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Taxonomic review of the Korean lumpsucker "Do-chi" reported previously as *Eumicrotremus orbis* (Pisces: Cyclopteridae) based on morphological and molecular characters

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Abstract

The Korean lumpsucker, "Do-chi", reported previously as *Eumicrotremus orbis*, was reinvestigated on the basis of specimens collected from Korea, Japan, and the USA. Morphological and genetic analyses showed that "Do-chi" corresponds to *Eumicrotremus taranetzi* and clearly differs from *E. orbis*. *Eumicrotremus taranetzi* is readily distinguishable from *E. orbis* by its large, high spiny tubercles with weak, small or no prickles (small, low spiny tubercles with distinct prickles in *E. orbis*) and 3–4 pairs of spiny tubercles in the dorsal rows (five pairs in *E. orbis*). We compared partial sequences (466 bp) of the mitochondrial cytochrome *c* oxidase subunit I genes of "Do-chi" and other *Eumicrotremus* species. "Do-chi" and *E. taranetzi* were clustered by the smallest Kimura two-parameter genetic distance (d = 0.000–0.002) and were clearly separated from *E. orbis* (d = 0.035–0.037). Therefore, our results suggest that the scientific name of the Korean lumpsucker, "Do-chi" should be changed to *E. taranetzi*.

Key words: Taxonomic review, Cyclopteridae, *Eumicrotremus taranetzi*, *Eumicrotremus orbis*, Korean fish

Introduction

Eumicrotremus orbis Günther, 1861, in the family Cyclopteridae order Perciformes, is one of the most common lumpsuckers in the North Pacific (Mecklenburg and Sheiko 2003). This species was reported originally based on an individual specimen collected from Esquimault Harbor in Canada on the eastern Pacific Ocean and was characterized by low interorbital, well-developed tubercles between the postorbital rows and the first dorsal fin and a first dorsal fin covered with small tubercles (Günther 1861; Ueno 1970). Ueno (1970) reported that *E. orbis* is very similar to *E. taranetzi* Perminov 1936, but is distinguishable from the latter by the size and structure of the tubercles on the head and body and the number of tubercles in the dorsal row. Many ichthyologists have reported that *E. orbis* is distributed widely in the North Pacific (Garman, 1892; Kendall, 922; Sato, 1937). However, Mecklenburg and Sheiko (2003) found that the *E. orbis* specimens collected in the western North Pacific were misidentified and revised the identification to include more than two different species, including *E. andriashevi* Perminov 1936, *E. taranetzi* and others. Mori (1928) was the first to describe *E. orbis* collected from the northern East Sea, Korea in the catalog of Korean fishes. Subsequently, all Korean ichthyologists have followed Mori (1928), who demonstrated that the morphological descriptions of Chyung (1977) and Kim et al. (2005) differed from those of *E. orbis* described by Günther (1861) and Ueno (1970). Therefore, a careful taxonomic review of the Korean lumpsucker (Korean name, Do-chi) is required.

In this study, eight "Do-chi" specimens were collected from

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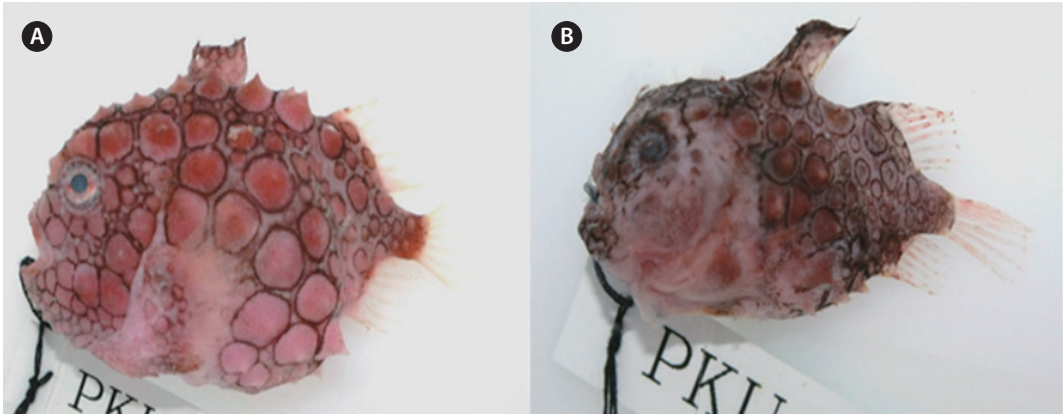

Fig. 1. *Eumicrotremus taranetzi* collected from Korea. (A) PKU8310, 48.0 mm standard length (SL), East Sea; (B) PKU8311, 36.2 mm SL, East Sea.

the East Sea, and their morphological and molecular characters were compared with those of *E. orbis* specimens from the USA and of *E. taranetzi* from Japan. Based on our results, we suggest that the scientific name for "Do-chi" should be changed to *E. taranetzi*.

