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Range extension of *Gerres infasciatus* (Perciformes: Gerreidae) from the Red Sea and the Arabian Gulf, with distributional implications for the *G. filamentosus* complex

by

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Résumé. – Extension géographique de *Gerres infasciatus* (Perciformes : Gerreidae) en mer Rouge et golfe Arabique, et conséquences sur la répartition du complexe *G. filamentosus*.

Gerres infasciatus Iwatsuki & Kimura, 1998 est répertoriée pour la première fois dans le sud de la mer Rouge et dans le golfe Arabique. Les espèces incluses dans le complexe *G. filamentosus* (*G. filamentosus*, *G. infasciatus* et *G. macracanthus*) en provenance de cette région ont été réexaminées avec une attention particulière pour leur distribution. L'analyse des relations phylogénétiques du complexe indique que les spécimens de l'océan Indien Centre-Est, incluant la mer Rouge et le golfe Arabique, longtemps identifiés comme *G. filamentosus*, appartenaient en réalité à l'espèce *G. infasciatus*. Cette découverte implique que la première espèce est peu susceptible d'être présente dans cette région de l'océan Indien. De nouvelles informations sur la répartition de *G. infasciatus* indiquent que l'espèce se trouve probablement présente uniquement le long des côtes de l'océan Indien Nord (incluant la mer Rouge et le golfe Arabique) et la Thaïlande. Une clé d'identification est fournie pour les espèces du complexe.

Key words. – Gerreidae - *Gerres infasciatus* - Red Sea - Arabian Gulf - Range extension.

Gerres infasciatus Iwatsuki & Kimura, 1998 was originally described on the basis of three type specimens collected from Samut Prakan, northern Gulf of Thailand, Western Pacific. Like other species of the whipfin mojarra species group with an elongate second dorsal-fin spine [*G. filamentosus* (Cuvier, 1829), *G. infasciatus* Iwatsuki & Kimura, 1998, *G. macracanthus* (Bleeker, 1854), and *G. microphthalmus* Iwatsuki, Kimura & Yoshino, 2002] (Fig. 1), *G. infasciatus* is characterized by having yellow tips to the first and second (rarely third) soft dorsal-fin rays in fresh specimens, and no obvious vertical bands on the body in either fresh or preserved specimens (Iwatsuki and Kimura, 1998). At the time of its formal description, the species was believed to be a Thailand endemic (Iwatsuki and Kimura, 1998).

Subsequently, Fukuhara *et al*. (2006) and Iwatsuki *et al*. (2013) reported Indian Ocean examples of *G. infasciatus* as common off Chennai, India and Mutrah, Oman, respectively. Efforts to collect further Indian Ocean examples of *G. infasciatus* yielded a single specimen (Fig. 1A) trawled off Jizan, Saudi Arabia, southern Red Sea. However, examination of specimens from Eritrea in the HUJF collection previously identified as *G. filamentosus*, were also found to be *G. infasciatus*.

Gerres infasciatus is reported herein for the first time from the Red Sea and the Arabian Gulf. Species of the *G. filamentosus* complex (*sensu* Iwatsuki and Kimura, 1998; Iwatsuki *et al*., 1996, 2002), were re-examined, new locations of *G. infasciatus* specimens include Iraq, the UAE, Iran (based on photographic and DNA evidence) and Qatar (first author, pers. obs.). However, from museum specimens and recent photographic evidence it became clear that *G. filamentosus* was unlikely to occur in the Red Sea or the Arabian Gulf, despite earlier records (Dor, 1984; Woodland, 1984).

It was concluded that *G. filamentosus* complex species inhabiting waters off the Arabian Peninsula, including the Red Sea, Arabian Gulf and Oman, was represented only by *G. infasciatus* and *G. macracanthus*.

