Acta Ichthyologica et Piscatoria 51(2), 2021, 153–158 | DOI 10.3897/aiep.51.68832

PENSOFT

ACTA ICHTHYOLOGICA ET PISCATORIA

Southward range extension of the goldeye rockfish, *Sebastes thompsoni* (Actinopterygii: Scorpaeniformes: Scorpaenidae), to northern Taiwan

Tak-Kei CHOU[1], Chi-Ngai TANG[2]

1 *Department of Oceanography, National Sun Yat-sen University, Kaohsiung, Taiwan*

2 *Department of Aquaculture, National Taiwan Ocean University, Keelung, Taiwan*

http://zoobank.org/5F8F5772-5989-4FBA-A9D9-B8BD3D9970A6

Corresponding author: Tak-Kei Chou (saifish5678@hotmail.com)

Academic editor: Ronald Fricke ♦ **Received** 18 May 2021 ♦ **Accepted** 7 June 2021 ♦ **Published** 12 July 2021

Citation: Chou T-K, Tang C-N (2021) Southward range extension of the goldeye rockfish, *Sebastes thompsoni* (Actinopterygii: Scorpaeniformes: Scorpaenidae), to northern Taiwan. Acta Ichthyologica et Piscatoria 51(2): 153–158. https://doi.org/10.3897/aiep.51.68832

Abstract

The goldeye rockfish, *Sebastes thompsoni* (Jordan et Hubbs, 1925), is known as a typical cold-water species, occurring from southern Hokkaido to Kagoshima. In the presently reported study, a specimen was collected from the local fishery catch off Keelung, northern Taiwan, which represents the first specimen-based record of the genus in Taiwan. Moreover, the new record of *Sebastes thompsoni* in Taiwan represented the southernmost distribution of the cold-water genus *Sebastes* in the Northern Hemisphere.

Keywords

cold-water fish, DNA barcoding, neighbor-joining, new recorded genus, phylogeny, *Sebastes joyneri*

Introduction

The rockfish genus *Sebastes* Cuvier, 1829 is the most speciose group of the Scorpaenidae, which comprises about 110 species worldwide (Li et al. 2006; Hyde and Vetter 2007; Kai and Nakabo 2013; Nelson et al. 2016). Members of *Sebastes* generally occur in cold-temperate and boreal waters (Wourms 1991; Mecklenburg et al. 2002; Hyde and Vetter 2007), except for four species residing in the North Atlantic and two species being found in the Southern Hemisphere (Chen 1971; Rocha-Olivares et al. 1999; Garabana 2005; Hyde and Vetter 2007). In addition, rockfishes are economically important species, especially in temperate regions (Muto et al. 2018; Wang et al. 2020). The distributions of rockfishes in the Northern Hemisphere are generally present from northern Japan and the waters of Alaska to California (Robins et al. 1980; Wourms 1991).

On an occasional survey in a local fish market (25°7.77′N, 121°44.47′E), a mature female individual of *Sebastes thompsoni* (Jordan et Hubbs, 1925) was obtained in the local catches, which were caught off Keelung, northern Taiwan, by a bottom trawl. Based on the literature records, however, the goldeye rockfish, *S. thompsoni*, was previously known from southern Hokkaido southward to Kochi and Nagasaki at a depth of 80–160 m (Masuda et al. 1984; Nakabo and Kai 2013; Yu and Kim 2018) and from the Korean Peninsula (Kim et al. 2009). Iwatsubo et al. (2015) reported a single specimen of *S. thompsoni* captured by hook-and-line from Yaku-shima Island, Kagoshima Prefecture of Japan, which reveals the southernmost occurrence of the species. Thus, our specimen represents a southward range extension of *S. thompsoni*.

Members of the *Sebastes* are similar in external appearance between the closely related species (Chen 1985; Muto et al. 2018), hence we performed the molecular

identification of the species using the DNA barcoding of the cytochrome c oxidase I (COI) gene, which is typically indicated as an effective genetic marker for identification of most fish species (Hebert et al. 2003; Ward et al. 2005; Ratnasingham and Hebert 2007; Ward et al. 2009). The identification of our specimen is confirmed as a new record from Taiwan and also the southernmost record for the genus *Sebastes* in the Northern Hemisphere. We herein describe the Taiwanese specimen in detail.

