First Japanese Specimen-based Records of *Sardinella gibbosa* (Teleostei: Clupeiformes: Clupeidae) from Okinawa Island

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Eighteen specimens of *Sardinella gibbosa* (Bleeker, 1849) collected from Okinawa Island, Ryukyu Islands, Japan represent the first Japanese specimen-based records of the species. All specimens conformed closely to the diagnosis of *S. gibbosa*, having the caudal fin uniformly pale, a black spot on the dorsal-fin origin, body scales with centrally discontinuous striae, 26–31 + 50–57 = 77–88 gill rakers on the first gill arch, and 18 or 19 + 14 or 15 = 32–34 keeled scutes along the body ventral surface. In addition, some previous Japanese records of unidentified clupeoid fishes are reviewed.

**Key Words:** *Sardinella aurita*, *Sardinella lemuru*, *Clupea immaculata*, Ryukyu Islands, sardine.

**Introduction**

*Sardinella* Valenciennes, 1847 is a circumtropical genus of marine, brackish and/or fresh water sardines (Clupeidae) (Whitehead 1985; Munroe et al. 1999; Stern et al. 2017). In their review of Japanese *Sardinella*, Aonuma and Yagishita (2013) reported three species, *Sardinella lemuru* Bleeker, 1853 [currently regarded as a junior synonym of *Sardinella aurita* Valenciennes, 1847 (Stern et al. 2017)], *Sardinella melanura* (Cuvier, 1829), and *Sardinella zunasi* (Bleeker, 1854). Subsequently, Hata and Motomura (2019a, c) described two new congeneric species, *Sardinella electra* Hata and Motomura, 2019 and *Sardinella alcyone* Hata and Motomura, 2019, based on specimens collected from the Ryukyu Islands (specimens from southern Taiwan were also used for the latter species), bringing to five the number of species of *Sardinella* recorded from Japanese waters, supported by voucher specimens. Although the photographed individual caught from Okinawa Island shown by Miura (2012) is presumably identified as *Sardinella gibbosa* (Bleeker, 1849), the specimen was not retained. However, Yoshigou (2007, 2014), Torii et al. (2011), and Uehara et al. (2015) all reported additional unidentified species of *Sardinella* from the Ryukyu Islands, indicating a need for further investigation of Japanese species.

Eighteen specimens collected from Nakagusuku Bay, Okinawa Island, and deposited in the Okinawa Churashima Foundation Research Center were identified as *Sa. gibbosa*, previously reported from the Indo-West Pacific north to Taiwan (Whitehead 1985; Munroe et al. 1999; Stern et al. 2016; Hata 2019). Described in detail herein, the specimens represent the first voucher specimen supported Japanese records and northernmost record of the species in the Pacific Ocean. Additionally, some previous Japanese records of unidentified clupeoid fishes are reviewed.

**Materials and Methods**

Counts and proportional measurements, expressed as percentages of standard length (SL) or head length (HL: measured from snout tip to most posterior point of opercle, without membranous structure), followed Stern et al. (2016). Snout length was measured from the snout tip to anterior margin of eye, and interorbital width was measured above the pupil centers. All measurements being made with digital calipers to the nearest 0.1 mm. The specimens examined in the present study are deposited at the Okinawa Churashima Foundation Research Center (OCF/URM).

**Taxonomic accounts**

*Sardinella gibbosa* (Bleeker, 1849)  
[English name: Goldstripe Sardinella; new standard Japanese name: Nankai-sappa]  
(Fig. 1; Tables 1, 2)