METHODS

Counts and measurements generally followed Iwatsuki *et al*. (1996) and identification of the *G. filamentosus* complex, Iwatsuki and Kimura (1998) and Iwatsuki *et al*. (1996, 2002). Standard length is abbreviated as SL. Institutional codes follow Sabaj Pérez (2013), with the following additions: Marine Biology Department, Faculty of Marine Sciences, King Abdulaziz University, Jeddah, Saudi Arabia (KAU); Oman Marine Science and Fisheries Centre, Muscat, Sultanate of Oman (OMMSFC); Zoological Sciences Division, Pakistan Museum of Natural History, Islamabad, Pakistan (PMNH). Muscle tissue samples were taken from fresh specimens and stored frozen in 99.9% ethanol. Genomic DNA was extracted from muscle tissue by protenase K digestion followed by a standard phenol chloroform method (Sambrook and Russell, 2001). Primers used for the amplification of the cytochrome c oxidase subunit I (COI) gene were Fish F1–5'-TCAACCAACCACAAAGACATTGGCAC-3' and Fish R1–5'-TAGACTTCTGGGTGGCCAAAGAATCA-3' (Ward *et al*., 2005). The thermal regime consisted of

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Table I. - Meristic data and proportional measurements of Red Sea and Arabian Gulf specimens and type specimens of *Gerres infasciatus*, expressed as percentages of standard length. * Holotype; ** Paratype.

	Present study			Iwatsuki and Kimura (1998)
	SMF 35412 *n* = 1	HUJF 16152, 2 spms; HUJF 16407, 3 spms *n* = 5	MUFS 46053-46055 *n* = 3	NSMT-P 47294*, FRLM 14378** and MUFS 10118** *n* = 3
Locality	Red Sea	Red Sea	Iraq, Arabian Gulf	Gulf of Thailand
Standard length (mm)	99.5	112-133	127-153	125-140
Dorsal and anal fins rays	IX, 10; III, 7	IX, 10; III, 7	IX, 10; III, 7	IX, 10; III, 7
Pectoral fin rays	16	16	15-16	16
Pelvic fin rays	I, 5	I, 5	I, 5	I, 5
Pored lateral line scales + additional pored scales on scaly sheath of base of caudal fin	44+4	44+4	40-44	39-40 + 3-4
Scales above and below lateral line	5 1/2/ 11 1/2	5 1/2/ 11 1/2	5 1/2/10 1/2	5 1/2- 6 ½ / 10 1/2-11 1/2
Scales between the 5th dorsal fin spine base and lateral line	5 1/2	4 1/2-5 1/2	5 1/2	4 1/2
Cheek scale rows	3	3	3	3
Gill rakers including rudiments (in parentheses)	6(1)+1+7	5-6(1-3)+1+7	5(4)+ 1+7	4-5(2-4)+1+7
Body depth	43.2	44.9-47.9	42.5-43.1	45.0-47.1
Body depth at first anal fin spine origin	37.7	36.8-39.2	35.9-36.8	36.4-39.2
Head length	31.7	32.4-34.8	31.5-32.4	31.4-32.1
Body width at pectoral fin base	14.1	15.1-17.2	14.2-15.7	13.2-17.4
Snout length	9.0	8.8-10.6	8.4-9.9	9.3-10.5
Orbit diameter	13.3	12.6-14.4	11.3-11.9	11.4-12.0
Dermal eye opening	11.2	10.5-12.6	10.5-10.7	9.8-10.5
Interorbital width	11.2	10.5-12.4	12.1-13.6	10.7-11.3
Upper jaw length	10.6	10.6-11.4	10.9-11.9	10.1-10.7
Caudal peduncle depth	13.3	11.9-13.3	12.6-13.0	11.8-13.2
Predorsal length	42.0	42.9-45.5	41.2-42.8	43.4-44.4
Preanal length	64.2	62.2-65.1	66.4-68.9	62.0-66.5
Prepelvic length	39.2	39.8-42.9	39.0-40.1	40.4-41.7
Dorsal fin base length	54.9	51.0-55.8	53.6-56.1	52.9-54.9
Anal fin base length	17.6	16.5-18.0	16.6-19.0	16.6-18.7
Caudal fin length	28.6	30.8-34.6	31.0	28.4-33.7
Pelvic fin spine length	16.0	15.1-21.5	15.9-17.2	16.5-17.3
First pelvic fin ray length	26.7	17.8-25.1	21.6-23.7	22.4-23.5
Longest pectoral fin ray length	37.4	35.7-39.3	37.9-39.5	34.4-43.1
First dorsal fin spine length	3.7	1.3-2.6	2.2-3.6	1.6-2.2
Second dorsal fin spine length	56.4	41.6-57.1	52.2-61.3	48.0-68.9
Third dorsal fin spine length	24.2	22.8-29.5	20.6-26.5	24.0-27.0
Last dorsal fin spine length	10.2	8.5-11.1	10.3	9.6-9.8
First dorsal fin ray length	17.2	13.9-16.0	broken	14.3-16.0
First anal fin spine length	2.7	2.4-3.2	2.3-3.2	2.2-2.8
Second anal fin spine length	12.6	11.5-12.6	10.5-11.5	9.0-11.2
Third anal fin spine length	13.3	12.0-13.8	9.8-11.9	9.9-11.3
First anal fin ray length	14.8	13.0-13.8	11.2-12.3	11.5-13.2