Methods

Counts and measurements generally followed Kai and Nakabo (2002) and Kai et al. (2011), including the definition of body depths 1 and 2. The last rays of the dorsal and anal fins are divided at their base and were counted as a single ray. Standard length is expressed as SL. Standardization of morphometric data is expressed as a percentage of SL. Measurements were taken by digital and common calipers, based on the length of the measured items, recorded to the nearest 0.1 mm. The terminology of the spines on the head followed Randall and Eschmeyer (2001). Osteological characters were determined by X-radiographs. The specimen was deposited in the Pisces Collection of the National Museum of Marine Biology and Aquarium (NMMB-P), Taiwan.

DNA was extracted from the muscle by the GeneMark Easy Tissue and Cell Genomic DNA Purification Kit, procedures following the manufacturer's protocol. PCR amplifications were used a 25 µL volume containing 3 µL of 10× Taq Buffer, 2 µL of dNTP mixture at 10 mM each, 1 µL each of forward and reverse primer at 5 µM, 0.125 µL of Pro Taq Plus DNA polymerase (Protech Technology Enterprise, Taiwan), 1 µL of template DNA and the remainder made up with ultrapure water. The portion of COI was amplified using combinations of universal COI primer pairs (Ward et al. 2005): FishF1 (5′-TCAACCAACCACAAAGAGATTGGCAC-3′) and FishR1 (5′-TAGACTTCTGGGTGGCCAAAGAATCA-3′). The thermal cycle profiles consisted of an initial denaturation step at 95°C for 4 min, followed by 35 cycles of 94°C for 30 s, 53°C for 30 s and 72°C for 1 min, with a final step at 72°C for 10 min. PCR products were verified in 2% agarose gels and were purified using SAP-Exo Kit (Jena Bioscience). PCR products were sequenced in the forward and reverse directions by a biotechnology company (Genomics, Taiwan). *Sebastes atrovirens* (Jordan et Gilbert, 1880), *Sebastes inermis* Cuvier, 1829 and *S. thompsoni* were selected as the comparative sequences (Chen 1985) that were downloaded from BOLD (the Barcode of Life Data System). K2P (Kimura-2-parameter) model was used for describing the genetic variation of COI gene in the genetic distance and phylogenetic analysis. The phylogenetic relation was reconstructed with the neighbor-joining (NJ) method using MEGA ver. 10.1.1 (Kumar et al. 2018). The branch support value was assessed by the bootstrapping criterion with 1000 replicates.

Results

This study identified the specimen NMMB-P33709 (Figs 1 and 2) as *Sebastes thompsoni* by morphological and molecular approaches. The counts and proportional measurements of the specimen are listed in Table 1 and described below. Molecular analysis is shown in Fig. 3 and explained. The COI sequence of *Sebastes thompsoni* (NMMB-P33709) was submitted to GenBank (accession number MZ144755).

Table 1. Morphometric measurements of examined specimen of *Sebastes thompsoni* from Taiwan (NMMB-P33709).

Character	Value	
	[%SL]	[mm]
Standard length		170.9
Head length	34.2	
Snout length	8.1	
Orbit length	10.8	
Interorbital width	8.2	
Postorbital length	16.6	
Upper jaw length	14.6	
Body depth 1	31.2	
Body depth 2	35.5	
Body width	17.1	
Caudal peduncle depth	10.0	
Upper peduncle length	11.6	
Lower peduncle length	18.1	
Pectoral-fin length	29.2	
Pelvic-fin length	21.9	
Dorsal-fin base length	60.4	
Spinous dorsal-fin base length	32.2	
Soft dorsal-fin base length	24.8	
Preanal length	69.5	
Predorsal length	33.2	
Prepelvic length	40.8	
Anal-fin base length	19.7	
Pelvic-to-anal-fin length	30.6	
1st dorsal-fin spine length	7.4	
2nd dorsal-fin spine length	10.4	
3rd dorsal-fin spine length	14.1	
1st anal-fin spine length	6.9	
2nd anal-fin spine length	13.4	
3rd anal-fin spine length	13.3	
Pelvic-fin spine length	13.3	
Gill raker length	16.1	

Family Scorpaenidae Risso, 1827
Sebastes Cuvier, 1829

Sebastes thompsoni (Jordan et Hubbs, 1925)

[English name: goldeye rockfish]

