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ADDITIONS TO THE TAIWAN MARINE EEL FAUNA WITH FIRST RECORDS OF THREE RARE MORAY EELS (ANGUILLIFORMES: MURAENIDAE)

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Acknowledgements

We expressed our appreciation to Captain Jiunn-Shiun Chiou and Ms. Min-Chia Chiang, who helped us to collect the specimens. We thanked the Center for Marine Bioenvironment and Biotechnology in National Taiwan Ocean University that funded our relative project of muraenid studies “97529002C3” and “98529002C3”. These studies were originally supported by Fisheries Agency, Council of Agriculture grants “97AS-11.2.1- FA-F1(4)” and “98AS-8.5.2-FA-F1(2-1)” to Hong-Ming Chen.

ADDITIONS TO THE TAIWAN MARINE EEL FAUNA WITH FIRST RECORDS OF THREE RARE MORAY EELS (ANGUILLIFORMES: MURAENIDAE)

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Key words: Muraenidae, *Enchelynassa*, *Gymnothorax*, moray eel.

ABSTRACT

The specimens of three new records of moray eels (Anguilliformes: Muraenidae) were identified for the first time off the eastern (Changbin) and southern (Kenting) coast of Taiwan. They were *Enchelynassa canina* (Quoy and Gaimard), *Gymnothorax elegans* Bliss and *Gymnothorax fuscomaculatus* (Schultz). The monotypic genus *Enchelynassa* which had only one species in the genus was also a newly recorded genus to Taiwan. In this paper, we reported the three rare moray species, included diagnostic characters and the fresh coloration on whole body, head, dorsal and ventral sides; as well as their dentitions; and the key to the relative species.

I. INTRODUCTION

The Muraenidae is a diverse family of eels found around the world with about 15 genera 185 species [23]. A total of 42 species belonging to 9 genera and 2 subfamilies of this family are indigenous to Taiwan [11]. During 2003-2008 in a series of projects entitled "Investigations and studies of endangered muraenid fishes from the waters around Taiwan" and "Diversity, molecular phylogeny and reproductive ecology of the Anguilliformes fishes of Taiwan and the Western Pacific", we described three new moray species i.e. *Gymnothorax shaoi* Chen and Loh, 2007 [9], *G. taiwanensis* Chen *et al*. 2008 [10] and *Uropterygius oligospondylus* Chen *et al*. 2008 described in Loh *et al*. [20], and many specimens of moray eels collected as well from the waters around Taiwan. Among these collections, it was noticed that some specimens did not belong to the other recorded moray species in Taiwan. After comparing their morphological characters with other similar moray species, we firstly recorded the three rare muraenid species. It will contribute to raise the species diversity for Taiwanese fish fauna.

II. MATERIALS AND METHODS

The specimens of moray eels were collected by the longline or ichthyocide rotenone from 2005 to 2008. The fresh specimens were stored in refrigerator after capture, then transferred to our laboratory. The specimens were fixed with 10% formalin firstly, then transferred to 70% ethanol solution for long-term preservation. The methods of measurements followed Böhlke and Randall [6]. Proportional measurements for the specimens of moray eels were expressed as percentage of the total length (TL) or the head length (HL). Body depth was measured at the gill openings (DGO), at the anus (DA) and did not include the fins; snout length was measured from snout tip to the anterior margin of the eye; upper jaw (UJ) length was from snout tip to rictus, lower jaw (LJ) length from lower jaw tip to rictus. Counts for the vertebral formula were obtained from radiographs, as explained in Böhlke [3] and Chen *et al*. [12]; the mean vertebral formula (MVF) gave the mean values for predorsal-preanal- total vertebrae counts. Teeth counts referred to Hatooka [15] were approximate and included sockets of missing teeth. Sexes of the specimens were determined by gross and histological examinations on their gonads. All specimens were deposited in the Laboratory of Aquatic Ecology, Department of Aquaculture, National Taiwan Ocean University (TOU-AE).

