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***In situ* Ontogenetic Color Changes of *Pentapodus aureofasciatus* (Perciformes, Nemipteridae) off Yakushima Island, Southern Japan and Comments on the Biology of the Species**

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Abstract. Ontogenetic color changes of *Pentapodus aureofasciatus* are documented on the basis of underwater observations off Yakushima Island, southern Japan from 2004 to 2006, and compared with those of a closely-related species, *P. caninus*. A photograph of a mature breeding male *P. aureofasciatus* is provided for the first time and sexual dichromatism in the species also discussed. Morphological and color variations recorded during the study suggested that *P. aureofasciatus* includes more than one species. The distributional range of *P. aureofasciatus* extends to Izu Peninsula and the Izu Islands, Yakushima Island being the most likely northernmost breeding ground, supplying juveniles and/or larvae to the Pacific coast of mainland Japan via the Kuroshio Current.

Key words: Nemipteridae, *Pentapodus aureofasciatus*, *Pentapodus caninus*, coloration, comparisons, distribution, ecology.

Introduction

Recently described by Russell (2001), the western Pacific nemipterid, *Pentapodus aureofasciatus*, had been previously reported and figured as an undescribed species by Russell (1990) and Randall *et al.* (1990). Randall *et al.* (1990: unnumbered figs) provided underwater photographs of a juvenile and adult from northeastern Australia, and Russell (1990: pl. 5h) and Randall (2005: unnumbered fig.) provided the same photograph of a fresh adult specimen (BPBM 27118) from New Caledonia. Randall (2005: unnumbered fig.) also included an underwater photograph of a juvenile from the Coral Sea. An adult specimen (identified as *P. nagasakiensis*) from Taiwan figured in Shen (1993: pl. 108, fig. 9) was re-identified as *P. aureofasciatus* by Russell (2001).

Thus, color photographs of juveniles and adults of *P. aureofasciatus* have been published on several occasions, the coloration of the species being relatively well known. However, ontogenetic color changes in the species, based on a series of life stages, have at no time been documented, although distinct color differences occur between juveniles and adults.

A year-long tracing survey of the *P. aureofasciatus* population off Yakushima Island revealed the extent of body color changes with growth in the species. In addition, numerous mature males in breeding coloration were observed during the study, such having not been previously reported. Underwater photographs of a series of life stages, including a breeding male, are herein provided for the first time. An examination of published and unpublished underwater photographs indicated that the geographic distribution of *P. aureofasciatus* extends to Izu Peninsula and the Izu Islands, Japan, approximately 1,400 km northeast of the previously recorded north-

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ernmost record (Okinawa Island). Several other aspects of the biology of *P. aureofasciatus* are also reported herein.

As Russell (1990, 2001) pointed out, the coloration of *P. aureofasciatus* is similar to that of *P. caninus* (Cuvier in Cuvier and Valenciennes, 1830), the latter co-occurring with *P. aureofasciatus* off Yakushima Island. A series of life stages of *P. caninus* from Yakushima Island is also provided and comparisons with *P. aureofasciatus* made.

Materials and Methods

Terminology and counting and measurement methods followed Russell and Gloerfelt-Tarp (1984), Russell and Golani (1993), and Russell (2001). Standard and total lengths are expressed as SL and TL, respectively. A tracing survey of the *P. aureofasciatus* population by underwater observations was conducted north of Yakushima Island from

2004 to 2006, some of the observed individuals being photographed. During the study, all stages of *P. aureofasciatus* from juvenile (less than 5 mm TL) to adult (over 25 cm TL) were observed, and two specimens collected to confirm identification (deposited in the Kagoshima University Museum, Japan: KAUM).

Specimens of *P. aureofasciatus* examined: KAUM-I. 35, female, 150.0 mm SL, off Shitogo, Yakushima Island, Kagoshima, Japan, 30°27'N, 130°31'E, 25 m depth, hand line, Nov. 2005, collected by H. Chuuman (Fig. 1a). KAUM-I. 285, male, 158.5 mm SL, 26 Jan. 2006, other data as for KAUM-I. 35 (Fig. 1b). Data for underwater photographs included in this report: *P. aureofasciatus*— Fig. 2a: 4 cm TL, 15 m depth, 30°27.32'N, 130°29.19'E, 22 July 2004; Fig. 2b: 6 cm TL, 25 m, 30°27.32'N, 130°29.19'E, 16 Jan. 2006; Fig. 2c: 10 cm TL, 25 m, 30°27.32'N, 130°29.19'E, 15 Jan. 2006; Fig. 2d: 15 cm TL, 25 m, 30°27.56'N, 130°30.11'E,



Fig. 1. Fresh specimens of *Pentapodus aureofasciatus* from Yakushima Island, Kagoshima, Japan. a: KAUM-I. 35, female, 150.0 mm SL (frozen for about 12 months after collection). b: KAUM-I. 285, male, 158.5 mm SL (frozen for about 6 months). Photos by H. Motomura.