Description of the Taiwanese specimen (NMMB-P33709). Dorsal-fin elements XIII, 14; anal-fin elements III, 7; all dorsal- and anal-fin rays branched; pectoral-fin rays 16, lowermost eight rays unbranched; pelvic-fin elements I, 5, all soft rays branched; total caudal-fin rays 37, principal caudal-fin rays 8 + 8 (upper + lower), procurrent rays 11 + 10 (upper + lower); pored lateral-line scales 54, not including 3 pored scales extending on to the caudal fin; gill rakers on first gill arch 11 + 27 (upper + lower), all rakers developed; pseudobranchial filaments ca. 40; branchiostegal rays 7; vertebrae 11 + 15 (precaudal + caudal) = 26 (total).

Figure 1. *Sebastes thompsoni*, NMMB-P33709, 170.9 mm SL, off northern Taiwan (fresh specimen).

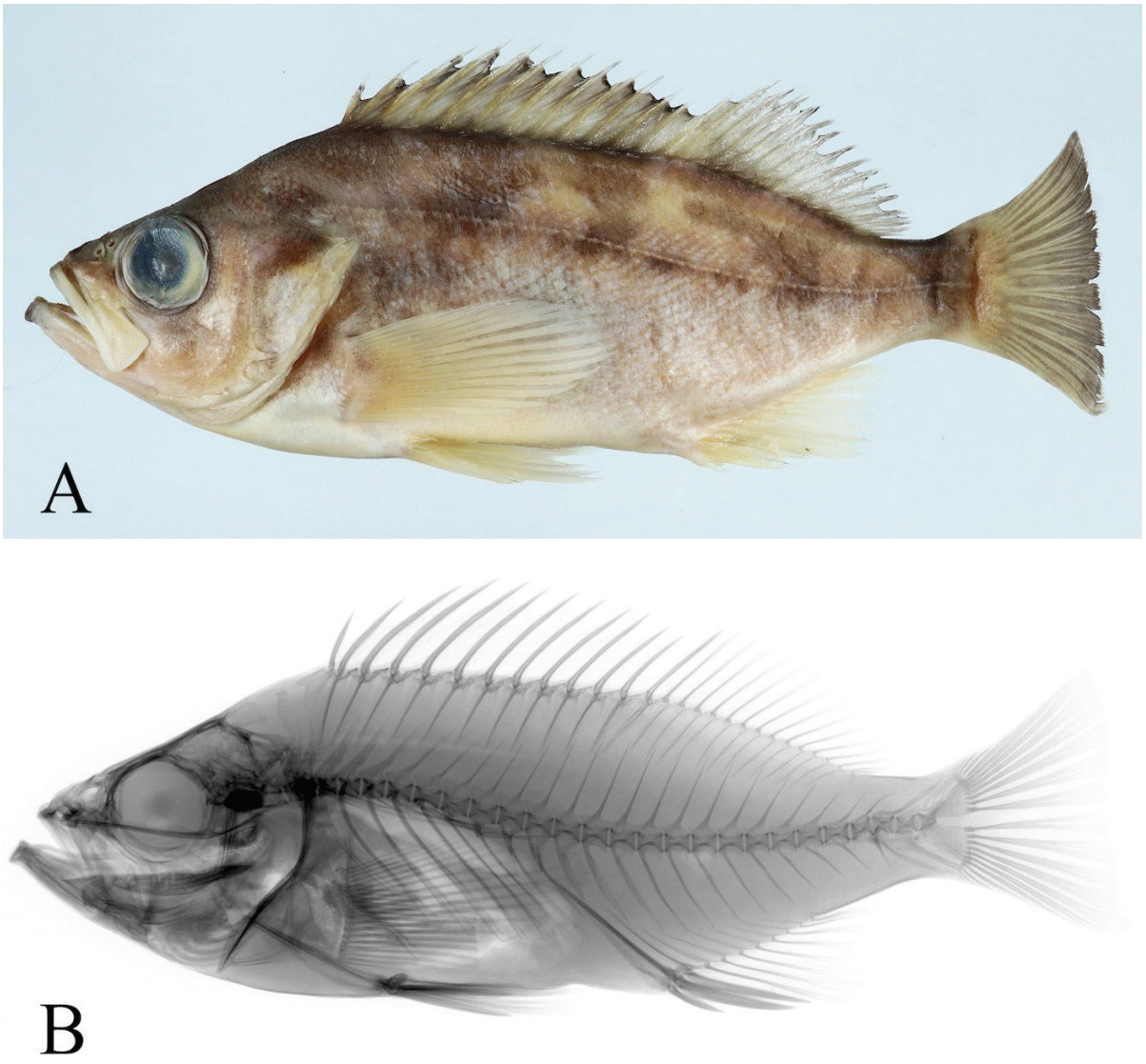

Figure 2. Preserved condition of *Sebastes thompsoni*, NMMB-P33709. **A:** After being preserved in 70% of ethanol, **B:** X-radiograph of the same specimen. It should be noted that the caudal-fin was folded artificially when preserved.