III. TAXONOMY

Enchelynassa canina (Quoy and Gaimard, 1824)
Viper moray
(Figs. 1 a, b, c; 4 a)

Muraena canina Quoy and Gaimard, 1824: 247 [25] (Holo-

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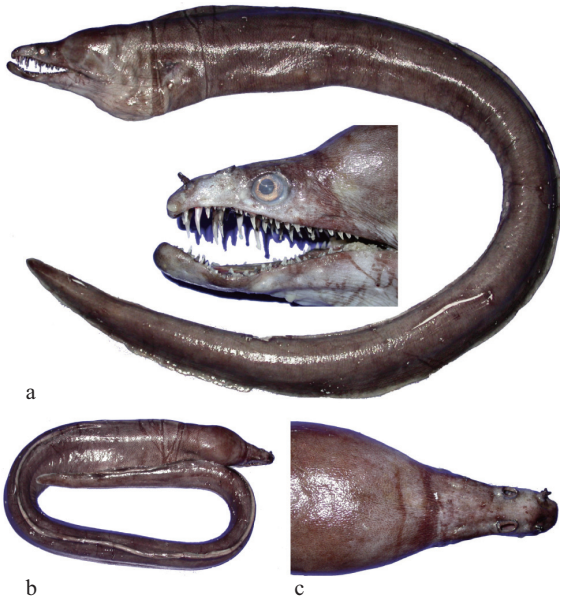

Fig. 1. The newly recorded species, *Enchelynassa canina*, TOU-AE 5142 (996 mm TL, Changbin, Taitung County, Taiwan). a, lateral views of body and head; b, dorsal view of body; c, dorsal view of head, showing the fleshy rims of enlarged posterior nostrils.

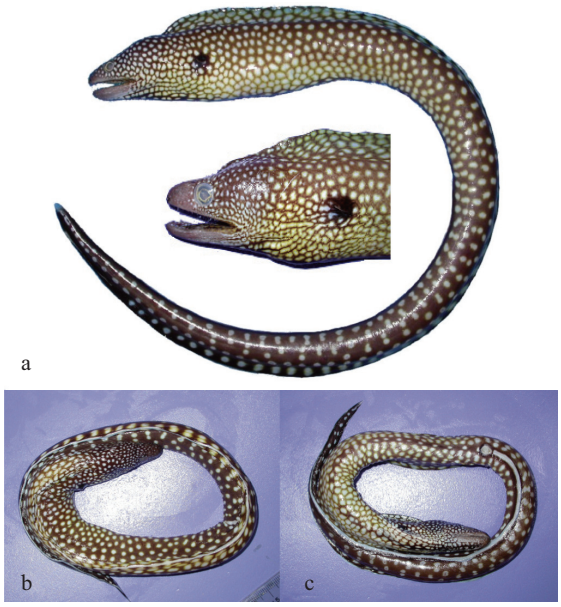

Fig. 2. The newly recorded species, *Gymnothorax elegans*, TOU-AE 1804 (439 mm TL, Changbin, Taitung County, Taiwan). a, lateral views of body and head; b, dorsal view of body; c, ventral view of body, showing the distinct coloration and spot pattern.

type not found) (Type locality: Waigiou [Waigeo], Indonesia; Rawak Island, Bismarck Archipelago).

Enchelynassa bleekeri Kaup, 1855: 214 [17].

Gymnothorax vinolentus Jordan and Evermann, 1903: 165 [16].

Enchelynassa canina (Quoy and Gaimard, 1824) [25]: Fowler, 1932: 141-142 [14]; Smith, 1994: 20 [31]; Böhlke *et al*., 1999: 1647 [5]; Böhlke and Randall, 2000: 222-224 [6]; Böhlke and McCosker, 2001: 77 [4]; Böhlke and Smith, 2002: 100 [7].

1. Material Examined

TOU-AE 5142, 996 mm TL, male, 24 October 2006, from Changbin, Taitung County, bottom longline by Captain Jiunn-Shiun Chiou.

2. Diagnosis

Anterior nostril bears a bilobate fleshy large projecting tube, posterior nostril in front of and above the eye, surrounded by a fleshy rim. Body brownish, grey color in the belly side. Tail length 2.0, trunk length 2.6, body depth at gill opening 16.5, body depth at anus 22.6, predorsal length 9.2, head length 7.4, all presented as proportions in TL (Table 1); Predorsal length 1.25, length of upper jaw 1.92, length of lower jaw 1.91, interorbital width 7.84, snout length 5.56, eye diameter 13.87, all presented as proportions in HL. Jaws highly arched, long fang-like teeth. Maxillary teeth biserial, outer row about 18-20 small teeth and inner row with 6-8 slender teeth; pre maxillary teeth 9 + 9, median premaxillary teeth 3-4; vomerine teeth uniserial about 9; dentary teeth biserial anteriorly, outer row with 19-20 small teeth, inner row with 3-5 larger teeth. Gill openings with a raised flap just below median of body. Two branchial pores, three superorbital pores, four infraobital pores, six mandibular pores. Total vertebrae 142, predorsal vertebrae 6, preanal vertebrae 64.