an initial step of 2 min at 95˚C followed by 35 cycles of 40 s at 94˚C, 40 s at 54˚C and 1 min 10 s at 72˚C, followed by final extension for 10 min at 72˚C. The PCR products were visualized on 1.2 % agarose gels. Sequencing of the samples was performed by the Dragon Genomics Center, TAKARA BIO INC (Yokkaichi, Mie, Japan).

Sequences from samples of the above four species, including: *G. infasciatus* (*n* = 6, SMF 35412, Accession No. AB983648, Red Sea; MUFS 32625, Acc. No. AB983649, UAE; MUFS 33713, Acc. No. AB983650, Oman; MUFS 39743, Acc. No. AB983651, Pakistan; and published sequence data for HQ149852, Naybond, National Park Coast, Bushr, Iran, Gulf of Aden, erroneously identified as *G. filamentosus*; *G. macracanthus* (*n* = 1, KAUM 16963, Acc. No. AB983647, Malaysia); *G. microphthalmus* (*n* = 1, MUFS 24879, Acc. No. AB983646, Miyazaki, Japan); *G. filamentosus* (*n* = 1, MUFS 21927, Acc. No. AB983645, India); plus *G. oyena* (*n* = 1, KAUM-I 16962, Acc. No. AB983652, Malaysia) were submitted to the DNA Data Bank of Japan (DDBJ). The sequences were aligned using CLUSTAL X (Larkin *et al*., 2007), and 615 bp of COI gene obtained. Sequence divergences were calculated using the Kimura two parameter (K2P) distance model (Kimura, 1980). A neighbor-joining (NJ) tree of K2P distances shows the divergence pattern between species (Saitou and Nei, 1987), following bootstrapping using ''MEGA6'' software with 1,000 replications (Tamura *et al*., 2013).

