

Annotated checklist of gobioid fishes (Perciformes, Gobioidei) from Wakasa Bay, Sea of Japan[※]

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若狭湾のハゼ亜目魚類リスト

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抄録: 近年採集された標本と水中写真に基づき、若狭湾の沿岸域および汽水域に生息するハゼ亜目魚類の目録を作成した。その結果、2科35属56種の生息が確認され、うち22種は若狭湾初記録、4種は日本海初記録であった。本報告と過去の文献記録と照らし合わせると、少なくとも8種において若狭湾が日本海側の分布の北限および東限記録となった。また、レッドリストに掲載されている希少な汽水魚類が6種含まれていた。また、若狭湾のハゼ亜目魚類相の特徴について、日本海側の3地域（兵庫県、富山湾、新潟県）と比較して考察を行った。最後に、若狭湾のハゼ亜目魚類相の1960-1970年代から現在にいたる変遷について触れ、その要因を主に海水温変化に注目して検討した。

Abstract: A checklist of marine and estuarine gobioid fishes in Wakasa Bay, based on recently collected and photographed voucher specimens, includes a total of 56 Gobioidei species (35 genera in 2 families), 22 species being new records for Wakasa Bay and four for the Sea of Japan. Wakasa Bay is the northernmost locality recorded in the Sea of Japan for at least eight species. In addition, six threatened estuarine species currently included in the Red List were represented. The gobioid fish fauna of Wakasa Bay is discussed and compared with that of three other coastal regions (Hyogo Prefecture, Toyama Bay and Niigata Prefecture) in the Sea of Japan. In addition, changes in the gobioid fish fauna of Wakasa Bay over the past 50 years are discussed in relation to environmental factors, with particular emphasis on changes in seawater temperature.

Key Words: Gobioidei; marine goby; estuarine goby; Wakasa Bay; Sea of Japan.

Wakasa Bay, located centrally on western Honshu Island, Japan (Fig. 1), is one of the few large bays along the Sea of Japan coast. The bay is defined as the inner area of a line connecting Echizen Cape, Fukui Prefecture (35.98°N, 135.96°E) and Kyoga Cape, Kyoto Prefecture (35.78°N, 135.22°E), the coastline comprising diverse environments, such as ria coasts including many sub-basins with steep slopes, extensive sandy beaches and brackish lakes. The water depth is greatest (> 250 m) in the eastern part of the bay-mouth, being 50-100 m in a large part of the bay. The distribution of bottom sediments (such as mud, sand-mud mixture, sand and gravel) is

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complex, reflecting the topography (Minami *et al.*, 1977; Shiki and Hayashi, 1985). The physical environment (such as water temperature and salinity) changes constantly, due mainly to the Tsushima Current flowing off Wakasa Bay and freshwater input from rivers such as the Yura River (Asaoka *et al.*, 1985). Tidal fluctuations in the bay are typical for the Sea of Japan, the mean spring tidal range being much less than that on the Pacific Coast (less than 50 cm at Maizuru, western Wakasa Bay; Japan Meteorological Agency, 2012a), with annual fluctuations in tidal levels being mainly dependent upon atmospheric pressure and thermal expansion of sea water (Asaoka *et al.*, 1985). Because of such tidal characteristics, no tidal flats have formed in Wakasa Bay.

From a biogeographic viewpoint, Wakasa Bay marks the northern part of range of subtropical coastal fishes and southern part of range of subarctic coastal fishes in the Sea of Japan, being a major feature in the distribution of subtropical, temperate and subarctic coastal fishes (cf. Kamohara, 1961; Nakabo, 2013). Accordingly, a rich ichthyofauna can be expected to occur in Wakasa Bay, although to date the former has been poorly studied [but see Mori (1956), Takegawa and Morino (1970), Kadota (1977), Masuda (2008), and Kawano *et al.* (2011b)]. Species included in the aforementioned accounts were listed under scientific and/or standard Japanese names only, there being no voucher specimen support. In addition, the relatively recent studies of Masuda (2008) and Kawano *et al.* (2011b), respectively dealt with fishes only from a part in Wakasa Bay or simply provided a summary of previous works. Although many fish species have been newly recorded from Japanese waters, with scientific names sometimes changing as a result of recent taxonomic investigations, the identities and distributions of many Wakasa Bay species has remained uncertain.

Suborder Gobioidi is a species-rich group, characterized as having variably developed cephalic canals and often united pelvic fins below the pectorals (Nelson, 2006). This group includes ca. 2211 species worldwide (Nelson, 2006), ca. 518 of these occurring in Japan (Akihito *et al.*, 2013), having diversified mainly in coastal environments. In previous studies of Wakasa Bay fishes, some 35 gobioid species have been listed (Takegawa and Morino, 1970; Kadota, 1977; Masuda, 2008; Kawano *et al.*, 2011b). Because gobioid fishes are important as environmental indicator species, it is necessary to clarify their current distribution in Wakasa Bay, especially from the viewpoint of conservation ecology.

A list of marine and estuarine gobioid fishes recorded from Wakasa Bay (except larvae and juveniles of some *Rhinogobius* species), primarily based on recently collected voucher specimens, includes a total of 56 Gobioidi species (35 genera in 2 families), 22 species being first records from Wakasa Bay and 4 species being first records from the Sea of Japan coast. This is given below and comparisons made with three other coastal regions in the Sea of Japan.

Materials and methods

The arrangement of species, family names, and scientific names basically follow Akihito *et al.* (2013). Standard Japanese names (abbreviated as Jpn name) also follow Akihito *et al.* (2013), transliterated using the Hepburn system. The specimens listed here are deposited in the fish collections of Kyoto University (FAKU) and the Osaka Museum of Natural History (OMNH). Underwater photographs deposited in FAKU (FAKU_DI) are also included. Each species account includes registration number, number of specimens in parentheses, standard length (abbreviated as SL) and collection site (Fig. 1). Localities are described at the level of sub-basin, larger section or large river (Class A river systems), due to some species being threatened and/or locally distributed. Specimens obtained from the Kyoto Prefectural Fishery Cooperative were considered as having been collected from Wakasa Bay.