**Material examined.** 18 specimens, 111.2–142.4 mm SL: URM-P 6388, 142.4 mm SL, Nakagusuku Bay, Okinawa Island, Ryukyu Islands, Japan, 28 December 1982, set net; URM-P 8673, 137.7 mm SL, URM-P 8674, 137.1 mm SL, URM-P 8675, 116.3 mm SL, Nakagusuku Bay, 25 April 1984, set net; URM-P 32851, 137.8 mm SL, Tsuken Island, located within Nakagusuku Bay, 23 March 1990, set net; URM-P 44674, 128.9 mm SL, URM-P 44675, 117.8 mm SL, URM-P 44676, 124.0 mm SL, URM-P 44677, 118.4 mm SL, URM-P...
Counts and measurements given in Tables 1 and 2, respectively. Body rather elongate, laterally compressed, deepest at dorsal-fin origin. Dorsal profile gently elevated from snout tip to dorsal-fin origin, thereafter gradually lowering to uppermost point of caudal-fin base. Ventral profile lowering from lower-jaw tip to just below pectoral fin, thereafter nearly straight to anus, before gently rising to lowermost point of caudal-fin base. Ventral edge of body covered with 32–34 keeled scutes from isthmus to anus. Pectoral-fin insertion slightly anterior to posteriormost point of opercle, below level of snout tip. Dorsal, ventral, and posterior margins of pectoral fin nearly straight; posterior tip of fin pointed, not reaching pelvic-fin insertion. Uppermost fin ray of pectoral fin not extended as filament. Pelvic-fin insertion below base of seventh to tenth dorsal-fin ray. Posterior tip of depressed pelvic fin not reaching anus.

Dorsal-fin origin posterior to posterior tip of pectoral fin. Anterior margin of dorsal fin elevated from fin origin to fourth ray tip; middle portion of dorsal-fin margin slightly concave. Posteriormost dorsal-fin ray not filamentous. Anus situated just anterior to anal-fin origin. Anal-fin origin posterior to posterior end of dorsal-fin base. Two posteriormost anal-fin rays enlarged. Caudal fin forked, posterior tips of both lobes pointed. Dorsal and ventral margins of both lobes of caudal fin nearly straight. Snout tip pointed, slightly behind tip of lower jaw. Eye large, round, covered with adipose eyelid, positioned laterally on head dorsal to horizontal through pectoral-fin insertion, visible in dorsal view. Pupil round. Interorbital space flat. Orbit elliptical. Nostrils close to each other, anterior to orbit. Mouth terminal, small, posterior tip of maxilla slightly short of or just below anterior margin of pupil. Ventral margin of maxilla with small uni-serial teeth. Premaxilla and hypomaxilla without teeth. First supramaxilla elongate. Second supramaxilla paddle-shaped, symmetrical. Posterior ramus of lower jaw elevated. Posterior margins of preopercle, subopercle and opercle convex, rounded, without serrations. Pseudobranchial filaments present, exposed. Two fleshy outgrowths on posterior margins on gill opening; a single large papilla on ventral margin. Gill rakers long, slender, with numerous asperities on anterior and posterior faces. Scales cycloid, thin, decidu-
ous, those on lateral body surface with several centrally discontinuous vertical striae, posteriorly somewhat fimbriated (Fig. 2). Predorsal scales paired. No elongate wing-like scales present beneath normal paired scales. No scales on head and most fins; a broad triangular sheath of scales on caudal fin.

Color of preserved specimens: Dorsum to upper part of lateral surface of body dark brown. Lower part of lateral surface and ventral surface of body uniformly silver or pale brown. Several narrow longitudinal stripes on upper part of body. Pectoral, pelvic, and anal fins semitransparent, pale, without melanophores except for uppermost pectoral-fin ray. Dorsal and caudal fins uniformly pale, melanophores scattered along fin rays. Dark blotch on dorsal-fin origin (Fig. 1J). Melanophores densely scattered on tips of both jaws.

Distribution. *Sardinella gibbosa* is widely distributed in the Indo-West Pacific from the east coast of Africa (including the eastern Mediterranean Sea as invasive species) to northern Australia and the Ryukyu Islands (Whitehead 1985; Munroe et al. 1999; Matsumuna 2011, 2013, 2018; Miura 2012; Stern et al. 2015, 2016; Hata 2017a, 2019; this study). In Japan, the species is known only from Nakagusuku Bay, southeastern Okinawa Island, Ryukyu Islands (Miura 2012; this study).