Material examined. - *Gerres filamentosus*: MUFS 21927, 111 mm SL, Mangalore, south-western India; KAUM 12250, 139 mm SL, off Sabah, Borneo Island, Malaysia. *Gerres infasciatus*: HUJF 16152, 2 specimens, 125-133 mm SL, southern Red Sea; HUJF 16407, 3 spms 112-127 mm SL, southern Red Sea; SMF 35412, 99.5 mm SL, off Jizan, Saudi Arabia, Red Sea (16˚57.294'N, 42˚29.045'E), 13-15 m, 29 Jun. 2013, coll. S.V. Bogorodsky & A.O. Mal; MUFS 16837-16838, 2 spms, 101-143 mm SL, Chennai (Madras), Tamil Nadu, India, 2 Dec. 1998; MUFS 16857-16862, 6 spms, 113-132 mm SL, Chennai (Madras), Tamil Nadu, India, 2 Dec. 1998; MUFS 32625 (pectoral fin only), from specimen ca. 150 mm SL, Fish Souk at Mina Zayed, Abu Dhabi, UAE; MUFS 33713, 139 mm SL, Mutrah fish market, Oman; MUFS 39743, 163 mm SL, West Wharf Fish Harbour, Karachi, Pakistan; MUFS 46053-46055, 3 spms, 124-153 mm SL, Iraq (29º46'N, 48º48'E); NSMT-P 47294, holotype, 133 mm SL, female, Samut Prakan Fish Market, near estuary of Chao Praya River, Samut Prakan Province, Thailand; FRLM 14378, paratype, 125 mm SL, female, same data as holotype; MUFS 10118, 140 mm SL, male, same data as holotype. *Gerres macracanthus*: uncatalogued specimens, 11 spms, 98-122 mm SL, Basrah, Iraq; HUJF 16002, 2 spms, 92-93 mm SL, southern Red Sea; HUJF 10888, 2 spms, 91-98 mm SL and HUJF 16253, 3 spms, 86-91 mm SL, Horkiko Bay, southern Red Sea; KAUM-I 16963, 115 mm SL, off Kuala Terengganu, Terengganu, Malaysia; SMF 35037, 1 spm, 98 mm SL, off Jizan, Saudi Arabia. *Gerres microphthalmus*: MUFS 24879, 1 spm, 156 mm SL, Iorigawa, Kadokawa-cho, Miyazaki, Japan. *Gerres oyena*: KAUM-I 16962, 116 mm SL, off Kuala Terengganu, Terengganu, Malaysia.

RESULTS

Meristic counts and proportional measurements of *G. infasciatus* from the Red Sea and coastal waters of Iraq (Arabian Gulf) are given as percentages of SL in table I. The specimens are characterized by the following important diagnostic characters: second dorsal-fin spine very long (41.6-61.3% of SL); no obvious bands on body (see Discussion and Fig. 1A); first and second (rarely third) soft dorsal-fin ray tips yellow in fresh specimens. These characters were identical to those noted by Iwatsuki and Kimura (1998) for the type specimens of *G. infasciatus*. However, pored lateral-line scales of *G infasciatus* from the type locality (Thailand) numbered 39 or 40, whereas specimens from the Red Sea, Iraq (Arabian Gulf), Mutrah (Oman), Abu Dhabi (UAE), Karachi (Pakistan) and Chennai (India) possessed 40-44 such scales. These differences most likely represented intraspecific variation, since other diagnostic characters of *G. infasciatus* were the same in all specimens. Genetic analysis of a Red Sea specimen also confirmed its conspecificity with specimens from Oman, UAE and Pakistan (Fig. 2). Although tissue of a specimen (*G. infasciatus*) from the type locality (Thailand) was not available for analysis, the COI sequence of a Red Sea specimen was almost identical to that obtained from specimens from Oman, UAE, Pakistan and Iran (Fig. 2). Sequence data for the specimen from Iran (Acc. No. HQ149852), originally identified as *G. filamentosus*, matched that for *G. infasciatus*, whereas true *G. filamentosus* represented another clade in figure 2, leading to the re-identification of the specimen as *G. infasciatus*. Many examined specimens, photographs and other observations made by the first author confirmed the identities of specimens from Iraq, UAE, Qatar, Oman and Iran as *G. infasciatus*, rather than *G. filamentosus*, which has long been reported in the Middle East (Khalaf, 1961; Mahdi, 1962; Sivasubramaniam and Ibrahim, 1982; Al-Baharna, 1986; Kuronuma and Abe, 1986; Carpenter *et al*., 1997).