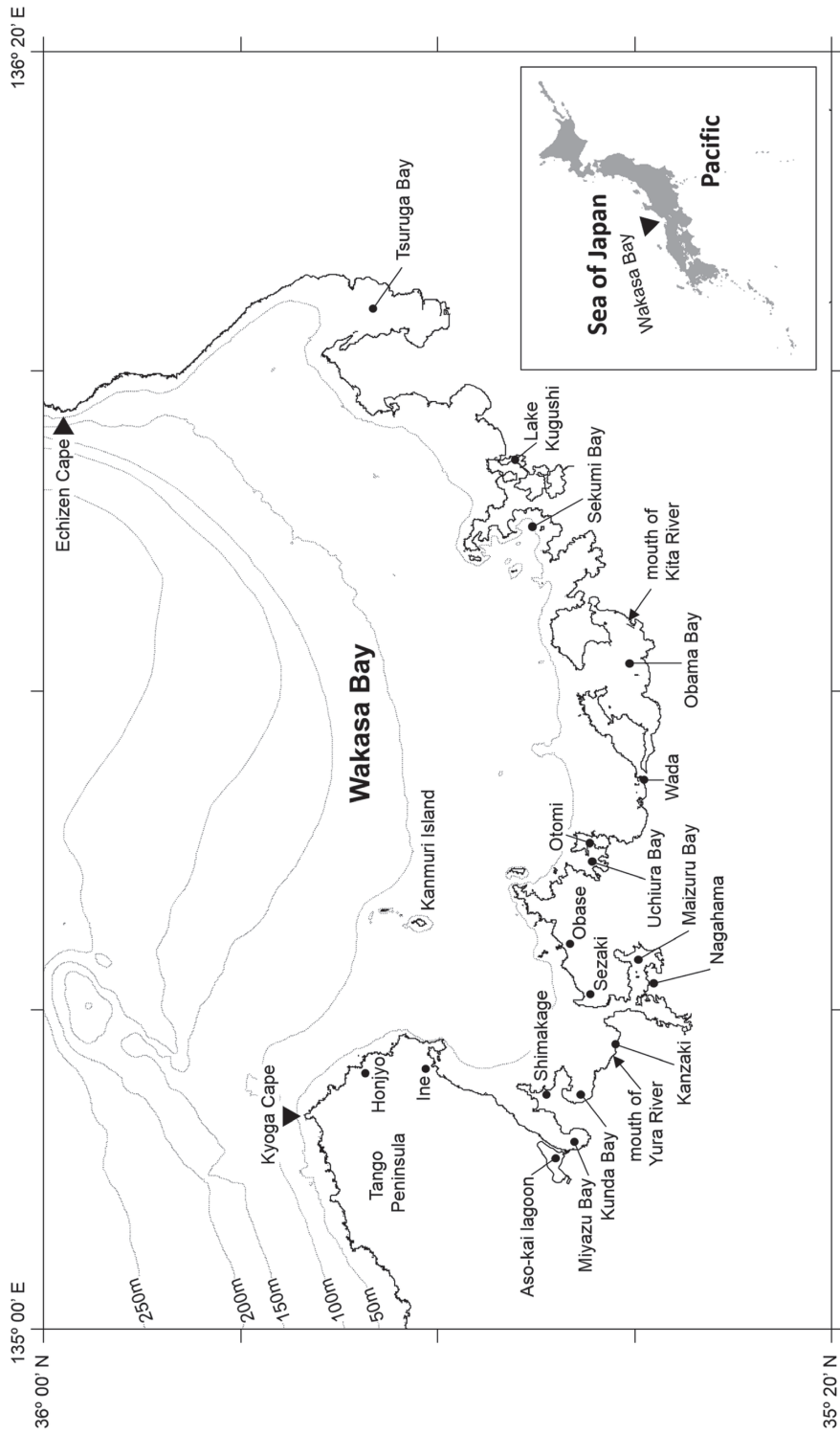


Fig. 1. Location of Wakasa Bay and collection or observation sites of gobioid species. Grayish dotted lines indicate water depths at 50 m intervals.

Checklist

Family Gobiidae

Luciogobius elongatus Regan, 1905

[Jpn name: Naga-mimizuhaze] (Plate I-1)

FAKU 134814 (2), 24.7-34.1 mm SL, Maizuru Bay, 22 March 2012.

Remarks. This is the first record of this species in Wakasa Bay.

Luciogobius guttatus Gill, 1859

[Jpn name: Mimizuhaze] (Plate I-2)

FAKU 134259 (1), 34.6 mm SL, Obama Bay, 13 May 2011; FAKU 134263 (1), 41.6 mm SL, Obama Bay, 13 May 2011; FAKU 134775 (1), 69.2 mm SL, Obama Bay, 23 March 2012; FAKU 134786 (2), 38.5-65.1 mm SL, Maizuru Bay, 22 March 2012; OMNH-P 38950-38956 (9), 35.5-47.7 mm SL, Maizuru Bay, 22 March 2012.

Luciogobius sp.

[Jpn name: Iso-mimizuhaze] (Plate I-3)

FAKU 134799 (1), 34.0 mm SL, Maizuru Bay, 22 March 2012.

Remarks. This specimen agreed well with *Luciogobius* sp. 6 of Akihito *et al.* (2013) in having a dark body without white spots and a black caudal-fin with a pale posterior margin. This is the first record of this species in Wakasa Bay.

Eutaenichthys gilli Jordan and Snyder, 1901

[Jpn name: Himohaze] (Plate I-4)

FAKU 134268 (1), 42.0 mm SL, Obama Bay, 13 May 2011; FAKU 134788 (1), 39.2 mm SL, Maizuru Bay, 22 March 2012; OMNH-P 38957-38959 (5), 23.6-42.6 mm SL, Obama Bay, 23 March 2012.

Remarks. This is the first record of this species in Wakasa Bay.

Leucopsarion petersii Hilgendorf, 1880

[Jpn name: Shiro-uo] (Plate I-5)

FAKU 132998 (15), 34.4-42.1 mm SL, Maizuru Bay, 7 April 2011; FAKU 134285 (1), 41.0 mm SL, Yura River, 12 May 2011; FAKU 134771 (2), 35.9-43.2 mm SL, Obama Bay, 23 March 2012; OMNH-P 38947-38949 (5), 35.8-41.9 mm SL, Maizuru Bay, 22 March 2012.