16 Jan. 2006; Fig. 2e: 20 cm TL, 20 m, 30°27.32'N, 130°29.19'E, 9 June 2005; Fig. 2f: female, 25 cm TL, 20 m, 30°27.32'N, 130°29.19'E, 24 May 2005; Fig. 2g: male, 25 cm TL, 25 m, 30°27.32'N, 130°29.19'E, 5 Oct. 2004. *P. caninus*—Fig. 3a: 4 cm TL, 15 m, 30°27.32'N, 130°29.19'E, 12 Aug. 2004; Fig. 3b: 15 cm TL, 30 m, 30°27.32'N, 130°29.19'E, 11 Nov. 2005; Fig. 3c: 20 cm TL, 20 m, 30°27.32'N, 130°29.19'E, 14 Apr. 2005; Fig. 3d: 25 cm TL, 20 m, 30°27.32'N, 130°29.19'E, 24 May 2005; Fig. 3e: 40 cm TL, 20 m, 30°27.32'N, 130°29.19'E, 16 Feb. 2005. All underwater photographs were taken off Issou, Yakushima Island, Japan, by H. Harazaki.

Results and Discussion

Identification—Both specimens collected (KAUM-I. 35, I. 285) were identified as *P. aureofasciatus*, confirming to the species diagnosis provided by Russell (2001): head scales not reaching forward dorsally to a line between posterior nostrils; lower limb of preopercle scaly; posterior tip of depressed pelvic fin just short of level of anus; caudal fin forked, without filamentous extensions, upper and lower lobes subequal in length; and no dark bar at pectoral-fin base. The following counts and proportional measurements of the specimens also agreed with those of the type specimens given by Russell (2001): dorsal-fin rays X–XI, 8–9; anal-fin rays III, 7; pectoral-fin rays 16–17; pelvic-fin rays I, 5; pored lateral-line scales 46; transverse scale rows above lateral line 3, below 11; transverse scale rows on preopercle 3–5+3; body depth 3.6–3.7 in SL; head length 3.5–3.6 in SL; snout 3.2–3.4 in head length; eye diameter 3.3–3.4 in head length, 1.0–1.1 in snout length; interorbital width 2.8–3.0 in head length; suborbital depth 8.1–8.9 in head length; caudal-peduncle depth 2.2–2.5 in caudal-peduncle length; dorsal-fin base length 1.9 in SL; fourth dorsal-fin spine longest, 2.0–2.1 times length of first dorsal-fin spine; sixth dorsal-fin soft ray longest, 0.8–0.9 times length of longest dorsal-fin spine; anal-fin base length 6.1 in SL; first anal-fin spine 1.9–2.1 in length of second anal-fin spine; second anal-fin spine

1.3–1.4 in length of third anal-fin spine. However, although Russell (2001: 55) stated “Maxilla reaching almost to or just behind anterior margin of eye”, both of the Yakushima specimens had the posterior margin of the maxilla well short of a vertical through the anterior margin of the eye (Fig. 4).

