (2001) and Motomura and Shinohara (2005), e.g., pectoral-fin rays 19; pored lateral-line scales 20; longitudinal scale series 38; gill rakers 13; body depth 2.2 times in SL; dorsal profile of anterior spinous portion of dorsal fin highly arched, giving a humpbacked appearance; head length 2.2 in SL; snout short and blunt 3.8 in HL; ascending process of premaxilla intruding into interorbital space; orbit diameter 4.4 in HL; nasal spine with 3 points; mouth oblique, forming an angle of about 60° to horizontal axis of head and body; postocular spine broadly joined to tympanic spine; occipital pit deep; suborbital pit deep; upper opercular spine doubled; first dorsal-fin spine length 1.5 in second dorsal-fin spine length; fourth dorsal-fin spine length 2.9 in HL; penultimate dorsal-fin spine length 1.2 in last dorsal-fin spine length; interorbital width at posterior end of preocular spine bases 4.1 in HL.

Scorpaenopsis obtusa was originally described by Randall and Eschmeyer (2001) on the basis of specimens from the Philippines (1 specimen, 79.0 mm SL) and Papua New Guinea (2, 36.5–49.7 mm SL). Motomura and Shinohara (2005) reassessed the diagnostic characters of *S. obtusa* given by Randall and Eschmeyer (2001), and reported the first specimen-based records of *S. obtusa* from Japan (1, 40.4 mm SL) and Australia (2, 34.8–37.8 mm SL), and second record from Papua New Guinea (25.6 mm SL). Subsequently, Motomura et al. (2011) reported the first record of the species from Taiwan (based on a single specimen, 47.7 mm SL). Later, *S. obtusa* was reported by Allen and Erdmann (2012: 234) from Indonesian waters (Nusa Penida and northern Sulawesi), based on underwater photographs. The presently reported specimen of *S. obtusa* from Alor Island, the ninth reported overall and largest known example of the species (91.1 mm SL), represents the first specimen-based record of the species from Indonesia (Fig. 2).

Scorpaenopsis obtusa, most similar to the western Indian Ocean humpback species *Scorpaenopsis gibbosa* (Bloch et Schneider, 1801) in inner pectoral fin surface color pattern (Eschmeyer and Randall 1975: 307, fig. 17c; Randall and Eschmeyer 2001; Motomura and Shinohara 2005: fig. 1), differs from the latter in four morphological characters: snout length, location of the premaxilla ascending process, and numbers of longitudinal scale rows and pectoral-fin rays (Randall and Eschmeyer 2001). Motomura and Shinohara (2005) confirmed the validity of these four characters, in addition to finding several additional diagnostic characters for *S. obtusa*, following

a comparison between *S. obtusa* (6 specimens, 25.6–49.7 mm SL) and *S. gibbosa* (9 specimens, 37.4–99.4 mm SL), e.g., distance between ventral margin of orbit and suborbital ridge, interorbital width between posterior end of preocular spine bases, condition of posterior margin of maxilla, and caudal-fin color pattern in preserved specimens.

However, the color pattern of the pectoral fin inner surface on a fresh specimen photograph of the presently reported specimen of *S. obtusa* (Fig. 3A) differed slightly from the illustration given by Motomura and Shinohara (2005: fig. 1), i.e., small black spots scattered on the axil and extending to the base of the membranes between the fifth to fourteenth rays (presently reported study) (vs. restricted to axil), and a broad blotch basally on the upper and lower rays (vs. on upper rays only). These differences are regarded here as intraspecific variations.

Although Motomura and Shinohara (2005) noted that the distance between the ventral margin of the orbit (VMO) and suborbital ridge in *S. obtusa* and *S. gibbosa* did not reflect growth-related changes (see fig. 4), examination of the presently reported specimen indicated that the proportion measured in the presently reported specimen (91.1 mm SL; distance between VMO and suborbital ridge: 2.3 mm) is significantly larger than that of the largest one (49.7 mm SL; ca. 1.1 mm) examined by Motomura and Shinohara (2005: fig. 4). Thus, this morphometric character actually reflect the growth-related change. Notwithstanding, the distance between the VMO and suborbital ridge remains a useful character for separating similarly-sized individuals of *S. obtusa* and *S. gibbosa*.

The interorbital space between the posterior ends of the preocular spine bases in the presently reported specimen of *S. obtusa* was contained 4.1 times in HL, confirming the reliability of this diagnostic character for *S. obtusa*. However, because it is subject to growth-related changes (see Motomura and Shinohara 2005: fig. 5), the proportion is unlikely to be reliable for distinguishing between similarly-sized individuals of *S. obtusa* and *S. gibbosa* greater than 100 mm SL.

The presently reported specimen of *S. obtusa* also had the posterior margin of the maxilla extending well beyond a line from the orbit posterior margin and posteroventral tip of the retroarticular (Fig. 3B), as noted by Motomura and Shinohara (2005). In addition, the caudal-peduncle band on the presently reported specimen was almost lost following preservation (Fig. 3C), as was noted in smaller specimens of *S. obtusa* (<49.6 mm SL), which were uniformly white (see Motomura and Shinohara 2005: fig. 3).

Acknowledgments

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PENSOFT

ACTA ICHTHYOLOGICA ET PISCATORIA

Age and growth of the Pacific hake, *Merluccius productus* (Actinopterygii: Gadiformes: Merlucciidae), in the Gulf of California: A multimodel approach

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Abstract

Over the past decade, the fishery of Pacific hake, *Merluccius productus* (Ayres, 1855), has increased in the Gulf of California, Mexico; therefore, any biological–fisheries information is highly relevant for the management of this fishery, and information on age and individual growth would be fundamental to evaluate populations. The objective of the presently study was to assess age, based on otolith structure, and estimate growth parameters through a multimodel approach. Specimens were collected during research cruises of *BIP XI* from 2014 to 2019. Pacific hake from the Gulf of California ranged in length from 12.5 to 105 cm TL, reaching a maximum age of 13 years, and females were four years older than males. The logistic model was the best model to describe age–size data for both sexes. Females reached 50% of the maximum length at five years old and males reached that length at four years old.

Keywords

age structure, asymptotic length, growth rate, individual growth

Introduction

The population of the Pacific hake, *Merluccius productus* (Ayres, 1855), is distributed from northern Vancouver Island, Canada, to the northern Gulf of California (Cohen et al. 1990). It has been identified as a stocks structured population, with one highly migratory stock distributed from southern California to Queen Charlotte Sound in Canada. Other stocks are found in limited geographic areas such as the Strait of Georgia, Queen Charlotte Strait, the western coast of the Baja California Peninsula (Iwamoto et al. 2004), and the Gulf of California (Mathews et al. 1973).

This species inhabits the California Current system and sustains important fisheries on the western coast of the USA, Canada, and southern Alaska, with catches of around 200 000 t per year, with a binational management

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strategy between USA and Canada, organized through annual quotas (Hammel et al. 2015). In the Gulf of California, Mexico, Pacific hake was part of a multispecific fishery called "escama" (fish with scales), from 1990 to 2017. Until 2012 the mean catch value of this species was 855 t, between 2013 and 2017 the catch increased rapidly exceeding 8000 t per year. In 2018, a directed Pacific hake fishery was established with two management criteria, quotas (with reference to the biologically acceptable catch) and a maximum of 80 fishing vessels. The resource is available to the fishery from December to May (Anonymous 2018). More than 95% of the catch is exported to Spain and the rest remains on the local market (Anonymous 2022).

Due to the importance of this fishery and in order to improve management criteria, during the last four years, significant effort has been devoted to generating biological and fishery information that contributes to evaluating the effect of fishing. Some of those data, namely mortality, longevity, length at first maturity, age, and individual growth are used in structured models to assess population dynamics, and the results used as a guide in effective management of the fisheries (Morales-Nin 1992; Cerviño 2013; Ruiz-Domínguez and Quiñonez-Velázquez 2018).

One of the first studies to evaluate Pacific hake growth was carried out by Dark (1975) who used the otolith growth ring counts of the fish obtained off the western coast of the USA. The author reported accelerated growth during the first three years of life and slower growth thereafter, as well as differences between males and females after two to three years of age. Longevity was reported at 13 years, with the mean furcal length (FL) of 61.8 cm. Beamish (1979) analyzed the number of growth marks on whole otoliths with those on transverse sections of otoliths of Pacific hake from the Strait of Georgia stock, finding that the latter showed a greater number of growth marks than whole otoliths. The growth marks were more evident in organisms younger than 7 years of age; at older ages, the growth marks overlapped. The above-mentioned author reported organisms of 16 years of age and a mean FL of 44 cm. McFarlane et al. (1983) reported organisms with a maximum age of 20 years and a mean FL of 48 cm for this same area, but 83% of specimens were 4–11 years old, which would correspond to specimens measuring between 39 and 46 cm FL.

Salinas-Mayoral (unpublished[*]) addressed the individual growth of Pacific hake off the western coast of the Baja California Peninsula. Based on otolith sections, up to 12 age groups with a mean standard length (SL) of 27.5 cm were identified, significantly lower than those of the stock from the western coast of the USA. For the stock that is fished in the northern area of the Gulf of California, individuals have been reported that reach 112 cm TL and weigh up to 7 kg (total weight, TW) (Nevárez-Martínez et al., unpublished[**]). This is the Pacific hake stock with the longest reported length (Zamora-García et al. 2020, Alvarez-Trasviña et al. 2022). However, basic biological aspects such as reproduction, feeding, age, and growth, are scarce for this region. This study focused on evaluating allometry, aging, and estimation of individual growth parameters of Pacific hake inhabiting the middle and northern Gulf of California, using the number of growth marks on otolith sections to estimate age, and a multimodel approach to analyze length at age data.

Materials and methods

Biological samples. Specimens of Pacific hake, *Merluccius productus*, examined in this study were obtained from exploratory fishing cruises carried out by the Instituto Nacional de Pesca y Acuacultura (INAPESCA) in February and April–May 2014, April and December 2015, October–November 2016, May 2017, and February 2019 with an average duration of 18 days. The cruises were conducted aboard the *BIP XI*, which was equipped with an otter trawl (33.8 m headline, 152-mm body mesh, and 89-mm codend mesh) cast from the stern and scientific echosounder (EK60). The prospected area comprises the middle and northern Gulf of California at depths close to 500 m (Fig. 1).

Once the echo sounder detected a fish school (energy), the vessel turned to drop the net and trawl for 30 min at an average speed of 3 knots. The catches obtained during each set were placed on the deck, separated by species, and weighed [kg]. Subsequently, the bycatch identification at the lowest taxonomic level was carried out using the diagnostic characteristics described by Fischer et al. (1995). When the Pacific hake per set exceeded 500 kg, a random sample of 100 organisms was selected and TL (±0.1 cm) and TW (±0.1 g) were recorded, grouped in intervals of 2 cm TL and from each interval were selected up to 5 organisms whose TL, SL (±0.1 cm), TW were measured, sex and gonadal maturity were assigned visually (macroscopic) and the otoliths were extracted (biological sample, BS).

Total length–total weight relation. This relation for Pacific hake, *Merluccius productus*, was calculated for each sex (male, female) and for pooled data, using the following equation (Sparre and Venema 1998)

$$TW = aTL^b$$

[*] Salinas-Mayoral CA (2018) Dinámica poblacional de la merluza del Pacífico *Merluccius productus* (Ayres, 1855), en la Costa Occidental de BCS, México. Tesis Maestría. Centro de Investigaciones Biológicas del Noroeste, S.C. La Paz, Baja California Sur, México.

[**] Nevárez-Martínez MO, Balmori-Ramírez A, Santos-Molina JP, Cervantes-Valle C, López-Martínez J, Méndez-Tenorio JF, Anguiano-Carrazco ML, Acevedo-Cervantes A, Miranda-Mier E, Morales-Azpeitia R, Valdivia-Herrera E (2007 [unpublished]) Prospección de merluza y bacalao: distribución, tamaño poblacional e ictiofauna asociada en el Golfo de California. Clave: SAGARPA-2003-C01-047.

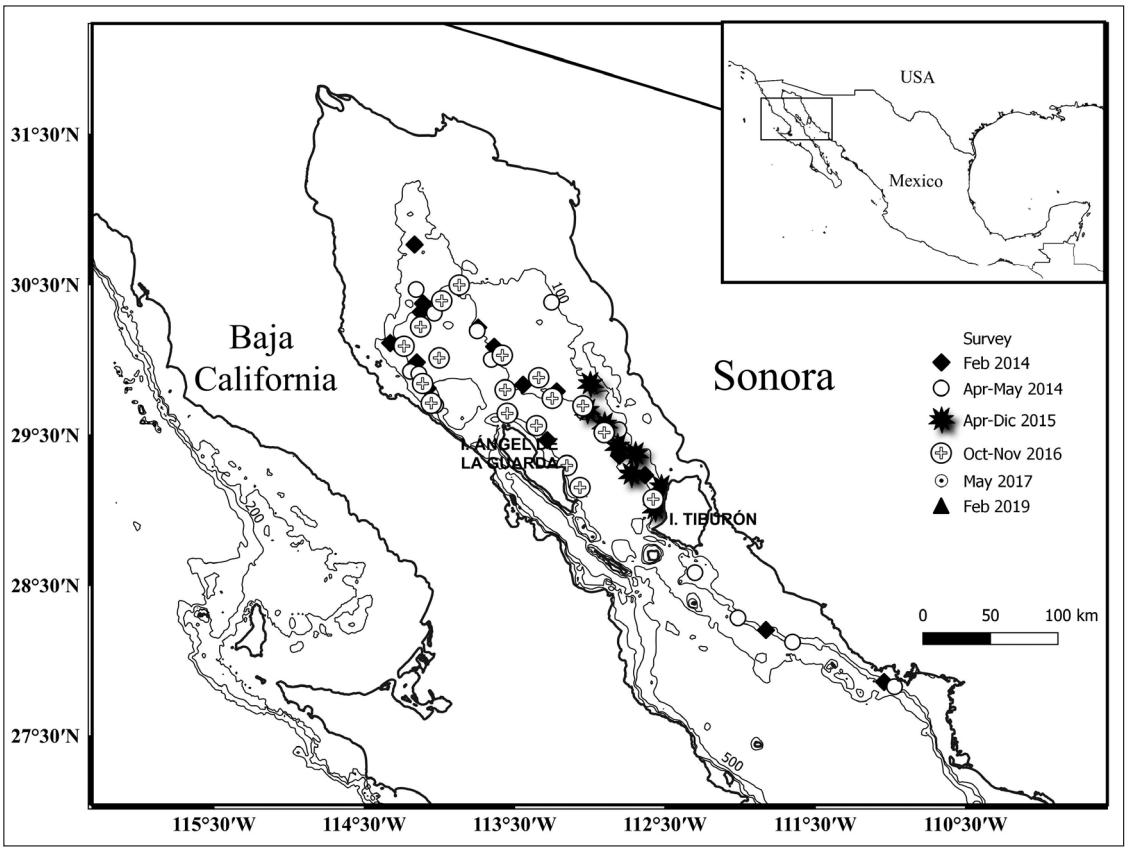

Figure 1. Study area the middle and northern Gulf of California, and sampling stations during research cruises.

where TW is the total weight [g], TL is the total length [cm], *a* is the intercept, and *b* is the allometry coefficient. A Student's *t*-test was used to identify the type of growth, i.e., isometric ($b = 3$) or allometric ($b \neq 3$): $t = (b - 3)SE^{-1}$, where SE is the standard error, with an α of 5%, $t = 1.96$ (Zar 1999).

Age determination. To select the organisms that will define the sub-sample for age determination, and be representative of the Pacific hake, *Merluccius productus*, length-structure from the total sample, the lengths of the SB per cruise were grouped in 2 cm TL intervals. To estimate the maximum number of organisms per interval to be selected, a random sampling was drawn, increasing the size of the sample selected in each event as a function of the interval absolute frequency. The differences between the re-samplings were evaluated with a multiple analysis of variance (Kruskal–Wallis) and when the test was significant, that sample size was defined as the number to select per length interval (Salcido-Guevara et al. 2014).

The otoliths selected for age determination were washed with fresh water and phosphate-free soap using a brush with fine bristles to avoid damaging the otoliths. The left otolith was used for reading the growth marks; if that otolith was damaged or lost, the right otolith was used. The otoliths were embedded in epoxy resin and allowed to cure for 24 h. Dorsal–ventral sections were taken from the center of the nucleus of each otolith using a ISOMET BuehlerMet Low Speed cutter. Sections were polished with sandpaper (800 µm grit and 1500 µm grit) until growth marks were clearly defined. To make growth marks more evident, sections were stained for 20 min in a solution of 0.2 g neutral red, 1 g sodium chloride, 100 ml distilled water, and 0.5 ml acetic acid (Easey and Millner 2008). Finally, the sections were photographed using a stereoscope with a video digitizer system (OLYMPUS SZ61) with reflected light.

The readings of the growth marks in the otolith sections were made by three readers independently. Due to the staining process of the otolith sections, the opaque band acquired a less intense color than the hyaline band (Fig. 2). We as-

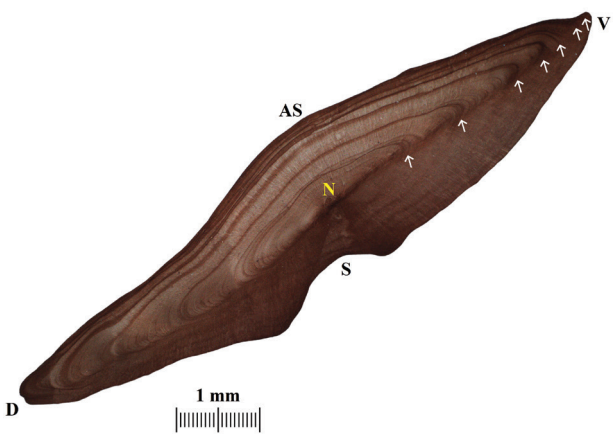

Figure 2. Transversal cuts of otolith sagitta of Pacific hake, *Merluccius productus*, in the Gulf of California. N = nucleus, D = dorsal, V = ventral, S = sulcus, AS =Antisulcus. Female of 68 cm TL.

sume an annual periodicity deposition of a growth mark (opaque band plus hyaline band) according to Dark (1975).

The index of the mean percentage error (IMPE) (Beamish and Fournier 1981)* was calculated to assess the precision of the age determinations between three independent readers using the following equation

$$\text{IMPE} = \frac{1}{N}\sum_{j=1}^{N}\left(\frac{1}{R}\sum_{i=1}^{R}\frac{\left|X_{ij}-X_j\right|}{X_j}\right)*100\%$$

where N is the number of fish aged, R = number of times each fish was aged, X_{ij} is the ith age determination of the jth fish, X_j is the mean age calculated for the jth fish.

The coefficient of variation (CV) proposed by Chang (1982) was also calculated, using the previously defined variables

$$\text{CV} = \frac{1}{N}\sum_{j=1}^{N}\frac{\sqrt{\frac{1}{R}\sum_{j=1}^{R}\frac{(Xij-Xj)2}{R-1}}}{Xj}*100$$

Evaluation of individual growth. A multimodel approach was applied to the age–length data of Pacific hake, *Merluccius productus*, according to Burnham and Anderson (2002). The candidate models describe a curve that tends towards an asymptotic value (L_∞ asymptotic); this parameter is the only one with the same biological meaning in all the models (Table 1). Growth models were fitted by maximizing the log–normal likelihood function with Newton's algorithm (Haddon 2001).

Table 1. Candidate growth models to describe trend age-length data for Pacific hake, *Merluccius productus*, in the Gulf of California.

Growth model	Curve	Parameter
VBGM	Inverse exponential	3
Gompertz	Sigmoid	3
Logistic	Sigmoid	3
Schnute–Richards	Sigmoid	5

VBGM = von-Bertalanffy growth model.

Selection of the best model. Akaike's information criterion (AIC) was used to select the best model to describe the age–length data trend of Pacific hake, *Merluccius productus*, considering the goodness-of-fit and the number of model parameters

$$\text{AIC} = 2(k - \text{LL})$$

where LL is the likelihood value of each adjusted model and k is the number of parameters of the model. The model with the lowest AIC value (AIC_{min}) was selected as the best model.

AIC differences ($\Delta i = \text{AIC}_i - \text{AIC}_{min}$) were estimated to evaluate the statistical support of the models (Burnham and Anderson 2002). Models with $\Delta i > 10$ have no statistical support and have to be omitted from the analysis; models with $\Delta i \leq 2$ have high support; and models with $4 < \Delta i < 7$ have medium support. Each model's parsimony was evaluated by calculating the AIC weight (w_i), using the equation proposed by Burnham and Anderson (2002):

$$w_i = \frac{e(-0.5\Delta i)}{\sum_{i=1}^{4} e(-0.5\Delta i)}$$

Comparison of individual growth. Once the best model for males and females of Pacific hake, *Merluccius productus* was obtained, a comparison of the growth parameters was made using the likelihood test of Kimura (1980).

$$x_k^2 = -N * \ln\left(\frac{SRCa}{SRCb}\right)$$

where k represents the degrees of freedom (number of parameters), N is the total number of observations from both curves combined, SCR_a is the total sum of squared residuals of the model adjusted to each dataset, and SCR_b is the total sum of squared residuals of the model using all data.

Confidence intervals. Once the best model was identified, the uncertainty associated with the estimated parameters was evaluated by estimating the 95% confidence intervals according to Venzon and Moolgavkar (1988) and Hilborn and Mangel (1997) using the likelihood profile method. The estimates are based on the χ^2 distribution with m degrees of freedom (Zar 1999), according to the following inequality:

$$2[\text{LL}(\theta\backslash\text{data}) - \text{LL}(\theta\backslash\text{best})] < \chi^2_{1,\,1-\alpha}$$

where LL (θ\best) is the likelihood of the most likely value of θ and $\chi^2_{1,1-\alpha}$ are the values of the χ^2 distribution with one degree of freedom at a confidence level of $1 - \alpha$.

Results

The size frequency distribution of Pacific hake, *Merluccius productus* ranged from 12.5 to 105 cm TL; females measured between 16 and 105 cm TL and males measured between 12.5 and 83 cm TL. Females weighed between 21 and 7500 g and males weighed between 9.8 and 4200 g (Fig. 3). The TL–TW relation of females, males, and sexes combined (Fig. 4. A, B, C) shows values of b ranging between 3.11 and 3.14 and were not significantly different from 3, so we concluded that the Pacific hake presents isometric growth (Table 2).

Age determination. The aging subsample was integrated by selecting up to 15 Pacific hake, *Merluccius productus* for each length interval (2 cm) (KW = 28.07, $P > 0.05$). The absolute frequency in the length intervals <16 cm and >78 cm TL was less than 15, all of which were incor-

* The original authors Beamish and Fournier (1981) and many subsequent ones referred to this index imprecisely as the "index of the average percentage error" (IAPE).

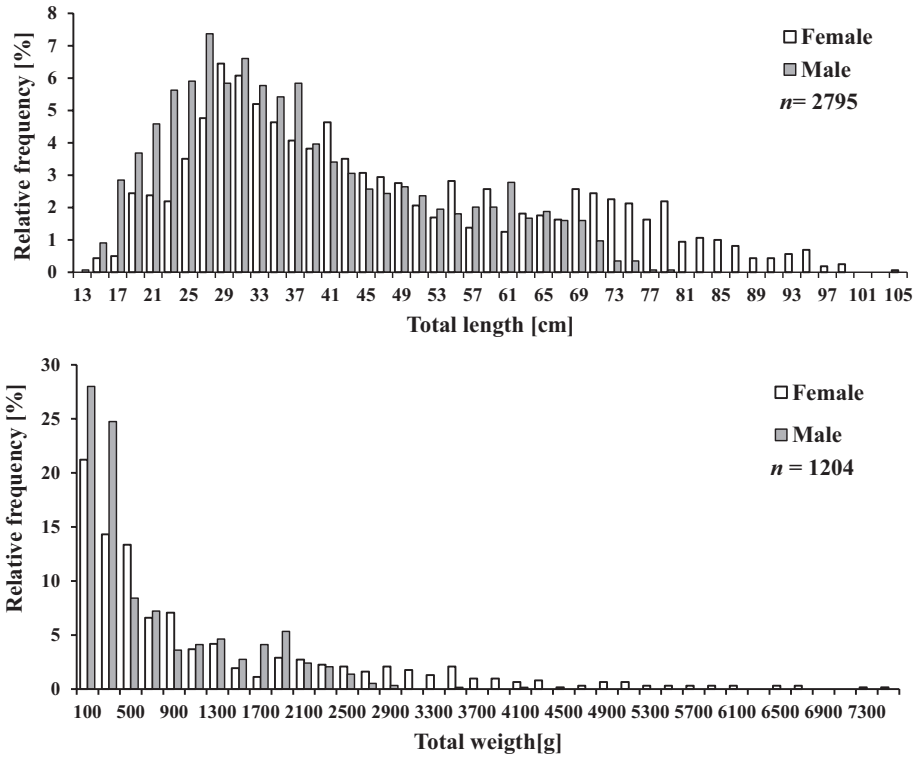

Figure 3. Length and weight frequency distribution by sex of Pacific hake, *Merluccius productus*, in the Gulf of California during research cruises from 2014 to 2019.

Table 2. Total length–total weight relation of the Pacific hake, *Merluccius productus*, in the Gulf of California.

Sex	*N*	Equation	R^2
Female	622	TW = 0.000003 × $TL^{3.11}$	0.98
Male	582	TW = 0.000003 × $LT^{3.14}$	0.97
Both sex	1204	TW = 0.000003 × $LT^{3.11}$	0.98

In all three cases the growth type was isometric ($P < 0.05$); *N* = number of specimens studied, TW = total weight, TL = total length.

porated into the age subsample. From the total organisms sampled (2795), 468 were selected to assign age (60% females and 40% males).