Paratrypauchen microcephalus (Bleeker, 1860)

[Jpn name: Aka-uo] (Plate I-6)

FAKU 134282 (1), 101.8 mm SL, Maizuru Bay, 10 May 2011.

Apocryptodon punctatus Tomiyama, 1934

[Jpn name: Tabirakuchi] (Plate I-7)

FAKU 132968 (1), 34.9 mm SL, Maizuru Bay, 21 September 2010; FAKU 132969 (1), 132972 (1), 132974 (1), 19.7-29.1 mm SL, Maizuru Bay, 13 September 2010; FAKU 132970 (1), 137971 (1), 137973 (1), 18.4-26.4 mm SL, Maizuru Bay, 1 September 2010; FAKU 132976 (1), 33.6 mm SL, Maizuru Bay, 8 October 2010.

Remarks. Wakasa Bay represents both the northern and easternmost range limits of this species in the Sea of Japan (Matsui *et al.*, 2011).

Asterropteryx semipunctata Rüppell, 1830

[Jpn name: Hoshi-haze] (Plate I-8)

FAKU_DI 19, Otomi, 21 October 2003.

Remarks. This specimen represents both the northern and easternmost records of this species in the Sea of Japan.

Amblychaeturichthys sciiistius (Jordan and Snyder, 1901)

[Jpn name: Komochijako] (Plate I-9)

FAKU 1349850-134851 (2), 37.6-41.8 mm SL, Maizuru Bay, 9 April 2012; FAKU 134942-134945 (4), 43.4-53.5 mm SL, off Ine, 10 July 2012; FAKU 134997 (1), 47.0 mm SL, off Kanmuri Island, 19 July 2012; FAKU 135100-135101 (2), 48.9-52.4 mm SL, off Honjyo, 13 August 2012; OMNH-P 38965 (1), 38.7 mm SL, Maizuru Bay, 10 May 2011.

Amblychaeturichthys hexanema (Bleeker, 1853)

[Jpn name: Aka-haze] (Plate I-10)

FAKU 132142 (6), 43.2-85.3 mm SL, Maizuru Bay, 5 September 2009; FAKU 134283 (1), 85.4 mm SL, Maizuru Bay, 10 May 2011.

Sagamia geneionema (Hilgendorf, 1879)

[Jpn name: Sabi-haze] (Plate I-11)

FAKU 129994 (2), 34.1-40.8 mm SL, Wakasa Bay, 12 May 2004; FAKU_DI 24, Shimakage, 18 July 2010.

Pterogobius virgo (Temminck and Schlegel, 1845)

[Jpn name: Nishiki-haze] (Plate I-12)

FAKU W704-W705 (2), 48.9-52.4 mm SL, Kyoto Prefectural Fishery Cooperative, 12 July 1979; FAKU_DI 20, Sezaki, 18 November 2003.

Pterogobius zacalles Jordan and Snyder, 1901

[Jpn name: Ryûgû-haze] (Plate I-13)

FAKU 114837 (1), 43.2 mm SL, Kyoto Prefectural Fishery Cooperative, 18 May 1983.

Remarks. Several earlier records, including Kadota (1970) and Minami *et al.* (1977), suggested that this species was common in Wakasa Bay. However, since 1983, when the voucher specimen listed in the present report was collected, there have been no further records supported by voucher specimens from Wakasa Bay.

Pterogobius elapoides (Günther, 1871)

[Jpn name: Kinubari] (Plate I-14)

FAKU 114685 (1), 66.1 mm SL, Maizuru Bay, 17 August 1983; FAKU 114714 (1), 55.5 mm SL, Maizuru Bay, 29 May 1983; FAKU_DI 25, Shimakage, 10 July 2010.

Remarks. This species was often found in Maizuru Bay in the 1960s and '70s (Takegawa and Morino, 1970; Kadota, 1977) but has been seldom found there recently (although it often occurs in other parts of Wakasa Bay).

Pterogobius zonoleucus Jordan and Snyder, 1901

[Jpn name: Chagara] (Plate I-15)

FAKU 135096 (1), OMNH-P 38972 (1), 30.0-33.9 mm SL, Maizuru Bay, 3 August 2012.

Suruga fundicola Jordan and Snyder, 1901

[Jpn name: Yami-haze] (Plate II-1)

FAKU 131275-131279 (5), 42.3-47.5 mm SL, off Kanmuri Island, 13 July 2006; FAKU 132894 (1), 46.8 mm SL, off Tango Peninsula, 21 December 2010; FAKU 134998 (1), 48.9 mm SL, off Kanmuri Island, 19 July 2012.

Remarks. This is the first record of this species in Wakasa Bay.

Acanthogobius flavimanus (Temminck and Schlegel, 1845)

[Jpn name: Ma-haze] (Plate II-2)

FAKU 134273 (1), 73.0 mm SL, Maizuru Bay, 13 May 2011; FAKU 134767 (1), 59.8 mm SL, Obama Bay, 23 March 2012; OMNH-P 38966-38967 (2), 53.6-53.6 mm SL, Maizuru Bay, 22 March 2012; OMNH-P 38968 (1), 45.0 mm SL, Maizuru Bay, 12 August 2012.

Acanthogobius lactipes (Hilgendorf, 1879)

[Jpn name: Ashishiro-haze] (Plate II-3)

FAKU 134271 (1), 46.5 mm SL, Maizuru Bay, 13 May 2011; FAKU 134808 (1), 33.1 mm SL, Maizuru Bay, 22 March 2012; FAKU 134757 (1), 134762 (2), OMNH-P 38969-38971 (5), 21.6-50.2 mm SL, Obama Bay, 23 March 2012.

Platygobiopsis sp.

(Plate II-4)

FAKU 131651-131652 (2), 132182-132186 (7), 48.1-64.0 mm SL, off Ine, 24 July 2008; FAKU 131672 (2), 55.6 mm SL, off Ine, 7 October 2008; FAKU 132827-132828 (6), 54.7-64.1 mm SL, off Ine, 5 November 2010; FAKU 132864 (34), 32.2-75.8 mm SL, off Ine, 25 November 2010; FAKU 135288 (3), 65.9-69.6 mm SL, off Ine, 24 January 2013.