3. Distribution

Known from Indo-Pacific Ocean: Chagos Islands, Reunion, Panama, Marcus, Hawaiian Islands, Tonga, Mangaréva, Japan and eastern Taiwan.

4. Remarks

Enchelynassa canina is readily identified by its long bilobed anterior nostrils and strongly arched jaws with exposing long fang-like teeth. Lee [18] reported the species from Lanyu, but Chen *et al*. [12] noted Lee's [18] specimen was misidentified as *E. canina*. It actually was *Enchelycore schismatorhynchus*, which also had similar arched jaws and exposed teeth, but only had simple tubular anterior nostrils. Chen and Yu [13] reported the species *E. canina* in "The synopsis of the vertebrates of Taiwan", but we could not found any specimen record of *E. canina* from their collections. It might also be misidentified from the specimen of the other muraenid species.

Gymnothorax elegans (Bliss, 1883)
Elegant moray
(Figs. 2 a, b, c; 4 b)

Gymnothorax elegans Bliss, 1883: 57 [2] (Type locality: Mauritius, southwestern Indian Ocean); Castle and McCosker, 1986: 169 [8]; Smith, 1994: 18 [31]; Randall and Golani, 1995: 857 [27]; Quéro and Saldanha, 1995: 66 [24]; Böhlke

Table 1. Total lengths, percentages, proportions, vertebral counts and gonadal types of the three newly recorded species and their cataloged speciments.

	Enchelynassa canina	*Gymnothorax fuscomaculatus*	*Gymnothorax elegans*							
Catalog number of specimen	TOU-AE 5142	TOU-AE 5017	TOU-AE 625	TOU-AE 1804	TOU-AE 4123	TOU-AE 4406	Mean	SD	Min.	Max.
Total length (mm)	996.00	189.00	427.00	439.00	367.00	399.00				
% of total length										
Tail length	49.10	53.44	57.80	56.00	55.90	56.40	56.53	0.88	55.9	57.8
Trunk length	37.90	35.45	42.40	33.00	34.30	35.10	36.20	4.22	33.0	42.4
Body depth at gill opening	6.10	4.55	4.10	4.80	4.70	5.00	4.65	0.39	4.1	5.0
Body depth at anus	4.40	4.22	3.70	3.90	4.10	3.80	3.88	0.17	3.7	4.1
Predorsal length	10.80	41.80	6.60	8.40	9.80	7.80	8.15	1.33	6.6	9.8
Head length	13.60	11.11	10.30	11.40	10.40	10.30	10.60	0.54	10.3	11.4
Proportions in total length										
Tail length	2.00	1.87	1.70	1.80	1.80	1.80	1.78	0.04	1.7	1.8
Trunk length	2.60	2.82	2.40	3.00	2.90	2.90	2.79	0.29	2.4	3.0
Body depth at gill opening	16.50	21.98	24.30	20.70	21.20	20.00	21.23	1.28	20.0	23.0
Body depth at anus	22.60	23.71	27.40	25.50	24.60	26.50	25.99	1.20	24.6	27.4
Predorsal length	9.20	2.39	15.30	11.90	10.20	12.90	12.20	1.54	10.2	13.8
Head length	7.40	9.00	9.70	8.80	9.70	9.70	9.48	0.45	8.8	9.7
% of head length										
Predorsal length	80.00	376.19	70.45	74.00	94.74	75.61	78.70	10.91	70.45	94.74
Length of upper jaw	51.99	39.38	45.59	43.60	47.74	40.98	44.48	2.88	40.98	47.74
Length of lower jaw	52.32	37.05	46.39	43.20	47.05	39.49	44.03	3.46	39.49	47.05
Interobital width	12.76	17.48	17.32	17.62	13.68	17.85	16.62	1.97	13.68	17.85
Snout length	17.97	17.76	19.80	19.44	17.87	19.44	19.14	0.86	17.87	19.80
Eye diameter	7.21	10.14	10.64	11.06	11.87	11.06	11.16	0.51	10.64	11.87
Proportions in head length										
Predorsal length	1.25	0.27	1.42	1.35	1.06	1.32	1.29	0.16	0.16	1.42
Length of upper jaw	1.92	2.54	2.19	2.29	2.09	2.44	2.25	0.15	2.19	2.44
Length of lower jaw	1.91	2.70	2.16	2.31	2.13	2.53	2.28	0.18	2.13	2.53
Interobital width	7.84	5.72	5.77	5.68	7.31	5.60	6.09	0.82	5.60	7.31
Snout length	5.56	5.63	5.05	5.14	5.60	6.01	5.45	0.44	5.05	6.01
Eye diameter	13.87	9.86	9.40	9.04	8.43	9.23	9.03	0.42	8.43	9.40
Vertebrae										
Predorsal	6	40	3	3	3	3	3.00	0.00	3	3
Preanal	64	48	53	52	54	54	53.25	0.96	52	54
Total	142	119	142	145	144	141	143.00	1.83	141	145
Gonadal type	testis	testis	testis	testis	ovary	ovary				