Sexual dichromatism in fresh adult specimens (Fig. 1)—Figure 1 shows fresh adult female and male specimens of *P. aureofasciatus* collected off Yakushima Island, although their being maintained frozen for a long period before being photographed may have resulted in slightly changed coloration from that occurring naturally. Nevertheless, the female specimen (Fig. 1a: 150.0 mm SL) was well consistent with the specimen (BPBM 27118, 156 mm SL) figured by Russell (1990, 2001) and Randall (2005), both having reddish caudal fins. The caudal fin of the male specimen (Fig. 1b: 158.5 mm SL), tinged with reddish on the upper lobe and yellowish-green on the lower lobe, with the posterior margin of the fin translucent was consistent with an adult specimen photograph of *P. aureofasciatus* (143 mm SL, labeled as *P. nagasakiensis*) given by Shen (1993). Bruce Carlson (*pers. comm.* in Russell, 2001) reported that some individuals in Fiji had the upper lobe of the caudal fin blackish. Such a color pattern, reddish (or blackish in the Fijian population) upper caudal-fin lobe and yellowish or yellowish-green lower lobe, is most likely to be that normally characteristic of adult male *P. aureofasciatus*, although coloration of the caudal-fin posterior margin seems to be variable. The Yakushima male and that figured in Shen (1993) both had the posterior margin of the caudal fin translucent (Fig. 1b), whereas Russell (2001) stated that an adult specimen (BPBM 29186, 155.4 mm SL) from Tonga had a blackish margin on the upper caudal-fin lobe. In addition, the caudal fin of the Yakushima female was entirely reddish, including the posterior margin (Fig. 1a), whereas that of the presumed female specimen figured by Russell (1990, 2001) and Randall (2005) was reddish with a whitish posterior margin.

The Yakushima male had a greenish body (Fig. 1b). However, Shen’s male specimen had a similar

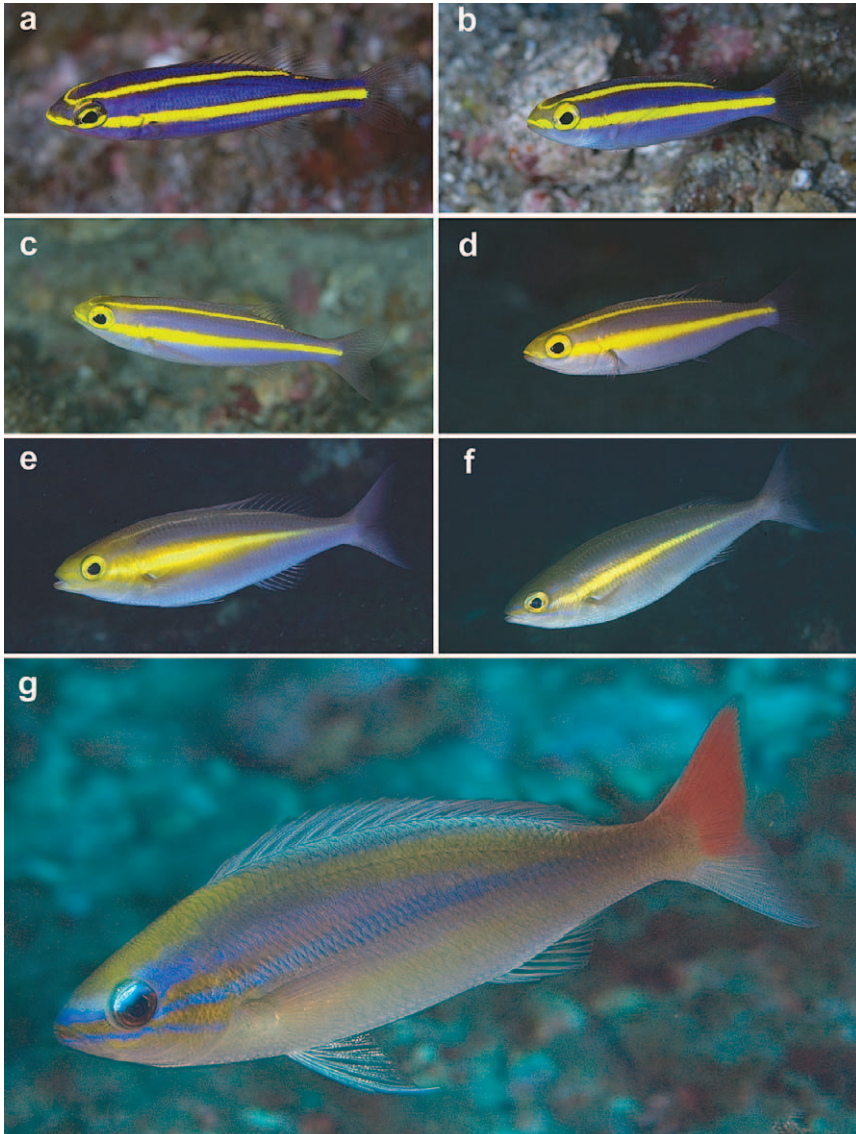


Fig. 2. Life stages of *Pentapodus aureofasciatus* off Yakushima Island, Japan. a: 4 cm TL. b: 6 cm TL. c: 10 cm TL. d: 15 cm TL. e: 20 cm TL. f: 25 cm TL. g: 25 cm (male). Photos by H. Harazaki (photo data in text).