Remarks. These specimens were collected from the muddy bottom in ca. 100 m depth. The species is most similar to *P. tansei* in having an extremely flattened body, but differs in having larger and more developed canine teeth on both jaws, and larger body size [maximum recorded length 75.8 mm SL (this report) vs. 48.2 mm SL in *P. tansei* (Okiyama, 2008)]. Further taxonomic investigation would be appropriate.

Silhouettea dotui (Takagi, 1957)

[Jpn name: Shiranui-haze] (Plate II-5)

FAKU 134938 (1), 35.1 mm SL, Kanzaki, 3 July 2012.

Remarks. This is the first record of this species in Wakasa Bay.

Mugilogobius abei (Jordan and Snyder, 1901)

[Jpn name: Abe-haze] (Plate II-6)

FAKU 134276 (1), 34.1 mm SL, Maizuru Bay, 13 May 2011.

Remarks. This is the first record of this species in Wakasa Bay.

Pseudogobius masago (Tomiyama, 1936)

[Jpn name: Masago-haze] (Plate II-7)

FAKU 135173 (1), 16.69 mm SL, Lake Kugushi, 9 October 2012; OMNH-P 38630 (1), 14.77 mm SL, Lake Kugushi, 9 October 2012.

Remarks. These specimens constitute both the northern and easternmost records of this species in the Sea of Japan. The only other known records from the Sea of Japan are from Tsushima and Iki Islands, Nagasaki Prefecture (Yoshigou, 2003; Yoshigou and Nakamura, 2003), and Fukuoka Prefecture (Inui *et al.*, 2012).*Lubricogobius exiguus* Tanaka, 1915

[Jpn name: Mijimbenihaze]

FAKU 131710 (1), 14.9 mm SL, off Ine, 9 May 2007.

Remarks. This is the northern and easternmost record of this species in the Sea of Japan. No photo was taken because of the bad condition of the specimen examined here.

Tridentiger trionocephalus (Gill, 1858)

[Jpn name: Akaobi-shimahaze] (Plate II-8)

FAKU 132100 (1), 41.2 mm SL, Maizuru Bay, 18 August 2009; FAKU 134257 (1), 52.9 mm SL, Obama Bay, 13 May 2011; OMNH-P 38983 (1), 45.1 mm SL, Maizuru Bay, 13 May 2011; OMNH-P 38984 (1), 38.4 mm SL, Maizuru Bay, 22 March 2012.

Remarks. Because two species, *T. trionocephalus* and *T. bifasciatus*, have been confused under "*T. trionocephalus* [Jpn name: Shimahaze]" (Akihito and Sakamoto, 1989), previous unsupported records of "*T. trionocephalus*" from Wakasa Bay cannot be attributed with certainty to either of the two former taxa.*Tridentiger bifasciatus* Steindachner, 1881

[Jpn name: Shimofuri-shimahaze] (Plate II-9)

FAKU 134756 (1), 41.7 mm SL, Kita River, 23 March 2012; FAKU 135116 (1), 49.4 mm SL, Aso-kai lagoon, 12 August 2012.

Tridentiger brevispinis Katsuyama, Arai and Nakamura, 1972

[Jpn name: Numa-chichibu] (Plate II-10)

FAKU 124100 (2), 35.6-36.8 mm SL, Maizuru Bay, 10 October 1960; FAKU 134279 (1), 59.0 mm SL,

Maizuru Bay, 13 May 2011; FAKU 134758 (1), 57.6 mm SL, Kita River, 23 March 2012; FAKU 134776 (1), 24.7 mm SL, Obama Bay, 23 March 2012; OMNH-P 38985 (1), 38986 (1), 36.3-63.6 mm SL, Maizuru Bay, 22 March 2012.

Tridentiger obscurus (Temminck and Schlegel, 1845)

[Jpn name: Chichibu] (Plate II-11)

FAKU 134277 (1), 48.3 mm SL, Maizuru Bay, 13 May 2011; FAKU 134774 (1), 56.6 mm SL, Obama Bay, 23 March 2012; FAKU 135175 (1), 24.62 mm SL, Lake Kugushi, 9 October 2012; OMNH-P 38987 (2), 30.5-43.9 mm SL, Maizuru Bay, 22 March 2012.

Parachaeturichthys polynema (Bleeker, 1853)

[Jpn name: Hige-haze] (Plate II-12)

FAKU 132144 (1), 57.3 mm SL, Maizuru Bay, 7 September 2009.

Redigobius bikolanus (Herre, 1927)

[Jpn name: Hina-haze] (Plate II-13)

FAKU 134275 (1), 20.0 mm SL, Maizuru Bay, 13 May 2011.

Remarks. Wakasa Bay constitutes both the northern and easternmost limits of the range of this species in the Sea of Japan (Arao and Tahara, 2011).

Heteroplopomus barbatus (Tomiyama, 1934)

[Jpn name: Nirami-haze] (Plate II-14)

FAKU 134939 (1), 35.3 mm SL, Kanzaki, 3 July 2012.

Obliquogobius yamadai Shibukawa and Aonuma, 2007

[Jpn name: Kiobi-chihirohaze] (Plate II-15)

FAKU 135312 (1), 23.0 mm SL, off Honjyo, 18 February 2013.

Remarks. This is the northern and easternmost record of this species in the Sea of Japan.

Rhinogobius giurinus (Rutter, 1897)

[Jpn name: Gokuraku-haze] (Plate III-1)

FAKU 134266 (1), 40.4 mm SL, Obama Bay, 13 May 2011; FAKU 134269 (1), 27.1 mm SL, Maizuru Bay, 13 May 2011; FAKU 134755 (1), 58.5 mm SL, Kita River, 23 March 2012.

Glossogobius olivaceus (Temminck and Schlegel, 1845)

[Jpn name: Uro-haze] (Plate III-2)

FAKU 134274 (1), 106.7 mm SL, Maizuru Bay, 13 May 2011; FAKU 135107 (1), 127.5 mm SL, Yura River, 20 August 2012; FAKU 135174 (1), 17.19 mm SL, Lake Kugushi, 9 October 2012; OMNH-P 38964 (1), 68.9 mm SL, Maizuru Bay, 12 August 2012.