Materials and Methods

Sampling

Eight *E. taranetzi* specimens were collected from the East Sea by gill net, set net and trawling. The specimens were preserved in 10% formalin and then in 70% ethanol. They were deposited in the Ichthyology Laboratory Collection, Pukyong National University (PKU) and the East Sea Fisheries Research Institute (ESFRI), National Fisheries Research and Development Institute. We borrowed nine *E. orbis* specimens from the University of Washington (UW), USA for comparison.

Morphological analysis

Counts and measurements were made according to Ueno (1970) and the taxonomic system and terminology follow Ueno (1970) and Mecklenburg and Sheiko (2003). Body measurements were made with digital calipers and rounded to the nearest 0.1 mm. The shapes and structures of the spiny tubercles were observed and photographed using a stereomicroscope (SZX-16; Olympus, Tokyo, Japan) with a digital camera (Motic Pro 205A; Motic, Xiamen, China).

Molecular analysis

Total DNA was extracted from the muscle tissues and fin clips with a DNA Extraction Kit (AccuPrep; Bioneer, Deajeon, Korea), according to the manufacturer's protocol. The cytochrome *c* oxidase subunit I gene (COI) sequence was amplified from DNA by polymerase chain reaction and a primer set reported previously by Ward et al. (2005). We also obtained mitochondrial DNA (mtDNA) COI sequences for the family Cyclopteridae from the National Center for Biological Information. The sequences were aligned with BioEdit ver. 7 (Hall, 1999). Genetic distances (*d*) were calculated using the Kimura-two-parameter model (Kimura, 1980) and a neighbor-joining tree was constructed with 1,000 bootstrap replications using MEGA 5 software (Tamura et al., 2011). The nucleotide sequence data reported here have been submitted to the DDBJ/EMBL/GenBank nucleotide sequence databases under the accession numbers: KT368918–KT368938.

Results and Discussion

Eumicrotremus taranetzi Perminov, 1936

(Korean name: Do-chi) (Figs. 1–3 and Table 1)

Eumicrotremus orbis taranetzi Perminov, 1936: 120 (type locality: Southwestern Bering Sea near Karaginskiy Island; western North Pacific at Avacha Bay, southeastern Kamchatka, Russia).

Eumicrotremus orbis (non Günther, 1861): Chyung, 1977: 553; Kim et al., 2005:265; Kim, 2011: 91.

Eumicrotremus taranetzi: Ueno, 1970: 70, Nakabo, 2002: 663, Mecklenburg and Sheiko, 2003; 10, Parin et al., 2014:312.

Material examined

Eumicrotremus taranetzi: PKU5184, 49.2 mm standard length (SL), Sokcho-si, Gangwon-do, Korea, caught by gill net, 4 Mar., 2011; PKU8311, 36.2 mm SL, Sokcho-si, Gangwon-do, Korea, caught by gill net, 28 Feb., 2013; PKU6837, 37.6 mm SL, Sokcho-si, Gangwon-do, Korea, caught by gill net, 10 Nov., 2011; PKU6838, 37.8 mm SL, Sokcho-si,

Gangwon-do, Korea, caught by gill net, 7 Dec., 2011; ESFRI885, 69.5 mm SL, Sokcho-si, Gangwon-do, Korea, caught by trawling, 4 Jan., 2013; ESFRI886, 55.0 mm SL, Sokcho-si, Gangwon-do, Korea, caught by trawling, 4 Jan., 2013; ESFRI1635, 33.6mm SL, Sokcho-si, Gangwon-do, Korea, caught by trawling, 24 Dec., 2013; ESFRI1731, 51.2 mm SL, Sokcho-si, Gangwon-do, Korea, caught by set net, 13 Feb., 2014. *Eumicrotremus orbis*: UW152999, 33.5 mm SL, Puget Sound, Washington, USA, caught by bottom trawling, 9 Nov., 2013; UW152976, 37.9 mm SL, Puget Sound, Washington, USA, caught by bottom trawling, 26 Oct., 2013; UW151785, 32.2 mm SL, Puget Sound, Washington, USA, caught by beam trawling, 20 Oct., 2012; UW151223, 37.7 mm SL, Deception Pass, Washington, USA, caught by fishing, 13 Dec., 2010; UW154240, 26.6 mm SL, Puget Sound, Washington, USA, 7 Nov., 2009; UW154243, 36.6 mm SL, Puget Sound, Washington, USA, 7 Nov., 2009; UW154237, 38.0 mm SL, Puget Sound, Washington, USA, 4 Oct., 2008; UW048821, 45.8 mm SL, Puget Sound, Washington, USA, caught by trawling, 21 May, 2003.