High inter-reader precision was observed for the number of growth marks on otolith sections (APE = 1.7 and CV = 2.4). Up to 13 age groups were identified for Pacific hake that inhabit the Gulf of California. Females were longer-lived than males, 13 and 9 years old, respectively. Age group 5 was the most abundant in females and age group 4 in males (Fig. 5).

Individual growth parameters and selection of the best model. All candidate models (von Bertalanffy, Gompertz, Logistic, and Schnute–Richards) presented similar theoretical curves to describe the length–age data trend for the Pacific hake, *Merluccius productus* (Fig. 6). The parameters of the models have different meaning except L_∞. This parameter varied from 112.85 to 214.15 cm TL in females and from 80.59 to 118.63 TL in males (Table 3).

AIC differences identified three of the four candidate models with sufficient statistical support ($\Delta < 4$) to describe the somatic growth of Pacific hake in the Gulf of

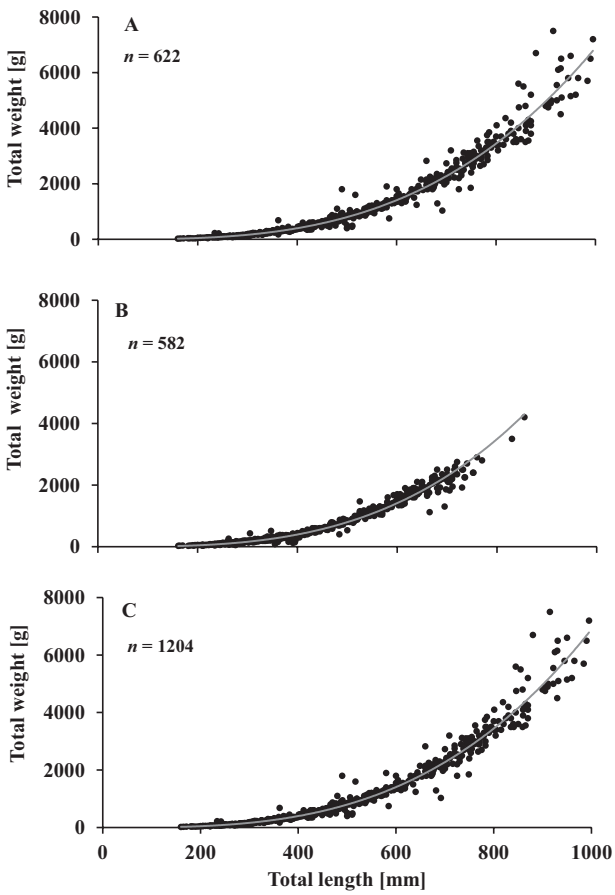

Figure 4. Total length–total weight relation of Pacific hake, *Merluccius productus*, in the Gulf of California (**A**) females, (**B**) males, (**C**) both sex.

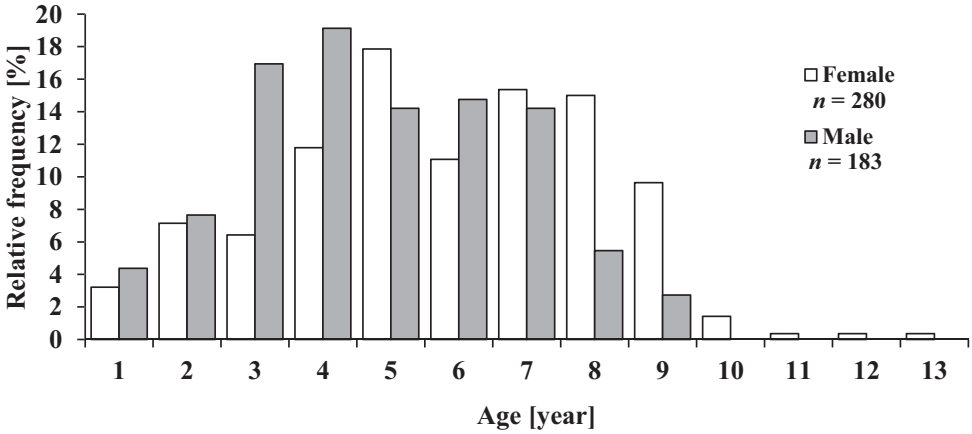

Figure 5. Age structure of Pacific hake, *Merluccius productus*, in the Gulf of California.

California (Table 4). However, none has a $w_i > 95\%$ to be a winning model (Burnham and Anderson 2002). The best model for females and males was Logistic with w_i = 74.00% and w_i = 60.03%, respectively.

The differences in growth (Logistic model) between sex were significant ($\chi^2 = 38.16$ $P < 0.05$). The asymptotic length estimates for females and males (127.57 cm TL, 85.40 cm TL, Table 5) were not significantly different ($\chi^2 = 1.44$ $P > 0.05$; $\chi^2 = 0.8$ $p > 0.05$, respectively) from the length maximum recorded in the samplings (105 cm in females and 83 cm in males).

Based on the multimodel approach, the mean asymptotic length for females was 136.33 cm TL, and 95.07 cm TL for males.

Table 3. Growth models parameter of the Pacific hake, *Merluccius productus*, for both sex.

Growth model	Sex	K (annual)	L_∞ [cm]	t_0 [years^{-1}]	LL	R^2
VBGM	F	0.08	163.72	0.00	24.73	0.99
Gompertz	F	0.13	214.15	8.10	58.57	0.99
Logistic	F	0.32	127.57	6.53	60.35	0.99
Schnute–Richard	F	0.06	112.85	0.00	60.72	0.99
Multimodel	F		136.33			
VBGM	M	0.11	108.89	0.00	28.84	0.99
Gompertz	M	0.19	118.63	4.69	44.90	0.99
Logistic	M	0.41	85.40	4.55	45.58	0.99
Schnute–Richard	M	0.11	80.59	0.00	45.84	0.99
Multimodel	M		95.07			

VBGM = von-Bertalanffy growth model; F = female, M = male; K = growth coefficient, L_∞ = asymptotic length, t_0 in VBGM and Schnute–Richards models is the hypothetical age at which the hake showed zero length; t_0 in Gompertz and Logistic model corresponds to and inflection point on the growth curve, LL = likelihood value.

Table 4. Akaike's information criterion (AIC) values, AIC differences, and AIC weight of the candidate models to describe the trend of the age–length data of the Pacific hake, *Merluccius productus*, by sex.

Growth model	Sex	AIC	ΔAIC	w_i%
VBGM	F	–43.38	71.25	2E–16
Gompertz	F	–111.06	3.57	12.43
Logistic	F	–114.63	0.00	74.00
Schnute–Richard	F	–111.23	3.39	13.54
VBGM	M	–51.54	33.48	0.00
Gompertz	M	–83.66	1.36	30.48
Logistic	M	–85.02	0.00	60.03
Schnute–Richard	M	–81.33	3.69	9.49

VBGM = von-Bertalanffy growth model; F = female, M = male.

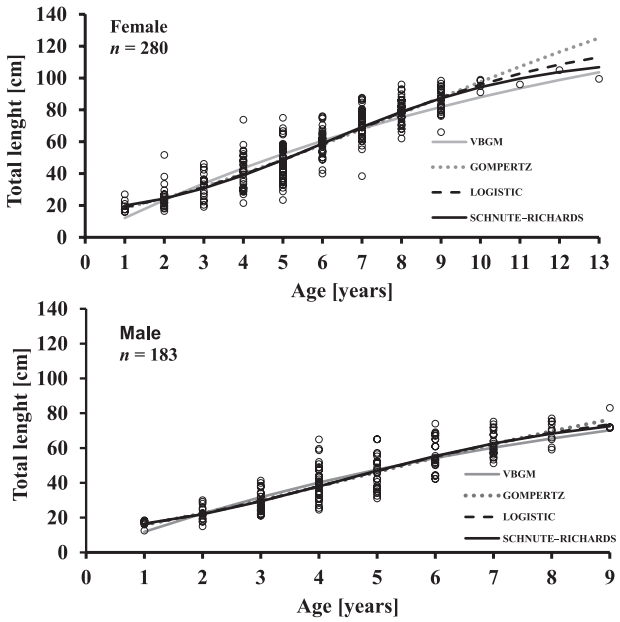

Figure 6. Individual growth curves (interpreted by four different models) of Pacific hake, *Merluccius productus*, in the Gulf of California.

Table 5. Logistic model, 95% confidence intervals (CI) of the growth parameters of the Pacific hake, *Merluccius productus*, by sex for the Gulf of California stock.

Parameter	Female			Male		
	Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
L_∞	125.00	127.57	130.50	83.00	85.40	87.50
K	0.30	0.32	0.33	0.39	0.41	0.43
t_0	6.42	6.53	6.63	4.43	4.55	4.67

Discussion

This study addressed the age determination, allometry, and individual growth of Pacific hake, *Merluccius productus*, with information from research cruises from 2014 to 2019 in the north-central part of the Gulf of California. In general, Pacific hake has a population structured in stocks (Iwamoto et al. 2004) with a maximum length of 112 cm TL (Nevárez-Martínez et al., unpublished[*]) and some individuals attaining up to 20 years of age (MacFarlane et al. 1983) throughout its distribution area in the eastern Pacific Ocean. The age structure is similar for all the stocks, while differences in the size structure between the stocks have been observed, being the one that inhabits the western coast of Baja California Sur with the smallest size and has been defined as a "dwarf stock" (Vrooman and Paloma 1977). The stock that inhabits the Gulf of California has the longest sizes (Zamora-García et al. 2020; Nevárez-Martínez et al., unpublished[*]).

According to data from fisheries and research cruises, the length structure of Pacific hake in the extreme north of its range (Canada) varies from 6 cm to 81 cm FL, for the coast of the USA from 10 to 80 cm TL and for the western coast of Baja California Sur from 9 cm to 28 cm SL. In comparison, the length structure for the Gulf of California varies from 10 cm to 112 cm TL. This suggests that in the northern part of the species' range, exploitation has reduced the largest groups in length. This is not the case for the stock on the western coast of Baja California Sur, since it has not been commercially exploited.

Changes in length structure should be reflected in allometry (Genner et al. 2010). For the Pacific hake, a long-lived species, the effects would be due to fishing that mainly reduces the largest groups in length. The species throughout its distribution has different periods of exploitation, the northern stocks have been exploited since the middle of the 20th century (Best 1962), while the stock in the Gulf of California has been exploited since the 1990s, and that of the western coast of Baja California Sur has not been exploited commercially. Throughout its distribution area and regardless of its size structure, the species presents isometric growth (Best 1962; MacFarlane and Beamish 1985; Zamora-García et al. 2020; Nevárez-Martínez et al., unpublished[*]; Salinas-Mayoral, unpublished[**]). The variation of the allometry coefficient (2.63 to 3.11) could be explained by differences in sampling period, year of study, region, and physical and environmental conditions (Soykan et al. 2015).

Changes to the size structure of species that are the target of fisheries is an important indicator of changes to community dynamics and population vulnerability (Tagliafico et al. 2012). This is because fishing will reduce the largest groups in the population and with the greatest reproductive potential, directly affecting recruitment and ecosystem dynamics through size-dependent predation. That is, by reducing the size structure of the reproductive stock, the number of oocytes produced is also reduced, due to the direct relation between the length of females and fecundity (McFarlane and Saunders 1997). In addition, Denton-Castillo (unpublished[***]) comments that females with longer sizes increase the reproductive potential of the population by producing higher quality oocytes and having more spawning events during the reproductive season.

We approached the age determination using the number of growth marks on otolith sections. Beamish (1979) for Pacific hake and Piñeiro and Saínza (2003) for European hake, *Merluccius merluccius* (Linnaeus, 1758), noted that otolith sections should be used for organisms > 5 years of age because growth marks in the older fish overlap. Although the number of growth marks between otolith sections and whole otoliths was not compared in this study, it was noted that growth marks on larger whole otoliths were not as evident as on otolith sections.

Differences in growth patterns by sex have been reported for Pacific hake (Dark 1975; McFarlane and Beamish 1985; Salinas-Mayoral, unpublished[**]). In the presently reported study, it has not been the exception; the females were longer-lived and reached greater length than the males and showed differences in the growth pattern. Apparently, this characteristic is common to the genus *Merluccius* due to morphological and biological differences between the sexes. Males reach maturity at an earlier length and age than females, hence this difference maximizes the reproductive potential for the species (Denton-Castillo, unpublished[***]). MacFarlane and Beamish (1985) show these differences by sex for the stock that inhabits the northern part of the distribution of the species, Dark (1975) for the stock that inhabits the coasts of the USA, Salinas-Mayoral (unpublished[**]) for the western coast of Baja California Sur and Zamora-García (unpublished[****]) for the Gulf of California.

[*] Nevárez-Martínez MO, Balmori-Ramírez A, Santos-Molina JP, Cervantes-Valle C, López-Martínez J, Méndez-Tenorio JF, Anguiano-Carrazco ML, Acevedo-Cervantes A, Miranda-Mier E, Morales-Azpeitia R, Valdivia-Herrera E (2007 [unpublished]) Prospección de merluza y bacalao: distribución, tamaño poblacional e ictiofauna asociada en el Golfo de California. Clave: SAGARPA-2003-C01-047.

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[***] Denton-Castillo J (2018) Agregaciones y aspectos reproductivos de la merluza *Merluccius productus* (Ayres, 1855) en el centro y norte del Golfo de California. Tesis Maestría. Universidad Autónoma de Sinaloa. Mazatlán, Sinaloa, México.

[****] Zamora-García OG (2021) Ecología pesquera y dinámica poblacional de la merluza norteña *Merluccius productus* (Ayres. 1855) del norte del golfo de California. Tesis Doctorado. Universidad Nacional Autónoma de México. Ciudad de México, México.

Finally, using the multimodel approach, it was possible to identify the best model to describe the change in length as a function of age in Pacific hake in the Gulf of California, this being the logistic model, which is characterized by presenting three growth stanzas, the first during the juvenile stage, the second a rapid growth in length and includes an inflection point of the curve, which is linked to the age of sexual maturity (L_{50}%) and later a reduction in the growth rate when approaching the asymptotic length. For the Gulf of California stock, the inflection point of the growth curve (related to the sexual maturity process, L_{50}) was estimated at 52.7 cm TL in females and 38.4 cm TL in males (Denton-Castillo, unpublished*).

With reference to the estimated length at age for each of the Pacific hake stocks, a decrease in the annual percentage reaching L_∞ is evident, showing a direct trend with respect to latitude, this being greater in the northern stocks on average 75% of L_∞ at the third year of age in Canada and up to 60% for the coast of the USA (Dark 1975; McFarlane and Beamish 1985), and lower in the stocks that are distributed in the south; west coast of Baja California Sur 28% of the L_∞ at the third year of age (Salinas-Mayoral, unpublished**), and in the presently reported study for the third year of age the Pacific hake reaches 30% of the L_∞ (Table 6). This could be related, mainly to the level of exploitation to which the stocks have been subjected (Genner et al. 2010) and indirectly to the surface temperature of the sea, which affects the productivity and prey availability.

In conclusion, the Pacific hake stock in the Gulf of California shows isometric growth, reaching up to 13 years of age and the growth pattern was significantly different between sex, and the model that best described the trend of the length–age data was the logistic model. The estimates of L_∞ for both sex are not significantly different from the reported lengths ($\chi^2 = 1.05$ $P > 0.05$; $\chi^2 = 0.80$ $P > 0.05$ for females and males, respectively. Regarding the periodicity of the growth marks, even though the results of Dark (1975) suggest an annual periodicity, we consider that this is still an unfulfilled task, especially due to the difficulty of having samples for at least a complete annual cycle (Campana et al. 1995).

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Table 6. Summary of estimates of growth parameters of Pacific hake, *Merluccius productus*, by various authors.

Reference	Growth model	Sex	Age [years]	L_∞ [cm]	k [years]	t_0	Area
Dark 1975	von Bertalanffy	Female	13	61.23 FL	0.30	0.01	California, Oregon and
		Male	12	56.29 FL	0.34	0.20	Washington
Mcfarlane and Beamish 1985	von Bertalanffy	Both	20	44.5 FL	0.45	–0.173	Strait of Georgia, Canada
		Both	18	56.9 FL	0.23	–3.94	Off Shore Stock
Balart-Páez, unpublished[1]	von Bertalanffy	Both		31.3 SL	0.48	–1.29	Western coast of the Baja
		Female	5	31.5 SL	0.49	–1.25	California Peninsula
		Male	4	31.5 SL	0.47	–1.35	
Salinas-Mayoral, unpublished[2]	von Bertalanffy	Both		31.02 SL	0.11	0.01	Western coast of the Baja
		Female	12	40.03 SL	0.04	0.01	California Peninsula
		Male	5	34.1 SL	0.06	0.01	
Zamora-García, unpublished[3]	Gompertz	Female	13	87.16 SL	0.28	2.24	Gulf of California, Mexico
		Male	9	78.27 SL	0.30	1.99	
Presently reported study	Logistic	Female	13	127.57 TL =113.23 SL	0.32	6.53	Gulf of California, Mexico
		Male	9	85.40 TL =82.33 SL	0.41	4.55	

[1] Balart-Páez EF (2005) Biología y ecología de la merluza Bajacaliforniana, *Merluccius angustimanus* Garman, 1899, en la Costa Occidental de Baja California Sur, México. Tesis de Doctorado. Universidad Autónoma de Nuevo León. Nuevo León, México.The thesis of Balart-Páez originally referred to "*Merluccius angustimanus*" which is currently accepted as *Merluccius productus*.

[2] Salinas-Mayoral CA (2018) Dinámica poblacional de la merluza del Pacífico *Merluccius productus* (Ayres, 1855), en la Costa Occidental de BCS, México. Tesis Maestría. Centro de Investigaciones Biológicas del Noroeste, S.C. La Paz, Baja California Sur, México.

[3] Zamora-García OG (2021) Ecología pesquera y dinámica poblacional de la merluza norteña *Merluccius productus* (Ayres. 1855) del norte del golfo de California. Tesis Doctorado. Universidad Nacional Autónoma de México. Ciudad de México, México.

L_∞ = asymptotic length, K = growth coefficient, t_0 in von Bertalanffy model is the hypothetical age at which the hake showed zero length; t_0 in Gompertz and Logistic model corresponds to and inflation point on the growth curve, FL = furcal length, SL = standard length, TL = total length.

* Denton-Castillo J (2018) Agregaciones y aspectos reproductivos de la merluza *Merluccius productus* (Ayres, 1855) en el centro y norte del Golfo de California. Tesis Maestría. Universidad Autónoma de Sinaloa. Mazatlán, Sinaloa, México.

** Salinas-Mayoral CA (2018) Dinámica poblacional de la merluza del Pacífico *Merluccius productus* (Ayres, 1855), en la Costa Occidental de BCS, México. Tesis Maestría. Centro de Investigaciones Biológicas del Noroeste, S.C. La Paz, Baja California Sur, México.

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PENSOFT

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Occurrence of contact organs and sexual dimorphism in fishes of the family Profundulidae (Actinopterygii: Cyprinodontiformes)

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Abstract

The family Profundulidae is one of the few families of freshwater fishes endemic to the Mesoamerican region, and one of the least speciose within the order Cyprinodontiformes, with only 13 valid species. Sexual dimorphism is poorly developed and sparsely studied in this family. Herein, we report the presence of spicule-like organs of contact in scales and fins (anal and dorsal) in fishes of the family Profundulidae and discuss the use of spicules as a means to facilitate the identification of male and female in this family. Data from museum specimens of the 13 species of profundulid fishes were analyzed. We studied the following species: *Tlaloc labialis* (Günther, 1866); *Tlaloc candalarius* (Hubbs, 1924); *Tlaloc hildebrandi* (Miller, 1950); *Tlaloc portillorum* (Matamoros et Schaefer, 2010); *Profundulus punctatus* (Günther, 1866); *Profundulus guatemalensis* (Günther, 1866); *Profundulus oaxacae* (Meek, 1902); *Profundulus balsanus* Ahl, 1935; *Profundulus kreiseri* Matamoros, Schaefer, Hernández et Chakrabarty, 2012; *Profundulus parentiae* Matamoros, Domínguez-Cisneros, Velázquez-Velázquez et McMahan, 2018; *Profundulus mixtlanensis* Ornelas-García, Martínez-Ramírez et Doadrio, 2015; *Profundulus adani* Dominguez-Cisneros, Velázquez-Velázquez, McMahan, et Matamoros, 2021; *Profundulus chimalapensis* Del Moral-Flores, López-Segovia et Hernández-Arellano, 2020. Scales were observed and photographed with a Hitachi VP-MEB SU1510 scanning electron microscope; the spicules in fins were observed from specimens cleared and double-stained. This study revealed the presence of 1–10 spicules on the surface of the scales in males and its absence in females of all species analyzed. Numerous, small and thin spicules were also observed and they were restricted to the middle rays of the anal and dorsal fins of the males. The observation of spicules in the anal fins for the sexual identification of profundulid fishes constitutes an advantage of operational simplicity, speed, and potential for its application in taxonomic and ecological studies.

Keywords

Mesoamerica, endemic species, nuptial tubercles, profundulids fish, sexual differences, spicules

Introduction

Contact organs are structures composed of dermal bony outgrowths or spicules projecting from a fin ray or scale margin and surrounded by the epidermis, through which the bony outgrowths may protrude (Tripathi 2018). Such organs, present on scales or fin rays, exist primarily to facilitate contact between individuals during spawning (Wiley and Collette 1970). These structures are maintained through the continuous renewal of the most superficial keratinized layer for the entire life of the fish, playing an essential role in stimulating egg release during spawning

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in zebrafish (Kang et al. 2013). In the majority of species, contact organs are present only in males or are more developed in males than in females (Wiley and Collette 1970).

The Profundulidae represents one of the few freshwater fish families endemic to Mesoamerica and constitutes a lineage with a limited geographical distribution that extends from southern Mexico to Central America (Miller 1955; Morcillo et al. 2016). Members of the Profundulidae are small (maximum standard length around 120 mm), and are often the only fish species found in the upper parts of river basins (Calixto-Rojas et al. 2021). Profundulids are among the least studied cyprinodontiforms. The sexual dimorphism, in this family of fishes, is poorly developed and inadequately studied.

Recently, we had the opportunity to describe a new species in the family Profundulidae (*Profundulus adani* Dominguez-Cisneros, Velázquez-Velázquez, McMahan, et Matamoros, 2021), a killifish distributed in the Papaloapan Basin in the upper reaches of the Papaloapan River in the Mexican state of Oaxaca (Domínguez-Cisneros et al. 2021). During the study, we noticed the presence of spicules in the scales and fins of males, which suggested a possible case of sexual dimorphism. Therefore, our objective was to describe the occurrence of secondary sexual dimorphism in the species of the family Profundulidae.

Material and methods

The specimens deposited in the Fish Collection of the Zoology Museum of the University of Sciences and Arts of Chiapas were analyzed (collection code: 1138, MZ-UNICACH) (Sabaj 2020). The following species were studied: *Tlaloc labialis* (Günther, 1866); *Tlaloc candalarius* (Hubbs, 1924); *Tlaloc hildebrandi* (Miller, 1950); *Tlaloc portillorum* (Matamoros et Schaefer, 2010); *Profundulus punctatus* (Günther, 1866); *Profundulus guatemalensis* (Günther, 1866); *Profundulus oaxacae* (Meek, 1902); *Profundulus balsanus* Ahl, 1935; *Profundulus kreiseri* Matamoros, Schaefer, Hernández et Chakrabarty, 2012; *Profundulus parentiae* Matamoros, Domínguez-Cisneros, Velázquez-Velázquez et McMahan, 2018; *Profundulus mixtlanensis* Ornelas-García, Martínez-Ramírez et Doadrio, 2015; *Profundulus adani* Dominguez-Cisneros, Velázquez-Velázquez, McMahan, et Matamoros, 2021; *Profundulus chimalapensis* Del Moral-Flores, López-Segovia et Hernández-Arellano, 2020. The specimens were fixed in a 10% formalin solution and preserved in 70% ethanol. The sex of the fishes was determined through dissection; scales were carefully taken out from near the head region above the lateral line, and from other areas for microscopic observations. The scales were observed and photographed using a Hitachi VP-MEB SU1510 scanning electron microscope. The spicules in fins were observed in specimens of the 13 above-mentioned profundulids species. The samples were cleared and double-stained (bone alizarin and cartilage counter-stained with Alcian blue), according to the technique described by Taylor and van Dyke (1985).

Material examined. The list below includes material examined. Data on material is organized in the following sequence: species name, catalog number, number of specimens cleared and stained. *Profundulus balsanus*: MZ-UNICACH 6712, 7. *Profundulus oaxacae*: MZ-UNICACH 6714, 4; MZ-UNICACH 6715, 2. *Profundulus parentiae*: MZ-UNICACH 6575, 5; MZ-UNICACH 6576, 3. *Profundulus adani*: MZ-UNICACH 7382, 3; MZ-UNICACH 7342, 2. *Profundulus chimalapensis*: MZ-UNICACH 7559, 7. *Profundulus punctatus*: MZ-UNICACH 6632, 3; MZ-UNICACH 6578, 2. *Profundulus mixtlanensis*: MZ-UNICACH 6716, 9. *Profundulus guatemalensis*: MZ-UNICACH 7194, 4; MZ-UNICACH 7195, 2. *Profundulus kreiseri*: MZ-UNICACH 7205, 3; MZ-UNICACH 7214, 2. *Tlaloc hildebrandi*. MZ-UNICACH 4330, 3; MZ-UNICACH 5711, 2; MZ-UNICACH 2266, 2. *Tlaloc portillorum*: MZ-UNICACH 7220, 4; MZ-UNICACH 7222, 2. *Tlaloc labialis*: MZ-UNICACH 3467, 2; MZ-UNICACH 6740, 2; MZ-UNICACH 7233, 2. *Tlaloc candalarius*: MZ-UNICACH 6813, 4; MZ-UNICACH 7565, 2.