Identification. The specimens collected from Okinawa Island were assigned to the genus *Sardinella* as defined by Whitehead (1985) and Munroe et al. (1999), having the abdomen covered with prominently keeled scutes, paired predorsal scales, a symmetrical second supramaxilla, toothless hypo-maxilla, two posteriormost anal-fin rays enlarged, the dorsal fin without filamentous rays, and two fleshy outgrowths on the hind margin of the gill opening. Moreover, they conformed to *Sa. gibbosa*, having the following combination of characters that closely matched the diagnostic features given by Whitehead (1985), Munroe et al. (1999), and Stern et al. (2016): caudal fin uniformly pale, without distinct blotch on posterior tips of both lobes; black spot on dorsal-fin origin; striae on scales on lateral surface of body.

### Table 1. Counts of specimens of *Sardinella gibbosa*.

|                           | This study | “Putative neotype” in Whitehead et al. (1966) | Stern et al. (2016) |
|---------------------------|------------|-----------------------------------------------|---------------------|
|                           | Okinawa Island, Japan | BMNH 1867.11.28.46 | Western Pacific Ocean |
| n=18                      | 111.2–142.4 | 148.6                                         | 102.9–136.4 |
| Standard length (mm)      | Modes      | Modes                                         | Modes |
| Dorsal-fin rays (unbranched) | 4          | 25                                            | 17–20 |
| Dorsal-fin rays (branched) | 14–16      | 26                                           | 19 |
| Dorsal-fin rays (total)    | 18–20      | 24                                           | 17–20 |
| Anal-fin rays (unbranched) | 3          | 17                                           | 19 |
| Anal-fin rays (branched)   | 15–18      | 14                                           | 19 |
| Anal-fin rays (total)      | 18–21      | 17                                           | 19 |
| Pectoral-fin rays (unbranched) | 1        | 1                                            | 1 |
| Pectoral-fin rays (branched) | 14–15     | 14                                           | 13 |
| Pectoral-fin rays (total)  | 15–16      | 14                                           | 15 |
| Pelvic-fin rays (unbranched) | 1        | 1                                            | 1 |
| Pelvic-fin rays (branched)  | 7          | 7                                            | 7 |
| Gill rakers on 1st gill arch (upper) | 26–31 | 27                                          | 23–37 |
| Gill rakers on 1st gill arch (lower) | 50–57 | 55                                           | 42–69 |
| Gill rakers on 1st gill arch (total) | 77–88 | 81                                          | 77 |
| Gill rakers on 2nd gill arch (upper) | 24–29 | 26                                          | 24 |
| Gill rakers on 2nd gill arch (lower) | 50–60 | 56                                           | 53 |
| Gill rakers on 2nd gill arch (total) | 74–87 | 83                                          | 77 |
| Gill rakers on 3rd gill arch (upper) | 23–28 | 25                                          | 24 |
| Gill rakers on 3rd gill arch (lower) | 37–48 | 40                                          | 44 |
| Gill rakers on 3rd gill arch (total) | 60–74 | 65                                          | 68 |
| Gill rakers on 4th gill arch (upper) | 21–24 | 22                                          | 21 |
| Gill rakers on 4th gill arch (lower) | 29–34 | 29                                          | 30 |
| Gill rakers on 4th gill arch (total) | 50–58 | 52                                          | 51 |
| Gill rakers on posterior face of 3rd gill arch | 18–24 | 21                                          | 20 |
| Prepelvic scutes           | 18–19      | 18                                          | 17–19 |
| Postpelvic scutes          | 14–15      | 16                                          | 14–15 |
| Total scutes               | 32–34      | 32                                          | 34 |
| Scale rows in longitudinal series | 38–41 | 39                                          | 14 |
| Pseudobranchial filaments  | 17–23      | 19                                          | 14–21 |
| Abdominal vertebrae        | 29–32      | 31                                          | 17 |
| Caudal vertebrae           | 15–17      | 17                                          | 17 |
| Total vertebrae            | 46–49      | 47                                          | 47 |
interrupted in the center; 26−31+50−57=77–88 gill rakers on first gill arch; and 18 or 19+14 or 15=32–34 keeled scutes along the body ventral surface. In particular, their meristic and morphometric characters generally matched those given by Stern et al. (2016) for western Pacific Sa. gibbosa, although they slightly differed from Stern et al.'s (2016) specimens in having slightly higher total ray counts for the anal and pectoral fins, generally more pseudobranchial filaments (18–21, 15–16, and 17–23 vs. 17–20, 14–15, and 14–21), and a slightly narrower body (22.8–26.2% SL vs. 23.8–29.8%). Because ranges of anal- and pectoral-fin ray numbers greater than five and three, respectively, have been reported in congeneric species (Stern et al. 2016; Hata and Motomura 2019a–d), the pseudobranchial filament and body depth differences are considered as interspecific variations only.