body color to the Yakushima female (Fig. 1a); *i. e.* pinkish dorsal-fin membranes and pectoral fin, whitish pelvic and anal fins, brownish dorsal and silvery ventral body, and a distinct yellow stripe on the side of the body from behind the eye to the anterior portion of the caudal peduncle. The Yakushima male specimen was probably exhibiting nuptial col-

ors when it was collected, judging from the coloration evident in an underwater photograph of a breeding male (Fig. 2g).

All published photographs of fresh specimens of *P. aureofasciatus* have shown the upper lobe (at least) of the caudal fin to be reddish. However, underwater photographs showing a reddish caudal

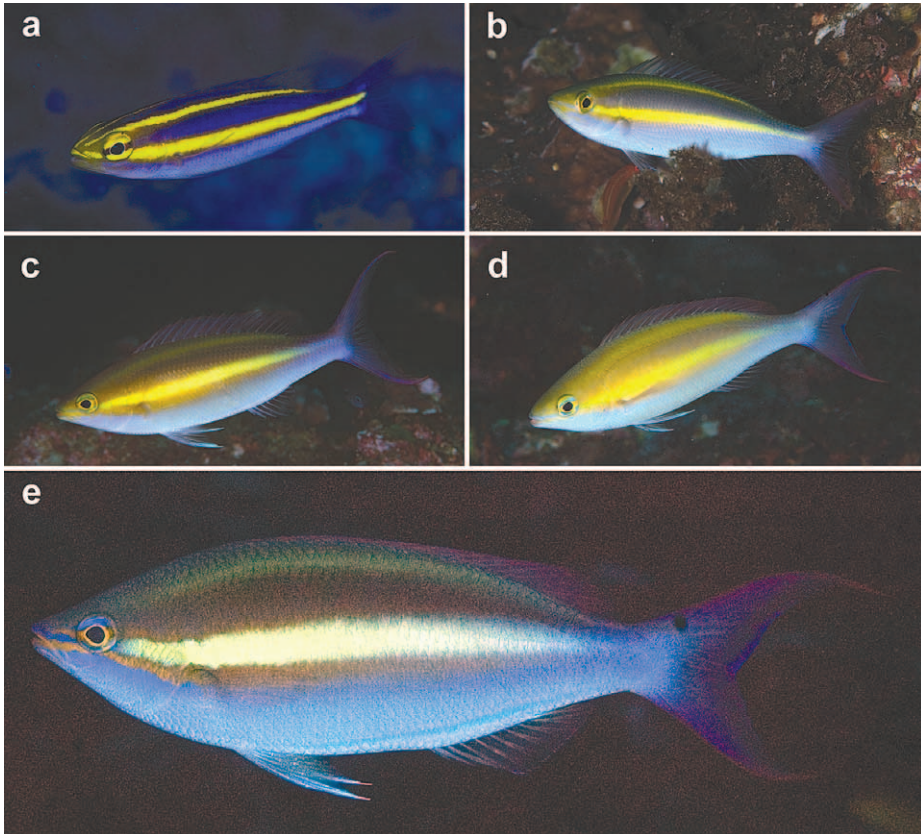


Fig. 3. Life stages of *Pentapodus caninus* off Yakushima Island, Japan. a: 4 cm TL. b: 15 cm TL. c: 20 cm TL. d: 25 cm TL. e: 40 cm TL. Photos by H. Harazaki (photo data in text).

fin have never been reported (Randall *et al.*, 1990: unnumbered figs.; Randall, 2005: unnumbered fig.). In addition, all adults, except breeding males, observed during this study had a translucent caudal fin (see Fig. 2). Apparently, the reddish caudal-fin coloration in fresh female specimens is a post-mortem development, paralleling a similar condition known to occur in the mullid fish, *Mulloidichthys vanicolensis* (Valenciennes in Cuvier and Valenciennes, 1831).