Results

The examined fish specimens were in the range of 26.59–101.93 mm standard length (SL) (Table 1). The males were slightly larger than females, the mean SL value was higher in males of 10 species except in *Profundulus punctatus*, *P. balsanus*, and *P. oaxacae*; the largest specimen recorded was a male of *Tlaloc hildebrandi* (SL = 111.49 mm); while the maximum size recorded in a female was in *Tlaloc labialis* (SL = 101.93 mm).

The contact organs were particularly prominent in the flank scales and dorsal and anal fins of males in all species of the genera *Tlaloc* and *Profundulus*. In the scales of the operculum and the caudal peduncle, the highest concentration of spicule-like organs of contact were observed (Fig. 1). The scales are large and cycloid, with numerous radii. The body and the head were entirely scaled, except on the anterior portion of the ventral surface of the head.

The study revealed the presence of 1 up to 10 spicules (commonly from 1 to 3) on the surface of the scales in males (Fig. 2). The spicules were absent in females of all species analyzed.

In males of all species of profundulids studied, the dorsal and the anal fins had similar morphology, whereas, in females, the anal was slightly elongated. Contact organs of anal-fin rays were arranged in rows along the inner surface of fin rays; spicules were numerous, small, and thin, and restricted to the middle rays of the anal and dorsal fins, much more numerous on the anal fin (Fig. 3).

Discussion

Contact organs have long been known in the ichthyological literature under a bewildering variety of terms. The majority of such records have been concealed in taxonomic

Table 1. Minimal (Min) and maximal (Max) standard length (SL) in males and females of profundulid species (genera *Tlaloc* and *Profundulus*).

Species	Females					Males				
	Min	Max	Mean	SD	*n*	Min	Max	Mean	SD	*n*
T. labialis	39.63	**101.93**	49.56	13.26	68	37.70	79.94	50.54	11.96	38
T. candalarius	38.81	79.35	48.53	10.14	50	39.53	99.20	53.18	11.30	47
T. hildebrandi	37.94	92.76	56.80	11.02	42	40.97	**111.49**	64.68	22.35	16
T. portillorum	35.93	71.35	49.56	10.37	34	40.03	68.72	50.36	7.65	24
P. punctatus	32.50	77.50	52.80	9.89	76	36.40	82.20	51.90	9.65	75
P. guatemalensis	39.40	58.60	48.70	7.52	9	38.40	**83.90**	53.50	15.86	17
P. oaxacae	39.62	53.60	50.55	7.00	8	35.35	45.81	43.72	5.17	8
P. balsanus	38.76	66.04	53.92	8.60	8	38.87	58.83	49.25	6.98	10
P. kreiseri	37.20	66.10	48.00	7.23	27	38.50	72.70	50.40	9.72	23
P. parentiae	36.94	67.80	48.30	9.97	21	36.80	73.90	54.80	10.47	21
P. mixtlanensis	40.60	60.80	49.20	5.66	30	39.00	70.60	50.40	8.90	30
P. adani	36.70	**77.90**	53.50	10.45	35	38.70	83.70	54.50	12.49	39
P. chimalapensis	38.91	65.06	46.36	46.36	14	34.11	80.30	54.61	14.98	8

n = number of individuals, SD = standard deviation; **bold** font denotes maximum size values.

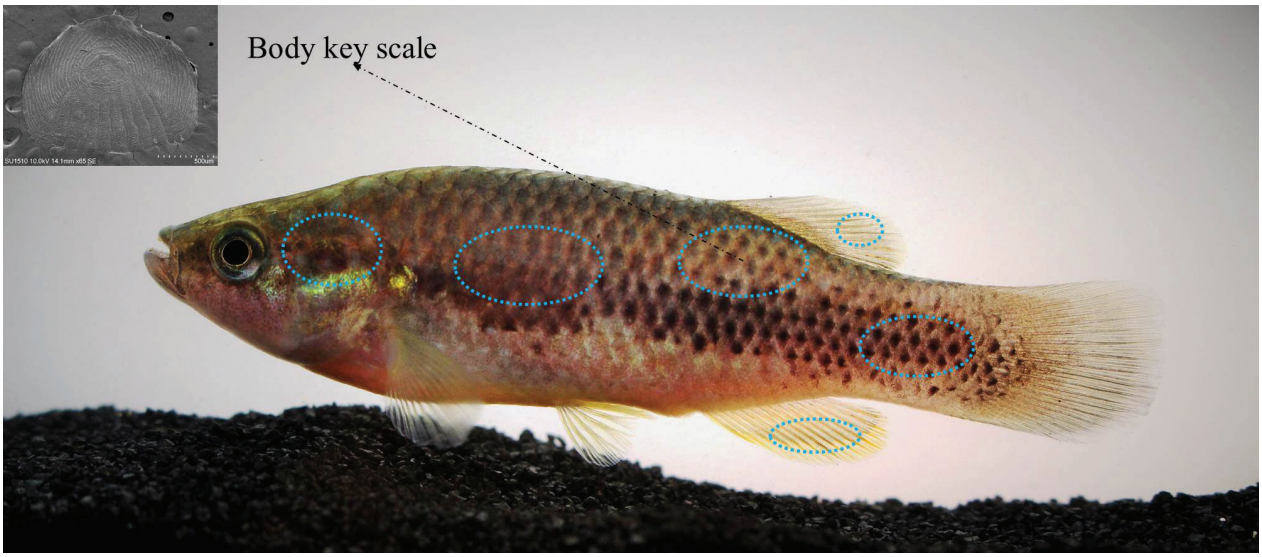

Figure 1. Left side of the fish specimen (Male of *Profundulus chimalapensis*) shows the location between the dorsal fin and lateral line, where the key scales were removed. Dotted circles indicate organs' contact clusters.

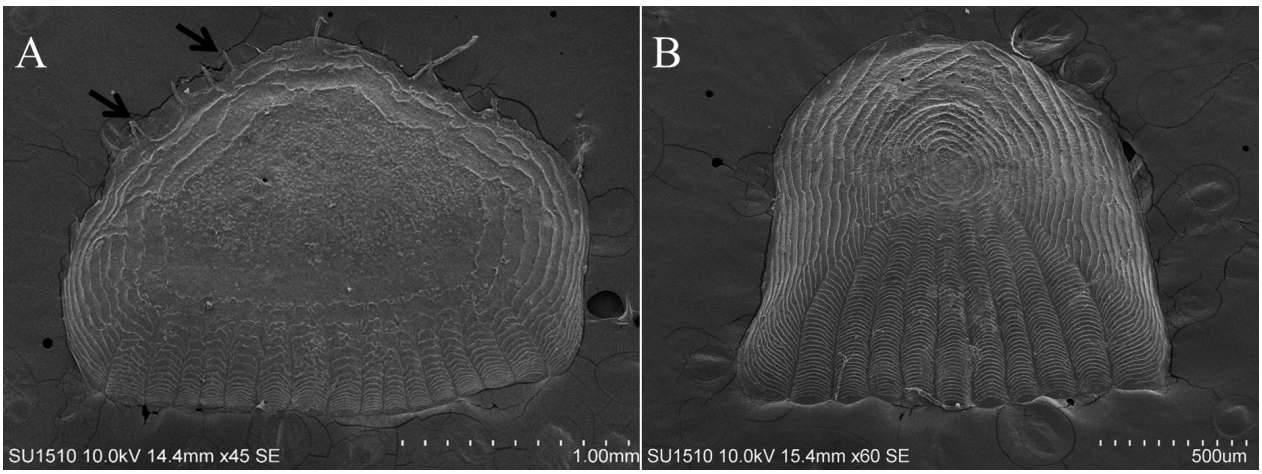

Figure 2. Scales of *Tlaloc portillorum* (male: **A**) and *Tlaloc candalarius* (female: **B**). The arrow points the spicules on the scales.

papers as parts of new species descriptions (Wiley and Collette 1970; Costa 2002; Volcan and Severo-Neto 2019). In the presently reported study, the examination of scales and fins in profundulid fishes revealed the presence of numerous spicules. The location, number, and extent of contact organ development varied intra and interspecifically.

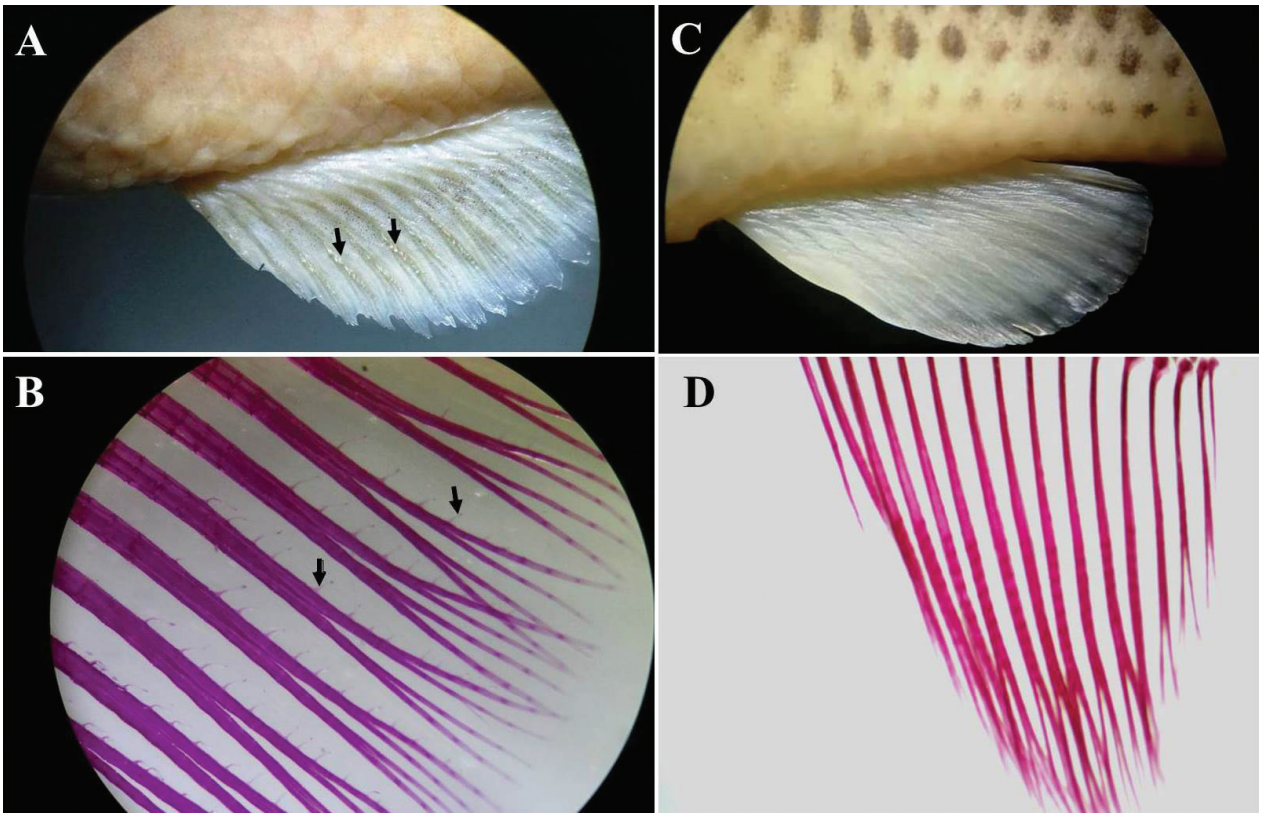

Figure 3. Anal-fins of *Tlaloc hildebrandi* (male: **A**–**B**) and *Profundulus punctatus* (female: **C**–**D**). Arrows indicate the spicules. **B** and **D** = anal fin rays (cleared).

Contact organs or spicules are common in atherinomorph fishes (Atheriniformes, Cyprinodontiformes, and Beloniformes). Possibly, they are important to the maintenance of body contact between sexes during reproductive behavior (Wiley and Collette 1970). Contact organs of the Cyprinodontiformes have been reported for numerous species of topminnows (Cashner et al. 2020), killifishes (Costa 2006), and pupfishes (Teimori et al. 2017). In profundulids, Miller (1950) described the presence of contact organs or ctenii as a difference (though not striking) between the nuptial male and female of the *Profundulus hildebrandi*; although he noticed only a few tubercules on the anal fin. In rivulids, they are present on the scales and fin rays in males of some taxa, during all the adult stage (Costa 2006). The occurrence of these structures in male fish of the family Profundulidae, seems to be throughout adult life since the spicules were observed in the cleared fish, which were collected at different times of the year. Velázquez-Velázquez and Schmitter-Soto (2004) pointed out that the reproductive period in *Tlaloc hildebrandi* is markedly seasonal, which occurs between February and June.

The determination of sex using contact organs requires the examination of the corporal surface and anal fin of the fish, which will reveal the presence or absence of spicules; these are clearly visible from above as thin elongated spicules along the central fin rays of the fins in males (Fig. 3A). Spicules are easily visible in adults with the help of a stereomicroscope. In particular, the observation of spicules in the anal fins, for the sexual identification of profundulid fishes, presents advantages of operational simplicity, speed, and potential for its application in taxonomic and ecological studies.

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PENSOFT

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A northward range extension of *Thysanophrys papillaris* (Actinopterygii: Scorpaeniformes: Platycephalidae) to Taiwan

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Abstract

The smallknob flathead, *Thysanophrys papillaris* Imamura et Knapp, 1999, is redescribed based on six specimens collected from southern Taiwan, which constitutes a northward range extension of the species [previously recorded from the Andaman, Timor, and Arafura seas (eastern Indian Ocean), and Nha Trang, Vietnam (western Pacific Ocean)]. *Thysanophrys papillaris* is distinguished from all congeneric species in having a combination of 11 second dorsal-fin rays, 12 anal-fin rays, 58–75 scale rows below the lateral line (slanting downward and forward), a longer snout (snout length / orbital diameter ratio 1.1–1.3), 1 or 2 small papillae on the eye, the upper iris lappet with short branches, a single preorbital spine and 3–5 suborbital spines. Previously suggested intraspecific variation in the number of eye papillae is confirmed.

Keywords

intraspecific variation, northernmost record, smallknob flathead

Introduction

The smallknob flathead, *Thysanophrys papillaris* Imamura et Knapp, 1999, was originally described, based on six specimens collected from the Andaman, Timor, and Arafura seas, (eastern Indian Ocean) (Imamura and Knapp 1999), and listed as an Australian and Northern Territory, Australia species, respectively, by Hoese et al. (2006) and Larson et al. (2013). Imamura et al. (2019) later reported a single specimen from Nha Trang, Vietnam (western Pacific Ocean). Recently, the first author (HI) had an opportunity to examine platycephalids collected from southern Taiwan and identified six specimens as *T. papillaris*, such having been previously reported as *Sunagocia arenicola* (Schultz, 1966) by Ho and Chong (2020). The presently reported specimens, which are described herein, represent the first record of the species from Taiwan and the northernmost distributional record of the species. In addition, intraspecific variation in the number of eye papillae, previously suggested by Imamura et al. (2019), is confirmed.

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Materials and methods

Methods for counts and measurements generally followed Imamura (2008), being routinely taken from the left side, although gill rakers, defined as depressible bony elements and not including tooth plates, were counted on the right side. Terminology of head spines follows Knapp et al. (2000). Pectoral fin rays are expressed as "upper unbranched rays + middle branched rays + lower unbranched rays = total rays". All measurements were made to the nearest 0.1 mm with calipers. Standard and head lengths are abbreviated as SL and HL, respectively. Institutional acronyms follow Fricke and Eschmeyer (2022), showing AMS (Australian Museum, Sydney), BMNH (Natural History Museum, London), CSIRO (Commonwealth Scientific and Industrial Research Organisation, Hobert), HUMZ (Hokkaido University Museum, Hakodate), NMMB-P (National Museum of Marine Biology & Aquarium, Pingtung), NMV (Museum Victoria, Melbourne), NSMT (National Museum of Nature and Science, Tsukuba), NTM (Museum and Art Gallery of Northern Territory, Darwin), QM (Queensland Museum, Brisbane), USNM (Smithsonian Institution National Museum of Natural History, Washington D.C.) and WAM (Western Australian Museum, Perth). A tissue sample of NMMB-P28534 is preserved in NMMBA with accession tissue number 4164.

Results

Family Platycephalidae Swainson, 1839
Genus *Thysanophrys* Ogilby, 1898

Thysanophrys papillaris Imamura et Knapp, 1999

English common name: smallknob flathead

New Chinese common name: 皮瓣多棘牛尾魚

Fig. 1; Tables 1 and 2

Sunagocia arenicola (not Schultz, 1966): Ho and Chong 2020: 589, unnumbered fig. (description, Ke-tzu-liao, Kaohsiung, southern Taiwan) (in part).

Thysanophrys papillaris Imamura et Knapp, 1999: 180, figs. 1–4, 5A (original description, type locality: southwest of Flat Top Bank, Timor Sea, Western Australia; Hoese et al. (2006: 947) (list, northern Australia); Larson et al. (2013: 93) (list, northern Australia); Imamura et al. (2019: 17, figs. 1, 2) (description, Nha Trang, Vietnam, western Pacific Ocean).

Material examined. Six specimens: NMMB-P26824 (5 specimens, 99.3–148.2 mm SL), off Dong-gang, Pingtung, southern Taiwan (ca. 22°28′N, 120°20′E), 11 March 2017, bottom trawl; NMMB-P28534 (137.3 mm SL), off Ke-tzu-liao, Kaohsiung, southern Taiwan (ca. 22°43′N, 120°15′E), 18 February 2018, bottom trawl.

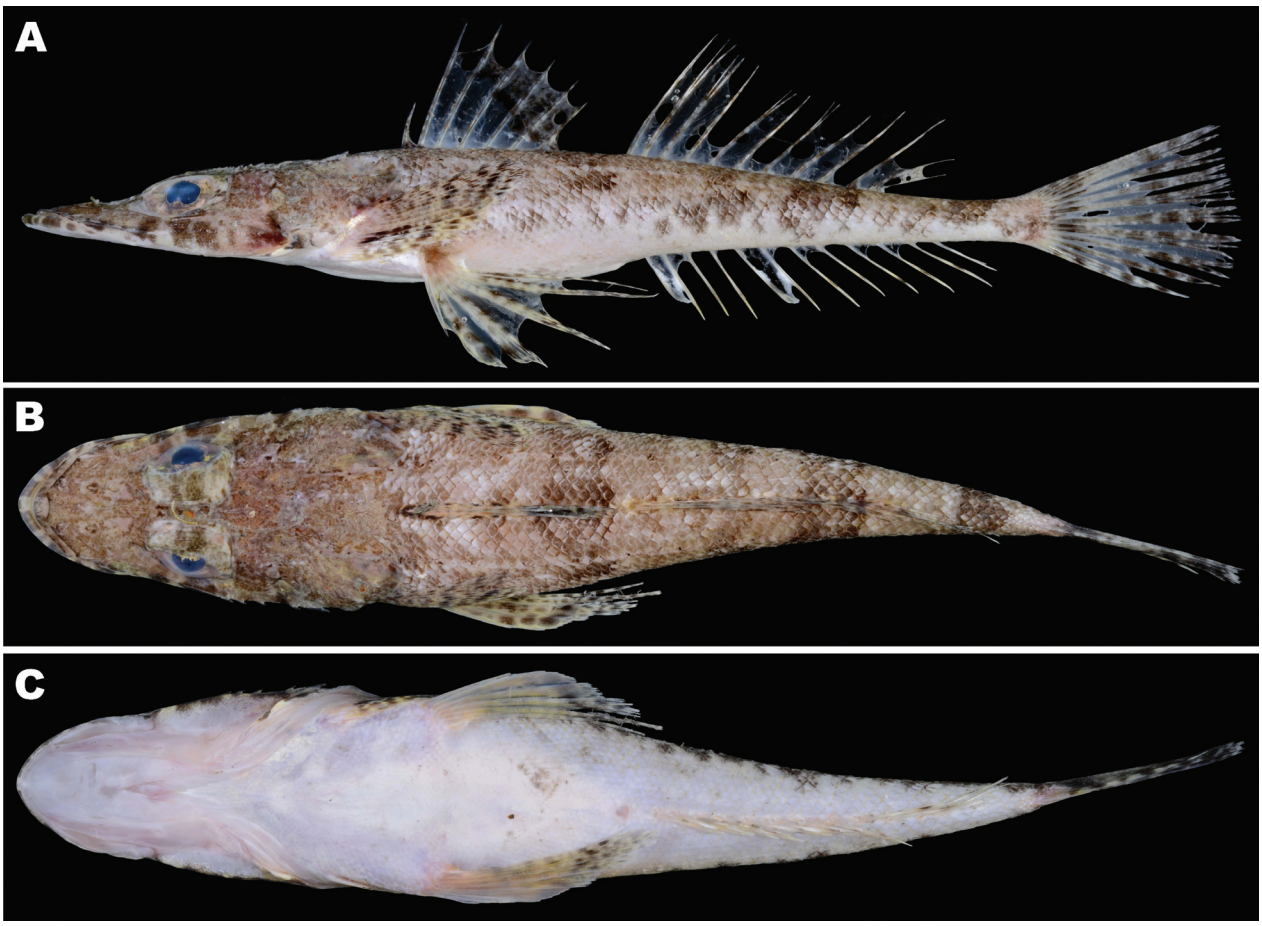

Figure 1. Lateral (**A**), dorsal (**B**), and ventral (**C**) views of *Thysanophrys papillaris* (fresh condition), NMMB-P28534, 137.3 mm SL, Ke-tzu-liao, Kaohsiung, southern Taiwan.

Table 1. Meristic characters of *Thysanophrys papillaris*.

Character	Present specimens (*n* = 6)	Holotype NTM S. 13325-001	Paratypes (*n* = 5)	Additional non-types (*n* = 5)
First dorsal-fin rays	I + VII–VIII	I + VIII	I + VI–VII	I + VII–VIII
Second dorsal-fin rays	11	11	11	11
Anal-fin rays	12	12	12	12
Pectoral-fin rays	2 + 12–14 + 4–6 = 19–20	2 + 12 + 6 = 20	1–2 + 10–13 + 5–8 = 19–20 (4)	2 + 12–15 + 3–6 = 20
Branched caudal-fin rays	10	10	10 (2)	10 (4)
Pored lateral-line scales (LLS)	52–54	51	52–54	52–53
Anterior LLS with spine	2–3	2	2–3	2–3
SADB	52–54	51	54 (1)	52–53
SADF	52–55	51	52 (1)	52–54 (4)
SBDF	59–74 (5)	69	58–71 (4)	58–75 (3)
Gill rakers	1 + 5–6 = 6–7	1 + 4 = 5	1 + 5–6 = 6–7	1 + 5 = 6

Pectoral fin rays are expressed as "upper unbranched rays + middle branched rays + lower unbranched rays = total rays"; SADB = Scale rows above lateral line slanting downward and backward; SADF = Scale rows above lateral line slanting downward and forward; SBDF = Scale rows below lateral line slanting downward and forward. Numbers in parentheses indicate the number of specimens examined.

Comparative material. Holotype: NTM S. 13325-001 (121.7 mm SL), southwest of Flat Top Bank, Timor Sea, Western Australia (12°28′S, 128°37′E), 98 m depth, 8 December 1990. Paratypes (5 specimens): NTM S. 12912-008 (101.3 mm SL), Arafura Sea, Northern Territory, Australia (10°15′S, 134°42′E), 64 m depth, 10 Nov. 1990; USNM 344833 (2 specimens, 77.8–99.4 mm SL), Andaman Sea, Indian Ocean (13°28′N, 97°19′E), 73–81 m depth, 30 March 1963; USNM 344834 (2 specimens, 99.3–113.3 mm SL), Andaman Sea, Indian Ocean (14°07′N, 97°05′E), 69–73 m depth, 30 March 1963. All USNM paratypes were trawled by R/V *Anton Bruun*. Additional non-types (5 specimens): CSIRO H1037-1 (2 specimens, 124.4–149.7 mm SL), north-northwest of Port Hedland, Western Australia (19°03′S, 117°59′E–19°04′S, 118°01′E), 90–97 m depth, FRV *Soela*, demersal trawl, 27 September 1987; CSIRO H1500-01 (124.7 mm SL), north-northwest of Port Hedland, Western Australia (19°06′S, 118°12′E–19°05′S, 118°10′E), 84–87 m depth, FRV *Soela*, demersal trawl, 3 October 1988; HUMZ 229721, 170.3 mm SL, fish landing port, Cua Be, Nha Trang, Vietnam (12°11′N, 109°12′E), 25 July 2018, coll. by N. V. Quan and party; WAM P.34804-005 (112 mm SL), Lynher Bank, Western Australia (15°32.69′S, 122°12.43′E–15°32.65′S, 122°12.45′E), 63.2–64.3 m depth, 30 October 2016, coll. by M.G. Allen.