Although Sa. gibbosa closely resembles Sardinella goni Stern, Rinkevich, and Goren, 2016 (recorded only from Boracay Island, Philippines), the two species sharing body scales with discontinuous vertical striae, a black spot on the dorsal-fin origin and caudal fin without black blotch, and almost identical numbers of gill rakers on the first gill arch, the former has 14 or 15 postpelvic scutes (vs. 13 in S. goni; Stern et al. 2016). Although Kishinouye (1908). Although Whitehead (1985) regarded C. immaculata as a junior synonym of C. gibbosa, Bleeker, 1849, and Sa. gibbosa, based on examination of the syntypes of H. dollfusi. In addition, Hata and Motomura (2019d) regarded Clupea jussieu as a nomen dubium, leaving Sp. tembang, C. immaculata, H. dollfusi, F. dactylolepis, and Sa. taiwanensis as junior synonyms of Sa. gibbosa. Subsequently, Stern et al. (2015, 2016) regarded Harangula dollfusi Chabanaud, 1933, believed to be a junior synonym of Sardinella albella (Valenciennes, 1847) by Whitehead (1985), as a junior synonym of Sa. gibbosa, based on examination of the syntypes of H. dollfusi. In addition, Hata and Motomura (2019d) regarded Clupea jussieu as a nomen dubium, leaving Sp. tembang, C. immaculata, H. dollfusi, F. dactylolepis, and Sa. taiwanensis as junior synonyms of Sa. gibbosa.

One of these, C. immaculata, was described by Kishinouye (1908). Although Whitehead (1985) regarded C. immaculata as a junior synonym of Sa. gibbosa, this was questioned by Aonuma and Yagishita (2013). Although Kishinouye (1908) stated that he collected one specimen each from Saga, Japan, Swatow, Guangdong, China, and Xiamen,

Table 2. Morphometrics of specimens of Sardinella gibbosa.

| Standard length (mm; SL) | This study | "Putative neotype" in Whitehead et al. (1966) | Western Pacific Ocean |
|--------------------------|------------|---------------------------------------------|----------------------|
| Okinawa Island, Japan    | n=18       | BMNH 1867.11.28.46 | n=42                 |
| As % SL                  |            | 111.2–142.4 | 148.6                 | 102.9–136.4 |
| Head length (HL)         |            | 21.7–23.7  | 23.8                  | 21.5–23.7  |
| Body depth               |            | 22.8–26.2  | 25.8                  | 23.8–29.8  |
| Pre-dorsal fin length    |            | 42.7–44.8  | 44.5                  | 40.9–44.8  |
| Snout tip to pectoral-fin insertion | | 22.2–25.6 | 25.9                  | 27.1       |
| Snout tip to pelvic-fin insertion | | 48.5–51.2 | 50.6                  | 49.3       |
| Snout tip to anal-fin origin | | 75.7–79.2 | 78.9                  | 76.8       |
| Dorsal-fin base length   |            | 13.1–14.6  | 13.4                  |            |
| Anal-fin base length     |            | 14.6–16.2  | 15.6                  |            |
| As % HL                  |            | 41.8–45.5  | 42.9                  | 41.0–45.5  |
| Interorbital width       |            | 13.0–21.1  | 17.2                  | 20.2–24.2  |
| Snout length             |            | 28.3–31.3  | 30.1                  | 28.2–33.9  |
| Maxilla length           |            | 39.3–41.9  | 39.2                  | 38.1–43.8  |
| Eye diameter             |            | 25.9–29.3  | 26.0                  | 25.6–30.5  |

Hata and Motomura (2016) pointed that Bleeker (1849) gave no size range or number of specimens, which or how many specimens belonged to the type series of the nominal species being uncertain. They indicated BMNH 1867.11.28.46, a specimen collected from Makassar, as "putative neotype" of C. gibbosa Bleeker, 1849. Subsequently, Stern et al. (2016), treated the BMNH specimen as the neotype of the nominal species. However, a formal designation was not provided by Whitehead et al. (1966) or Stern et al. (2016); therefore, the neotype designation failed to meet the full mandatory requirements listed under Article 75.3.1 of the Code. The formal neotype designation is needed if taxonomic confusion related to Sa. gibbosa is found in the future.