DISCUSSION

Determining that specimens with an elongate second dorsal-fin spine from the Arabian Peninsula, including the Red Sea, and the Arabian Gulf and Oman, were consistent with *Gerres infasciatus*, rather than *G. filamentosus*, highlighted the need to reassess the distribution of both species. *Gerres infasciatus* is now seen to be distributed along the northern coasts of both the Indian Ocean, including the Red Sea and the Arabian Gulf, and the Gulf of Thailand, western Pacific Ocean, compared with an earlier notion of a distribution limited to the Gulf of Thailand. *Gerres limbatus* has a similar distribution pattern [Arabian Gulf and coastal India to southern China (Iwatsuki *et al*., 2001; Borkenhagen, 2011; Ali *et al*., 2014)].

Although casual examination of old museum specimens from Eritrea, southern Red Sea (HUJF 16152, 16407, Tab. I), previously identified as *G. filamentosus*, showed no bands on the body (Iwatsuki *et al*., 1996), careful examination of a specimen from the Red Sea (SMF 35412, 99.5 mm SL) revealed subtle, although indistinct, vertical bands on the body (Fig. 1A, angled view). Furthermore, some larger fresh specimens (over ca. 150 mm SL) of *G. infasciatus* from Oman, UAE, Pakistan and Iraq had vertical 'bands' of yellowish ovoid spots beneath the body scales (particularly obvious after removal of the scales), as in *G. filamentosus* (fig. 2E-H *in* Iwatsuki *et al*., 1996). These 'bands' are usually lost after preservation in ethanol and/or formalin. In the case of fresh *G. filamentosus* specimens, vertical bands of black or dusky ovoid spots (apparent as melanophores after fixation in formalin or ethanol) on the body become clearer in preserved specimens. Adults specimens of *G. infasciatus* from the western Pacific larger than 150 mm SL needed to determine this character.

Gerres filamentosus is widespread species and had been recorded from Pakistan and India, from Kenya (East Africa) to south of South Africa, Mozambique, the Andaman Sea (eastern Indian Ocean) and widely throughout the western Pacific, including Southeast Asia and northern Australia, but, in fact, *G. filamentosus* does not occur from the Middle East where it has long been misidentified with *G. infasciatus* and/or *G. macracanthus* (Iwatsuki *et al*., 1996; present study). *Gerres macracanthus* is widely distributed in