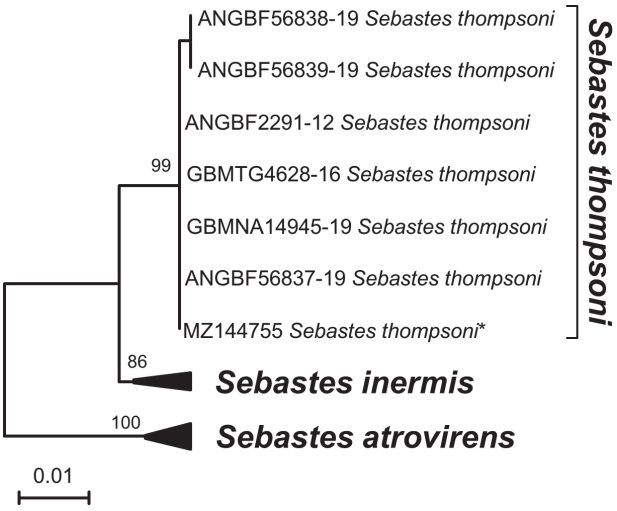

Figure 3. Neighbor-joining tree of COI gene was reconstructed with sequences of *Sebastes atrovirens*, *S. inermis*, and *S. thompsoni*. Bootstrap support values are shown at the nodes. Name with asterisk represents the sample from the presently reported study.

Body relatively deep and compressed. Mouth moderately large, slightly oblique, posterior margin of maxilla not reaching middle level of orbit. Dorsal fin continuous, fourth spine longest, length of remaining spines gradually shorter posteriorly, except last spine (13th) distinctly longer than penultimate spine; shape of soft portion of dorsal fin triangular, length of soft rays gradually shorter posteriorly. Anal fin with three spines, second and third spine long, subequal in length; shape of soft portion of anal fin triangular, length of soft rays gradually shorter posteriorly. Caudal fin emarginate.

Lower jaw with short symphyseal knob, pointed and protruding anteriorly; upper jaw with band of tiny conical teeth, outermost row larger; lower jaw with band of tiny conical teeth; both jaws without enlarged canines; vomer with V-shaped tooth patch, formed by tiny conical teeth; palatine with two long narrow tooth patches with tiny conical teeth.

Head spines relatively short, except spines on opercle and pre-opercle; lachrymal with two sharp, developed spines, posterior one slightly longer than anterior; nasal spines present, situated above each anterior nostrils; upper margin of orbits with pre-orbital and postorbital spines; pair parietal ridge, posterior end terminating with weak spine; single, short cleithral spine present, located above uppermost edge of opercle membrane; short supracleithral spine, located anterior to cleithral spine; opercle with two prominent spines, subequal in length; margin of pre-opercle with five robust and developed spines.

Body mostly covered with tiny ctenoid scales. Head fully scaled, including snout, cheek, lower jaw (dentary and angular surface) and maxilla; scales present on branchiostegal membrane. Dorsal and anal fins scaled; tiny ctenoid scales covering more than half of fin, some scales extending further along fin rays; pectoral fin base with ctenoid scales, scales gradually becoming smaller and extending to fin along fin rays; pelvic fin with scales present along spine and rays, scales becoming cycloid distally; caudal-fin fully scaled, its base covered with relatively larger ctenoid scales, remaining area generally covered with tiny ctenoid scales, distal end of fin covered with tiny cycloid scales.

Color. In fresh condition (Fig. 1), body pale red, duskier along dorsum; five dark-brown irregular transverse bands under base of dorsal fin and caudal peduncle. A faint brown blotch on upper part of opercle. Dorsal fin dusky red with two faint and elongated blotches at base of soft-rayed portion; anal, caudal, and pelvic fins dusky red; pectoral fin reddish. In preserved specimen (Fig. 2A), body, dorsal and caudal fin dusky. Anal and paired fins pale. Transverse bands along dorsum shown in fresh condition remain dark.