Description. Counts and proportional measurements are given in Tables 1 and 2, respectively. The following description was based on the six Taiwanese specimens. Body moderately depressed; caudal peduncle somewhat cylindrical. Head strongly depressed. Snout longer than orbit diameter; ratio of snout length / orbit diameter 1.1–1.2. Posterior end of upper jaw nearly or just reaching below anterior margin of pupil. Villiform teeth in bands on jaws and palatine, in 2 separate patches on vomer, except for anteromedial portion of upper jaw with short slender conical teeth. Notch absent on posterior margin of upper jaw tooth band. Anterior and posterior nostrils tubular; former with single flap on posterior margin. Single papilla on upper surface of eye; additional papilla present posteriorly and posteromedially to former on right side eye in 99.3 mm SL specimen of NMMB-P26824 and right side eye in NMMB-P28534, respectively. Upper iris lappet with short branches; lower iris lappet simple in 5 specimens, bilobed in left eye in 99.3 mm SL specimen of NMMB-P26824. Interorbital space narrow, concave. Dorsal surface of head with many spines but lacking tubercles. Two antrorse lachrymal spines present. Nasal with 1 small spine. Ethmoid spines absent in 5 specimens, 1 spine present on left side in 147.4 mm SL specimen of NMMB-P26824. Single preorbital spine present. Single preocular spine present, lacking small spines on base. Supraorbital ridge finely serrated. Single postocular spine, followed by 2 or 3 pterotic spines. One or two stout parietal spines present. Two to six frontal spines present between posteriormost supraorbital spine and parietal spine. One or two nuchal spines present posterior to parietal spine. Suborbital ridge with single preorbital spine anteriorly, followed by 4–6 stout suborbital spines. Three preopercular spines present; uppermost longest, not reaching posterior margin of opercle, with supplemental spine on base. Two stout spines on opercle, each with short supporting ridge and without serrations or tubercles. Supratemporal, posttemporal and supracleithrum each with single stout spine. Well-developed fleshy sensory tubes completely covering cheek region. Interopercular flap absent. Small ctenoid scales on postorbital area and opercle. Scales on body ctenoid dorsally and laterally, cycloid ventrally. Lateral-line scales each with 2 sensory ducts directed upward and downward, respectively; each duct terminating with single external opening. First dorsal fin originating nearly level with opercular margin, narrowly separated from second dorsal fin. Posterior margin of pectoral fin rounded. Tip of pelvic fin reaching anus in 147.4 mm SL specimen of NMMB-P26824, to base of second ray of anal fin in remaining specimens. Caudal fin slightly rounded posteriorly.

Color when fresh [based on color photographs of NMMB-P28534 (Fig. 1)]. Dorsal surface of body and head pale brown, ventral surface white. Two brownish

Table 2. Absolute and relative morphometric characters of *Thysanophrys papillaris*.

Character	Present specimens (*n* = 6)	Holotype NTM S. 13325-001	Paratypes (*n* = 5)	Additional non-types (*n* = 5)
Absolute values [mm]				
Standard length (SL)	99.3–148.2	120.7	77.8–113.3	111.9–170.3
Relative values [%SL]				
Head length (HL)	36.3–37.5	38.4	36.0–39.4	36.2–38.5
Predorsal length	36.6–37.4	38.4	36.0–39.3	36.5–39.5
Length of first dorsal-fin base	16.5–19.8	17.7	13.6–16.6	16.2–18.6
Length of second dorsal-fin base	25.1–26.0	24.3	24.4–26.7	25.3–28.0
Length of anal-fin base	29.7–31.5	28.7	30.0–32.8	29.5–31.9
Snout length	10.9–11.7	11.4	11.3–12.2	10.5–12.2
Orbital diameter	9.4–9.9	9.9	8.6–10.5	9.4–10.1
Upper jaw	13.1–14.0	14.0	12.9–15.1	13.5–13.7 (3)
Lower jaw	20.4–20.9	20.9	20.9–22.0 (4)	20.1–20.6
Interorbital width	1.3–1.7	1.7	1.4–1.5	1.4–1.9
Pectoral-fin length	14.8–16.1	15.6	14.1–16.8	14.9–16.4
Pelvic-fin length	21.3–24.6	24.0	22.9–24.6	22.2–26.0
Caudal-fin length	20.4–22.3	21.5	22.1–22.6 (3)	20.6–22.7 (4)
Relative values [%HL]				
Snout length	29.8–31.8	29.5	29.4–31.5	28.7–31.8
Orbital diameter	25.6–26.8	25.6	23.8–27.7	25.1–26.8
Upper jaw	35.9–37.8	36.4	35.9–38.4	36.2–36.8 (3)
Lower jaw	55.3–56.5	54.3	53.1–57.2 (4)	52.3–55.5
Interorbital width	3.5–4.7	4.5	3.7–4.0	3.8–5.1
Ratio of snout length / orbital diameter	1.1–1.2	1.2	1.1–1.3	1.1–1.3

Numbers in parentheses indicate the number of specimens examined.

bands crossing interorbit and both eyes; several small brown or dark brown blotches laterally on head, including single dark brown blotch posteriorly on preopercle. Dorsal surface of body with four irregular dark brown bands, level with posterior portion of first dorsal fin, middle and posterior portions of second dorsal fin, and caudal peduncle, respectively. First dorsal fin with broad blackish band distally; spines with several brown spots. Second dorsal fin with brown spots along rays. Anal fin pale (coloration details unclear). Pectoral and pelvic fins pale brown with small brown spots tending to form irregular narrow bands. Anteroventral portion of pectoral fin with elongate dark brown spot. Basal portion of caudal fin dark brown; remaining area of caudal fin with four irregular dark brown bands.

Color in alcohol. Dorsal surface of body and head pale brown, ventral surface pale yellow. One or two brownish bands crossing interorbit and both eyes; several small brown or dark brown blotches laterally on head, including a single dark brown blotch posteriorly on preopercle. Dorsal surface of body with four irregular brown or dark brown bands, level with posterior portion of first dorsal fin, middle and posterior portions of second dorsal fin, and caudal peduncle, respectively. First dorsal fin with broad blackish band distally; spines with several brown spots. Second dorsal fin with brown or dark brown spots along rays. Anal fin pale; posterior 2–10 rays with a brown spot distally. Pectoral and pelvic fins pale brown with small brown spots tending to form irregular narrow bands. Anteroventral portion of pectoral fin with elongate dark brown spot. Basal portion of caudal fin dark brown; remaining area of caudal fin with several irregular brown to dark brown bands.

Distribution. Recorded from the Andaman, Timor, and Arafura seas (eastern Indian Ocean) (Imamura and Knapp 1999), and Nha Trang, Vietnam (Imamura et al. 2019) and southern Taiwan (western Pacific Ocean) (this study).

Remarks. The presently reported six specimens, collected from southern Taiwan, conformed to the genus *Thysanophrys* Ogilby, 1898 in having the upper iris lappet with short branches, many spines on the dorsal surface of the head (but lacking tubercles), the suborbital ridge with 5 or 6 spines (including 1 preorbital spine), the lateral-line scales each with 2 sensory ducts (directed upward and downward, respectively, and terminating in a single external opening), and well-developed fleshy sensory tubes completely covering the cheek region, and lacking an interopercular flap (Imamura 1996; Imamura et al. 2019). To date, the genus includes the following 10 valid species: *Thysanophrys armata* (Fowler, 1938); *Thysanophrys celebica* (Bleeker, 1855); *Thysanophrys chiltonae* Schultz, 1966; *Thysanophrys cirronasa* (Richardson, 1848); *Thysanophrys longirostris* Shao et Chen, 1987; *T. papillaris*; *Thysanophrys randalli* Knapp, 2013; *Thysanophrys rarita* Knapp, 2013; *Thysanophrys springeri* Knapp, 2013; and *Thysanophrys tricaudata* Knapp, 2013 (see Imamura 1996; Imamura and Knapp 1999; Knapp 2013; Imamura et al. 2019). *Thysanophrys haploblepharis* Prokofiev, 2017 was regarded as a junior synonym of *Insidiator cooperi* (Regan, 1908) by Imamura et al. (2019). The presently reported specimens from southern Taiwan conformed to *T. papillaris*, differing from all congeners in having the following combination of characters: 11 second dorsal-fin rays,

12 anal-fin rays, 59–74 scale rows below the lateral line slanting downward and forward, a longer snout (snout length / orbit diameter ratio 1.1–1.2), 1 or 2 small papillae on the eye, the upper iris lappet with short branches, a single preorbital spine and 3–5 suborbital spines (see Imamura et al. 2019 for a detailed comparison of all 10 species of *Thysanophrys*, and materials of six of the nine species deposited in the collections of AMS, BMNH, CSIRO, NMV, NSMT, NTM, QM, USNM, and WAM). Accordingly, this study identified the six Taiwanese specimens as *T. papillaris*. Imamura and Knapp (1999) originally described *T. papillaris* as having a single small papilla on the eye (based on six specimens). Recently, however, Imamura et al. (2019) recorded a single specimen with an additional papilla on the right eye from Nha Trang, Vietnam, and noted the potential for intraspecific variation in the number of eye papillae. Recognition herein of two specimens of *T. papillaris* with an additional papilla on the eye confirms such intraspecific variation. The presently reported specimens represent the first record of *T. papillaris* from Taiwan and the northernmost distributional record of the species.

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PENSOFT

ACTA ICHTHYOLOGICA ET PISCATORIA

First record and new size record for the oceanic species *Psenes sio* (Actinopterygii: Scombriformes: Nomeidae) in the northern Gulf of California, Mexico

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Abstract

The biological information for many species of the family Nomeidae is scarce, given the difficulty of capturing these species in the oceanic environment. A specimen of the twospine driftfish, *Psenes sio* Haedrich, 1970, was collected in the northern Gulf of California with a bottom trawl net at the depth of more than 250 m. This specimen represents the northernmost record of this species to date, and provides valuable information on this fish, such as maximum weight and height recorded, vertical distribution and latitudinal range, in addition to meristic counts and body morphometry.

Keywords

Mexico, oceanic fish, range extension, record size, twospine driftfish

Introduction

Marine fishes of the family Nomeidae, known as driftfishes, primarily inhabit ocean areas outside of the continental shelf in subtropical and tropical waters (Froese and Pauly 2022). This family includes three genera and 18 valid species (WoRMS Editorial Board 2022), five of which are distributed in the eastern Pacific (Haedrich 1995; Froese and Pauly 2022). Nevertheless, there is scarce biological information on many of the species in the family, given the difficulty of capturing these species in the open ocean (Allen and Robertson 1994; Haedrich 1995).

The genus *Psenes* has two slightly separated dorsal fins, the first one located above the pectoral fin; teeth may be present in the palatine or basibranchial in some species, but never in the glossohyal, and the body is deeply to moderately elongated (Chirichigno 1974).

Particularly, the twospine driftfish, *Psenes sio* Haedrich, 1970, belongs to a group of species that bears small conical recurved teeth in the upper jaw, while the teeth in the lower jaw are laterally flattened and bladelike (Haedrich 1970). This species is distributed in the eastern Pacific, from southern Baja California, Mexico, to Peru, including most of the Gulf of California (Love et al. 2005). However, the records for this species in the Gulf of California come from samples collected by plankton hauls in the central and southern Gulf (Alhstrom et al. 1976; Aceves-Medina et al. 2003; Avendaño-Ibarra et al. 2009).

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Materials and methods

One specimen of the twospine driftfish, *Psenes sio*, was collected on February 2017, between 17:08 and 18:40 hours, in the northern region of the Gulf of California in the fishing area known as *La Herradura* (30°19′54.947″N, 113°44′25.548″W) by the hake fishing fleet (Fig. 1). The fishing gear used was a bottom trawl net with 33 m headrope, 39 m footrope, 12.7 cm body and 10.6 cm codend, pulled by a shrimp boat modified for commercial hake fishing at the depth of ~267 m.

The specimen was identified using keys and specialized catalogs (e.g., Haedrich 1970; Chirichigno 1974; Robertson and Allen 2015). X-ray images were made to observe internal structures such as the hypural plate or pharyngeal sacs. In order to broaden the biological information, body weight (0.1 g) and several body measurements (0.1 mm) were recorded, including total length, standard length, head length, snout length, eye diameter, length of the upper jaw, interorbital width, pectoral length, pelvic length, predorsal distance, preanal distance, body depth, and caudal peduncle depth, as in Horn and Haedrich (1973). Also, the gonads were observed macroscopically considering Saber et al. (2019). Finally, this specimen was fixed in a 10% solution of formaldehyde with sodium borate as a buffer and then preserved in 70% isopropyl alcohol; this was cataloged and deposited in the ichthyological collection of the Centro Interdisciplinario de Ciencias Marinas, Instituto Politecnico Nacional, with catalog number CICIMAR-CI 8336. A review of the main ichthyological marine collections of Mexico (CICIMAR-CI, IBUNAM, CI-UABC) and the biological databases GBIF (2022), Fishnet2 (2022), and BOLD (2022) was made with the intention of obtaining more biological data.

Results

A review of the ichthyological collections and biological databases indicate that the presently reported specimen of the twospine driftfish, *Psenes sio*, is the only adult specimen of this species registered in Mexican ichthyological collections.

The specimen examined here exceeded the length and weight (335 mm TL, 282 mm SL, 325 g) of any other reported fish of this species (Table 1). The dorsal fin was slightly divided into two portions (XI + II, 27) while the anal fin featured 24 elements (II, 22), the pelvic fin six elements (I, 5), and the pectoral fin had 18 soft rays. Using X-rays it was not possible to observe internal details in the hypural complex of the caudal skeleton but the fragile forked fin comprised 9 dorsal and 8 ventral principal caudal rays.

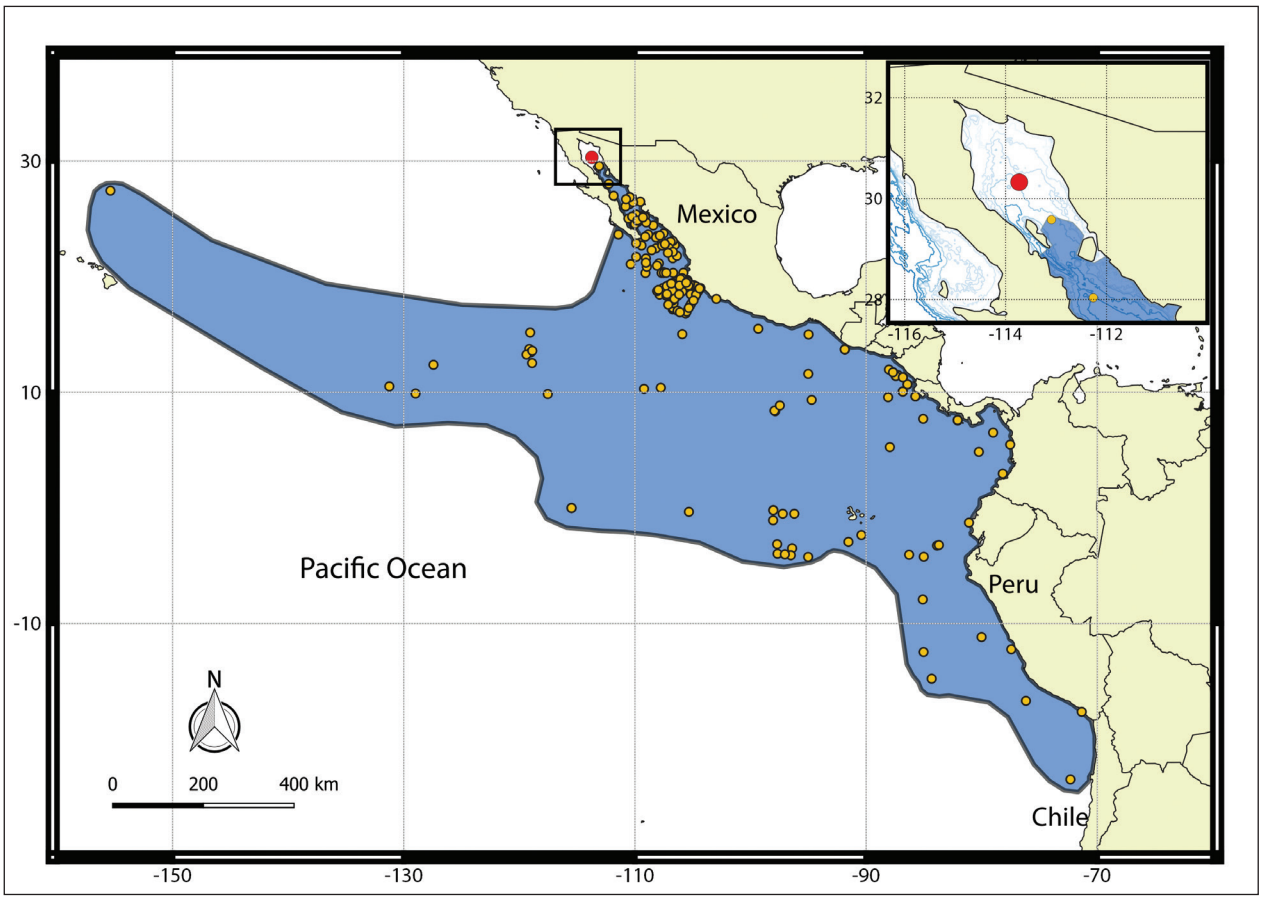

Figure 1. Previous distribution range (shaded area) with capture sites of other specimens deposited in different scientific collections (yellow dots) and collection site of the *Psenes sio* specimen (red dot), using bottom trawling in La Herradura fishing area; Gulf of California, northern zone (NGC).

The body was elongated but not strongly compressed, and the recent postmortem coloration was mainly black including all fins, except for the cephalic region where the color turned grayish (Fig. 2A). Muscles appeared firm, being intensely white below the dermis. According to the macroscopic observation of the gonad in other species of the order Scombriformes described in Saber et al. (2019), the specimen examined presented male structures that were large, flaccid, and branched with a color from light pink to white. No scales were observed but the insertion points of scales were appreciated. The thoracic pelvic fins were located below the base of the pectoral fin.

The maxilla extended beyond the anterior margin of the pupil. The X-rays reveal two big pharyngeal sacs like a broad bean, considered by Fujita (1991) as an important feature in the cephalic region of this species (Fig. 2B).

Table 1. Morphometric measurements provided by different authors and incorporation of data from the *Psenes sio* specimen in the presently reported study, expressed as a percentage of the standard length.

Reference	Absolute values [mm]		Relative values [% SL]										
	Total length	Standard length	HL	SL	ED	LU	IW	PL	PEL	PD	PAD	BD	CP
Haedrich 1970	74.5	60.3	36.0	9.5	10.8	9.6	9.1	25.2	22.2	36.3	52.2	30.7	7.1
	>75.0	65.8	33.6	8.5	9.4	9.4	—	23.6	—	34.0	51.8	29.6	6.7
	—	43.7	30.9	—	—	—	—	25.2	26.1	35.7	49.0	30.9	7.3
	—	25.7	—	—	—	—	—	26.8	26.5	38.1	51.4	40.1	7.0
	26.5	23.4	35.9	9.0	13.2	12.8	12.0	25.2	26.1	39.7	53.8	41.0	9.4
Horn and Haedrich 1973	—	219.0	31.3	9.7	6.4	8.4	7.6	17.6	8.4	31.6	51.8	21.8	6.8
Chirichigno 1978	237.0	193.0	29.5	9.8	6.7	8.2	7.3	15.5	8.8	32.1	51.8	18.7	6.7
	167.0	134.0	28.4	9.3	7.5	9.0	8.2	18.7	13.4	27.6	52.2	21.6	6.7
	134.0	109.0	32.1	10.1	7.3	9.2	8.3	19.3	14.7	33.9	56.9	24.8	6.4
Fujita 1991	54.3	42.5	36.2	—	9.9	10.8	7.3	25.9	—	—	56.5	31.3	6.1
	54.9	42.5	—	8.5	10.1	12.0	8.9	27.5	27.1	36.0	55.8	28.9	6.6
	61.0	48.2	36.3	9.1	10.4	10.8	9.5	25.7	23.7	37.3	55.8	33.8	6.4
	61.6	49.7	34.2	9.5	11.1	11.3	9.3	25.1	22.5	35.2	—	33.6	7.0
	69.0	55.9	34.0	8.9	10.0	10.0	8.2	22.7	20.9	34.5	—	30.2	6.8
	84.1	66.7	33.6	9.3	10.0	10.3	8.2	22.9	22.9	35.1	51.6	27.9	7.0
	91.0	73.3	33.3	8.7	9.0	9.1	7.1	21.1	18.4	32.5	56.5	28.1	6.7
	172.5	143.1	31.0	9.4	7.1	8.9	8.0	19.4	10.4	32.8	52.1	22.9	7.0
	178.0	144.5	28.6	9.4	6.5	7.8	6.9	19.7	10.7	29.1	49.1	22.7	6.0
Presently reported study	335.0	281.0	28.8	9.3	5.0	9.6	8.5	11.7	5.3	32.7	52.0	27.8	9.6

TL = total length, SL = standard length, HL = head length, SL = snout length, ED = eye diameter, LU = length of upper jaw, IW = interorbital width, PL = pectoral fin length, PEL = pelvic fin length, PD = predorsal distance, PAD = preanal distance, BD = body depth, CP = caudal peduncle depth.

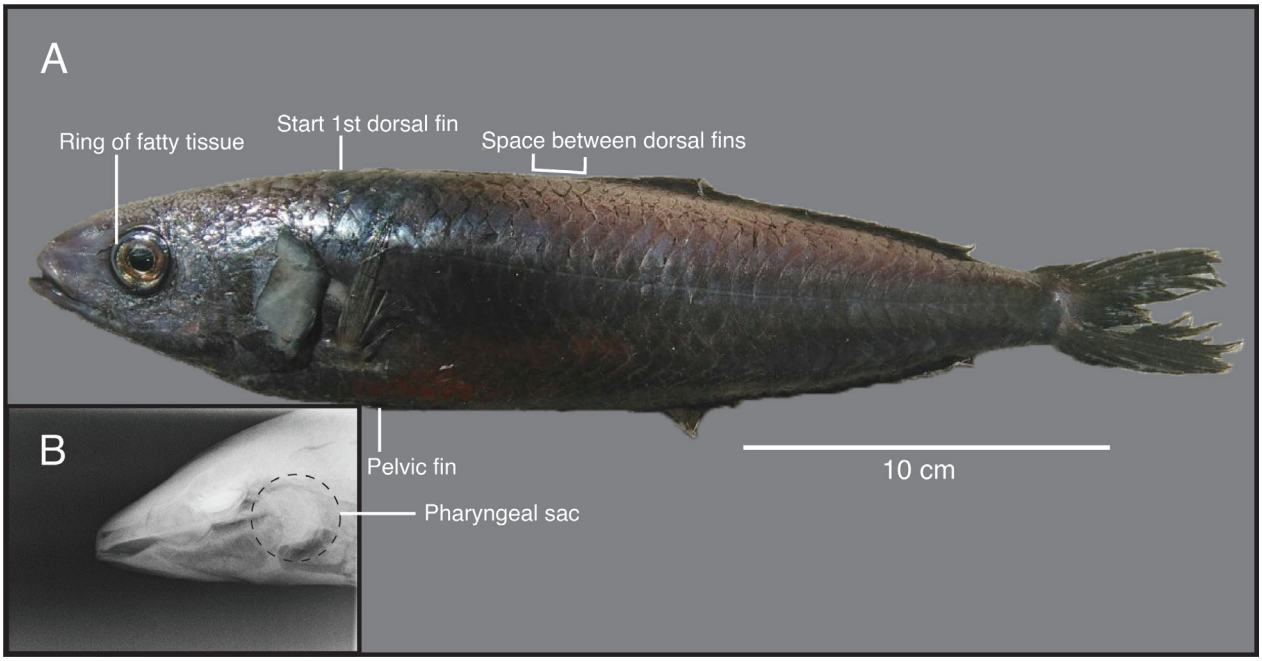

Figure 2. A) New record of *Psenes sio*, deposited in the Ichthyological Collection, Centro Interdisciplinario de Ciencias Marinas, Instituto Politécnico Nacional (CICIMAR-CI 8336), 335 mm TL, 282 mm SL; **B**) X-ray of the head showing the internal pharyngeal sac.

The teeth were present at both sides of the palatines and absent in the vomer and glossohyal bones. The teeth of the upper jaw were small and conical, and were conspicuously elongated like blades in the dentary, being recurved in the premaxilla. The snout was truncated and elongated (about ¼ of cephalic length).

The two dorsal fins of the specimen were divided by a conspicuous space and the iris of the eye was light brown. On the other hand, it was not possible to examine the scales, probably because they were rooted in the dermis, and detached from the skin during the fishing operation (~2 h). However, the insertion points of scales were appreciated; in the dorsal region of the head, these insertion points were evident beyond the anterior edge of the eye.

Discussion

Previous size record. Relevant literature data on the twospine driftfish, *Psenes sio*, started with the description of the species based on specimens measuring 23.4 to 60.3 mm in standard length Haedrich (1970). Subsequently, the maximum size recorded for the species (219.0 mm) was reported by Horn and Haedrich (1973). The specimens included in the Collection of Marine Vertebrates of the Scripps Institute of Oceanography (SIO) correspond to a size range of 10–230 mm in total length.

On the other hand, if the measures of the presently reported specimen are fed into the relation analysis between the body depth/standard length ratio and standard length made by Fujita (1991) with other specimens, the depth of the body decreases with growth until 60–70 mm of SL. However, it is reported by Fujita (1991) that *P. sio* maintains a constant size in the body depth from about 110 mm. With the presently reported finding it becomes evident that the current information regarding 19 specimens can be completed as more specimens are collected.

Previous distribution range. The twospine driftfish, *Psenes sio*, has been reported from the southern part of Baja California, Mexico, to Punta Doña Maria, Peru (Love et al. 2005). The diagnosis of the species was carried out by Haedrich (1970) based on five juveniles collected in the equatorial eastern Pacific Ocean. Subsequently, Horn and Haedrich (1973) recorded another specimen of the same species collected south of Cabo San Lucas, Mexico, which represented an extension of its distribution range. For his part, Fujita (1991) found 9 specimens of *P. sio* in the stomachs of the bigeye tuna, *Thunnus obesus* (Lowe, 1839), captured in equatorial latitudes. Chirichigno and Vélez (1998) examined three juvenile *P. sio* specimens caught in the sea off the Peruvian coast. Finally, there is one record of a small-size specimen with this preserved dark coloration reported in the BOLD Systems public database captured in the Nicaraguan Pacific and that has been considered in the previous distribution in BOLD (2022).

The majority of the records of nomeid fishes throughout their distribution range refer to larval or juvenile stages collected with fishing gear targeting zooplankton, or as part of the stomach contents of other fish (Chirichigno and Vélez 1998; Froese and Pauly 2022). As a result, our knowledge of the biology of this species is scarce.