Description

All counts and measurements are given in Table 1. Dorsal fin rays, VI-9–10; anal fin rays, 9–10; pectoral fin rays, 23–24; caudal fin rays, 10. Body proportions, expressed as percentages of SL: head length, 36.0–46.1; body depth, 41.7–56.3; first dorsal fin base length, 12.7–20.8; predorsal distance, 35.7–55.7; disk length, 22.7–32.7; caudal peduncle length, 9.8–13.3; snout length, 6.8–11.4; interorbital width, 21.9–26.0; anterior internasal width, 8.2–11.6.

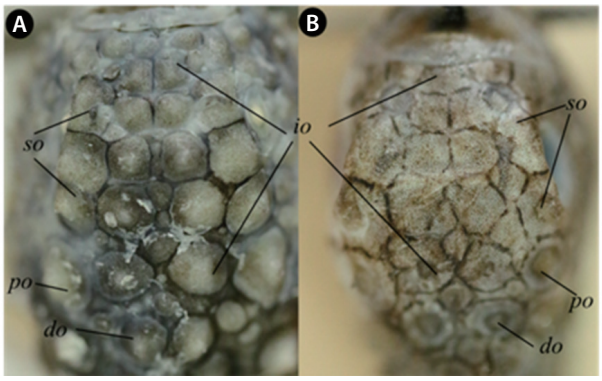

Fig. 2. Head of *Eumicrotremus taranetzi.* (A) PKU8310; (B) PKU8311. io-interorbital row, so-superorbital row, po-postorbital row, do-dorsal row.

Table 1. Comparison of the counts and measurements of *Eumicrotremus taranetzi* and *E. orbis*

Characters	*Eumicrotremus taranetzi*		*Eumicrotremus orbis*		
	Present study	Ueno (1970) (Japan)	Günther (1861)	Ueno (1970) (Japan)	Present study (USA)
Standard length (mm)	33.6-58.5	-	-	-	26.6-45.8
	(n=8)	-	(n=1)	(n=86)	(n=8)
Dorsal fin rays	VI, 9-10	V-VI, 9-10	VII, 9	V-VII, 9-11	VI, 9-10
Anal fin	9-10	9-10	9	9-11	9-10
Pectoral fin rays	23-24	24-26	-	19-27	23-24
Caudal fin rays	10	10-11	9	9-12	10
Head length	36.0-46.1	40.0-47.6	-	35.7-45.5	37.2-46.9
Body depth	41.7-56.3	50.0-58.8	-	52.6-62.5	39.1-49.9
First dorsal-fin base length	12.7-20.8	-	-	-	12.4-15.5
Second dorsal-fin base length	15.2-22.1	-	-	-	10.5-23.6
Anal-fin base length	13.1-18.9	-	-	-	12.1-17.0
Interdorsal distance	12.8-20.2	20.4-29.4	-	10.8-15.2	8.5-18.9
Predorsal distance	35.7-55.7	-	-	-	34.5-49.9
Pectoral-fin length	19.4-27.7	-	-	-	19.5-26.4
Anus to anal fin origin	16.7-29.6	16.9-23.2	-	17.5-33.3	17.9-26.0
Disk length	22.7-32.7	24.4-31.2	-	25.6-33.3	23.6-34.3
Disk width	22.7-28.9	26.3-35.7	-	27.7-33.3	21.0-30.4
Caudal peduncle length	9.8-13.3	10.3-13.3	-	9.4-13.2	10.1-16.6
Caudal peduncle depth	8.9-10.9	9.2-11.7	-	8.4-11.2	8.5-10.5
Caudal-fin length	19.3-25.6	-	-		22.5-27.3
Snout length	6.8-11.4	-	-	11.0-14.7	6.9-11.3
Postorbital head length	15.5-20.4	-	-		14.6-19.5
Orbit diameter	10.6-14.9	11.1-15.1	-	11.9-15.2	12.4-16.7
Interorbital width	21.9-26.0	23.8-27.0	-	20.0-24.4	19.2-24.2
Mouth width	23.1-27.6	25.0-29.4	-	22.2-31.2	15.3-24.9
Anterior internasal width	8.2-11.6	-	-	-	7.1-11.6