Genetics. In the molecular analysis, a total of 22 COI sequences of three species of *Sebastes* were obtained to reconstruct the neighbor-joining tree (Fig. 3) by the Kimura-2-parameter (K2P) model. The result showed the sequence determined here was placed in the cluster of previously determined sequences of *S. thompsoni* with a high bootstrap value (99%). The interspecific K2P distance ranged from 1.1% to 5.1% (mean 2.7%). Therefore, the identification of *S. thompsoni* was further confirmed by the molecular approach.

Discussion

According to several studies of biodiversity of fishes in Taiwan, 62 species of the Scorpaenidae (*sensu* Smith et al. 2018) were documented in Taiwanese waters (Chen 1981; Shao et al. 2008; Motomura et al. 2011; Shen and Wu 2011; Koeda and Ho 2019). The presently reported specimen (NMMB-P33709) cannot be keyed or classified into the ichthyofauna of Taiwan. Therefore, it represents a new recorded genus and species in Taiwan.

We identified this specimen as the genus *Sebastes*, based on a combination of characters: weak spines on head and opercular bones; dorsal-fin spines XIII; relatively large body size; and fins were not elongated. In addition, the genus *Sebastes* can easily be distinguished from most Scorpaenidae species by having a greater number of vertebrae (mostly more than 25), except for *Adelosebastes*, *Hozukius*, *Sebastolobus*, and *Trachyscorpia* (see Ishida 1994). In this study, the vertebrae count of the specimen (NMMB-P33709) was 26 (Fig. 2) which agreed with the range of *Sebastes*.

Based on the morphological and molecular evidence, we recognized the specimen (NMMB-P33709) as *Sebastes thompsoni* in the presently reported study. It was originally described, based on two type specimens collected from Iwate and Osaka in Japan, respectively (Jordan and Hubbs 1925). The presently described specimen (NMMB-P33709) agrees with the original description of *S. thompsoni*. It could be distinguished from the most related species, *Sebastes joyneri* Günther, 1878, by three

characters: five dark brown transverse bands on lateral body in *S. thompsoni* (vs. round blotches in *S. joyneri*); a faint blotch on opercle (vs. without); 51–56 pored lateral-line scales (vs. 47–53) (Ida et al. 1982; Masuda et al. 1984; Nakabo and Kai 2013).

The genus *Sebastes* is generally limited to temperate and boreal regions (Chen 1971; Wourms 1991; Rocha-Olivares et al. 1999; Mecklenburg et al. 2002; Garabana 2005; Hyde and Vetter 2007). Hence, the objective record of *Sebastes thompsoni* in Taiwan implied that the distribution of the cold-water fish *Sebastes* extended to the southernmost part in the Northern Hemisphere. However, although *S. joyneri* was listed in Taiwan by Jin (2006), we considered this record as questionable as no voucher specimen is available. In addition, Masuda et al. (1984) indicated that *S. thompsoni* live in colder waters than *S. joyneri*. The potential dispersal mechanism of the southward extension of *S. thompsoni* is uncertain.

A similar case was reported in Koeda and Muto (2019) of another cold-water species, *Pholis fangi* (Wang et Wang, 1935), which was previously only known from the Bohai and Yellow seas. However, a single specimen of *Pholis fangi* was captured by a bottom trawl off Donggang, south-western Taiwan. It represents the first and unexpected case of cold-water species from the Northern Hemisphere with a southward distribution extension to Taiwan. Morphological examination and DNA barcoding analysis highly supports the identification of the specimen. The specimen of *Sebastes thompsoni*, obtained in the presently reported study, is highly similar to the reported case of Koeda and Muto (2019) and yet, it is still uncertain whether the presently described specimen represented a rare local population or a rare dispersal from the Bohai or Yellow Seas.

Acknowledgments

We thank C.-H. Chan (NMMBA) for the curatorial assistance. We thank Dr H.-C. Ho for critically reading the manuscript. We are grateful to Dr. T.-Y. Liao (NSYSU) for the support of molecular work. This study was partly supported by the National Marine Museum of Biology and Aquarium and National Sun Yat-sen University, Taiwan.