Whitehead (1985), who reviewed the genus Sardinella, considered Clupanodon jussieu Lacepède, 1803, Spratella tembang Bleeker, 1851, Clupea immaculata Kishinouye, 1908, Fimbriclupea dactylolepis Whitley, 1940, and Sardinella taiwanensis Raja and Hiyama, 1969 to all be junior synonyms of Sa. gibbosa. Subsequently, Stern et al. (2015, 2016) regarded Harangula dollfusi Chabanaud, 1933, believed to be a junior synonym of Sardinella albella (Valenciennes, 1847) by Whitehead (1985), as a junior synonym of Sa. gibbosa, based on examination of the syntypes of H. dollfusi. In addition, Hata and Motomura (2019d) regarded Clupea jussieu as a nomen dubium, leaving Sp. tembang, C. immaculata, H. dollfusi, F. dactylolepis, and Sa. taiwanensis as junior synonyms of Sa. gibbosa.
Fujian, China, his description of *C. immaculata* included meristics without value ranges, suggesting that the description was based only on a single specimen. However, it is unknown which specimen the description was based on. Unfortunately, the type specimens of *C. immaculata* have since been lost (Wongratana 1980; Fricke et al. 2021; this study). In fact, Kishinouye’s (1908) characters of *C. immaculata* generally matched those of *Sardinella gibbosa* shown in Whitehead (1985), Munroe et al. (1999), and Stern et al. (2015, 2016), as well as the Okinawan specimens examined here: dorsal-fin rays 17, pectoral-fin rays 15, pelvic-fin rays 8, abdomen covered with 19+14 scutes, and dorsal-fin origin nearer to snout tip than caudal-fin base. However, *Sa. gibbosa* has at no time been recorded from temperate Japanese waters, including Saga (northern coast of Kyushu), one of the type localities of *C. immaculata* although intensive ichthyofaunal surveys have been carried out in Japanese waters (Aonuma and Yagishita 2013; Motomura 2020).

On the other hand, the abovementioned characters of *C. immaculata* also match those of *Sardinella aurita* Valenci-
ennies, 1847, except the pelvic-fin ray count [8 in Kishinouye (1908)’s *C. immaculata* vs. 9 in *Sa. aurita* (Whitehead 1985; Munroe et al. 1999; Stern et al. 2017)]. Furthermore, *Sa. aurita* has been frequently reported from southern Japan, including the northern coast of Kyushu (frequently reported as *Sa. lemaru* Bleeker, 1853) [e.g., Omori 2007; Kagoshima City Aquarium Foundation 2008, 2018; Hasegawa 2011; Hata and Motomura 2011, 2017; Kadowaki et al. 2015; Kuragai 2016; Tashiro et al. 2017; Hata 2017b, 2018a, b, 2020; Funaki and Saitoh 2018; Kobayashi 2019; Nakashimada and Hibino 2020; Hata and Koeda 2020: fig. 2]. Judging from these facts, Kishinouye’s (1908) specimen from Saga was probably *Sa. aurita*. To confirm the taxonomic status of *C. immaculata*, more researches are needed.