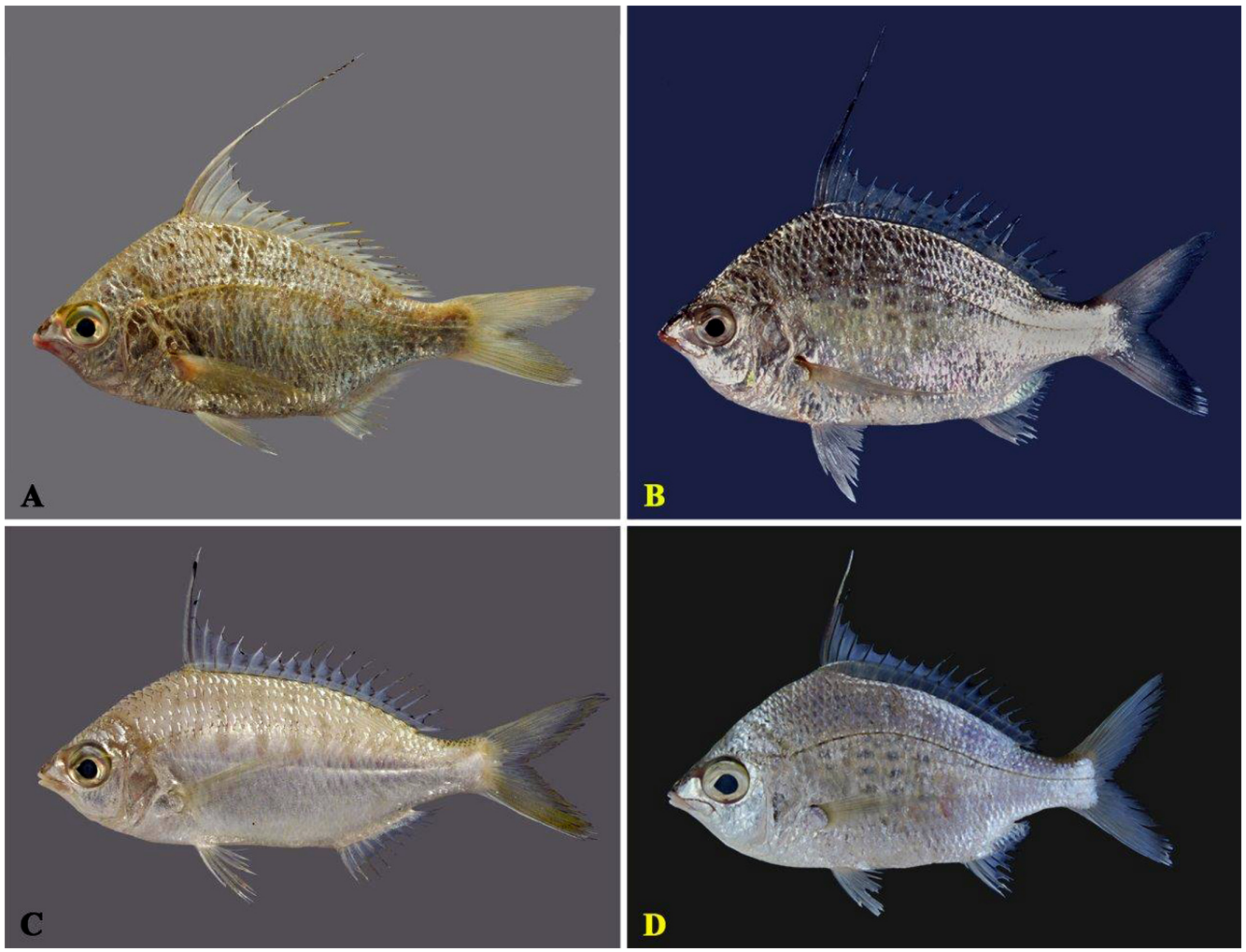

Figure 1. - *Gerres filamentosus* complex. **A**: *Gerres infasciatus*. SMF 35412, 99.5 mm SL, off Jizan, Saudi Arabia, Red Sea; **B**: *G. microphthalmus,* NSMT-P 45901, holotype, female, 189 mm SL, Kyushu, Japan; **C**: *G. macracanthus,* SMF 35037, 98 mm SL, off Jizan, Saudi Arabia, Red Sea; **D**: *G. filamentosus*, KAUMI 12250, 139 mm SL, off Sabah, Borneo Island, Malaysia. Photographs (A, C) were taken by S.V. Bogorodsky and (D) by M. Matsunuma.