References

Chen L-C (1971) Systematics, variation, distribution, and biology of the subgenus *Sebastomus* (Pisces, Scorpaenidae, *Sebastes*). Bulletin of the Scripps Institution of Oceanography 18: 1–115.

Chen L-C (1981) Scorpaenid fishes of Taiwan. Quarterly Journal of the Taiwan Museum 34: 1–60.

Chen L-C (1985) A study of the *Sebastes inermis* species complex with delimitation of subgenus *Mebarus* (Pisces, Scorpaenidae). Journal of Taiwan Museum 33: 23–37.

Garabana D (2005) The genus *Sebastes* Cuvier, 1829 (Pisces, Scorpaenidae) in the North Atlantic: Species and stock discrimination using traditional and geographic morphometrics. PhD Thesis, University of Vigo, Galicia.

Hebert PDN, Cywinska A, Ball SL, deWaard JR (2003) Biological identifications through DNA barcodes. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences 270: 313–322. https://doi.org/10.1098/rspb.2002.2218

Hyde JR, Vetter RD (2007) The origin, evolution, and diversification of rockfishes of the genus *Sebastes* (Cuvier). Molecular Phylogenetics and Evolution 44(2): 790–811. https://doi.org/10.1016/j.ympev.2006.12.026

Ida H, Iwasawa T, Kamitori M (1982) Karyotypes in eight species of *Sebastes* from Japan. Japanese Journal of Ichthyology 29(2): 162–168.

Ishida M (1994) Phylogeny of the suborder Scorpaenoidei (Pisces: Scorpaeniformes). Bulletin of Nansei National Fisheries Research Institute 27: 1–112.

Iwatsubo H, Yamaguchi M, Hata H, Motomura H (2015) Occurrence of goldeye rockfish, *Sebastes thompsoni* (Perciformes: Sebastidae), from Yaku-shima Island in the Osumi Group, Kagoshima Prefecture, southern Japan. Nature of Kagoshima 41: 41–45.

Jin XB (2006) Fauna Sinica, Osteichthyes, Scorpaeniformes. Science Press, Beijing, 133–135. [In Chinese]

Jordan DS, Hubbs CL (1925) Record of fishes obtained by David Starr Jordan in Japan, 1922. Memoirs of the Carnegie Museum 10(2): 93–346.

Kai Y, Nakabo T (2002) Morphological differences among three color morphotypes of *Sebastes inermis* (Scorpaenidae). Ichthyological Research 49(3): 260–266. https://doi.org/10.1007/s102280200037

Kai Y, Nakabo T (2013) Taxonomic review of the *Sebastes pachycephalus* complex (Scorpaeniformes: Scorpaenidae). Zootaxa 3637(5): 541–560. https://doi.org/10.11646/zootaxa.3637.5.3

Kai Y, Nakayama K, Nakabo T (2011) Genetic and morphological divergence within the *Sebastes pachycephalus* complex (Scorpaeniformes: Scorpaenidae). Ichthyological Research 58(4): 333–343. https://doi.org/10.1007/s10228-011-0236-0

Kim B-J, Kim I-S, Nakaya K, Yabe M, Choi Y, Imamura H (2009) Checklist of the fishes from Jeju Island, Korea. Bulletin of Fisheries Sciences. Hokkaido University 59: 7–36.

Koeda K, Ho H-C (2019) Fishes of southern Taiwan. National Museum of Marine Biology and Aquarium, Pingtung, Taiwan, 1353 pp.

Koeda K, Muto N (2019) An unexpected distribution record of the cold water fish *Pholis fangi* (Pholidae) from southern Taiwan. Zootaxa 4702(1): 87–93. https://doi.org/10.11646/zootaxa.4702.1.13

Kumar S, Stecher G, Li M, Knyaz C, Tamura K (2018) MEGA X: Molecular Evolutionary Genetics Analysis across computing platforms. Molecular Biology and Evolution 35(6): 1547–1549. https://doi.org/10.1093/molbev/msy096

Li Z, Gray AK, Love MS, Asahida T, Gharrett AJ (2006) Phylogeny of members of the rockfish (*Sebastes*) subgenus *Pteropodus* and their relatives. Canadian Journal of Zoology 84(4): 527–536. https://doi.org/10.1139/z06-022

Masuda H, Amaoka K, Araga C, Uyeno T, Yoshino T (1984) The fishes of the Japanese Archipelago. Vol. 1. Tokai University Press, Tokyo, 456 pp.