Acentrogobius sp.

[Jpn name: Tsumaguro-sujihaze] (Plate III-3)

FAKU 134761 (1), 36.1 mm SL, Obama Bay, 23 March 2012; FAKU 134791 (1), 40.4 mm SL, Maizuru Bay, 22 March 2012; FAKU 135172 (1), 27.39 mm SL, Lake Kugushi, 9 October 2012; FAKU 135176-135179 (4), 27.05-53.37 mm SL, Aso-kai lagoon, 12 August 2012; FAKU 135180 (1), OMNH-P 38975 (1), 17.12-29.14 mm SL, Maizuru Bay, 12 August 2012; OMNH-P 38629 (1), 25.02 mm SL, Lake Kugushi, 9 October 2012.

Remarks. This specimen agreed well with *Acentrogobius* sp. 2 of Akihito *et al.* (2013) in having a pelvic-fin with a black posterior edge, a caudal-fin with a dark line on the base, and no predorsal scales. Previously recognized "*A. pflaumii*" [Jpn name: Suji-haze] has included several cryptic species (Akihito *et al.*, 2013), and three of these, *Acentrogobius* sp., *Acentrogobius pflaumii*, and *Acentrogobius virgatulus*, being widely distributed around the Japanese archipelago (Matsui *et al.*, 2012). "*A. pflaumii*" recorded from Wakasa Bay in previous studies cannot be attributed with certainty to any one of the above three species due to the lack of voucher specimens.

Acentrogobius pflaumii (Jordan and Snyder, 1901)

[Jpn name: Moyou-haze] (Plate III-4)

FAKU 134267 (1), 50.6 mm SL, Obama Bay, 13 May 2011; FAKU 135126 (1), 47.7 mm SL, Miyazu Bay, 4 July 2012; FAKU 135193 (3), OMNH-P 38980 (3), 29.13-33.84 mm SL, Kunda Bay, 9 July 2012; FAKU 135194 (7), OMNH-P 38981 (6), 26.13-38.26 mm SL, Ine, 4 July 2012.

Acentrogobius virgatulus (Jordan and Snyder, 1901)

[Jpn name: Sujihaze] (Plate III-5)

FAKU 135117 (1), 36.9 mm SL, Maizuru Bay, 12 August 2012; FAKU 135127, OMNH-P 38976 (1), 46.7-55.5 mm SL, Miyazu Bay, 4 July 2012; FAKU 135186 (2), OMNH-P 38977 (1), 30.03-44.78 mm SL, Ine, 12 August 2012; FAKU 135187 (1), OMNH-P 38978 (1), 31.40-31.98 mm SL, Aso-kai lagoon, 12 August 2012; FAKU 135188 (3), OMNH-P 38979 (3), 33.20-42.45 mm SL, Kunda Bay, 9 July 2012.

Favonigobius gymnauchen (Bleeker, 1860)

[Jpn name: Hime-haze] (Plate III-6)

FAKU 132235 (4), 31.9-41.6 mm SL, Maizuru Bay, 22 July 1992; FAKU 134260 (1), 30.5 mm SL, Obama Bay, 13 May 2011; FAKU 135123 (1), 46.8 mm SL, Kunda Bay, 9 July 2012; FAKU 135125 (1), 54.1 mm SL, Miyazu Bay, 4 July 2012; FAKU 135108-135109 (2), 47.6-48.6 mm SL, Yura River, 20 August 2012; OMNH-P 38973 (1), 36.7 mm SL, Obama Bay, 23 March 2012; OMNH-P 38973 (1), 32.9 mm SL, Miyazu Bay, 4 July 2012.

Favonigobius sp.

(Plate III-7)

FAKU 135117 (1), 36.9 mm SL, Aso-kai lagoon, 12 August 2012.

Remarks. This specimen was collected on the sandy-muddy bottom in about 1 m depth near the mouth of the lagoon. It is similar to *F. gymnauchen* in having a sandy-colored body with dark blotches on the sides,

slightly compressed head and smoothly rounded ventral fin, but differs from the latter in having 8 dorsal fin rays (vs. 9 in *F. gymnauchen*), 8 anal fin rays (vs. 9), and double lines of sensory papillae under the eye and on the cheek (vs. single lines) (Akihito *et al.*, 2013; this study). It is also similar to *F. reichei* in dorsal and anal fin ray numbers, and condition of the sensory papillae, but differs in having a dark spot posteriorly on the first dorsal fin (vs. no dark spot in *F. reichei*) and 8 predorsal scales (vs. 3) (Akihito *et al.*, 2013; this study). Further taxonomic investigation would be appropriate. This is the first specimen-supported record of the genus *Favonigobius* (other than *F. gymnauchen*) in the Sea of Japan.

Istigobius hoshinonis (Tanaka, 1917)

[Jpn name: Hoshino-haze] (Plate III-8)

FAKU 135121 (1), 43.4 mm SL, Kunda Bay, 9 July 2012.

Istigobius campbelli (Tanaka, 1917)

[Jpn name: Kutsuwa-haze] (Plate III-9)

FAKU_DI 22, Maizuru Bay, 1 September 2006.

Gymnogobius petschiliensis (Rendahl, 1924)

[Jpn name: Sumi-ukigori] (Plate III-10)

FAKU 127427 (1), 102.4 mm SL, Yura River, 11 October 1996; FAKU 134280 (1), 134286 (1), 22.5-69.9 mm SL, Maizuru Bay, 13 May 2011.

Gymnogobius urotaenia (Hilgendorf, 1879)

[Jpn name: Ukigori] (Plate III-11)

FAKU 134262 (1), 58.4 mm SL, Obama Bay, 13 May 2011.

Gymnogobius heptacanthus (Hilgendorf, 1879)

[Jpn name: Niku-haze] (Plate III-12)

FAKU 135119 (1), 31.6 mm SL, Maizuru Bay, 12 August 2012.

Gymnogobius breunigii (Steindachner, 1879)

[Jpn name: Biringo] (Plate III-13)

FAKU 134264-134265 (2), 43.5-55.1 mm SL, Obama Bay, 13 May 2011; FAKU 134272 (1), 40.3 mm SL, Maizuru Bay, 13 May 2011; OMNH-P 38962-38963 (2), 134773 (1), 51.4-58.3 mm SL, Obama Bay, 23 March 2012.