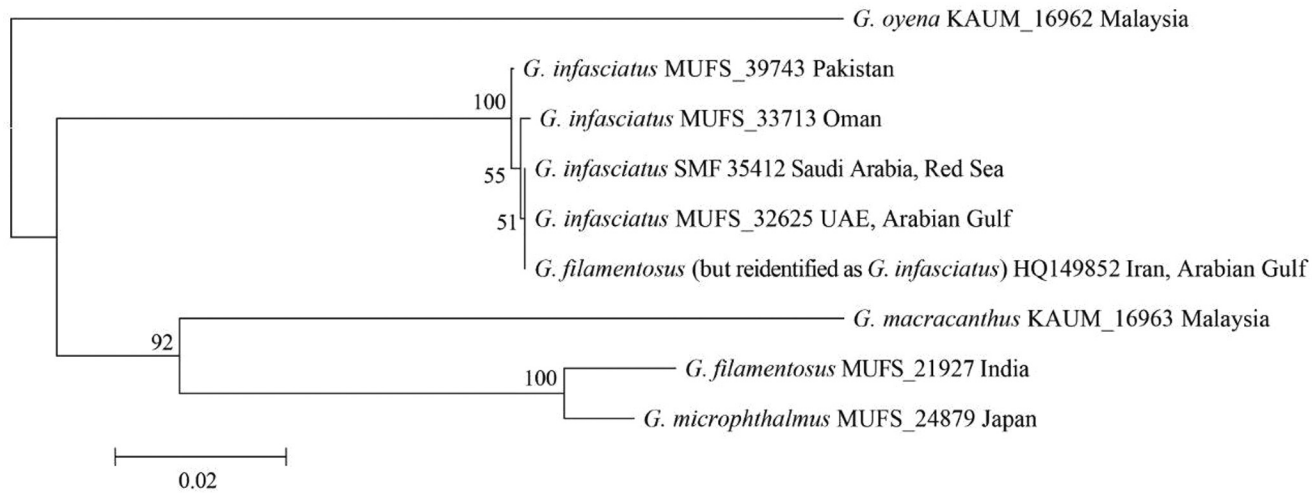

Figure 2. - K2P distance neighbouring-joining tree of COI sequences (615 bp) of gerreid species in the *Gerres filamentosus* complex; *G. oyena* used as outgroup.

the Indo-West Pacific, whereas *G. microphthalmus* is endemic to a limited area off southern Japan. The tree constructed for the COI gene (615 bp) indicates that *G. infasciatus* is the least derived of the species of the *Gerres filamentosus* complex (Fig. 2), reflected in the unique distribution pattern of the former.

Key to species of the *Gerres filamentosus* complex in the Indo-Pacific

1a. Second dorsal-fin spine not elongate, less than 50% SL at any size . . . . . .other gerreids
1b. Second dorsal-fin spine elongate, more than 50% SL in fish > 5-7 cm SL; dusky bars often present on body in fish > 5 cm SL 2

2a. Body relatively slender, depth 2.2-2.8 in SL; usually with 6-10 faint dark bars on body [noticeable at 13-16 cm SL, but not forming vertical rows of dark ovoid spots even in larger adults (ca. 17 cm SL); often no obvious white tips on pelvic fins, anal-fin spines or lower lobe of caudal fin in fresh specimens from Red Sea] . . . . . .*G. macracanthus* (Indo-West Pacific)
2b. Body depth 1.9-2.4 in SL; usually with 4-10 faint dark bars on body of fish < 10 cm SL, larger fish with vertical series of dark ovoid spots, or no bars or ovoid spots 3

3a. Body usually without dark bars or bands of ovoid spots dorsally, even in fish > 10 cm SL (rarely 5–6 very faint yellowish bars may be visible upon angled view, becoming more obvious after removal of scales or just after preservation); first and second (rarely third) dorsal-fin ray tips yellow in fresh specimens . . . . . .*G. infasciatus* (northern Indian Ocean and Gulf of Thailand)
3b. Juveniles (< 9 cm SL) with 4-8 dark bars on body; adults (> 10 cm SL) with 4-8 columns of ovoid spots dorsally on body, more obvious after removal of scales or in preserved specimens; fresh specimens lacking yellow dorsal-fin ray tips 4

4a. Eyes moderately large, orbit diameter 10%-16% SL (2.2-3.3, mean 2.7 in head length); pored lateral-line scales 43-46; overall body appearance not rounded in larger adults (fig. 2H *in* Iwatsuki *et al*., 2002) . . . . . *G. filamentosus* (Indo-West Pacific except Middle East)
4b. Eyes relatively small, orbit diameter 8%-11% SL (2.9-3.5, mean 3.2 in head length); pored lateral-line scales 40-43; overall body appearance extremely rounded in larger adults (fig. 2D *in* Iwatsuki *et al*., 2002) . . . . . .*G. microphthalmus* (southern Japan)

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