In Mexico, there have been a number of studies aimed at describing the diversity of the ichthyoplankton in the central area of the Mexican Pacific, near the coasts of Colima, Jalisco, and Sinaloa. These studies make reference to *P. sio* larvae, reporting that this area is part of the distribution range of the species (Franco-Gordo et al. 1999, 2003; León-Chávez et al. 2010). Particularly in the Gulf of California (GC), León-Chávez et al. (2010) report larvae of *P. sio* collected in two different zones; one of them near the coast, at the south of Cabo Corrientes where the sea surface temperature is low and chlorophyll-a concentration, is high and the other in an oceanic area with higher sea surface temperature and low chlorophyll-a concentration, both at the mouth of the GC. Within the GC, Alhstrom et al. (1976) reported a presence of larvae of *P. sio* from the southern zone (south of the Archipelago zone); in addition, these authors report juvenile specimens in the ocean area ranging from 22°N near Colima, Mexico, down to 2°S around the Galapagos Islands. Aceves-Medina et al. (2003) and Avendaño-Ibarra et al. (2014) also reported the presence of *P. sio* larvae within the GC.

Global distribution range. The southernmost capture site recorded was in oceanic waters in front of Antofagasta, northern Chile, with a specimen of 56.5 mm in total length, captured in 1975 and deposited in the Marine Vertebrate Collection of the SCRIPPS Institution of Oceanography. To the west, there is a record near the Hawaiian Islands of one specimen of 8 mm of total length, preserved at the SCRIPPS Institute. Finally, the new locality of this study represents the northernmost capture point to date of the whole distribution of the species, not only at the interior of the Gulf of California.

Another key aspect is the vertical distribution of the species. In some catalogs (i.e., Chirichigno 1978; Froese and Pauly 2022) *P. sio* is classified as an epipelagic or benthopelagic species. However, the review of fish collection databases for references of the species (SIO, MNHN) revealed several specimens collected by trawl between 100 and 479 m. With the exception of the localities when the specimens were in the larval stage, no reference has been found involving juveniles or adult specimens being clearly captured near the surface. Therefore, in addition to the depth of the specimen reported here (>250 m), these references provide evidence that this species inhabits mesopelagic or benthopelagic environments, although such a statement may be deceptive because the fishing nets with which they are captured, are open at different depths and strain the entire water column.

However, the northern zone and the upper Gulf of California show distinct conditions in terms of currents, temperature, and productivity (0.27 ms^{-1};18–30.5°C; 50.40–623.80 mg of C × m^{-3} × d^{-1}, respectively) (Lavin and Marinone 2003; Mercado-Santana et al. 2017), as

well as less deep bathymetric depressions relative to other regions such as Guaymas and Carmen basins. These conditions restrain the distribution of mesopelagic ichthyofauna in this area. It has been observed that species such as *Diogenichthys laternatus* (Garman, 1899) or *Vinciguerria lucetia* (Garman, 1899) have a considerably wider distribution along the Gulf, but as far north as 29°N its distribution stops abruptly Robison (1972). Another example occurs with *Triphoturus mexicanus* (Gilbert, 1890), which dominate the mesopelagic community throughout most of the Gulf, but, apparently, on account of a limited tolerance for colder temperatures, its presence decreases significantly in the Northern Gulf (Robison 1972; Sarmiento-Lezcano et al. 2022). The above is a likely explanation for the apparent absence of *P. sio* within the list of ichthyoplankton species in the northern zone and the upper Gulf of California (e.g., Ordoñez-Guillén 2014).

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PENSOFT

ACTA ICHTHYOLOGICA ET PISCATORIA

Length–weight relations of 16 mesopelagic fishes (Actinopterygii: Myctophiformes and Stomiiformes) from the eastern Mediterranean Sea

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Abstract

For many mesopelagic fishes, even basic knowledge regarding their biology is missing, greatly impeding their effective management. Here we present length–weight relations for 16 mesopelagic fishes sampled during research surveys in the Greek seas (eastern Mediterranean). The following species were studied: *Benthosema glaciale* (Reinhardt, 1837); *Ceratoscopelus maderensis* (Lowe, 1839); *Diaphus holti* Tåning, 1918; *Diaphus metopoclampus* (Cocco, 1829); *Diaphus rafinesquii* (Cocco, 1838); *Hygophum benoiti* (Cocco, 1838); *Hygophum hygomii* (Lütken, 1892); *Lampanyctus crocodilus* (Risso, 1810); *Lobianchia dofleini* (Zugmayer, 1911); *Myctophum punctatum* Rafinesque, 1810; *Notoscopelus elongatus* (Costa, 1844); *Symbolophorus veranyi* (Moreau, 1888) [**Myctophidae**]; *Argyropelecus hemigymnus* Cocco, 1829; *Maurolicus muelleri* (Gmelin, 1789) [**Sternoptychidae**]; *Stomias boa* (Risso, 1810); *Chauliodus sloani* Bloch et Schneider, 1801 [**Stomiidae**].With the exception of *Diaphus holti* and *Symbolophorus veranyi*, parameter *b* diverged significantly from isometry. Only two species (*Benthosema glaciale* and *Chauliodus sloani*) displayed negative allometry, while for the remaining 12 species a positive allometry was found, with the highest parameter *b* values estimated for *Stomias boa* and *Diaphus rafinesquii*. The median value of parameter *b* for all species was 3.236 and 50% of its values ranged from 3.173 to 3.323. Some variations of the parameter *b* were observed between our findings and other studies from the Atlantic and the western Mediterranean.

Keywords

LWR, Mediterranean Sea, mesopelagic fish, micronekton, myctophids, twilight zone

Introduction

Mesopelagic fishes constitute the most abundant group of vertebrate animals on the planet (Irigoien et al. 2014) and represent a high diversity of species (López-Pérez et al. 2020) with the family Myctophidae having the higher number of species among them. These species inhabit the part of the ocean known as the mesopelagic zone, usually set between 200–1000 m of depth, also referred to as the twilight zone, forming Deep Scattering Layers detected in oceanic mid-waters by echosounders (Godø et al. 2009; Kaartvedt et al. 2019). The majority of the mesopelagic fish species are known for their diel vertical migrations to the epipelagic layer during the night, following the ascension of their zoo-planktonic prey to shallower oceanic depths, while during daytime they descend back to the mesopelagic zone to avoid predation (Kaartvedt et al. 2019).

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Mesopelagic fishes play an important ecological role, linking primary consumers to top predators (Woodstock and Zhang 2022), many of which are commercial pelagic and demersal fishes (or protected, endangered, or threatened species) (Catul et al. 2011). Therefore, they constitute an important part of open ocean energy dynamics and contribute considerably to the transfer of organic carbon from the surface to the deep sea via their diel vertical migrations (Kaartvedt et al. 2019). Mesopelagic fishes have been regarded as a potential harvestable resource since the 1970s either for human consumption or as raw material supply to the fish meal and marine oil industry, but efforts in this direction were mainly exploratory or economically unsustainable (Caiger et al. 2021). In the recent decade, their global biomass estimate has been substantially revised upwards (Irigoien et al. 2014), and interest in commercial exploitation is being revisited. Despite their ecological importance and fisheries potential, these species remain one of the least investigated components of the marine environment. For many mesopelagic fishes, even basic knowledge regarding their biology is missing, greatly impeding their effective and sustainable management (Hidalgo and Browman 2019; Caiger et al. 2021).

Length–weight relations (LWRs) constitute essential knowledge for the application of fish stock assessment and management, necessary for the estimation of fish biomass from sampled length data and for ecological modeling and the estimation of growth in fish (Froese 2006). Length–weight relation studies for Mediterranean mesopelagic fishes have been particularly scarce (Battaglia et al. 2010), especially in the eastern basin, where information is almost absent. In the presently reported study, we estimated the length–weight relations for 16 mesopelagic fish species, representing 3 families, sampled during research surveys in the Greek seas.

Materials and methods

Fish samples were collected with pelagic trawls and midwater frames, during dedicated mesopelagic surveys as well as other routine acoustic surveys (Leonori et al. 2021), onboard the R/V *Philia* in the Greek seas (North Aegean Trough, northern Euboean Gulf, Saronic Gulf, Cretan Sea, Gulf of Corinth) (Fig. 1) from November 2018 to December 2019. Sampled fish were immediately packed and frozen onboard until their transfer to the laboratory for examination, where the total length (TL) of each individual was measured to the nearest 1 mm and the total weight (W) to the nearest 0.001 g, using a high precision digital scale. The LWRs were estimated for 16 fish species, 12 of which represented the family Myctophidae, two species to the family Sternoptychidae, and two to the family Stomiidae (Table 1). The following species were studied: *Benthosema glaciale* (Reinhardt, 1837); *Ceratoscopelus maderensis* (Lowe, 1839); *Diaphus holti* Tåning, 1918; *Diaphus metopoclampus* (Cocco, 1829); *Diaphus rafinesquii* (Cocco, 1838); *Hygophum benoiti* (Cocco, 1838); *Hygophum hygomii* (Lütken, 1892); *Lampanyctus crocodilus* (Risso, 1810); *Lobianchia dofleini* (Zugmayer, 1911); *Myctophum punctatum* Rafinesque, 1810; *Notoscopelus elongatus* (Costa, 1844); *Symbolophorus veranyi* (Moreau, 1888) [**Myctophidae**]; *Argyropelecus hemigymnus* Cocco, 1829; *Maurolicus muelleri* (Gmelin, 1789) [**Sternoptychidae**]; *Stomias boa* (Risso, 1810); *Chauliodus sloani* Bloch et Schneider, 1801 [**Stomiidae**].

Measured fish weight (W) [g] and length (TL) [cm] data were fitted to the power function

$$W = a\mathrm{TL}^b$$

where a and b are the intercept and slope of the power equation, respectively. Data were transformed, using their natural logarithmic values and adjusted to a linear regression model by application of the least squares method, as to estimate length–weight parameters a, b (Kuriakose 2017). Intercept values (parameter a) give an indication of the expected weight at 1 cm of length for each species (Olivar et al. 2013). Confidence intervals (CI) of the parameters were calculated at the 95% confidence level and the resulting parameter b was evaluated, using a Student's t-test (López-Pérez et al. 2020), as to inspect whether or not the sampled populations' divergence from isometric growth ($b = 3$) was statistically significant, consequently indicating positive ($b > 3$) or negative ($b < 3$) allometry (Froese 2006).

The estimated values of the parameter b were compared to values reported for the same species in similar studies from the western Mediterranean (Olivar et al. 2013), the North (Fock and Ehrich 2010) and the tropical Atlantic (López-Pérez et al. 2020).

Results

A total of 6214 fish individuals were used in the current length–weight analysis, but they were not equally distributed across species (Table 1). Fitted length–weight equations gave high coefficients of determination (r^2) with values ranging from 0.943 for *Argyropelecus hemigymnus* to 0.983 for *Diaphus metopoclampus*. With the exception of *Diaphus holti* and *Symbolophorus veranyi*, the parameter b diverged significantly from isometry. Only two species (*Benthosema glaciale* and *Chauliodus sloani*) displayed negative allometry, while for the remaining 12 species a positive allometry ($b > 3$) was found, with the highest growth coefficient claimed by *Stomias boa* and *Diaphus rafinesquii*. The median value of parameter b for all species was 3.236 and 50% of its values ranged from 3.173–3.323.

Considerable variations of the parameter b between our findings and other studies from the Atlantic and the western Mediterranean were observed, especially compared to those from the North Atlantic (Table 2) (Fock and Ehrich 2010; Olivar et al. 2013; López-Pérez et al. 2020).

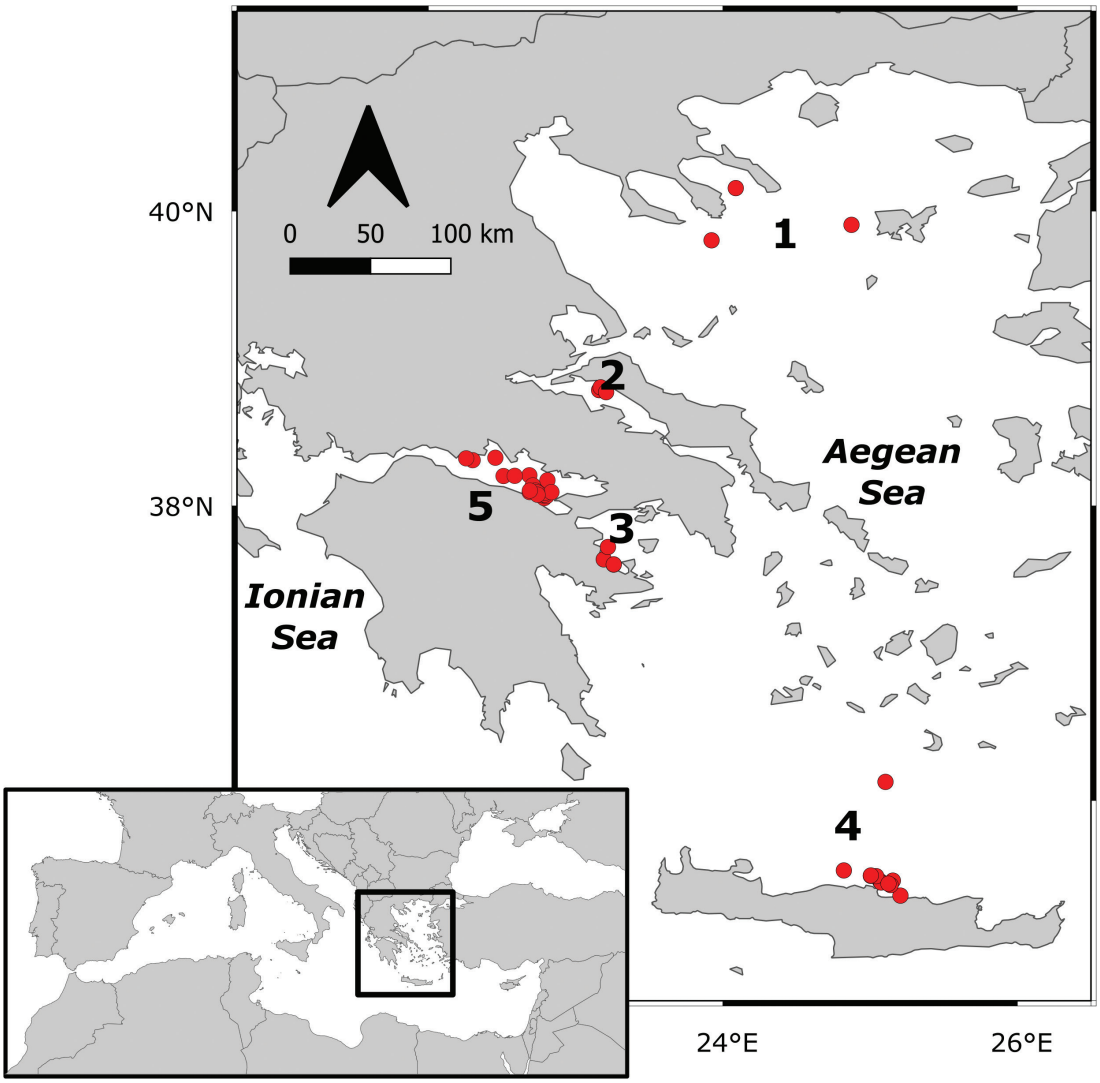

Figure 1. Sampling locations: North Aegean Trough (1), northern Euboean Gulf (2), Saronic Gulf (3), Cretan Sea (4), Gulf of Corinth (5).

Table 1. Length–weight relation parameters of 16 mesopelagic fish species sampled in Greek seas.

Species	*a*	95%CI of *a*	*b*	95%CI of *b*	*n*	r^2	Length [cm]	Weight [g]	*P*-value	Growth type
Myctophidae										
Benthosema glaciale	0.0106	0.0099–0.0115	**2.916**	**2.863–2.969**	691	0.944	2.0–7.4	0.055–2.925	0.002	– allometry
Ceratoscopelus maderensis	0.0038	0.0036–0.0040	**3.243**	**3.209–3.277**	1318	0.964	1.9–8.9	0.02–4.709	<0.001	+ allometry
Diaphus holti	0.0095	0.0081–0.0111	3.066	2.967–3.166	175	0.955	2.3–6.8	0.079–6.175	0.193	isometry
Diaphus metopoclampus	0.0075	0.0055–0.0104	**3.332**	**3.164–3.501**	30	0.983	3.9–9.6	0.832–15.707	<0.001	+ allometry
Diaphus rafinesquii	0.0050	0.0034–0.0072	**3.521**	**3.302–3.740**	41	0.965	1.7–9.4	0.028–11.49	<0.001	+ allometry
Hygophum benoiti	0.0049	0.0046–0.0053	**3.318**	**3.273–3.363**	498	0.977	1.9–7.8	0.028–4.834	<0.001	+ allometry
Hygophum hygomii	0.0058	0.0045–0.0075	**3.281**	**3.131–3.432**	78	0.961	3.3–8.1	0.292–5.63	<0.001	+ allometry
Lampanyctus crocodilus	0.0023	0.0019–0.0027	**3.314**	**3.214–3.415**	244	0.946	2.7–17.0	0.025–40.312	<0.001	+ allometry
Lobianchia dofleini	0.0067	0.0059–0.0076	**3.228**	**3.141–3.314**	194	0.966	2.7–6.0	0.138–2.003	<0.001	+ allometry
Myctophum punctatum	0.0055	0.0051–0.0060	**3.220**	**3.167–3.272**	423	0.972	2.2–10.0	0.056–8.532	<0.001	+ allometry
Notoscopelus elongatus	0.0043	0.0038–0.0049	**3.189**	**3.118–3.261**	146	0.982	2.9–12.5	0.128–13.561	<0.001	+ allometry
Symbolophorus veranyi	0.0055	0.0039–0.0078	3.190	2.997–3.383	24	0.982	4.4–12.5	0.625–18.732	0.053	isometry
Sternoptychidae										
Argyropelecus hemigymnus	0.0092	0.0086–0.0098	**3.325**	**3.262–3.389**	653	0.943	0.5–4.8	0.003–1.419	<0.001	+ allometry
Maurolicus muelleri	0.0069	0.0068–0.0071	**3.168**	**3.137–3.199**	1437	0.966	1.9–6.3	0.049–2.65	<0.001	+ allometry
Stomiidae										
Stomias boa	0.0004	0.0003–0.0005	**3.523**	**3.394–3.653**	67	0.980	5.5–25.3	0.253–43.026	<0.001	+ allometry
Chauliodus sloani	0.0026	0.0021–0.0031	**2.775**	**2.681–2.868**	195	0.947	4.6–19.9	0.127–12.805	<0.001	– allometry

Values of parameter *b*, estimated to diverge significantly from isometry are indicated in bold; *P*-values are from Student's *t*-tests for divergence of *b* from isometric growth ($b = 3$).

Table 2. Values of parameter *b* and length ranges (LR) of mesopelagic fishes from other regions.

Species	North Atlantic Fock and Ehrich 2010		Tropical Atlantic López-Pérez et al. 2020		W. Mediterranean Olivar et al. 2013		This study	
	LR	*b*	LR	*b*	LR	*b*	LR	*b*
Argyropelecus hemigymnus	18–40	**2.750**	—	—	13–34	**3.032**	5–48	3.325
Benthosema glaciale	21–81	**3.020**	15–35	**3.251**	14–47	**3.093**	20–74	2.916
Ceratoscopelus maderensis	27–85	3.172	—	—	16–64	3.191	19–89	3.243
Chauliodus sloani	57–293	**3.028**	—	—	—	—	46–199	2.775
Diaphus holti	10–69	**3.350**	11–50	3.006	25–53	**3.360**	23–68	3.066
Diaphus metopoclampus	48–66	**3.074**	19–40	3.353	—	—	39–96	3.332
Diaphus rafinesquii	28–84	3.433	11–70	**2.850**	—	—	17–94	3.521
Hygophum benoiti	35–54	**3.052**	—	—	13–48	**2.983**	19–78	3.318
Hygophum hygomii	44–48	**3.052**	—	—	39–58	3.136	33–81	3.281
Lampanyctus crocodilus	38–183	3.240	—	—	22–128	3.345	27–170	3.314
Lobianchia dofleini	28–62	**2.609**	13–30	3.130	21–43	3.338	27–60	3.228
Maurolicus muelleri	27–60	3.296	—	—	—	—	19–63	3.168
Myctophum punctatum	22–89	**3.448**	16–69	3.221	19–60	**3.052**	22–100	3.22
Notoscopelus elongatus	—	—	—	—	30–107	3.248	29–125	3.189
Stomias boa	70–205	**3.184**	53–153	**3.042**	—	—	55–253	3.523
Symbolophorus veranyi	34–113	3.248	—	—	23–90	3.181	44–125	3.19

Bold values indicate differentiations higher than 5% or with different allometric pattern (positive vs negative) compared to the current study. Length ranges are given for standard length (SL) in mm, except in the current study which are total lengths (TL). SL–TL conversion formulas can be retrieved from Froese and Pauly (2022).

Discussion

The current study attempted to assess length–weight equations for mesopelagic fish populations from the eastern Mediterranean Sea, setting the base for further biological studies necessary to support future management and research. Length–weight relations in the region have been examined in a localized context for only a few of the species considered here (e.g., *Argyropelecus hemigymnus*, *Diaphus metopoclampus*, *Stomias boa*; see Deval et al. 2014, *Lampanyctus crocodilus*, *Chauliodus sloani*; see Bayhan et al. 2020), while for others, to our knowledge, information is completely absent from the eastern basin or even from the entire Mediterranean (*Diaphus rafinesquii*). Length–weight parameters have been suggested to reflect environmental variations in species' habitats, as well as adaptive mechanisms and intrinsic characteristics, which affect their ontogenetic development (Froese 2006; Eduardo et al. 2020b). In the presently reported study, fish samples derived from multiple seasons and across a wide geographical area encompassing open seas and enclosed gulfs and possibly including populations with indications of genetic differentiations (e.g., *Hygophum benoiti*) (see Sarropoulou et al. 2022); therefore, results can help derive conclusions for the estimated values of parameter *b* at the species level (Froese 2006).

For the majority of fishes studied herein, *b* was within the expected range of 2.5 and 3.5, (Froese 2006), although *Stomias boa* and *Diaphus rafinesquii* exhibited slightly higher values (3.52). The positive allometric growth observed in the majority of species is an indication of a more robust body growing faster in mass than in length, an attribute which may be essential for their diel vertical migrations (Olivar et al. 2013; López-Pérez et al. 2020). Contrarily, the negative allometric growth pattern, displayed here by two species, may be related to living in deep waters and to the absence of extended vertical migration (López-Pérez et al. 2020); this explanation seems plausible for *Chauliodus sloani* for which a temperature barrier inhibits its migration in warm regions (Eduardo et al. 2020a), but probably not for *Benthosema glaciale*, which shows a partial vertical migratory activity elsewhere (Dypvik et al. 2012), as well as in the study area (authors' unpublished data).

Some intraspecific differentiations of the allometric coefficient among the current study and similar works were identified, which were more diverse compared to estimates from the North Atlantic. These can be attributed to fish growth affected by internal and external triggers (such as diet and habitat temperature) (Mazumder et al. 2016), to discrete population characteristics, but also to the sampled size ranges (Czudaj et al. 2022), and the type of length measurements (López-Pérez et al. 2020).

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PENSOFT.

ACTA ICHTHYOLOGICA ET PISCATORIA

Records of the critically endangered *Squatina aculeata* and *Squatina oculata* (Elasmobranchii: Squatiniformes: Squatinidae) from the Mediterranean Sea

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Abstract

All three species of angelsharks that inhabit the Mediterranean Sea, *Squatina aculeata* Cuvier, 1829; *Squatina oculata* Bonaparte, 1840; and *Squatina squatina* (Linnaeus, 1758), are classified as Critically Endangered on the IUCN Red List of Threatened Species, since their populations have suffered severe decline and range reduction, mainly due to fishing pressure. The presently reported study aims to further update records of *S. aculeata* and *S. oculata* in the basin in order to achieve a clearer picture of their current status and geographical distribution. In this way, we were able to add a contribution to our knowledge about their biological characteristics. Records on the incidental capture and observation of specimens of *S. aculeata* and *S. oculata* between 2005 and 2022 were collected through the input of alerted professional fishermen, fisher amateurs, and specialist observers on fishery landings or on board in the context of specific surveying programs as well as of citizens' science initiatives. Biological characters such as total length, total weight, sex, and maturity were determined whenever possible. A total of 18 *S. aculeata* and 34 *S. oculata* specimens were recorded. Data corroborate the current occurrence, which is almost rare, of these two Critically Endangered elasmobranchs from the central to the east part of the basin, revealing furthermore the presence of *S. aculeata* in Sardinian waters, in the western part of the basin. Data document the important habitats for both species existing in the Strait of Sicily, especially in the area around Malta, and confirm the occurrence of *S. aculeata* in the southern Aegean Sea. The current presence of both species is also established in Mediterranean Egyptian waters. Our study suggests the urgent need for a wider application and/or reinforcement of existing protection measures for these angelshark species and their habitat, including populations of the southern Mediterranean waters.

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Keywords

angelsharks, biodiversity, critically endangered species, elasmobranchs, spatial distribution

Introduction

Three angelshark species dwell in the Mediterranean Sea: *Squatina aculeata* Cuvier, 1829, *Squatina oculata* Bonaparte, 1840, and *Squatina squatina* (Linnaeus, 1758) (see Serena 2005). Some ecological and biological characteristics of angelsharks, i.e., sedentariness, association with coastal locations, slow growth, and low fecundity, render their populations vulnerable to fishing pressures and to other factors, such as habitat perturbation. All three taxa are classified as Critically Endangered on the International Union for the Conservation of Nature's (IUCN) Red List of Threatened Species, since their populations have suffered severe decline and range reduction, mainly due to intense demersal fishing activities (Nieto et al. 2015; Miller 2016; Zava et al. 2016, 2020; Bradai et al. 2018; Gordon et al. 2019; Bargnesi et al. 2020; Lawson et al. 2020).