Gymnogobius uchidai (Takagi, 1957)

[Jpn name: Chikuzen-haze] Plate III-14)

FAKU 135278 (1), OMNH-P 38961 (1), 26.4-27.25 mm SL, Aso-kai lagoon, 27 November 2011.

Remarks. This is the first record of this species in Wakasa Bay.

Gymnogobius scrobiculatus (Takagi, 1957)

[Jpn name: Kubo-haze] (Plate III-15)

FAKU 134270 (1), 34.2 mm SL, Maizuru Bay, 13 May 2011; FAKU 134787 (1), OMNH-P 38960 (1), 32.4-32.9 mm SL, Maizuru Bay, 22 March 2012.

Remarks. Wakasa Bay represents both the northern and easternmost limits of the range of this species in the Sea of Japan (Matsumiya *et al.*, 2001; Arao and Tahara, 2011).

Chaenogobius annularis Gill, 1859

[Jpn name: Ago-haze] (Plate IV-1)

FAKU 135171 (1), 24.24 mm SL, Sekumi Bay, 9 October 2012; OMNH-P 38631 (1), 25.05 mm SL, Sekumi Bay, 9 October 2012.

Chaenogobius gulosus (Guichenot, 1882)

[Jpn name: Dorome] (Plate IV-2)

FAKU 134796 (1), 58.3 mm SL, Maizuru Bay, 22 March 2012.

Cryptocentrus filifer (Valenciennes, 1837)

[Jpn name: Itohiki-haze] (Plate IV-3)

FAKU 132811 (1), 62.8 mm SL, off Ine, 6 October 2010; FAKU 134287 (1), 86.2 mm SL, Maizuru Bay, 26 August 2011; FAKU 135122 (1), 41.3 mm SL, Kunda Bay, 9 July 2012.

Cryptocentrus sp.

(Plate IV-4)

FAKU 131385 (1), 24.4 mm SL, off Ine, 24 October 2007; FAKU 131671 (1), 24.0 mm SL, off Ine, 7 October 2008; FAKU 132990 (1), 32.1 mm SL, off Ine, 23 March 2011.

Remarks. This specimen was collected from the muddy bottom in ca. 80-100 m depth, apparently being the same species as that described as "*Cryptocentrus* sp." in Kawase and Kai (2012). It differed from other *Cryptocentrus* species in having brownish bands on the body, the first dorsal fin without a dark spot, the caudal fin pointed rather than rounded, 11 dorsal fin rays and 10 anal fin rays. Further taxonomic investigation would be appropriate.

Priolepis sp.

(Plate IV-5)

FAKU 132000 (1), 28.9 mm SL, off Yura, 28 August 2008; FAKU 132132 (1), 25.5 mm SL, off Yura, 27 August 2009.

Remarks. These specimens, collected from the muddy bottom in ca. 75-100 m depth, were similar to *Priolepis winterbotomi* in having a faintly pink body, 7 wide transverse darkish bars on the lateral body surface, 28 lateral scales and 14 predorsal scales (Nogawa and Endo, 2007). However, the nature of the sensory papillae on the present specimens was unclear due to deformation and an unequivocal species identification could not be made.

Trimma grammistes (Tomiyama, 1936)

[Jpn name: Ichimonji-haze] (Plate IV-6)

FAKU 131732 (1), 28.1 mm SL, Obase, 2 February 2009; FAKU_DI 21, Nagahama, 30 December 2004.

Eviota masudai Matsuura and Senou, 2006

[Jpn name: Aka-isohaze] (Plate IV-7)

FAKU 130894 (1), 24.2 mm SL, Maizuru Bay, 6 October 2006; FAKU 134176 (2), 23.5-24.0 mm SL, off Honjo, 17 November 2011.

Remarks. Matsuura and Senou (2006) noted that this species inhabits shallow rocky reefs at 2-20 m depth but one specimen was collected from an oyster shell bed in 59-64 m in the Sagami-nada Sea, off central Honshu. However, two specimens (FAKU 134176) from a shell bed in 90-100 m depth, the deepest known habitat record for the species. In the Sea of Japan, *E. masudai* has been previously recorded from Yamaguchi Prefecture (Kawano *et al.*, 2011a). The Wakasa Bay records constitute both the northern and easternmost records of the species in the Sea of Japan.

Eviota abax (Jordan and Snyder, 1901)

[Jpn name: Isohaze] (Plate IV-8)

FAKU 135104 (1), 23.5 mm SL, Maizuru Bay, 16 August 2012.

Family Ptereleotridae

Ptereleotris hanae (Jordan and Snyder, 1901)

[Jpn name: Hana-haze] (Plate IV-9)

FAKU_DI 23, Otomi, 4 November 2011.

Remarks. This is the first record of this species in Wakasa Bay.

Parioglossus dotui Tomiyama, 1958

[Jpn name: Satsuki-haze] (Plate IV-10)

FAKU 134258 (1), 26.0 mm SL, Obama Bay, 13 May 2011.

Remarks. This is the first record of this species in Wakasa Bay.

Discussion

Diversification of gobioid species in Wakasa Bay

This paper provides a checklist of 56 gobioid species from Wakasa Bay. In addition, *Bathygobius fuscus* (Jpn name: Kumo-haze) was collected in the late 1960's (Takegawa and Morino, 1970), but has not been found in recent surveys. Gobioid species diversity in Wakasa Bay is closely related to the variety of habitats (such as ria coasts with sub-basins, sandy beaches, brackish lakes and relatively deep water) and biogeographical features of the bay. Several apparently undescribed species were also listed, some from relatively deep water (70-100 m). In addition, several threatened species included in the Red List (Ministry of the Environment of Japan, 2013): *Gymnogobius scrobiculatus* (categorized as endangered), *Leucopsarion petersii*, *Apocryptodon*

punctatus, *Pseudogobius masago* *Gymnogobius uchidai* (vulnerable), *Eutaeniichthys gilli*, *Silhouettea dotui* (near threatened) were also recorded.