et al., 1999: 1651 [5]; Böhlke and Randall, 2000: 233- 234 [6]; Böhlke and Smith, 2002: 107-108 [7].

Gymnothorax goldsboroughi Jordan and Evermann, 1903: 167 [16].

Gymnothorax elegans Seale, 1917: 91 [30].

Lycodontis elegans Smith, 1962: 436 [32]; Ajiad and El-absy, 1986: 297-298 [1].

1. Materials Examined

4 specimens: TOU-AE 625, 427 mm TL, male, 24 January 2005; TOU-AE 1804, 439 mm TL, male, 14 November 2005; TOU-AE 4123, 367 mm TL, female, 27 September 2006; TOU-AE 4406, 399 mm TL, female, 12 February 2007; all from Changbin, Taitung County, bottom longline by Captain Junn-Shiun Chiou.

2. Diagnosis

Body medium brown to yellow, with numerous close set white to yellow spots on head, becoming larger and farther apart on trunk. Dorsal and anal fins with prominent white margin and yellow large spots. Dark brown stripe extends from tip of chin to anus. Gill openings dark, inside of mouth spotted, similar to skin color pattern. Tail length 1.7-1.8 (1.78 ± 0.04), trunk length 2.4-3.0 (2.79 ± 0.29), body depth at gill opening 20.0-24.3 (21.23 ± 1.28), body depth at anus 24.6-27.4 (25.99 ± 1.20), predorsal length 10.2-15.3 (12.20 ± 1.54), head length 8.8-9.7 (9.48 ± 0.45), all presented as proportions in TL (Table 1). Predorsal length 1.06-1.42 (1.29 ± 0.16), length of upper jaw 2.09-2.44 (2.25 ± 0.15), length of lower jaw 2.13-2.53 (2.28 ± 0.18), interorbital width 5.60-7.31 (6.09 ± 0.82), snout length 5.05-6.01 (5.45 ± 0.44), eye diameter 8.43-9.40 ($9.03 \pm$

0.42), all presented as proportions in HL. Maxillary teeth uniserial about10-11, premaxillary teeth 6 + 6, median premaxillary teeth 1, vomerine teeth uniserial about 6, dentary teeth uniserial about 13 at left or right side. Two branchial pores, three superorbital pores, four infraobital pores, six mandibular pores. Total vertebrae 141-145, predorsal vertebrae 3, preanal vertebrae 52-54; mean vertebral formula 3-53-143.

3. Distribution

Known from Hawaiian Islands, Mauritius, Mozambique, Samoa and eastern Taiwan.

4. Remarks

Bliss [2] described *Gymnothorax elegan*s and *G. albo maculates* in the same paper; *G. elegans* was later redescribed under the same name by Seale [30]. The species was named once more by Jordan and Evermann [16] as *G. goldsboroughi*, the name was considered as the synonym of *G. elegans* by Randall *et al*. [26]. Böhlke and Randall [6] reviewed the taxonomy of the moray eels from Hawaiian Islands, the species *G. elegans* also included.