The sawback angelshark, *S. aculeata*, is a species that prefers temperate and tropical waters and muddy bottoms at depths from 50 to 500 m in the eastern Atlantic and the Mediterranean; similarly, the smoothback angelshark, *S. oculata*, is a warm-temperate and tropical angelshark in the eastern Atlantic, from off southern Portugal and Spain to Morocco and as far as Angola and Namibia, and the whole Mediterranean Sea; it is a bottom dweller on sand and mud, from 10 m to 500 m, mostly between 50 m and 100 m, deeper in tropics (Compagno 1984; Serena 2005; Carpenter and De Angelis 2016; Weigmann 2016).

In order to briefly integrate the distribution of records of *S. aculeata* and *S. oculata* already exhaustively reported by Miller (2016 and references therein) and Lawson et al. (2020 and references therein), a few additions concerning the records of both species in the Mediterranean published in the literature will follow here. The occurrence of *S. oculata* has been recorded from the northern Aegean Sea in 2014–2015 (Yemişken et al. 2016) and 2018 (Yığın et al. 2019) and in the southeastern Aegean Sea in 2003–2004 (Öziç and Yilmaz 2006; Corsini and Zava 2007). The smoothback angelshark has been also recorded from the Mediterranean waters of Turkey by Meriç et al. (2007), Ergüden et al. (2019 and references inside), Özgür Özbek and Kabasakal (2022 and references inside), and Mutlu et al. (2022). In Lebanon, the occurrence of *S. aculeata* and *S. oculata* has been recently confirmed (Lteif et al. 2014; Bariche and Fricke 2020; Lteif unpublished*). In Syria, both species showed an extremely low abundance in 2014–2016 (Alkusairy and Saad 2018). In northern Tunisia *S. oculata* was recorded in 2018 and 2022 (Rafrafi-Nouira et al. 2019, 2022); in the south of the country (Gulf of Gabès), the occurrence of both *S. aculeata* and *S. oculata* was very rare according to surveys of bottom trawler landings carried out between 2004 and 2010 (Enajjar et al. 2015). Only one specimen of *S. oculata* was recorded in the eastern Ionian Sea in the Fisheries Database of the Hellenic Centre for Marine Research obtained in the framework of 15 scientific projects carried out during the period of 1983–2016 (Damalas et al. 2018). Extremely limited data for *S. oculata* as bycatch were obtained between 1991 and 2018 in Levantine waters and none for the Aegean Sea, Turkey (Bengil and Başusta 2018). Also, no landings of angelsharks from the Mediterranean waters of Turkey were observed during the period 1970–2015 (Başusta et al. 2016). Between 2011 and 2020, twenty records of incidentally captured *S. aculeata* specimens from the west to the central sectors of the basin and up to the eastern side, off the south of Crete and in the southeastern Aegean Sea, have been reported by Zava et al. (2020); in this last area, *S. aculeata* has been recorded also in 2009–2010 (Filiz et al. 2018) and very recently (Montesanto et al. 2022). In the Adriatic Sea, *S. oculata* is considered regionally extinct in Croatian waters (Pešić 2020; Pešić et al. 2021).

During the surveys of the MEDITS (Mediterranean Trawl Survey) conducted in the western Mediterranean in the period 1994–2015, no *Squatina* spp. were detected (Ramírez-Amaro et al. 2020). In the whole of the northern Mediterranean, the surveys of the same MEDITS project did not reveal any capture of *S. oculata* during the period 2012–2015, while *S. aculeata* was very rare and found only in the Aegean Sea (Follesa et al. 2019). According to the MEDITS surveys carried out in the Mediterranean between 2016 and 2018, both *S. aculeata* and *S. oculata* were absent (Anonymous 2017, 2019). The database of the Mediterranean Large Elasmobranchs Monitoring (MEDLEM) showed that both angelshark species considered to reside there were very rare throughout the whole basin (Mancusi et al. 2020).

Taking into account the extremely critical situation of Squatinidae populations in the Mediterranean, the occurrence of *S. aculeata*, *S. oculata*, and *S. squatina* was recently assessed as rare in the western Mediterranean and the Adriatic Sea and as occasional in the central and eastern parts of the basin (Serena et al. 2020).

* Lteif M (2015) Biology, distribution and diversity of cartilaginous fish species along the Lebanese coast, eastern Mediterranean. Ecology, environment. PhD Thesis, Université de Perpignan, France, 262 pp.

The need for the documented occurrence of each of the three endangered angelsharks living in the basin is urgent, since the widely diffused grouping of sharks and rays in landing statistics and the misidentification of species or confusion between species, continue to make it difficult to achieve a clear picture of their status and distribution in the Mediterranean Sea (UNEP-MAP 2019; Cashion et al. 2019; Gordon et al. 2019; Lawson et al. 2020).

In the presently reported study, data on the incidental capture or observation of *S. aculeata* and *S. oculata* and specimens collected between 2005 and 2022 in the Mediterranean Sea are reported in order to contribute to a better understanding of the geographical distribution of these taxa in the basin. This may be helpful for the application and widening of existing regulations for the protection of these endangered species to improve conservation actions and boost our knowledge of some of their biological aspects.

Material and methods

Alerted professional fishermen operating prevalently in the eastern and central Mediterranean waters and appropriately trained, promptly provided information to authors on the incidental capture of specimens of *S. aculeata* and *S. oculata* between 2005 and 2022. Other data were collected by fisher amateurs as well as by specialists on fishery landings or on board in the context of specific survey programs. Data from the Malta Archipelago include those from commercial fishery and those obtained from the MEDITS and MEDLEM monitoring programs. Furthermore, the collection of data from Sicily was enriched through the initiative called "Spot the rare fish", launched by the Museo Civico di Storia Naturale di Comiso, Ragusa, Italy (MSNC). This initiative has been active since 2015 and involves citizen science and professional fishermen of Sicily (cf. Zava et al. 2020).

A total of 18 specimens of *S. aculeata* and 34 specimens of *S. oculata* were detected in various Geographical Subareas (GSAs) of the General Fisheries Commission for the Mediterranean (GFCM) (FAO 2018) (Fig. 1) (Table 1). The distribution map of angelshark findings was prepared using Quantum GIS software (QGIS Development Team 2020).

Specimens were identified according to Compagno (1984), Bauchot (1987), and Serena (2005). Identification was carried out through the accurate examination of photos taken on board, immediately after their capture, or taken underwater, or at landing locations or fish markets. The samples stored at the MSNC and in the collections of the Biological Museum of the Department of Biological and Geological Sciences, Faculty of Education, Alexandria University (Table 1), all retrieved dead, were identified directly in the laboratory.

Sex, maturity, total length (TL), and total weight (TW) were determined, whenever possible.

The relation between TW [g] and TL [cm] was calculated for *S. oculata* using the equation

$$TW = aTL^b$$

where a is a constant depending on the species, and b is the allometric parameter. Data of TW and TL collected in the presently reported study were integrated with data of 21 Mediterranean *S. oculata* specimens retrieved from the literature.

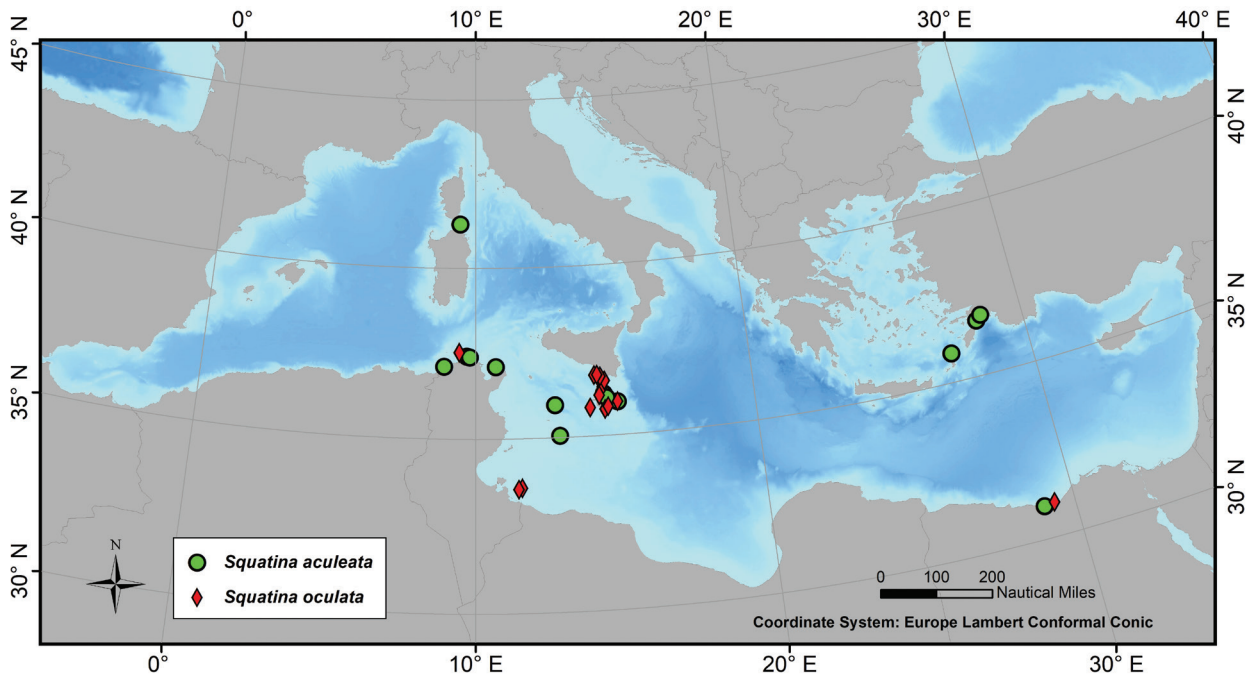

Figure 1. Map of the Mediterranean Sea showing the finding locations of *Squatina aculeata* (green dot) and *Squatina oculata* (red diamond) in the period of 2005–2022.

Table 1. Locations and characteristics of the captures of *Squatina aculeata* and *Squatina oculata* in the Mediterranean Sea (2005–2022).

ID	Date D/M/Y	Country	Place	Coordinates	GSA	Depth [m]	*n*	Sex	M	TL [cm]	TW [g]	Gear/ other	Bottom type	Status	Source of data
Sa1	5/2007	Tunisia	Bizerta	37.4056°N, 9.6836°E	12	120	1	♂	A	>120		BT	Sandy-muddy	Dead and landed, sold	JBS
Sa2	6/2007	Tunisia	Bizerta	37.3808°N, 9.7958°E	12	75	1	♀	A	>130		BT	Sandy-muddy	Dead and landed, sold	JBS
Sa3	1/8/2009	Malta			15		1	♀		128				Dead and landed, sold	AD
Sa4	2/2009	Tunisia	Near Zembra MPA	37.0936°N, 10.7436°E	12	70	1	♂	A	>120		LL	Rocky and sandy	Dead and landed, sold	JBS
Sa5	1/6/2011	Malta		35.9598°N, 15.1013°E	15	105	1	♀	I	49.5	920	BT/MEDITS			MEDITS
Sa6	6/2012	Tunisia	Gulf of Tunis	37.0936°N, 10.7436°E	12	50	1	♂	A	>120		LL	Muddy		JBS
Sa7	3/2013	Tunisia	Tabarka	37.1061°N, 8.8503°E	12	100	1	♂	A	>120		LL	Sandy	Dead and landed, sold	JBS
Sa8	16/12/2014	Malta		36.2125°N, 14.6175°E	15	137	1	♀	I	43	640	BT/ MEDITS			MEDITS
Sa9	31/8/2016	Malta		36.0923°N, 14.7102°E	15	128	1	♀	I	29	200	BT/ MEDITS			MEDITS
Sa10	12/2/2021	Italy	SE of Lampedusa Isl.	35.0500°N, 12.9833°E	13	90	1	♀ + 2 fetuses	P	~150	30000–40000	BT		Released alive	BZ
Sa11	18/4/2021	Egypt	Off El Alamein, Marsa Matruh city	30.9142°N, 28.9742°E	26	55–70	1	♀		113.7	10781	BT	Sandy with coarse grains	Retrieved dead-sold	OMN
Sa12	23/4/2021		Between Rhodes Isl. and Turkey	36.5833°N, 28.3333°E	22	530	1	♀		>130		BT		Released alive	BZ
Sa13	3/5/2021	Greece	Saria Isl., Karpathos	35.8326°N, 27.1796°E	22	80	1	♀		~130		TN		Retrieved dead, sold	GK
Sa14	3/5/2021	Greece	Saria Isl., Karpathos	35.8326°N, 27.1796°E	22	80	1	♀		~120		TN		Retrieved dead, sold	GK
Sa15	7/5/2021	Egypt	Off El Alamein, Marsa Matruh city	30.9142°N, 28.9742°E	26	60–70	1	♀		89	4300	BT	Sandy with coarse grains	Retrieved dead Deposited BMAU	OMN
Sa16	22/5/2021	Italy	Corcelli Isl., Sardinia	41.2970°N, 9.4019°E	11.2	40	1	♂		150	30000	TN		Released alive	BZ
Sa17	11/4/2022	Italy	Linosa Isl., Sicily	35.8548°N, 12.8764°E	16	35	1	♂		~150	40000	TN		Released alive	BZ
Sa18	7/9/2022		Between Rhodes and Turkey	36.7639°N, 25.2220°E	22		1	♀		120		BT		Released alive	BZ
So	6/1980	Italy	Marzamemi, Sicily		19		1			110.0				Dead and landed, sold	GI
So	18/8/1993	Italy	Banco Scalambri, south Sicily		16	250	1	♀	I	29.2		BT		Retrieved dead. Deposited MSNC4769	GI
So1	14/9/2005	Malta		35.8333°N, 14.1000°E	15		1			96.0					MEDLEM AD
So2	28/9/2005	Malta			15		1	♀		156.0					MEDLEM AD
So3	22/6/2006	Malta		35.7658°N, 14.6358°E	15	126	1					BT/ MEDITS			MEDITS
So4	11/2007	Tunisia	Bizerta	37.5203°N, 9.4047°E	12	150	1	♂		>80	~3000	BT	Sandy-muddy	Dead and landed, sold	JBS
So5	11/2007	Tunisia	Bizerta	37.5203°N, 9.4047°E	12	150	1	♀		>80	~3000	BT	Sandy-muddy	Dead and landed, sold	JBS
So6	11/2007	Tunisia	Bizerta	37.5203°N, 9.4047°E	12	150	1	♂		>80	~3000	BT	Sandy-muddy	Dead and landed, sold	JBS
So7	11/2007	Tunisia	Bizerta	37.5203°N, 9.4047°E	12	150	1	♂		>80	~3000	BT	Sandy-muddy	Dead and landed, sold	JBS
So8	11/6/2008	Malta		36.4092°N, 14.5762°E	15	145	1	♀	I	42	430	BT/ MEDITS			MEDITS
So9	12/6/2008	Malta		36.1785°N, 14.4470°E	15	173	1	♀	I	29.5		BT/ MEDITS			MEDITS
So10	12/6/2008	Malta		36.1785°N, 14.4470°E	15	173	1		I	32		BT/ MEDITS			MEDITS
So11	13/6/2008	Malta		35.7613°N, 14.6307°E	15	132	1	♂	I	37.5	520	BT/ MEDITS			MEDITS
So12	13/6/2008	Malta		35.8408°N, 14.7495°E	15	80	1	♀	M	94	7000	BT/ MEDITS			MEDITS
So13	17/6/2013	Malta		35.9690°N, 15.0960°E	15	101	1	♂	I	74	1680	BT/ MEDITS			MEDITS
So14	4/2014	Tunisia	Zarzis	33.5764°N, 11.6125°E	14	47	1	♂	A	>100		BT	Muddy	Dead and landed, sold	JBS

Table 1 continues on next page.

Table 1. cont.

ID	Date D/M/Y	Country	Place	Coordinates	GSA	Depth [m]	*n*	Sex	M	TL [cm]	TW [g]	Gear/ other	Bottom type	Status	Source of data
So15	5/2014	Tunisia	Zarzis	33.5383°N, 11.4928°E	14	26	1	♀	SA	<80		BT	Muddy	Dead and landed, sold	JBS
So16	12/2/2016	Italy	Off Scoglitti Sicily	36.7590°N, 14.4116°E	16	120	1	♀		70.5	3300	BT	Coralligenous, muddy	Frozen MSNC	GI
So17	6/2016	Malta			15		1	♂		77.5		TN		Discards	AD
So18	6/2016	Malta			15		1	♂		77.5		TN		Discards	AD
So19	6/2016	Malta			15		1	♀		97.0		TN		Discards	AD
So20	6/2016	Malta			15		1			71.0		TN		Discards	AD
So21	2/8/2016	Italy	Off Pozzallo, Sicily	36.5930°N, 14.6657°E	16	110	1	♂		74.7	3100	TN	Coralligenous, muddy	Frozen MSNC	GI
So22	15/8/2016	Malta			15	35	1	♀		~100		UW			GI
So23	17/3/2017	Italy	Off Scoglitti Sicily	36.7693°N, 14.3064°E	16	180	1	♂		73.4	2750	BT	Muddy	Frozen MSNC	GI
So24	28/6/2017	Italy	Off Marina di Ragusa Sicily	36.7256°N, 14.5197°E	16	50	1			98.0		TN	Coralligenous, muddy	Released	GI
So25	6/2017	Malta			15		1	♀	I	31.0		BT		Discards	AD
So26	6/2017	Malta			15		1	♀	I	29.5		BT		Discards	AD
So27	6/2017	Malta			15		1	♀	I	29.0		BT		Discards	AD
So28	30/8/2017	Italy	Off Scoglitti Sicily	36.7764°N, 14.4081°E	16	50	1	♀		90.3	6550	BT	*Posidonia* meadows, sandy	Frozen MSNC	GI
So29	5/2018	Malta			15		1	♀		94.5		BT		Discards	AD
So30	3/2019	Malta			15		1	♂		122.0		BT		Discards	AD
So31	3/2019	Malta			15		1	♂		75.0		BT		Discards	AD
So32	10/2019	Malta			15		1	♀	I	29.0		BT		Discards	AD
So33	28/3/2021	Egypt	Off El-Hamam	30.9599°N, 29.3287°E	26	55–70	1	♂		70	2741	BT	Sandy with coarse grains	Retrieved dead Deposited BMAU	OMN
So34	28/3/2021	Egypt	Off El-Hamam	30.9599°N, 29.3287°E	26	55–70	1	♀		49.2	841	BT	Sandy with coarse grains	Retrieved dead Deposited BMAU	OMN

Sa = *Squatina aculeata*; So = *Squatina oculata*; ID = species acronym and specimen identification number; GSA = GFCM geographical subarea; *n* = number of specimens; M = maturity; A = adult; I = immature; M = mature; P = pregnant; TL = total length [cm]; TW = total weight [g]; BT = bottom trawl; TN = trammel net; LL = longline; UW = underwater observation; MSNC = Museo Civico di Storia Naturale di Comiso, Ragusa, Italy; BMAU = Collections of the Biological Museum of the Department of Biological and Geological Sciences, Faculty of Education, Alexandria University, Egypt; MPA = Marine Protected Area; MEDITS = Mediterranean Trawl Survey; MEDLEM: Mediterranean Large Elasmobranchs Monitoring. Bold font denotes samples not considered in Results.

Results

Squatina aculeata. Among the 18 specimens of *S. aculeata* detected between 2007 and 2022, one specimen was incidentally captured in the western basin, off Sardinia (GSA11.2), 11 specimens were incidentally captured in the central Mediterranean, of which five from north Tunisian waters (GSA12), four from Malta (GSA15), one from Lampedusa, and Linosa (Italy) (GSA13) respectively, while the remaining six were found in the eastern basin, four in the Aegean Sea (GSA22), and two in the Egyptian waters (GSA26) (Table 1) (Figs. 1, 2). Ten specimens were caught by bottom trawling, three by longline, and four by trammel net, at depths from 35 m to 530 m, generally on the soft bottom. Apart from two females from Egypt with TL < 120 (Fig. 2B, E) and a juvenile female of 50 cm TL from Malta, the remaining specimens of both sexes had a TL ≥ 120 cm (Fig. 3A) (Table 1). The majority of the sawback angelsharks were captured in spring, followed by summer and winter (Fig. 3B). It must be emphasized that, during the handling of the female caught off Lampedusa Island (Sa10, Table 1), two fetuses of about 15 cm in length were recovered on board (video available at https://youtu.be/6LQTrvzTQTQ). The fetuses carried a yolk sac attached to their ventral side. The live female and fetuses were immediately released.

Squatina oculata. Among the 34 specimens of *S. oculata* incidentally captured or observed between 2005 and 2021, the majority (32 specimens) were found in the central Mediterranean, of which 21 specimens were detected off Malta Island (GSA15) (Fig. 4A1, A2), six off Tunisia (GSA12 and GSA14), and another five off south of Sicily, Italy (GSA16) (Fig. 4B), while the remaining two smoothback angelsharks were fished in the eastern basin, Egypt, GSA26 (Figs. 1, 4C, D) (Table 1).

Sex was determined in 29 smoothback angelsharks, 16 females and 13 males (Table 1). One specimen of *S. oculata* was observed at 35 m of depth during scuba diving, six specimens were caught with trammel nets, and 25 with bottom trawls, at depths from 26 m to 180 m, generally on muddy or muddy sandy bottoms, but also on *Posidonia oceanica* or other vegetated seabeds (Fig. 4A1, A2) (Table 1).

Eleven specimens had a TL between 41 cm and 80 cm and another 12 between 81 cm and 120 cm (Fig. 3A). Total length for both sexes and undetermined sex ranged from 29 cm to 156 cm (69.0 ± 32.4 cm, *n* = 25); total

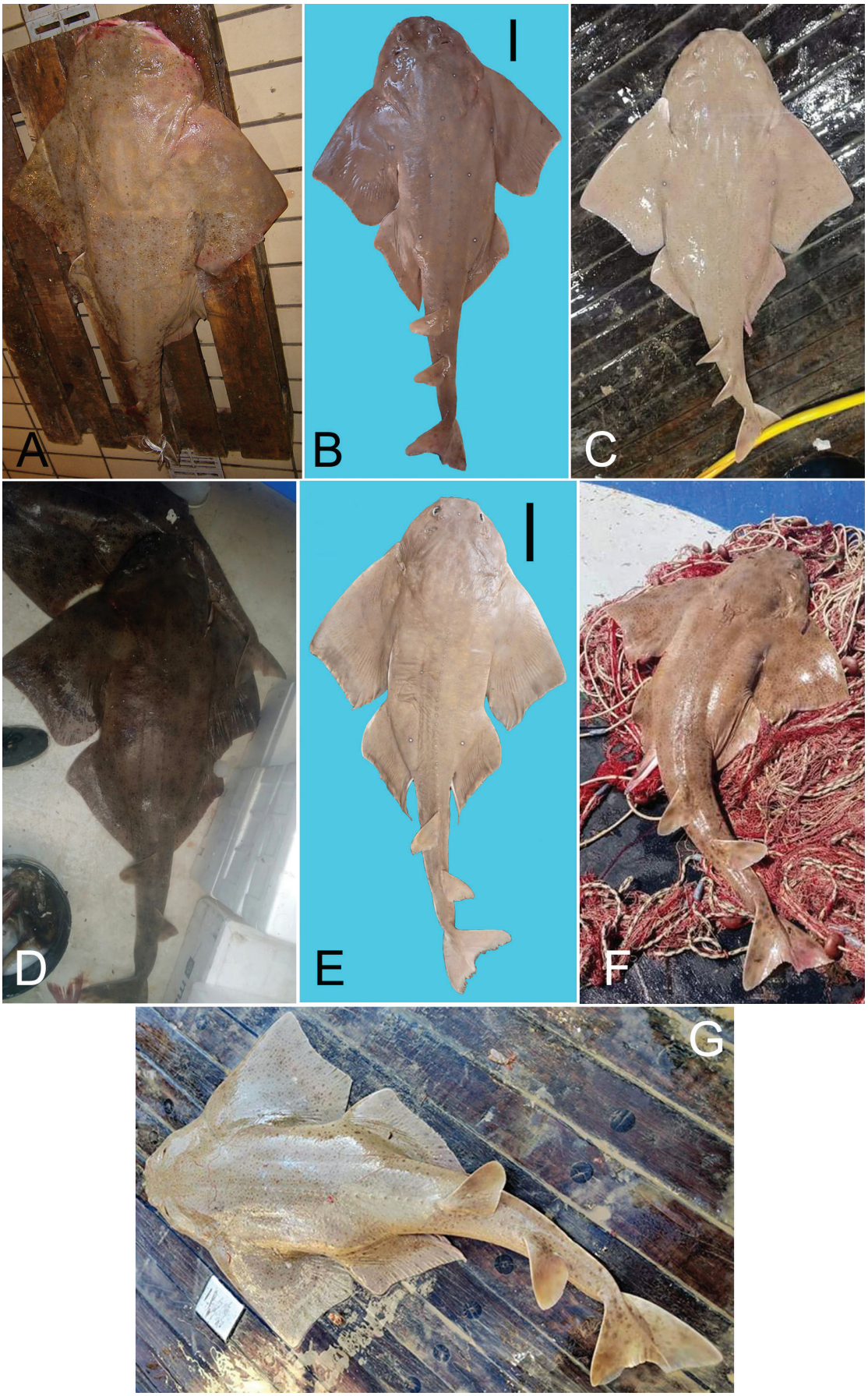

Figure 2. Specimens of *Squatina aculeata* from the Mediterranean Sea. Letters correspond to the following acronyms in Table 1: A = Sa3 (Photo by G. Nowell), B = Sa11, E = Sa15 [Scale bar: 10 cm] (Photos by O.M. Nour), C = Sa12 (Photo by G. Pilla), D = Sa13 and Sa14 (Photo by H. Kioukekli), F = Sa16 (Photo by E. Vitiello), G = Sa18 (Photo by G. Pilla).