In situ color changes with growth (Figs 2–3) — Four cm TL juveniles of *P. aureofasciatus* (Fig. 2a) had a deep purplish blue head and body with two brown-edged bright yellow stripes, the uppermost of the latter extending on each side from the upper part of the caudal peduncle over the eye to above the anterior eye margin, thereafter joining in the dorsal

midline on the head. The width of the stripe was narrower than the pupil diameter, that part of the stripe above the eye being the narrowest. The lower bright yellow stripe ran from the tip of the upper lip to the anteroventral margin of the eye, and from the posteroventral margin of the eye through above the pectoral-fin base to the middle of the posterior margin of the caudal-fin base. The posterior part (posterior to eye) of the lower strip was wider than both the anterior part (anterior to eye) and the upper stripe. The widest part of the lower stripe, between the pectoral- and anal-fin bases, was subequal to the pupil diameter. The eye, except for the black pupil, was usually bright yellow. All fins were transparent.

Although four cm TL juveniles of *P. caninus* (Fig. 3a) shared almost identical coloration with *P. aureofasciatus* (Fig. 2a), differences existed in the



Fig. 4. Head of *Pentapodus aureofasciatus*. KAUM-I. 285, male, 158.5 mm SL. Left and right vertical bars indicate locations of the posterior margin of the maxilla and anterior margin of the eye, respectively.

condition of the anterior portion of the upper stripe (extending anterior to the eye and not joining in the middle) and the presence of faint narrow yellow stripe extending from the lip along the dorsal midline of the head (Fig. 3a).

In *P. aureofasciatus*, the deep purplish-blue body found in four cm TL juveniles gradually became brownish dorsally and bluish-white ventrally with growth (Figs. 2a–f). The anterior portion of the upper yellow stripe (above anterior margin of eye) disappeared at *ca* 15 cm TL, the anterior portion of the lower yellow stripe (anterior to eye) also being lost at *ca* 25 cm TL (Fig. 2f). The body color change pattern with growth of *P. caninus* was similar to that of *P. aureofasciatus*, although the upper body stripe of *P. caninus* between the eye and caudal peduncle remained throughout life, despite fading somewhat (Figs 3a–e). The mid-dorsal head stripe in *P. caninus* juveniles subsequently disappeared (Figs 3a, b).

With the exception of the nuptial colored males, the caudal-fin coloration of live *P. aureofasciatus* was always transparent or translucent throughout life (Figs 2a–f). In contrast, *P. caninus* over *ca* 15–20 cm TL had reddish anterior margins on the upper and lower caudal-fin lobes (Figs 3b–e).

During this study, numerous breeding males of *P. aureofasciatus* were observed off Yakushima. A photograph of a nuptial colored male (Fig. 2g), taken

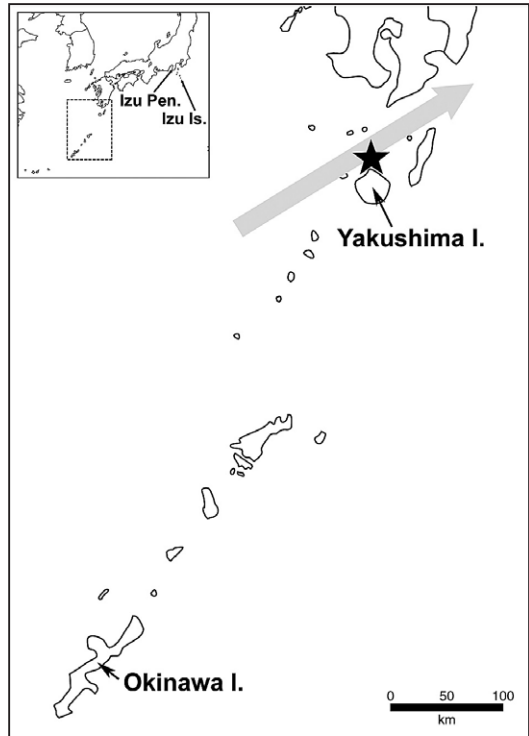


Fig. 5. Map of southern and central Japan. Enlargement indicates positions of Yakushima and Okinawa Islands, location of underwater observations and specimens collected during the study (star) and direction of the Kuroshio Current (arrow).

at 25 m on 5 October 2004, is the first published record of such. That individual (25 cm TL) was the same size as the female (or normal colored male?) illustrated in Fig. 2f. Nuptial colored males were clearly distinct from normal colored adults, subadults and juveniles, being characterized by the following color patterns: head and body yellowish-green dorsally and yellowish-white ventrally, with three blue stripes; the first stripe from posterodorsal margin of eye to a vertical through anal-fin origin, the second from above upper lip to anterior margin of eye and subsequently from posterior margin of eye to caudal peduncle, the third from below lower lip passing below eye to opercular margin; caudal fin reddish on upper lobe and upper part of lower lobe, remaining lower lobe and posterior margin of fin translucent; yellow stripe absent (replaced by second

blue stripe). The nuptial coloration of a male *P. caninus* is shown in Fig. 3e.