Gymnothorax fuscomaculatus (Schultz, 1953)
Brown spotted moray
(Figs. 3 a, b, c; 4 c)

Rabula fuscomaculata Schultz in Schultz *et al*., 1953: 147, fig. 30 [29] (Type locality: Marshall Islands, Western Pacific).
Gymnothorax fuscomaculatus (Schultz, 1953) [29]: Randall *et al*., 1985: 31 [28]; Castle and McCosker, 1986: 170 [8]; Smith, 1994: 23-24 [31]; Böhlke *et al*., 1999: 1645 [5]; Böhlke and Randall, 2000: 237-239 [6]; Böhlke and McCosker, 2001: 77 [4]; Böhlke and Smith, 2002: 112 [7].

1. Materials Examined

TOU-AE 5017, 189 mm TL, male, 17 July 2008; Kenting, Pingtung County, rotenone by Ms. Min-Chia Chiang.

2. Diagnosis

A small size moray, dorsal-fin origin closer to anus than gill opening. Body color light brown with diffuse brown spots posteriorly. Iris has a black perpendicular bar. Tail length 1.87, trunk length 2.82, body depth at gill opening 21.98, body depth at anus 23.71, predorsal length 2.39, head length 9.00, all presented as proportions in TL (Table 1). Predorsal length 0.27, length of upper jaw 2.54, length of lower jaw 2.70, interorbital width 5.72, snout length 5.63, eye diameter 9.86, all presented as proportions in HL. Mouth closed completely. Maxillary teeth biserial, outer row of about 14 small teeth and inner row with 8 slender teeth; premaxillary teeth 5 + 5, median premaxillary teeth 2; vomerine teeth uniserial about 11; dentary teeth biserial anteriorly, outer row with 19-20 small teeth, inner row with three (left) and four (right) larger teeth. Head pores in white spots. Two branchial pores, three superorbital pores, four infraobital pores, six mandibular pores in a line along lower jaw. Total vertebrae 119; predorsal vertebrae 40; preanal vertebrae 48.

Fig. 3. The newly recorded species, *Gymnothorax fuscomaculatus*, TOU-AE 5017 (189 mm TL, Kenting, Pingtung County, Taiwan). a, lateral views of body and head; b, dorsal view of body; c, ventral view of body, showing the coloration and spot pattern.

3. Distribution

Known from Indo-Pacific: East Africa to Tuamotu Islands, south to Fiji, Marshall Islands, Samoa and southern Taiwan.

4. Remarks

Gymnothorax fuscomaculatus was first described by Schultz *et al*. [29] who named it *Rabula fuscomaculata*. The genus *Rabula* (diagnosed with a dorsal fin origin well behind the gill opening) became invalid by McCosker and Rosenblatt [21]. Because the holotype of the type species *Muraena aquaedulcis* of *Rabula* had a deformed and damaged dorsal fin origin. Böhlke and Randall [6], Randall *et al*. [28] remained the question that the species *G. fuscomaculatus* might require a new generic name. However, these remarks might need further more study to compare their Mt-DNA nucleotide sequences between this species and the other muraenid species, and confirm its current generic status.

IV. DISCUSSION

This three moray eels remain hidden in the reef and were not seen in Taiwan. We only collected one specimen of *Enchelynassa canina*, one specimen of *Gymnothorax fuscomaculatus* and four specimens of *G. elegans*, within the last six year (2003- 2008). *E. canina* was a large species, reported to 2500 mm TL in FishBase (www.fishbase.org), but reported to 1520 mm TL from Hawaiian Islands [6], our specimen was a