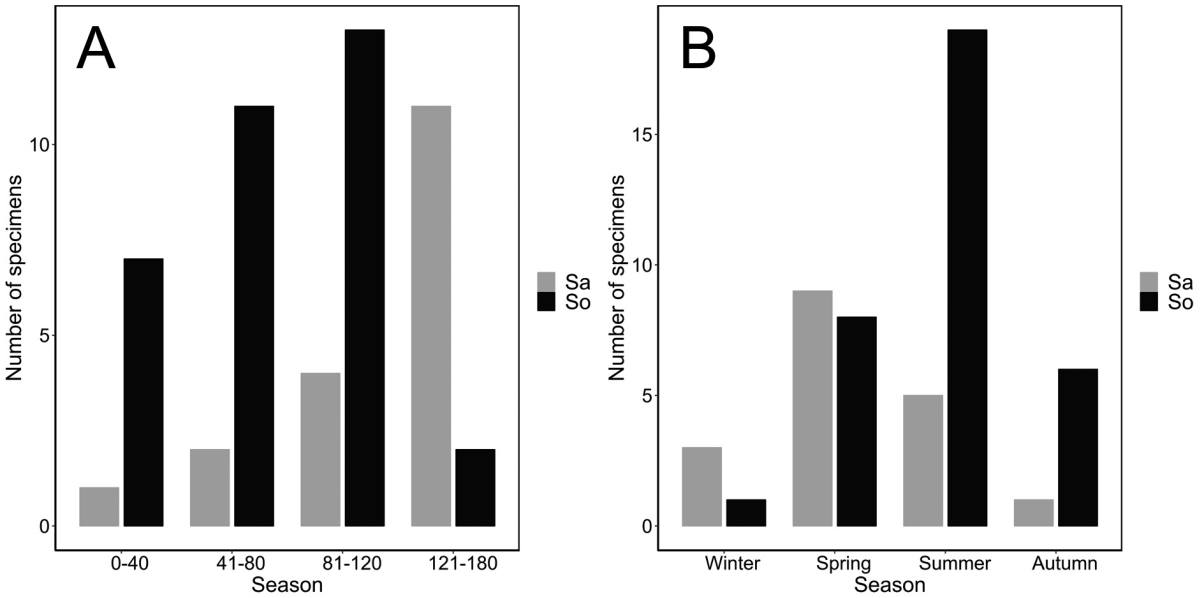

Figure 3. Total length distribution of *Squatina aculeata* (Sa) and *Squatina oculata* (So) detected between 2005 and 2022 in the Mediterranean Sea (**A**) and seasonal distribution of findings (**B**).

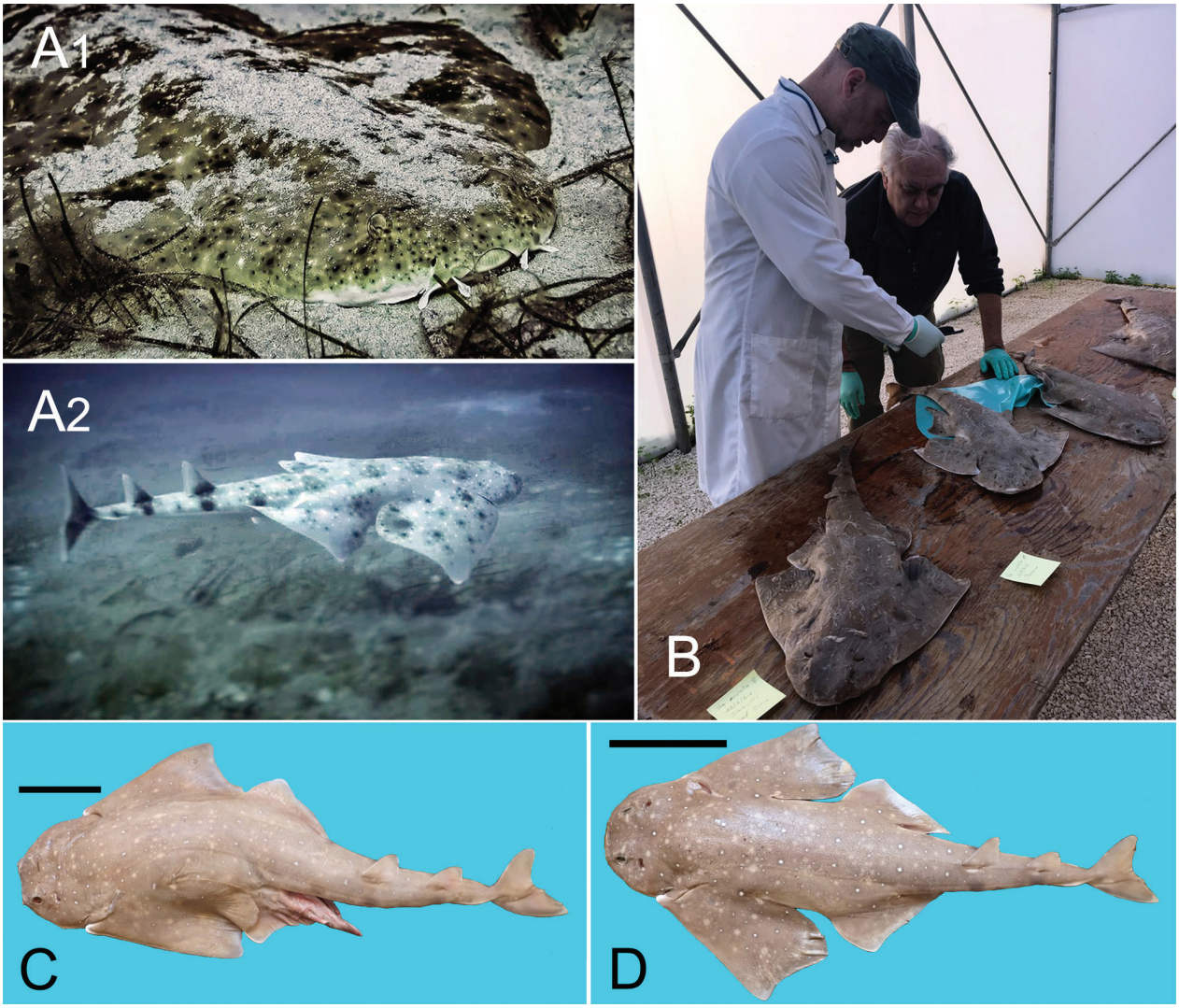

Figure 4. Specimens of *Squatina oculata* from the Mediterranean Sea. Letters correspond to the following acronyms in Table 1: A1 and A2 = So22 (Photos by J. Kuenzel); B = So16, So21, So23, So28 (Photo by G. Polizzi); C = So33, D = So34 (Photos by O.M. Nour) [Scale bars: 10 cm].

length ranged from 29 cm to 156 cm for females (64.7 ± 39.5 cm, n = 13), and from 37.5 cm to 122 cm for males (75.7 ± 21.4 cm, n = 9) (Table 1). The majority of *S. oculata* specimens were captured during the summer, followed by the spring (Fig. 3B).

In addition to the TW and TL measurements determined in 10 specimens of the presently reported study (Table 1), values from 21 Mediterranean specimens were retrieved from the literature for the TW–TL relation (Başusta et al. 1998; Kabasakal and Kabasakal 2004; Corsini and Zava 2007; Zava et al. 2016; Ergüden et al. 2019; Yığın et al. 2019; Özgür Özbek and Kabasakal 2022; Lteif unpublished*). The TW–TL relation for the above 31 specimens (TL 24–95 cm, TW 71–7000 g) resulted in $TW = 0.0038 \cdot TL^{3.1602}$ ($R^2 = 0.974$). The value of the estimated parameter b indicated a positive allometric growth.

During the examination of the stomach content of the 4 specimens stored at the MSNC, only the remains of flatfish eyes were observed, as for *S. aculeata* examined by Zava et al. (2020).

Two records of *S. oculata*, the first reported in 1980 and the second in 1995, are listed in Table 1 for historical reasons, but not considered in the Results.

Discussion

The results showed that *S. aculeata* and *S. oculata* are bycatch species mainly of bottom trawlers, as for *S. squatina*, but they are also impacted by trammel nets and longlines (Serena 2005; Lawson et al. 2020; Zava et al. 2020). The number of specimens released alive was insignificant compared to the number of specimens retrieved dead and sold or discarded. Both species were recorded in relatively shallow waters off Tunisia, south Sicily, Malta, and Egypt regions (26–180 m), apart from one *S. aculeata* from the southeastern Aegean Sea, caught in deep waters (530 m), as for the 60% of the sawback angelsharks listed in Zava et al. (2020). The majority of records of the two angelshark species considered here were reported during summer, followed by spring, both in the central and eastern Mediterranean. These results are probably due to more suitable weather conditions in spring and summer and the consequent intensification of fishery activities during these seasons. In Ragonese et al. (2013) no captures of these species were reported in spring and summer along the bottom trawl surveys carried out off the southern coasts of Sicily (1994 to 2009), while in Zava et al. (2020) the majority of *S. aculeata* were detected in winter.

The records listed in the presently reported study for both species were based predominantly on observations made by fishermen, observers on board, or observers of landings, accompanied in most cases by inaccurate measurements of total length and/or weight that evidently limited the availability of data for further biological study. The parameters obtained for the relation TW–TL of *S. oculata* were comparable to those obtained by Capapé et al. (2002) and Ellis et al. (2021), although the number of Mediterranean *S. oculata* specimens considered (n = 31) (ten of the presently reported study and 21 from literature), was significantly lower than the number of specimens from Senegal (n = 121, females), while it was similar to the number of specimens from the southeast Atlantic (n = 32) studied by the above-mentioned authors. Concerning *S. aculeata*, efforts to build a TW–TL relation for Mediterranean specimens have been recently applied (Zava et al. 2020).

Considering *S. oculata*, and according to Capapé et al. (1990, 2002), Miller (2016), and Ellis et al. (2021), the size of about all males corresponded to mature individuals (TL > 70 cm), while seven females were juveniles (TL < 70 cm), one sub-adult and four females had a size of mature individuals (TL > 90 cm). Almost all specimens of *S. aculeata* of both sexes were adults, apart from two subadult females from Egypt (cf. Capapé et al. 2005).

The occurrence of *S. oculata* juveniles in the waters off Malta and of a pregnant female *S. aculeata* off Lampedusa, as well as the occurrence of adults of both species in the region between the strait of Sicily and Malta, indicate that this area constitutes an important habitat and a nursery ground for both species (Zava et al. 2016, 2020).

Concerning the waters around the Malta Archipelago, it is to be noted that an old taxidermized specimen of *S. oculata* is displayed at the National Museum of Natural History in Mdina, Malta (Fig. 5), testifying that the species also occurred in the past in the area. After the accurate revision of shark and ray species records in the Maltese Islands by Schembri et al. (2003), the occurrence of the smoothback angelshark was considered rare or not frequent and the need for validation was therefore underlined. The findings of all sizes of *S. oculata* in the presently reported study over the last fifteen years ascertain the current presence of the species off Malta, confirming nevertheless that it is uncommon in the area.

Going back to historical documentation on *S. oculata* from Sicily, two stuffed specimens were stored at the Zoological Museum "Pietro Doderlein" of the University of Palermo (catalog numbers P-563 and P-564, Doderlein 1878–1879) (Fig. 6). The label of the display specifies that it was collected in "Mar di Palermo", in the sea of Palermo, northwest of Sicily. Furthermore, a female *S. oculata* could be noted in a postcard showing the fish market of Portopalo di Capo Passero, at the southeastern tip of Sicily, during the 1980s (Fig. 7). Finally, in June 1980, the capture of a large specimen at Marzamemi, southeastern Sicily, was registered by the curator of the MSNC, while a juvenile female *S. oculata* (TL 29.2 cm),

* Lteif M (2015) Biology, distribution and diversity of cartilaginous fish species along the Lebanese coast, eastern Mediterranean. Ecology, environment. PhD Thesis, Université de Perpignan, France, 262 pp.

Figure 5. Stuffed *Squatina oculata* displayed at the National Museum of Natural History in Mdina, Malta (Photo by B. Zava , 2016).

caught on 18 August 1993 by bottom trawl at 250 m of depth off Marina di Ragusa, southeastern Sicily is stored at the MSNC (MSNC4769) (Table 1).

As regards the Italian seas, the range of *S. aculeata* has been reported only for the Ligurian and southern Tyrrhenian waters in Vacchi and Serena (2010). The occurrence of the sawback angelshark in the south Tyrrhenian Sea has, in fact, been recently confirmed (Zava et al. 2020). Due to the lack of data over a long period from the northern Tyrrhenian Sea (Ferretti et al. 2005; Miller 2016), the species has been considered doubtfully present or absent in Sardinian waters (Gordon et al. 2019; Lawson et al. 2020). Consequently, the recent finding of *S. aculeata* in the shallow waters off the northeast of Sardinia, described in the presently reported study, is especially noteworthy. This surprising record probably denotes the existence of a suitable habitat, perhaps hitherto unexplored and unknown for the species.

The records described, substantiate furthermore that populations of *S. aculeata* dwell in the southern Aegean, as observed in Zava et al. (2020 and references therein) and Lawson et al. (2020 and references therein).

All three species of angelsharks are listed among the ichthyofauna of the Mediterranean Egyptian waters (Akel and Karachle 2017), but their presence is considered uncertain or very rare (Morey et al. 2019a, 2019b; Lawson et al. 2020), due to the lack of observations over a long period. In studies conducted off Alexandria in the last decade, the occurrence of *S. squatina* has been documented (Moftah et al. 2011; Azab et al. 2019). The records here described of *S. oculata* and *S. aculeata* in the same area, off Alexandria, are therefore remarkable, not only

Figure 6. Stuffed *Squatina oculata* (female) displayed at the Zoological Museum "Pietro Doderlein", University of Palermo, Italy (catalog number P-563) (Photo by B. Zava, 2014).

Figure 7. *Squatina oculata* at the fish market of Portopalo di Capo Passero, Sicily, in the 1980s. (Postcard) (Dino Oliva, kind permission. https://www.facebook.com/portopalodiunavolta).

because they verify their current occurrence in the Mediterranean waters of the country, but because they contribute furthermore to enrich the poorly known geographical distribution of both species in the southern waters of the Levantine basin.

Conclusions

Understanding the life-history strategies of endangered elasmobranchs and increasing our knowledge about their spatial distribution have important implications for conservation purposes. Given the high risks of extinction of the angelsharks in the Mediterranean Sea, effective protective measures across international boundaries should be adopted through the identification of critical habitats and knowing the period of key life-history events, namely, mating, spawning, and pupping. In addition, it would be advisable to implement protective measures in order to reduce mortality levels stemming from commercial fisheries.

The results of this study could be used to design *ad hoc* spatial protective measures limiting commercial fishing, for example, around the shallow waters in Lampedusa and Maltese Archipelago, preserving crucial habitats and potential nursery areas for *S. oculata* and *S. aculeata*. In parallel, it will be important to carry out awareness campaigns for fishermen by informing them of the vulnerability of the species and how to handle and release safely the captured individuals, so avoiding death and possible sale to the fish market.

Results of this study also indicate that the network of well-trained professional fishermen, and fisher amateurs, along with researchers, can be considered an ever-growing source of data on wildlife, which can fill the gaps of knowledge on the occurrence and distribution of threatened elasmobranch species in poorly known habitats.

Indeed, thanks to this well-structured network of experts, it was possible to update the spatial distribution of Mediterranean angelsharks, reporting for the first time the occurrence of *S. aculeata* in waters off the northeast of Sardinia and confirming the presence of *S. aculeata* and *S. oculata* in the Egyptian waters where they had been hitherto considered uncertain or very rare.

This stressed the necessity of enlarging the Mediterranean network interested in collecting information about angelsharks and activating a long-term monitoring project to obtain a more homogeneous and realistic description of the presence and distribution of these species throughout the whole Mediterranean basin, in order to estimate their relative abundance and to identify critical habitats in nearshore areas in terms of mating and pupping.

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PENSOFT

ACTA ICHTHYOLOGICA ET PISCATORIA

New record of anthiadine fish, *Plectranthias yamakawai* (Actinopterygii: Perciformes: Serranidae), from the Philippines

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Abstract

A single specimen of *Plectranthias yamakawai* Yoshino, 1972, 168.86 mm SL, obtained in a fish market in Zambales, Philippines, represents the first report in the country. Currently, the fish is only known to occur in Japan, Taiwan, and Samoa Islands. This anthiadine fish varies from other species of genus *Plectranthias* by having 30–33 lateral-line scales, a single red blotch below the lateral line, and numerous dark green blotches on the upper half of the body. The mitochondrial cytochrome oxidase subunit I (*COI*) is also described for the first time for this species in this article. The pairwise genetic distance computation reveals that *P. yamakawai* has a very low distance from the sequences of the other eight species of *Plectranthias* that have been submitted to GenBank. This is the sixth species of the genus *Plectranthias* to be reported from the western coast of Luzon, Philippines.

Keywords

Anthiadinae, *COI*, morphology, serranids, taxonomy, Zambales

Introduction

The genus *Plectranthias* Bleeker, 1873 was initially revised by Yoshino (1972), who also recognized the two species *Plectranthias anthioides* (Günther, 1872) and *Plectranthias yamakawai* Yoshino, 1972. Subsequently, Randall (1980) made a thorough revision of the genus, naming additional 13 species, and mentioning that *P. anthioides* identified by Yoshino (1972) was a synonym of *Plectranthias kamii* Randall, 1980. The revision made by Randall (1980) was later followed by the identification of 31 new species (Fricke et al. 2022). Fishes of the genus *Plectranthias* are members of the subfamily Anthiinae, which Anderson (2022) noted had been elevated to the familial level, and Dornburg and Near (2021) recognized them as belonging to the family Anthiadidae. However, the current paper recognizes this specimen as a member of the family Serranidae since no morphological evidence has been provided by Dornburg and Near (2021).

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The genus *Plectranthias* is one of the 29 genera that make up the subfamily Anthiadinae (Anderson 2018). This group is widely distributed throughout the tropical to subtropical seas of the Indo–Pacific and the western Atlantic and can be found in shallow to deeper waters (2–400 m) (Allen and Walsh 2015; Tang et al. 2020; Fricke 2021). This genus is distinguishable from other genera by its 10 dorsal spines, which are connected to the 13–20 dorsal-fin soft rays; three anal spines with 6–8 anal-fin soft rays; 12–18 pectoral-fin rays; 8–46 lateral-line tubed scales; absence of auxiliary scales on head or body; presence of teeth on the vomer and palatine but not on the tongue; having a V- or U-shaped vomer tooth patch; 26 (rarely 27) total vertebrae count, and presence of 12–31 total gill rakers (Gill et al. 2021). These fishes are difficult to catch using hook and line or bottom trawling, and they are also challenging to approach while scuba diving, and this, apparently, accounts for their underrepresentation in museum collections (Chen and Shao 2002; Heemstra and Randall 2009). Currently, there are 65 valid species of the genus (Fricke et al. 2022; Koeda et al. 2022), and only five species have been documented in the Philippines: *Plectranthias foresti* Fourmanoir, 1977; *Plectranthias inermis* Randall, 1980; *Plectranthias japonicus* (Steindachner in Steindachner et Döderlein, 1883); *Plectranthias knappi* Randall, 1996; and *Plectranthias sagamiensis* (Katayama, 1964) (see Fricke et al. 2022). With this report, *P. yamakawai* will now be included in the short list of the genus known from the waters of the Philippines.

Plectranthias yamakawai was firstly described by Yoshino (1972) from the Okinawa and Amami Islands. Wada et al. (2020) documented additional specimens from different islands of the Ryukyu Archipelago, which include Osumi, Yaeyama, and Tokara Islands, at depths of 100–300 m while Motomura and Harazaki (2017) reported the largest specimen, measuring 230.7 mm SL from Yaku-shima Island, Osumi Islands at 100 m deep. It has also been reported in Taiwan (Chen and Shao 2002) and Samoa in the South Pacific (Wass 1984). To our knowledge, no publication has provided a DNA barcode sequence of *P. yamakawai*. Thus, this publication will not only be the first to report the occurrence of this species in Philippine waters but also its mitochondrial cytochrome oxidase subunit I gene (*COI*), which is important for the validation of species identification.

Methods

A single specimen of *Plectranthias yamakawai* was collected in a fish market in Zambales Province, Western Luzon, Philippines. The specimen was transported to the University of the Philippines Visayas (UPV), Miagao, Iloilo in an insulated ice cooler with crushed ice. Curatorial techniques followed Motomura et al. (2013). All measurements were taken using a digital caliper to the nearest 0.01 mm and followed Hubbs and Lagler (1947). For the proportional measurement, the standard length (SL) and head length (HL) were used, and the results were compared to the measurement of Yoshino (1972).

Muscle tissue was collected from the nape area on the right side of the fish and preserved in absolute ethanol. DNA extractions were carried out according to the instructions of the GF-1 Nucleic Acid Extraction Kit (Vivantis Technologies Sdn. Bhd, Malaysia). The combination of the forward and reverse primers below designed by Ward et al. (2005) was used to amplify the mitochondrial cytochrome c oxidase subunit I (*COI*) gene:

FishF1 – 5′TCAACCAACCACAAAGACATTGGCAC3′
FishR1 – 5′TAGACTTCTGGGTGGCCAAAGAATCA3′

The 25 µL PCR reaction was composed of 18.4 µL nuclease-free water, 2.25 µL 10× buffer, 1.25 µL $MgCl^2$ (25 mM), 0.5 µL dNTP mix (10 mM), 0.25 µL of each primer, 0.1 µL Taq DNA polymerase (Vivantis Technologies Sdn. Bhd, Malaysia), and 2 µL DNA template. The PCR thermocycling conditions used are as follows: initial step at 95°C for 2 min, 35 cycles of 94°C for 30 s (denaturation), 54°C for 30 s (annealing), and 72°C for 1 min (extension), with a final extension at 72°C for 10 min. The PCR products were visualized using 1% agarose gel with gel red. Purification of PCR products was carried out using GF-1 PCR Clean-up Kit. The genomic DNA was quantified using a MultiSkanTM Skyhigh Microplate Spectrophotometer (Thermo Fisher Scientific). The PCR products were sent to Macrogen Inc. (South Korea) for sequencing. Consensus sequences were formed, cleaned, and trimmed using Unipro EUGENE software (Okonechnikov et al. 2012). The generated sequence was checked against *COI* sequences in GenBank using the Basic Local Alignment Search TOOL (BLAST) of the National Center for Biotechnology Information (NCBI). Using the Mega X software (Kumar et al. 2018), the phylogenetic tree was constructed using the Neighbor-joining (NJ) method (Saitou and Nei 1987), computed using the Kimura 2-parameter (K2P) model (Kimura 1980), and a bootstrap test of 1000 replicates (Felsenstein 1985). The pairwise distance between the sequences was computed using the Kimura 2-parameter model (Kimura 1980), and standard error estimates were obtained by a bootstrap procedure (1000 replicates). A total of 15 nucleotide sequences from 8 different species of genus *Plectranthias* that were submitted to GenBank were included in the analysis.

Results

Family Serranidae Swainson, 1839
Plectranthias Bleeker, 1873

Plectranthias yamakawai Yoshino, 1972

(Figs 1 and 3; Tables 1 and 2)

Material examined. UPVMI-01360, 168.86 mm SL, Zambales fish market, the Philippines, 1 March 2022, leg. R.P. Babaran.

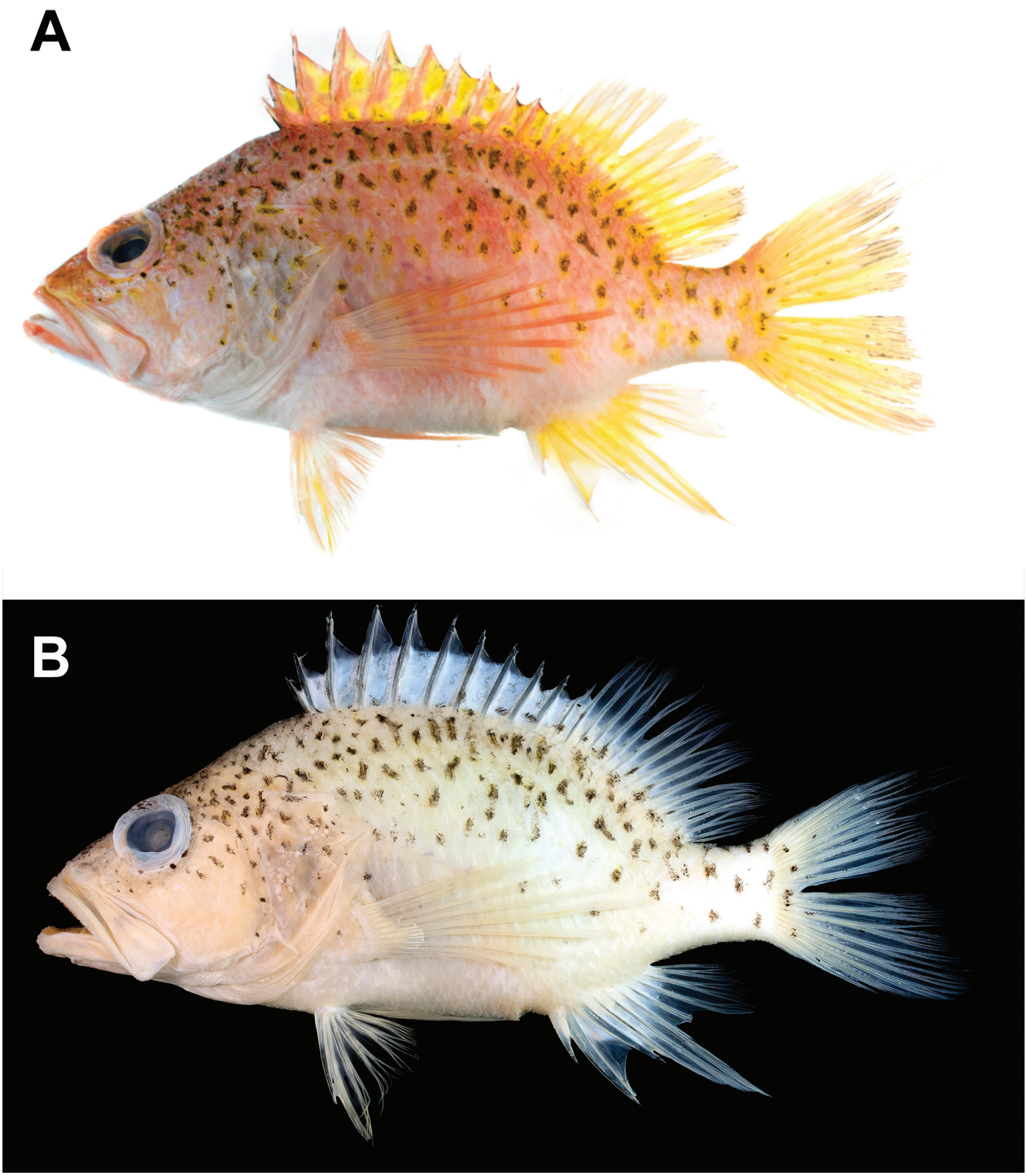

Figure 1. Images of fresh (**A**) and preserved (**B**) *Plectranthias yamakawai*, UPVMI-01360, 168.86 mm SL collected off Zambales, Western coast of Luzon, the Philippines.