Body round, oblong anteriorly, but compressed posteriorly; head and body covered with large and small spiny tubercles, each tubercle covered with small, short prickles or no prickles, most specimens had spiny tubercles with unseparated tips, but some specimens had tubercles with separated tips; eye small, with a diameter smaller than one-third of the head length; mouth moderate, equal or slightly greater in width than the interorbital width; teeth on both jaws small, conical, arranged in 3-4 irregular rows; first dorsal fin high, with the tip of each ray projecting above the fin membrane, and small scattered tubercles; sucking disk moderate, and length of disk slightly larger than mouth width; anus located closer to the sucking disk than to the origin of the anal fin; spiny tubercles on the trunk larger than those on head and tail; interorbital space containing four rows of spiny tubercles, forming two interorbital rows and two supraorbital rows; 3–4 pairs of tubercles present symmetrically in the dorsal rows, with the last tubercles between the two dorsal fins largest; a pair of large tubercles in front of the anal fin; irregular rows of small tubercles in the caudal region; no naked areas on the cheek, chin and throat; base of the pectoral fin covered with small tubercles.

Coloration

Fresh body entirely reddish or dark reddish and ventral body pale red or dark red; membrane of the first dorsal fin light red, and the soft rays and membranes of the second dorsal, anal and caudal fins pink and transparent, respectively; pectoral fin transparent. Occasional red spots on second dorsal and anal fin. Tubercles reddish, and margins of tubercle bases black (Fig. 1). Body and first dorsal fin entirely brown or dark brown after fixation; second dorsal, anal and caudal fins yellowish, and pectoral fin transparent; some black spots on the second dorsal and anal fins; tubercles brown and the tops of the tubercles occasionally yellowish (Fig. 3).

Distribution

Known from the western North Pacific: southwestern Bering Sea to Kuril Islands, eastern and southern Okhotsk Sea, northern Japan Sea (Mecklenburg and Sheiko, 2003) and the East Sea, Korea (present study).

Remarks

The Korean lumpsucker, "Do-chi" has been reported previously as *E. orbis* in Korea (Chyung, 1977; Kim et al., 2005; Kim, 2011). However, the present study suggests that "Do-chi" is *E. taranetzi*, based on the following morphological characters: four regular rows of tubercles in the interorbital space, large, high spiny tubercles with or without small, short prickles, 3–4 pairs of spiny tubercles in the dorsal rows, and the pectoral fin base covered with small tubercles (Figs.1–3). In the present study, we compared *E. taranetzi* from Korea with *E. orbis* from the USA. The two species were very similar in counts and measurements (Table 1), but were clearly distinguishable by the shapes and structures of the spiny tubercles and the numbers of spiny tubercles in the dorsal rows. A molecular analysis supported the morphological results. The 466-bp mtDNA COI sequences from 11 "Do-chi" specimens and nine *E. orbis* specimens were compared with sequences from other *Eumicrotremus* species (*E. taranetzi*, *E. andriashevi* and *E. spinosus*) and an outgroup (*Liparis tanakae*). The genetic distance between "Do-chi" and *E. taranetzi* from Japan was the smallest (d = 0.000–0.002), whereas the range of distances between *E. taranetzi* and *E. orbis* was 0.035–0.037 (Fig. 4). Ueno (1970) suggested that *E. orbis* is related to *E. taranetzi* Perminov 1936, but is distinguishable by the size and structure of the tubercles on its head and body (small, low tubercles covered with many sharp prickles in *E. orbis* vs. large, high tubercles with or without weak prickles in *E. taranetzi*) and the number of tubercles in the dorsal row (five in *E. orbis* vs. 3–4 in *E. taranetzi*). The results of the present study are similar to those of Ueno (1970), but with some differences. For example, a single specimen of *E. orbis* (UW154240) had four spiny tubercles in the dorsal row (Fig. 3). Voskoboinikova and Nazarkin (2015) proposed an *E. andriashevi* subspecies based on differences in the spiny tubercles, and Byrkjedal et al. (2007) demonstrated sexual dimorphism within the genus *Eumicrotremus*. Therefore, further studies are required to identify the presence of subspecies, sexual dimorphism or intraspecific variations in *E. orbis* based on additional specimens.