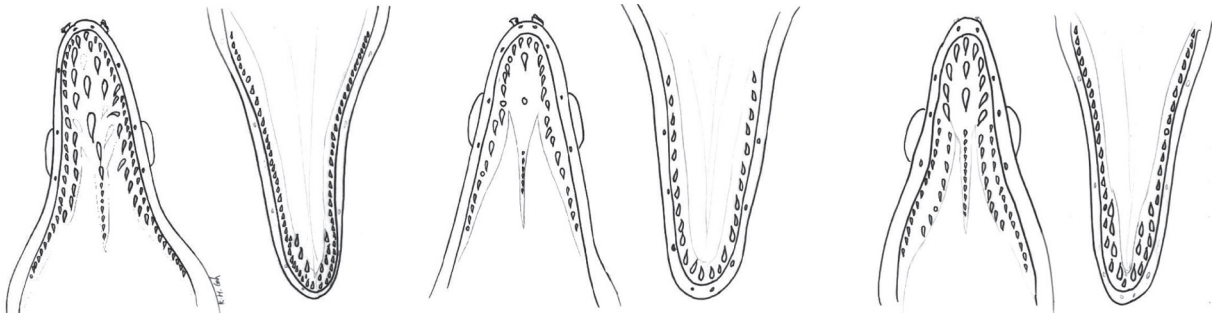

Fig. 4. Dentitions of the three newly recorded species. a, *Enchelynassa canina*, TOU-AE5142 (male, 996 mm TL); b, *Gymnothorax elegans*, TOU-AE 1804 (male, 439 mm TL); c, *Gymnothorax fuscomaculatus*, TOU-AE 5017 (male, 189 mm TL).

mature male individual with 996 mm TL. It was generally found inshore on reefs, exposed to strong surge, benthic at 1-30 m depth [19, 22]; *G. elegans* was also a large species, growed to 812 mm TL [6], occurred in crevices of steep drop-offs, and found in deeper waters at 25-450 m [27]. Our specimens were collected in middle to deep fore reef community, depth to 150 m. However, *G. fuscomaculatus* was a small size species, the largest specimen attained to 198 mm TL [6]. It occurred among corals and rubble of seaward reefs, recorded depths at 1-22 m [19], we collected the Taiwanese specimen in the sub-tidal zone, about 10 m depth. We also made a key to differentiate the morphological characters of the three newly recorded species from eight relative muraenids.

Key to the eight relative and three newly recorded muraenids species in this report

1a. Jaws elongate and significantly arched; elongate canine teeth exposed when jaws are closed ····· 2
1b. Jaws not elongate and not significantly arched; teeth not exposed when jaws are closed ····· ***Gymnothorax***, 5
2a. Anterior nostrils with bilobate flaps on posterior margins ····· ***Enchelynassa*** *canina*
2b. Anterior nostrils without large flaps ····· ***Enchelycore***, 3
3a. Posterior nostril long tubular like, longer than the anterior ····· *E. pardalis*
3b. Posterior nostril not long tubular like, far shorter than the anterior, or just an oval opening ····· 4
4a. Body not uniformly brownish, with many yellowish, moss-like spots ····· *E. lichenosa*
4b. Body uniformly brownish, without colored spots ····· *E. schismatorhynchus*
5a. Dorsal-fin origin behind gill opening, closer to anus than to gill opening; V. 117-119 ····· *G. fuscomaculatus*
5b. Dorsal-fin origin before gill opening ····· 6
6a. Gill opening blackish ····· 7
6b. Gill opening not blackish ····· 9
7a. With dark brown stripe extends from tip of chin to anus; body brown-yellowish with numerous close set white-yellowish spots; V. 141-145 ····· *G. elegans*
7b. Without dark brown stripe extends from tip of chin to anus ····· 8
8a. Inner skin of mouth whitish; body brownish with numerous dark-edged white spots; V. 126-128 ····· *G. meleagris*
8b. Inner skin of mouth yellowish; body yellow-brownish with numerous small white spots; V. 133-139 ····· *G. nudivomer*
9a. Body with several rows of black-brownish spots; V.124-137 ····· *G. eurostus*
9b. Body without several rows of black-brownish spots ·· 10
10a. Body with whitish, snowflake-like patches; V. 140-142 ·· ····· *G. niphostigmus*
10b. Body with numerous small yellow-whitish spots; V. 138-142 ····· *G. neglectus*

(Abbreviations: V, total vertebrae)

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We expressed our appreciation to Captain Jiunn-Shiun Chiou and Ms. Min-Chia Chiang, who helped us to collect the specimens. We thanked the Center for Marine Bioenvironment and Biotechnology in National Taiwan Ocean University that funded our relative project of muraenid studies “97529002C3” and “98529002C3”. These studies were originally supported by Fisheries Agency, Council of Agriculture grants “97AS-11.2.1-FA-F1(4)” and “98AS-8.5.2-FA-F1(2-1)” to Hong-Ming Chen.

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