Morphological diagnosis and description. Single specimen of *Plectranthias yamakawai* had following combination of characters: dorsal-fin spines X, dorsal-fin soft rays 18, anal-fin spines III, anal-fin soft rays 7, pectoral-fin rays 13, lateral-line scales 31, scales above lateral line 5, scales below lateral line 17, and gill rakers 6 + 10. Body compressed, moderately deep, depth 2.18 in SL; head large (length 2.19 in SL, depth 3.86 in SL), slightly convex dorsally. Mouth large, terminal; maxilla large, expanded easily, exposed when mouth closed; lower jaw significantly extending beyond upper jaw; opercle consisting of three spines (middle spine strongest and longest); preopercle serrated with three antrorse spines on lower margin of left side and two spines on right side; subopercle and interopercle margins not serrated. Teeth on both jaws minute; two enlarged conical teeth on right side and three on left side positioned anterior of upper

Table 1. A comparison of the counts and measurements of *Plectranthias yamakawai* from the Philippines (this study) with those of the Japanese holotype (Yoshino 1972).

Character	Holotype FAKU-44565	This study UPVMI-01360)	Difference [percentage point]
Meristics	X, 17	X, 18	
Anal fin	III, 7	III, 7	
Pectoral fin	13	13	
Gill rakers	6 + 10	6 + 10	
Lateral-line (LL) scales	33	31	
Scales above LL	—	5	
Scales below LL	—	17	
In %SL			
Head length	43.48	45.68	2.2
Head depth	—	25.92	
Body depth	37.17	45.86	2.4
Pectoral-fin length	35.34	39.84	4.5
Dorsal-fin base	—	57.79	
Anal-fin base	—	16.95	
Pectoral-fin base	—	8.24	
Pelvic-fin base	—	4.61	
In %HL			
Snout length	23.36	28.55	5.2
Maxillary length	44.44	45.02	0.6
Eye diameter	25.25	26.26	1.0
Interorbital width	13.81	10.40	–3.4
Pre-dorsal length	—	53.86	
Post orbital head length	56.18	50.29	–5.9
Caudal peduncle depth	31.25	28.31	–2.9
Caudal peduncle length	43.48	33.48	–10.0
Ventral fin length	47.17	49.97	2.8
Ventral spine length	27.86	31.13	3.3
3rd dorsal spine length	30.30	30.70	0.4
4th dorsal spine length	33.33	34.33	1.0
5th dorsal spine length	—	32.51	
Last dorsal spine length	17.54	20.34	2.8
Length of longest soft dorsal ray	41.49	Damaged	
1st anal spine length	15.27	18.27	3.0
2nd anal spine length	31.75	37.57	5.8
3rd anal spine length	28.57	35.84	7.3

FAKU-44565, 173.2 mm SL; 75.3 mm HL. UPVMI-01360, 168.86 mm SL; 77.14 mm HL.

jaw; single, enlarged, conical tooth positioned in middle area on both sides of lower jaw. Both vomerine and palatine patches consisting of villiform teeth; vomerine tooth patch V-shaped while palatine tooth patches narrow band-shaped. Teeth on tongue absent; base of tongue broad becoming narrow at front end. Scales on body large, ctenoid in shape; head area covered with scales except for snout, lips, maxillary, and ventral area; operculum completely covered with large scales; nape area covered with smaller scales; dorsal-, anal-, and pectoral-fin bases with small scales. Dorsal-fin spines stiff and connected to dorsal-fin soft rays; 4th dorsal-fin spine longest (26.48 mm vs. 5th spine 25.08 mm and 3rd spine 23.68 mm). Anal-fin spines long and rigid; 2nd anal-fin spine as longest (28.98 mm vs. 1st spine 14.09 mm and 3rd spine 27.65 mm). Pectoral-fin rays long, longest fin ray reaching beyond posterior end of anal-fin base, 1st pectoral-fin ray unbranched; 2nd–13th pectoral-fin rays branched. Pelvic fin inserted anterior to pectoral-fin base; longest pelvic-fin ray not reaching anus. Caudal fin emarginate; 5th–7th upper lobe-fin rays filamentous.

Color in fresh sample. Body reddish-yellow (dorsal side) and white (ventral area) (Fig. 1A); yellow-fringed dark greenish blotches scattered on upper half of body and head; similar blotches present in entire caudal peduncle, dorsal- and caudal-fin bases; smaller blotches observed in pre-dorsal area; large red spot located just below lateral line and center of body; pectoral fin reddish; dorsal, anal, pelvic, and caudal fin reddish-yellow; posterior end of dorsal-fin soft rays and caudal-fin ray edges both black.

Color of preserved sample. Body light brown (Fig. 1B); dark green blotches still visible; red spot faded; fins colorless; posterior end of dorsal-fin soft rays and caudal-fin ray edges remain black.

Distribution. *Plectranthias yamakawai* is commonly collected from various fishing grounds in Ryukyu Islands, Japan (Yoshino 1972; Motomura and Harazaki 2017; Wada et al. 2020), and reports of it have also come from Taiwan (Chen and Shao 2002), and Samoan Islands (Wass 1984), as well as the western coast of Luzon Philippines (Fig. 2).

Table 2. Pairwise genetic distance calculated using the K2P model between the *COI* gene sequences of *Plectranthias yamakawai* from the Philippines (this study) and the 15 sequences of different species of *Plectranthia*s from GenBank. The number of base substitutions per site is given between the sequences. The standard error estimate(s) indicated above the diagonal were obtained using a bootstrap procedure (1000 replicates).

UPVMI-01360 *P. yamakawai* (E510)	—	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02
KT601636_1 *P. bennetti* Australia	0.17	—	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
MF123989_1 *P. winniensis* Israel	0.19	0.20	—	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02
MF123988_1 *P. winniensis* Israel	0.19	0.20	0.00	—	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02
KC565480_1 *P. flammeus* Marquesas	0.21	0.20	0.22	0.22	—	0.00	0.00	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
KC565479_1 *P. flammeus* Marquesas	0.21	0.20	0.22	0.22	0.00	—	0.00	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
KC565478_1 *P. flammeus* Marquesas	0.21	0.20	0.22	0.22	0.00	0.00	—	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
KC565477_1 *P. flammeus* Marquesas	0.21	0.20	0.22	0.22	0.00	0.00	0.00	—	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
KC567663_1 *P. fourmanoiri* Marquesas	0.19	0.17	0.18	0.18	0.21	0.21	0.21	0.21	—	0.00	0.02	0.02	0.02	0.02	0.02	0.02
KC567662_1 *P. fourmanoiri* Marquesas	0.19	0.17	0.18	0.18	0.21	0.21	0.21	0.21	0.00	—	0.02	0.02	0.02	0.00	0.02	0.02
JQ432004_1 *P. longimanus* French polynesia	0.20	0.23	0.22	0.22	0.16	0.16	0.16	0.16	0.23	0.23	—	0.02	0.03	0.00	0.02	0.00
KU943548_1 *P. kamii* Taiwan	0.09	0.21	0.21	0.21	0.22	0.22	0.22	0.22	0.22	0.22	0.22	—	0.02	0.00	0.02	0.02
KU943449_1 *P. japonicus* Taiwan	0.18	0.17	0.20	0.20	0.20	0.20	0.20	0.20	0.15	0.15	0.25	0.18	—	0.00	0.02	0.03
KU943448_1 *P. japonicus* Taiwan	0.18	0.17	0.20	0.20	0.20	0.20	0.20	0.20	0.15	0.15	0.25	0.18	0.00	—	0.02	0.03
KC565483_1 *P. winniensis* Marquesas	0.19	0.21	0.10	0.10	0.20	0.20	0.20	0.20	0.18	0.18	0.21	0.22	0.20	0.20	—	0.02
KC565481_1 *P. nanus* Marquesas	0.20	0.23	0.22	0.22	0.16	0.16	0.16	0.16	0.22	0.22	0.00	0.22	0.25	0.25	0.21	—

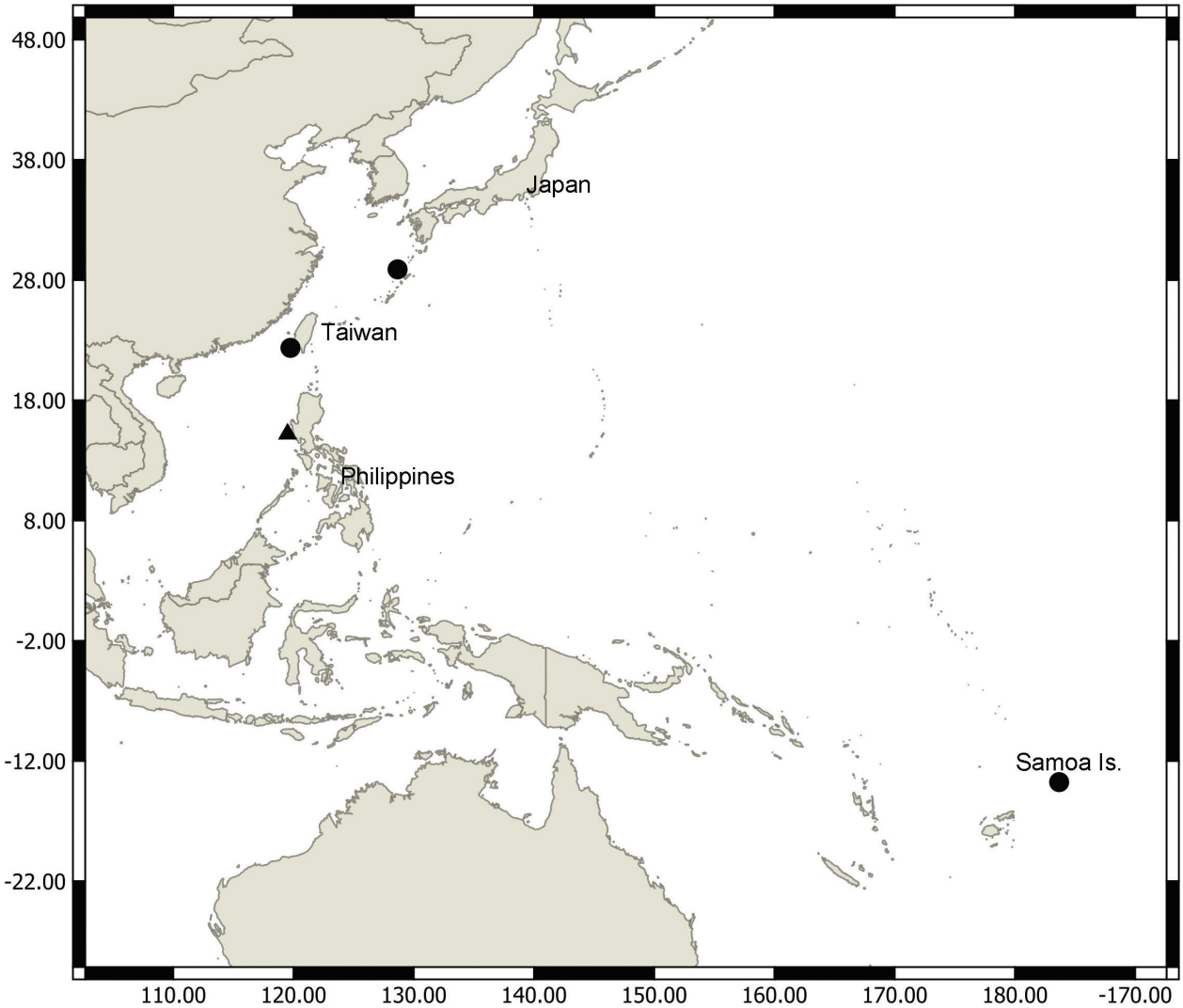

Figure 2. Distribution of *Plectranthias yamakawai*, based on published records and the presently reported study.

Previous Philippine records. Three of the five species of *Plectranthias* previously documented in the Philippines have been described as new species based on the Philippine specimens, *P. foresti*, *P. inermis*, and *P. knappi*, while the other two are documented as new records (*P. japonicus* and *P. sagamiensis*). *Plectranthias foresti* was described based on four specimens trawled at depths of 183–185 m off southwestern Luzon (Fourmanoir 1977; Randall 1980). *Plectranthias knappi*, was discovered in the Visayan Sea from a single specimen obtained at 90 m deep (Randall 1996). Similarly, the holotype of *P. inermis* was collected from Batangas, Southern Luzon Region, Philippines at 30 m deep, with later reports of the species from Mauritius, Christmas Island, Fiji, and Papua New Guinea (Randall 1980; Fricke et al. 2022). *Plectranthias sagamiensis*, originally described in Japan (Katayama 1964) was later collected off southwest Luzon at depths of 82–86 m and served as the first report of the species in the Philippines (Iwamoto and McCosker 2014). *Plectranthias japonicus* was originally described in Japan (Steindachner and Döderlein 1883) and first reported by Randall (1980) taken from 185–200 m off Manila Bay, Philippines.

Discussion

The presently reported specimen was identified as *Plectranthias yamakawai* based on the following characteristics: a single large red spot located just below the lateral line, yellow-fringed dark greenish spots scattered on the upper half of the body and head, 4th and 5th dorsal spine longer than the 3rd dorsal spine, and 30–33 lateral-line scales (Yoshino 1972; Randall 1980, 1996; Chen and Shao 2002; Wu et al. 2011; Wada et al. 2020). The specimen also matches the colored photograph provided by Motomura et al. (2019). According to Yoshino (1972), *P. yamakawai* and *P. anthioides*, which were later regarded as synonyms of *P. kamii* by Randall (1980), resemble each other in general appearance, but the former varies from the latter by having fewer lateral-line scale count (30–33 vs. 35–36), 4th dorsal spine is the longest instead of the 3rd spine. Moreover, *P. yamakawai* reported by Hobbs et al. (2014) from Christmas Island was a misidentified specimen of *P. kamii*. However, *P. yamakawai* can further be distinguished from *P. kamii* based on body coloration; *P. yamakawai* has numerous evenly distributed

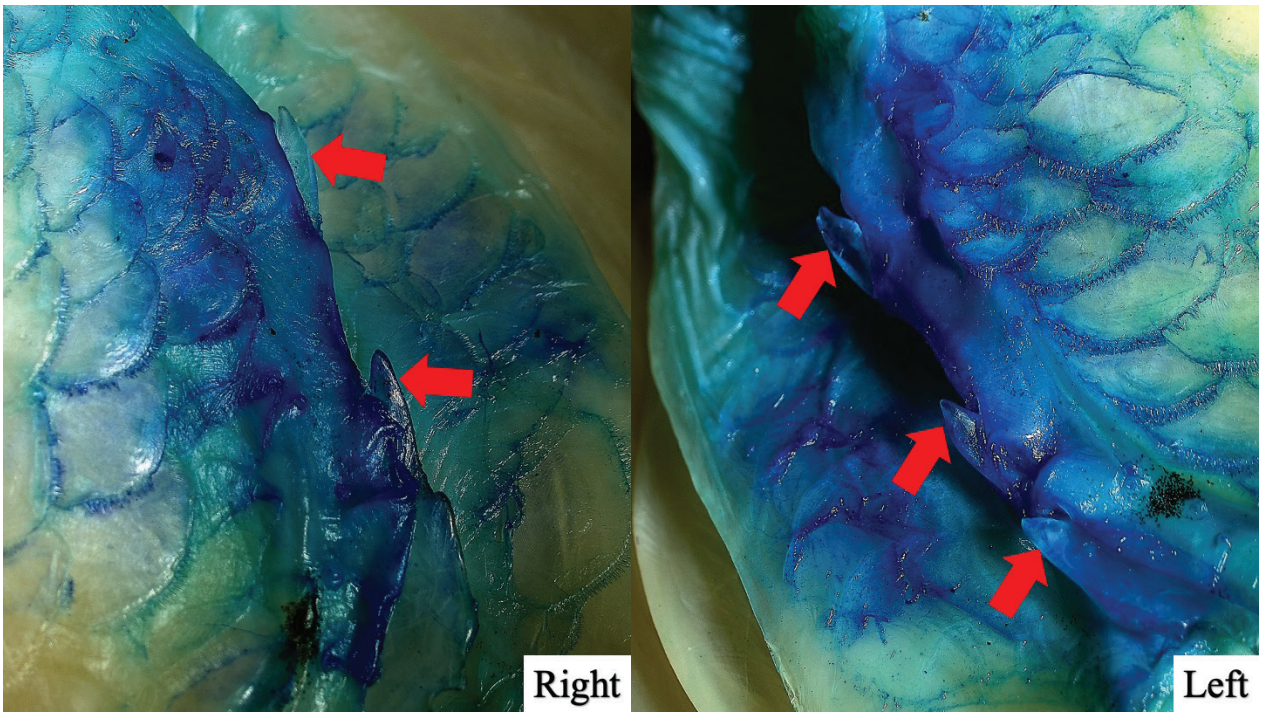

Figure 3. Antrorse spines observed on both sides of the *Plectranthias yamakawai* from the Philippines.

dark greenish spots on the upper half of the body while *P. kamii* has several orange patches on top of the head and upper half of the body, as well as similar coloration along the dorsal base and irregular longitudinal patches along the mid-side of the body. In addition, *P. kamii* lacks the single large red spot located just below the lateral line which was observed in the previous *P. yamakawai* specimens (Yoshino 1972; Gill et al. 2021) and in the presently reported study.

Plectranthias yamakawai has a lateral-line scale count similar to *Plectranthias whiteheadi* Randall, 1980 and *Plectranthias sheni* Chen et Shao, 2002; however, *P. yamakawai* differs from these two species due to distinct colored spots on the body as compared to the yellowish pink with a series of golden blotches on the body of *P. sheni* and the presence of two rows of large dark red blotches located dorsally on the body of *P. whiteheadi* (Chen and Shao 2002). Moreover, *P. yamakawai* varies from *P. sheni* by having the 4th dorsal spine as the longest instead of the 3rd spine.

Yoshino (1972) reported that there are two antrorse spines located on the lower margin of the preopercle, but our specimen shows three spines on the left side and only two on the right (Fig. 3). This apparent abnormality needs further verification and may be clarified through future specimen collections of this species.

A comparison of the measurements of the Philippine specimen and the holotype of this species is presented by recalculating Yoshino's (1972) proportional measurements as a percentage of the standard length and head length (Table 1). The majority of the morphological characters (12 of 18 or 67%) varied within 3 percentage points, indicating that the measurement taken from the Philippine specimen is close to the holotype. The result also indicates that all other morphological parameters, excluding interorbital width, post-orbital length, depth of caudal peduncle, and length of caudal peduncle, are greater in the specimen from the Philippines compared to the holotype. Some of the characters varied by as much as 10 percentage points, but this result is not unusual as some characters of paratypes of Yoshino (1972) also had similar variations.

The mitochondrial DNA sequence obtained from this study was submitted to GenBank under accession number OP614925 and serves as the first report on the cytochrome c oxidase subunit I gene (*COI*) of *Plectranthias yamakawai*. The BLAST analysis shows that there are no close matches of the Philippine sequence with the submitted sequences in GenBank. Pairwise genetic distances are shown in Table 2 and indicate that the Philippine sequence of *P. yamakawai* is closest to the *P. kamii* from Taiwan (KU943548) with a K2P distance of 9 percentage points. Moreover, the neighbor-joining tree (Fig. 4) constructed using the sequences of the nine different species of *Plectranthias*, shows that *P. yamakawai* is closest to *P. kamii*. The Philippine specimen, however, cannot be *P. kamii* since it has 36 lateral-line scales (Randall 1980; Peristiwady et al. 2018) whereas the Philippine specimen has only 31.

Conclusion

Reporting *Plectranthias yamakawai* as a new record from the Philippines is very important to update the information on the distribution of the organism as well as the current information on fishes occurring in the country.

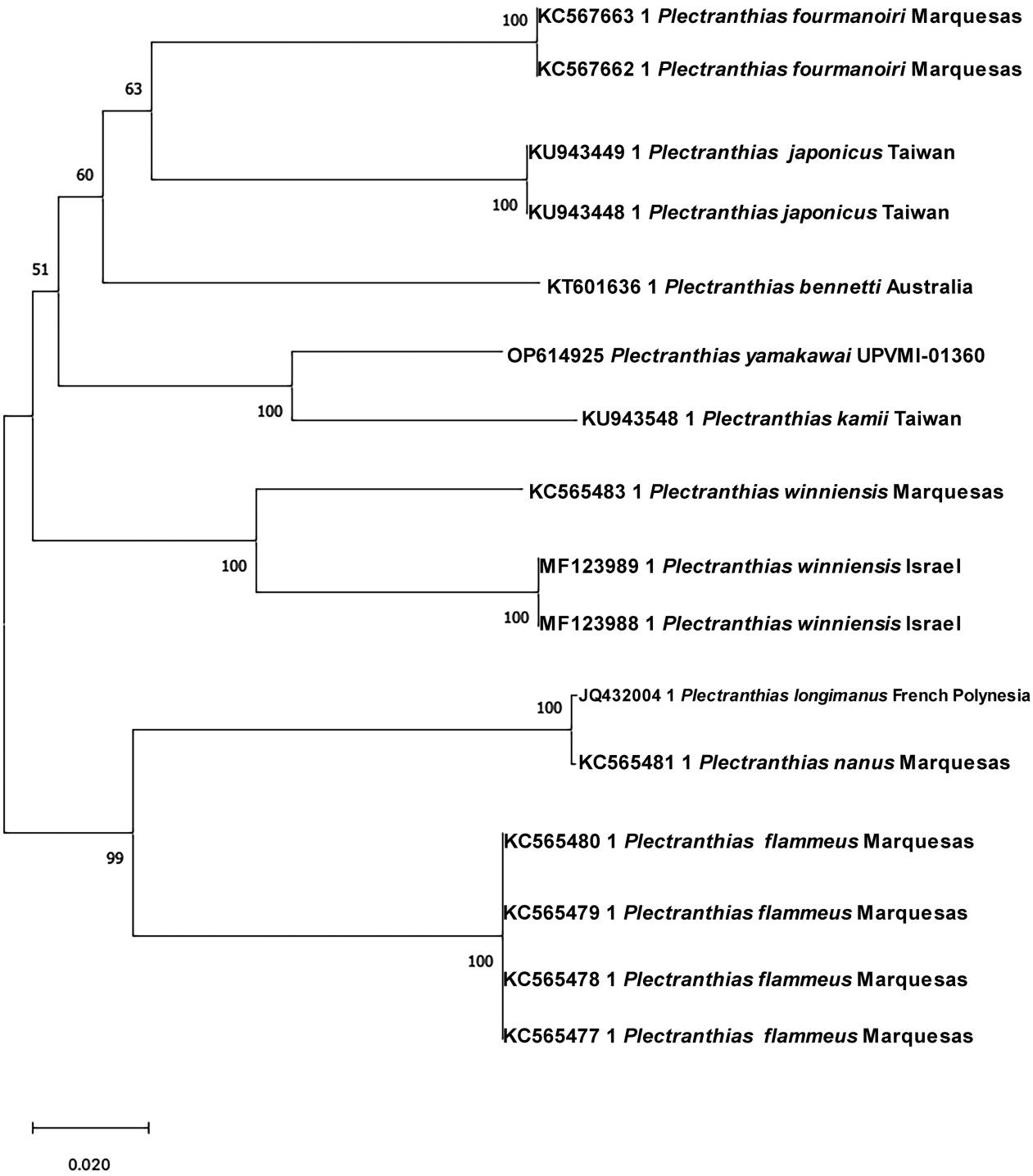

Figure 4. Phylogenetic tree constructed using the neighbor-joining tree method of only one *COI* sequence of *Plectranthias yamakawai* from the Philippines (this study) and the 15 sequences of eight different *Plectranthias* species from GenBank.

As a result of this study, six species of *Plectranthias* are now known to exist in the country. Furthermore, none of the five species of this genus previously reported in the Philippines presently have genetic information in GenBank. Since the majority of the species of *Plectranthias* were described using only one or two specimens and lacked genetic information, species identification is challenging. Therefore, studies such as this, and further documentation of other species in this group, will help in filling in data gaps.

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