Mecklenburg et al. (2011) suggested 15 species in the genus *Eumicrotremus*, and 12 species have been reported in the western North Pacific. In the present study, *E. taranetzi* was readily distinguishable from the other species reported in the western North Pacific based on morphological characteristics. For example, *E. taranetzi* is distinguishable from *E. soldatovi* Popov 1930, *E. pacificus* Schmidt 1904 and *E. derjugini* Popov 1926 by a pectoral fin base covered with small tubercles (present in *E. taranetzi* vs absent in others). *Eumicrotremus barbatus* Lindberg & Legeza 1955 and *Eumicrotremus gyrinops* Garman 1892 are distinguishable from *E. taranetzi* by their numerous long dermal papillae on the chin and throat, and four series of small tubercles on each side of the body, respectively (no dermal papillae and no four series of small tubercles in *E. taranetzi*). *Eumicrotremus asperrimus* Tanaka 1912 and *E. schmidti* Lindberg & Legeza 1955 are distinguishable from *E. taranetzi* by a very low first dorsal fin and strong prickles on the tubercles, respectively (high first dorsal fin and weak prickles on the tubercles in *E. taranetzi*) (Ueno, 1970; Mecklenburg and Sheiko, 2003). Finally, *E. taranetzi* is distinguishable from *E. andriashevi* by weak, small or no prickles on its spiny tubercles and regular rows of tubercles in the interorbital space (strong prickles on the tubercles and irregular rows in the interorbital space in *E. andriashevi*) (Voskoboinikova and Nazarkin, 2015).

In Korea, Chyung (1977), Kim et al. (2005) and Kim (2011)

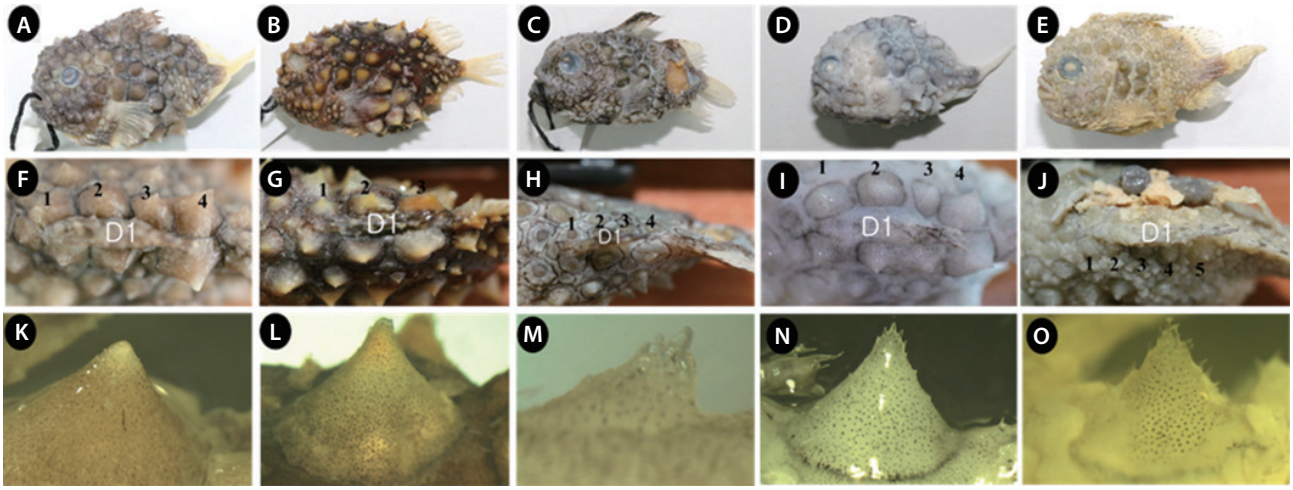

Fig. 3. Lateral view of *Eumicrotremus taranetzi* (A-C) and *E. orbis* (D-E) examined in the present study. (A) PKU5184, 49.2 mm SL; (B) PKU6837, 37.6 mm SL; (C) PKU8311, 36.2 mm SL; (D) UW154240, 26.6 mm SL; (E) UW151223, 37.7 mm SL. (F-J) numbers of spiny tubercles on the dorsal rows in (A-E), respectively. (K-O) micrographs of spiny tubercles (K shows the 4th tubercle of F; L the 3th tubercle of G; M the 4th tubercle of H; N the 4th tubercle of I; O the 5th tubercle of J). D1 indicates the first dorsal fin.