Wakasa Bay lacks tidal flats and permanent brackish water is uncommon in the bottom layer in estuaries (except brackish lakes), due to low tidal influence and high water volumes from rivers, all being characteristics unsuitable for brackish water species (Kishida *et al.*, 2011). Notwithstanding, several brackish water species, which typically occur on tidal flats or in estuaries along the Pacific and/or East China Sea coasts of Japan, were recorded from Wakasa Bay, small numbers of individuals having been collected in the vicinity of spring water or on sandy-muddy bottoms near the mouths of small rivers, suggesting that they represented small-sized populations in the inner parts of sub-basins, characterized by wide salinity ranges. Significantly, Wakasa Bay represents both the northern and easternmost limits of the distribution ranges for several such species, *Apocryptodon punctatus*, *Pseudogobius masago*, *Redigobius bikolanus* and *Gymnogobius scrobiculatus* (Matsumiya *et al.*, 2001; Arao and Tahara, 2011; Matsui *et al.*, 2011; this study).

Comparison of the gobioid fish fauna of Wakasa Bay with those in other regions along the Sea of Japan coast

A relatively large number of accounts on the distributions of gobioid species have been compiled for Hyogo Prefecture, Toyama Bay and Niigata Prefecture. Although some species of *Luciogobius*, *Astrabe* and *Clariger* (occurring on the Sea of Japan coast of Hyogo Prefecture (see Suzuki *et al.*, 2000) have not yet been found in Wakasa Bay, all of the former inhabit gravel coasts and present difficulties in their collection or observation in the field. They may yet be found in Wakasa Bay following more rigorous collecting. On the other hand, approximately 19 species occurring in Wakasa Bay have not been found on the Sea of Japan coast of Hyogo Prefecture; of these, *Paratrypauchen microcephalus*, *Amblychaeturichthys hexanema* and *Parachaeturichthys polynema*, for example, were found in protected environments, such as inner bays, while *Silhouettea dotui* and *Heteroplopomus barbatus* occurred on the large sandy beach at the mouth of the Yura River. The Sea of Japan coastline of Hyogo Prefecture is primarily a ria coast, lacking protected inner bays or large sandy beaches, possibly leading to the above gobioid assemblage structure differences.

Gobioid species occurring in Toyama Bay (see Nambu and Hayashi, 1990; Uozu Aquarium, 1997; Sakai, 1998; Nambu, 2013) were similar to those in Wakasa Bay, being represented by those inhabiting protected inner bays and deeper bottom substrates. However, several species (such as *Apocryptodon punctatus*, *Pseudogobius masago*, *Lubricogobius exiguus*, *Redigobius bikolanus*, *Gymnogobius scrobiculatus*, and *Eviota masudai*) found in Wakasa Bay have not been recorded in Toyama Bay. On the other hand, *Pterogobius zacalles* and *Gymnogobius mororanus* both occur in Toyama Bay, whereas in Wakasa Bay no records exist for *Pterogobius zacalles* or *Gymnogobius mororanus*, except for an early record of the former (Takegawa and Morino, 1970; Minami *et al.*, 1977; this study). One factor influencing distribution may be differences in water temperature, especially from winter to early spring; in early spring over most of the previous century, the water temperature of shallow coastal water at 0-10 m depth in Toyama Bay was 9.34-9.86°C (average water temperature) and 7.20-8.24°C (lowest water temperature), whereas it was 10.74-10.78°C and 8.10-8.23°C, respectively, in Wakasa Bay (mean March water temperatures, 1906-2003, Japan Oceanographic Data Center, 2004). In addition, the Noto Peninsula, located between Wakasa Bay and Toyama Bay, acts as a geographical barrier against range expansion.

The gobioid fish fauna occurring on sandy beaches of Niigata Prefecture (see Honma, 1952; Honma *et*

al., 1972; Honma and Kitami, 1978; Honma and Mizusawa, 1980; Honma *et al.*, 1984; Honma, 1991; 1995; Honma *et al.*, 2002), is similar to that of Wakasa Bay, although more species inhabiting protected inner bays have been collected in Wakasa Bay, probably because of the many sub-basins.

Changes in the gobioid fish fauna of Wakasa Bay over the last 50 years

Two species collected in Wakasa Bay in the 1960's and 70's have not been found since that period (see Takegawa and Morino, 1970, Kadota, 1977 and Minami *et al.*, 1977). On the other hand, 24 species have been collected throughout the last 50 years and 32 only after the 1970's. Although these figures cannot be compared directly due to differences in the collection techniques, most of the more recently recorded species are also widely distributed south of Wakasa Bay (Wakasa Bay represents the northern range limit in the Sea of Japan for at least 8 species). This implies that recent changes in the distribution of gobies may be associated with increased water temperatures in the region. Annual water surface temperatures (SSTs) in the southern part of the Sea of Japan increased by an average of 0.47°C from the 1960's and 70's to 2000's (calculated from the Japan Meteorological Agency database, 2012b). Some studies have shown that the fish fauna in Maizuru Bay (Masuda, 2008) and off Yamaguchi Prefecture (Kobayashi *et al.*, 2006) had also changed over the previous 30 years, and questioned whether such changes might have been attributable to increased seawater temperatures due to global warming and/or shifts in seawater temperature regimes in the North Pacific. Additionally, in Wakasa Bay several nuclear power plants began operations in the 1970's, the consequent warm water discharges being responsible for water temperature increases in the vicinities of the plants (Kyoto Prefecture, 2011), probably providing suitable habitat conditions for some tropical species. *Asterropteryx semipunctata*, for example, recorded in Uchiura Bay, a sub-basin of Wakasa Bay, after the start of operations of the Takahama nuclear power plant fronting Uchiura Bay (in 1974), has not been found since the closure of the plant (in 2012). In addition to fluctuations in seawater temperature, other environmental factors, such as water quality, bottom sediment and algal vegetation (possibly associated with road and drainage system development since the 1980's) may have also influenced gobioid fish distribution in Wakasa Bay.

The conservation of present gobioid species diversity and restricted/endangered populations in Wakasa Bay, and future assessments of environmental changes based on gobioid indicator species, both require the establishment of a future species assessment and distribution strategy.