Russell (2001: 55) described “pearly blue band on ventral surface from behind pelvic fins to caudal peduncle present in larger specimens” as the life color of *P. aureofasciatus*. Although such a blue band is not found in the *P. aureofasciatus* population off Yakushima Island (Fig. 2), it is found in nuptial colored *P. caninus* males (Fig. 3e). As mentioned above, several color pattern and morphological (Fig. 4) differences occur among *P. aureofasciatus* populations from different localities, indicating that ‘*P. aureofasciatus*’ includes more than one species or geographic subspecies or, at least, genetically distinct populations. Molecular analysis may be required in future to assess these possibilities.

Distribution and ecological notes—*P. aureofasciatus* is widely distributed in the western Pacific, where it ranges from Okinawa Island south to northern New South Wales, and around New Caledonia, Fiji, Tonga and Samoa (Russell, 2001). Yakushima Island, where the present specimens were collected or photographed, is located approximately 500 km north-northeast from the previously-known northernmost record (Okinawa Island) of the species (Fig. 5).

North of Yakushima Island *P. aureofasciatus* is one of the most abundant fish species. Numerous epibenthic juveniles occur on the rocky reef slopes, they gradually moving into mid-water with growth. While epibenthic juveniles have a bright blue body (Figs 2a–b), this changes to brownish with habitat change (Figs 2c–f). Subadult and adult fish form mid-water schools, usually comprising 200–300 individuals (but often over 500) off Yakushima Island. Although large numbers of *P. aureofasciatus* are found north of Yakushima Island throughout the year, few occur south of the island and at other Japanese localities, including the Ryukyu Islands. Only juveniles of *P. aureofasciatus* have been reported from the Pacific coast of mainland Japan, the northernmost records, based on underwater observations, being from Izu Peninsula (several underwater photographs on web sites) and the Izu

Islands (S. Kato, *pers. comm.*, 14 Oct. 2004). Such juveniles are most likely to have been accidentally transported from Yakushima Island by the Kuroshio Current, normally flowing from west of the Ryukyu Islands through Yakushima and Tanegashima Islands (Fig. 5, gray arrow) to the Pacific coast of Japan. Northern reefs off Yakushima Island appear to be the northernmost (and largest in Japanese waters) breeding ground for *P. aureofasciatus*.

Because of their abundance north of Yakushima Island, *P. aureofasciatus* is often collected by local fishermen for use as bait for the Bigfin Reef Squid, *Sepioteuthis lessoniana* (Lesson, 1830).

Masuda and Kobayashi (1994: 166) provided underwater photographs of *Pentapodus* sp. 1 (10 cm TL) and *Pentapodus* sp. 2 (2 cm TL) from the Yaeyama Islands (south of Okinawa Island), both fish identified here as *P. caninus*. Okamura (1997: 364) described *P. paradiseus* (7 cm TL) from Kochi and *Pentapodus* sp. (8 cm TL) from Iriomote Island, providing underwater photographs. These species are identified here as *P. aureofasciatus* and *P. caninus* respectively.

Names—Russell (1990), Randall *et al.* (1990) and Randall (2005) proposed different English names, Yellow-striped Whiptail, Blue Butterfish and Goldstripe Bream, respectively, for *P. aureofasciatus*. Recently, Yellowstripe Threadfin Bream has been officially registered in the “list of standardised Australian fish names” provided by CSIRO Marine and Atmospheric Research, Fisheries Research and Development Corporation, and Seafood Services Australia (Yearsley *et al.*, 2006). Yakushima-kitsuneuo is herein proposed as the new standard Japanese name for the present specimens of *P. aureofasciatus*, although local fishermen at Yakushima Island refer to the species (and also *P. caninus*) as Maddo-Ibo.

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