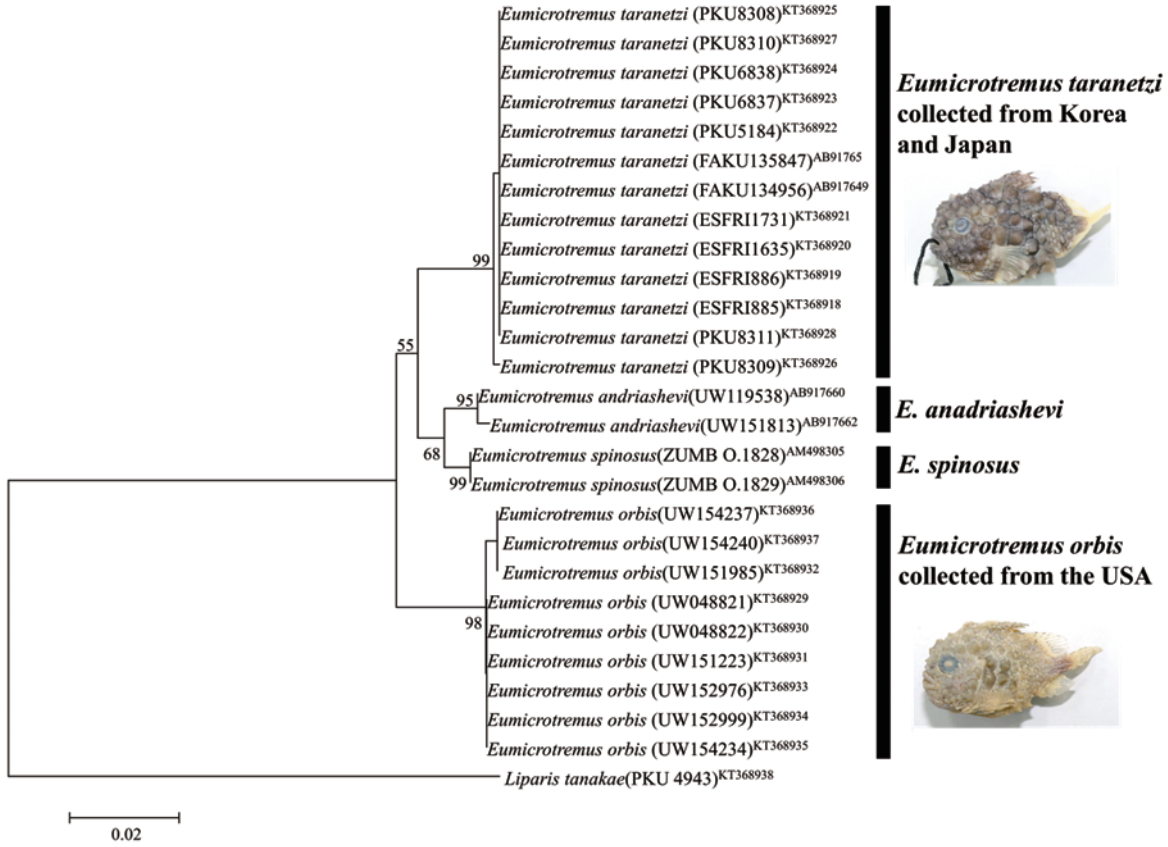

Fig. 4. Neighbor-joining tree based on 466-bp sequences of the mtDNA *COI* gene of *Eumicrotremus taranetzi* collected from Korea and Japan, *E. orbis* collected from USA, and other Cyclopteridae species. *Liparis tanakae* was used as an outgroup. Superscripts indicate the accession number of GenBank.

suggested *E. orbis* as the scientific name of "Do-chi" and described very small prickles on its spiny tubercles. However, this morphological character corresponds to that of *E. taranetzi*, because *E. orbis* has very distinct, strong prickles on its tubercles. Therefore, further studies are needed to clarify if *E. orbis* actually occurs in Korean waters.

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