**Previous records of *Sa. gibbosa* from Japan.** As mentioned above, a number of unidentified species of *Sardinella* has been reported from Japan. In addition, *C. exile* Kishinouye, 1911 was described as a new species, based on specimens collected from Chichi-jima Island, Ogasawara Islands, Japan. In the original description of the species, Kishinouye (1911) stated that it was the most abundant clupeoid fish in the Ogasawara Islands. As with *C. immaculata*, no type specimens of *C. exile* exist (Wongratana 1980; Fricke et al. 2021; this study). Subsequently, Matsubara (1955) treated *C. exile* as a junior synonym of *Sardinella jussieu* (Lacepède, 1803), a nominal species regarded as a nomen dubium by Hata and Motomura (2019d). *Clupea exile* was not treated by Whitehead (1985) in his taxonomic review of the family Clupeidae and the taxonomic status of the nominal species is unknown. Aonuma and Yagishita (2013) similarly excluded *C. exile* in their review of Japanese clupeoids, due to the lack of detailed information on the species. However, the vertebral count of *C. exile* described by Kishinouye (1911) was significantly lower than in specimens of *Sa. gibbosa* examined here (40 vs. 46–49; Table 1). Therefore, *C. exile* is clearly not synonymous with *Sa. gibbosa*. In fact, Yoshigou (2002) suggested that *C. exile* is a junior synonym of *Herklotzicthys quadrimalculatus* (Rüppell, 1837), based on the correspondence of characters of *C. exile*, shown by Kishinouye (1911), and specimens of *H. quadrimalculatus* collected from the Ogasawara Islands, reported by Yoshigou (2002). To clarify the taxonomic status of *C. exile*, further consideration of closely related genera is necessar.

Aoyagi (1941) reported three clupeoid specimens (54.7–60.2 mm SL) collected from Miyako Island, Japan, as *Sardinella sindensis* (Day, 1878), although the species is considered to be distributed only in the northwestern Indian Ocean, from the Gulf of Aden to the western coast of India (Whitehead 1985). Subsequently, Matsubara (1955) reported the following diagnostic characters of *Sa. sindensis* sensu Aoyagi (1941): pelvic fin with eight fin rays, black spot on dorsal-fin origin, lower gill rakers on first gill arch 58–62, body depth 3 to 4 times (approx. 25–33.3%) in SL, and eye diameter 3.5 to 4 times (approx. 25–28.6%) in head length. Although the pelvic-fin ray count, dorsal-fin marking, and eye diameter to head length ratio of *Sa. sindensis* given by Matsubara (1955) closely matched those of Okinawa specimens of *Sa. gibbosa* presented here, the gill-raker counts and body depth in SL ratio were quite different. Accordingly, *Sa. sindensis* sensu Aoyagi (1941) is not considered to be *Sa. gibbosa*, although its possible identity as *Sa. albellia* or *Sa. alcyone* cannot be discounted, due to their similar lower gill-raker counts and deeper body (counts of lower gill rakers on first gill arch 47–64 in *Sa. albellia* in 63.9–130.0 mm SL specimens, 67–72 in *Sa. alcyone* in 66.6–109.8 mm SL specimens; body depth 28.8–33.8% SL in *Sa. albellia*, 26.4–36.8% in *Sa. alcyone*) (Stern et al. 2016; Hata and Motomura 2019c). It should be noted, however, that the northern distribution limit of *Sa. albellia* in the Pacific Ocean is Taiwan, the species not having been recorded from Japanese waters (Whitehead 1985; Munroe et al. 1999; Stern et al. 2016; Hata 2019). Miura (2012) reported an unidentified photograph of a sardine from Sakagusuku Bay, southern coast of Okinawa Island, where specimens of *Sa. gibbosa* examined in the present study were collected, as “sappa-zoku-no-isshu-2” (meaning *Sardinella* sp. 2 in Japanese), noting that the species was rarely caught in Sakagusuku Bay. Although the specimen photographed is here presumably identified as *Sa. gibbosa* due to its elongated body, this identification cannot be validated as no voucher specimens have been retained in Miura (2012). Consequently, the specimens described here represent the first records of *Sa. gibbosa* from Japanese waters, with Sakagusuku Bay, Okinawa Island being confirmed as the northern distribution limit of the species.

Because no Japanese name has previously been applied to specimens of *Sa. gibbosa*, the new standard Japanese name “Nankai-sappa” is herein proposed for the species (based on URM-P 4462; Figs 1F, 2), "nankai" meaning "southern sea"; in reference to the primarily tropical distribution of the species, and "sappa" being the Japanese name for the genus *Sardinella*.

**Comparative material examined.** BMNH 1867.11.28.46, Makassar, Indonesia; listed as “putative neotype of *Clupea gibbosa*” in Whitehead et al. (1966) (see “Taxonomic status of *Clupea immaculata* Kishinouye, 1908”).

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