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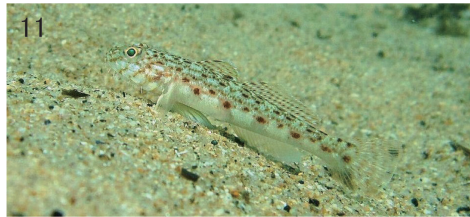
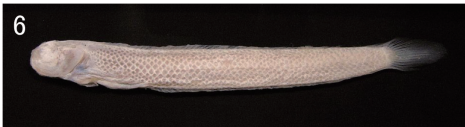
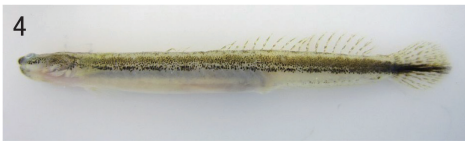
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- Plate I-1. *Luciogobius elongatus* (FAKU 134814, 34.1 mm SL).
Plate I-2. *Luciogobius guttatus* (FAKU 134775, 69.2 mm SL).
Plate I-3. *Luciogobius sp.* (FAKU 134799, 34.0 mm SL).
Plate I-4. *Eutaeniichthys gilli* (FAKU 134763, 37.8 mm SL).
Plate I-5. *Leucopsarion petersii* (FAKU 132998, 40.7 mm SL).
Plate I-6. *Paratrypauchen microcephalus* (FAKU 134282, 101.8 mm SL).
Plate I-7. *Apocryptodon punctatus* (FAKU 132976, 33.6 mm SL).
Plate I-8. *Asterropteryx semipunctata* (FAKU_DI 19).
Plate I-9. *Amblychaeturichthys sciistius* (FAKU 134943, 50.6 mm SL).
Plate I-10. *Amblychaeturichthys hexanema* (FAKU 132142, 85.3 mm SL).
Plate I-11. *Sagamia geneionema* (FAKU_DI 24).
Plate I-12. *Pterogobius virgo* (FAKU_DI 20).
Plate I-13. *Pterogobius zacalles* (FAKU 114837, 43.2 mm SL).
Plate I-14. *Pterogobius elapoides* (FAKU_DI 25).
Plate I-15. *Pterogobius zonoleucus* (FAKU 135096, 33.9 mm SL).

Plate I



- Plate II -1. *Suruga fundicola* (FAKU 132894, 46.8 mm SL).
Plate II -2. *Acanthogobius flavimanus* (FAKU 134273, 73.0 mm SL).
Plate II -3. *Acanthogobius lactipes* (FAKU 134271, 46.5 mm SL).
Plate II -4. *Platygobiopsis* sp. (FAKU 135288, 65.9 mm SL).
Plate II -5. *Silhouettea dotui* (FAKU 134938, 35.1 mm SL).
Plate II -6. *Mugilogobius abei* (FAKU 134276, 34.1 mm SL).
Plate II -7. *Pseudogobius masago* (OMNH-P 38630, 14.77 mm SL).
Plate II -8. *Tridentiger trigonocephalus* (FAKU 134257, 52.9 mm SL).
Plate II -9. *Tridentiger bifasciatus* (FAKU 135116, 49.4 mm SL).
Plate II -10. *Tridentiger brevispinis* (FAKU 134797, 63.6 mm SL).
Plate II -11. *Tridentiger obscurus* (FAKU 134807, 43.9 mm SL).
Plate II -12. *Parachaeturichthys polynema* (FAKU 132144, 57.3 mm SL).
Plate II -13. *Redigobius bikolanus* (FAKU 134275, 20.0 mm SL).
Plate II -14. *Heteroplopomus barbatus* (FAKU 134939, 35.3 mm SL).
Plate II -15. *Obliquogobius yamadai* (FAKU 135312, 23.0 mm SL).

Plate II



- Plate III -1. *Rhinogobius giurinus* (FAKU 134755, 58.5 mm SL).
Plate III -2. *Glossogobius olivaceus* (FAKU 135107, 127.5 mm SL).
Plate III -3. *Acentrogobius* sp. (FAKU 134761, 36.1 mm SL).
Plate III -4. *Acentrogobius pflaumii* (FAKU 135126, 47.7 mm SL).
Plate III -5. *Acentrogobius virgatus* (FAKU 135128, 46.7 mm SL).
Plate III -6. *Favonigobius gymnauchen* (FAKU 135125, 54.1 mm SL).
Plate III -7. *Favonigobius* sp. (FAKU 135117, 36.9 mm SL).
Plate III -8. *Istigobius hoshinonis* (FAKU 135121, 43.4 mm SL).
Plate III -9. *Istigobius campbelli* (FAKU_DI 22).
Plate III -10. *Gymnogobius petschiliensis* (FAKU 134280, 22.5 mm SL).
Plate III -11. *Gymnogobius urotaenia* (FAKU 134262, 58.4 mm SL).
Plate III -12. *Gymnogobius heptacanthus* (FAKU 135119, 31.6 mm SL).
Plate III -13. *Gymnogobius breunigii* (FAKU 134759, 57.7 mm SL).
Plate III -14. *Gymnogobius uchidai* (FAKU 135279, 27.25 mm SL).
Plate III -15. *Gymnogobius scrobiculatus* (FAKU 134787, 32.4 mm SL).

Plate III



- Plate IV -1. *Chaenogobius annularis* (OMNH-P 38631, 25.05 mm SL).
Plate IV -2. *Chaenogobius gulosus* (FAKU 134796, 58.3 mm SL).
Plate IV -3. *Cryptocentrus filifer* (FAKU 132811, 62.8 mm SL).
Plate IV -4. *Cryptocentrus* sp. (FAKU 132990, 32.1 mm SL).
Plate IV -5. *Priolepis* sp. (FAKU 132000, 28.9 mm SL).
Plate IV -6. *Trimma grammistes* (FAKU_DI 21).
Plate IV -7. *Eviota masudai* (FAKU 130894, 24.2 mm SL).
Plate IV -8. *Eviota abax* (FAKU 135104, 23.5 mm SL).
Plate IV -9. *Ptereleotris hanae* (FAKU_DI 23).
Plate IV -10. *Parioglossus dotui* (FAKU 134258, 26.0 mm SL).

Plate IV