Mecklenburg CW, Mecklenburg TA, Thorsteinson LK (2002) Fishes of Alaska. American Fisheries Society, Bethesda, [xxxvii,] 1037 pp.

Motomura H, Matsunuma M, Ho H-C (2011) New records of three scorpaenid fishes (Teleostei: Scorpaeniformes) from Taiwan. Taiwan Shuichanxue Hui Kan 38: 97–107.

Muto N, Kai Y, Nakabo T (2018) Taxonomic review of the *Sebastes vulpes* complex (Scorpaenoidei: Sebastidae). Ichthyological Research 66: 9–29. https://doi.org/10.1007/s10228-018-0641-8

Nakabo T, Kai Y (2013) Sebastidae. In: Nakabo T (Ed.) Fishes of Japan with pictorial keys to the species. 3rd edn. Tokai University Press, Tokyo, 668–681, 1933–1938.

Nelson JS, Grande TC, Wilson MVH (2016) Fishes of the world. 5th edn. John Wiley and Sons, Hoboken, 707 pp. https://doi.org/10.1002/9781119174844

Randall JE, Eschmeyer WN (2001) Revision of the Indo-Pacific scorpionfish genus *Scorpaenopsis*, with descriptions of eight new species. Indo-Pacific Fish 34: 1–79.

Ratnasingham S, Hebert PDN (2007) BOLD: The Barcode of Life Data System. Molecular Ecology Notes 7(3): 355–364. https://doi.org/10.1111/j.1471-8286.2007.01678.x

Robins CR, Dailey RM, Bond CE, Brooker JR, Lachner EA, Lea RN, Scott WB (1980) A list of common and scientific names from the United States and Canada. 4th edn. American Fisheries Society, Special Publication 12: 174 pp.

Rocha-Olivares A, Rosenblatt RH, Vetter RD (1999) Cryptic species of rockfishes (*Sebastes*; Scorpaenidae) in the southern hemisphere inferred from mitochondrial lineages. Journal of Heredity 90(3): 404–411. https://doi.org/10.1093/jhered/90.3.404

Shao K-T, Ho H-C, Lin P-L, Lee P-F, Lee M-Y, Tsai C-Y, Liao Y-C, Lin Y-C, Chen J-P, Yeh H-M (2008) A checklist of the fishes of southern Taiwan, northern South China Sea. Raffles Bulletin of Zoology (Suppl. 19): 233–271.

Shen S-C, Wu G-Y (2011) Fishes of Taiwan. National Museum of Marine Biology and Aquarium, Pingtung, 895 pp. [In Chinese]

Smith WL, Evermann E, Richardson C (2018) Phylogeny and taxonomy of flatheads, scorpionfishes, sea robins, and stonefishes (Percomorpha: Scorpaeniformes) and the evolution of the lachrymal saber. Copeia 106(1): 94–119. https://doi.org/10.1643/CG-17-669

Wang LJ, Wu ZH, Wang YJ, Liu MX, Song AH, Liu HJ, You F (2020) Genetic assessment of a black rockfish, *Sebastes schlegelii*, stock enhancement program in Lidao Bay, China based on mitochondrial and nuclear DNA analysis. Frontiers in Marine Science 7: e94. [11 pp.] https://doi.org/10.3389/fmars.2020.00094

Ward RD, Zemlak TS, Innes BH, Last PR, Hebert PDN (2005) DNA barcoding Australia's fish species. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences 360(1462): 1847–1857. https://doi.org/10.1098/rstb.2005.1716

Ward RD, Hanner R, Hebert PDN (2009) The campaign to DNA barcode all fishes, FISH-BOL. Journal of Fish Biology 74(2): 329–356. https://doi.org/10.1111/j.1095-8649.2008.02080.x

Wourms JP (1991) Reproduction and development of *Sebastes* in the context of the evolution of piscine viviparity. Environmental Biology of Fishes 30(1): 111–126. https://doi.org/10.1007/BF02296882

Yu HJ, Kim JK (2018) Upwelling and eddies affect connectivity among local populations of the goldeye rockfish, *Sebastes thompsoni* (Pisces, Scorpaenoidei). Ecology and Evolution 8(9): 4387–4402. https://doi.org/10.1002/ece3.3993