Cirrhitops mascarenensis, a new species of hawkfish from the Mascarene Islands, southwestern Indian Ocean

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Abstract. The hawkfish *Cirrhitops mascarenensis* is described as a new species from 12 specimens collected from 4–62 m on reefs of Mauritius (type locality) and Réunion, and is also reported from Madagascar. It has long been identified as *C. fasciatus* (Bennett), otherwise known only from the Hawaiian Islands. Although there is some difference in life colour of fish between the two archipelagoes, as would be expected from the vast distance separating them, it could not be linked to any definitive morphological or meristic differences, except for apparent larger size in the Hawaiian Islands (largest specimen, 91 mm SL, compared to 75 mm SL in the Mascarene Islands). However, mitochondrial DNA comparisons (cytochrome *b* and cytochrome *c* oxidase I) reveal high levels of divergence (11% and 6%, respectively), consistent with species-level designation.

Keywords: Cirrhitidae, *Cirrhitops*, new species, Mascarene Islands

INTRODUCTION

The hawkfish *Cirrhitops fasciatus* was described by E.T. Bennett (1828: 39) as *Cirrhites fasciatus* (the generic name a frequent misspelling of *Cirrhitus*), with a type locality of Sandwich Islands (Hawaiian Islands). Cuvier in Cuvier & Valenciennes (1829: 76, pl. 47) described a new hawkfish with the same name, giving the type locality as Pondichéry, India. Günther (1860: 73) believed that Bennett's date of publication was 1829, but later in the same year that Cuvier's description of *fasciatus* appeared, so he provided the replacement name *Cirrhites cinctus* for Bennett's species. He listed four specimens in the British Museum (now the Natural History Museum): Bennett's holotype from the Hawaiian Islands (we provide its photograph here as Fig. 1), one from Madagascar, one from Mauritius, and a fourth from an unstated locality, noted as "not in good state." Fowler (1938: 49) realized that the correct date for Bennett is 1828; therefore Cuvier's *C. fasciatus* is the junior homonym. He proposed the new name *Amblycirrhitus indicus* for Cuvier's specimen. However, Randall (2001: 870) showed that Cuvier's *C. fasciatus* from India is the western Atlantic *Amblycirrhitus pinos* Mowbray in Breder (1927), a result of locality error, and Fowler's replacement name is invalid.

Fig. 1. Holotype of *Cirrhitops fasciatus* (Bennett), BMNH 1855.12.26.495, 71.5 mm, Hawaiian Islands.

Smith (1951: 637) reviewed the Cirrhitidae of the western Indian Ocean. He created the new genus *Cirrhitops* for *Cirrhites fasciatus* Bennett, which he mistakenly regarded as a synonym of *C. cinctus* (Günther). He also erred in writing, "*Amblycirrhites hubbardi* Schultz, 1943, is almost certainly a juvenile of this species."

In a review of the Cirrhitidae, Randall (1963) recognized the genus *Cirrhitops* for two species, *C. fasciatus* and *C. hubbardi*, the latter then known from the Phoenix Islands (type locality) and the Tuamotu Archipelago, now recorded west to Tonga in the South Pacific and the Ogasawara Islands in the North Pacific. He listed *C. fasciatus* from the Hawaiian Islands, Yokohama (this Japanese locality subsequently determined as an error), and the Günther records from Mauritius and Madagascar.

The first author collected and photographed *Cirrhitops fasciatus* in 1973 in Mauritius (Fig. 2) and Réunion. He later photographed it underwater in Mauritius (Fig. 3). There are some differences in colour

from the species in the Hawaiian Islands (Fig. 4), where it is known throughout the archipelago from the island of Hawaii to Midway (but not Johnston Atoll to the south). Fish in the Mascarene Islands have a fifth narrow reddish brown bar on the body before the large oval black spot on the caudal peduncle, compared to only a trace of a fifth bar on the Hawaiian fish. Also, the first four dark bars do not extend as far ventrally on the body in the Mascarene individuals, and there are large reddish blotches instead of a single narrow bar in the pale ventral interspaces. No morphological or meristic differences were found to distinguish Mascarene from Hawaiian specimens. Both have the same fin-ray counts, 49–52 lateral-line scales, 17–19 gill rakers, and the same number of preopercular serrae (increasing with growth). Over the years, no specimens of *C. fasciatus* have been found in the vast distance between the Mascarene Islands and the Hawaiian Islands, and *C. fasciatus* has continued to be regarded as a single species with a remarkable disjunct population (Randall, 2007: 202).

We recently asked Daniel Pelicier, an aquarium-fish collector in Mauritius, if he could provide specimens of *Cirrhitops fasciatus* preserved in ethanol. He sent us two. The second author made a comparison of the DNA with fresh material of the species collected on O'ahu by the first author. Her results (Fig. 5) indicate species-level differentiation. We describe the Mascarene hawkfish here as a new species.

MATERIALS AND METHODS

Type specimens are deposited at the Natural History Museum, London (BMNH); Bernice P. Bishop Museum, Honolulu (BPBM); Muséum National d'Histoire Naturelle, Paris (MNHN); National Museum of Nature and Science, Tokyo (NSMT), and the National Museum of Natural History, Washington, D. C. (USNM).

Lengths of specimens are given as standard length (SL), measured from the median anterior point of the upper lip to the base of the caudal fin (posterior end of the hypural plate); body depth is the maximum depth; body width is measured at the base of the pectoral fins; head length (HL) from the front of the upper lip to the posterior end of the opercular membrane, and snout length from the same anterior point to the nearest fleshy edge of the orbit; orbit diameter is the greatest fleshy diameter, and interorbital width the least fleshy width; upper-jaw length is taken from the front of the upper lip to the end of the maxilla; caudal-peduncle depth is the least depth, and caudal-peduncle length the horizontal distance between verticals at the rear base of the anal fin and the caudal-fin base; lengths of spines and rays are measured from the extreme base of these elements; caudal- and pectoral-fin lengths are the length of the longest ray; caudal concavity is the horizontal distance between tips of the longest and shortest principal caudal rays; pelvic-fin length is measured from the base of the pelvic spine to the tip of the longest soft ray. The counts of lateral-line scales include one pored scale on the base of the caudal fin. The gill-raker counts contain rudiments; the raker at the angle is included in the lower-limb count. Morphometric data presented in Table 1 as percentages of the SL. Proportional measurements in the text are rounded to the nearest 0.05. Data in parentheses refer to paratypes.

For genetic analyses, a 1 mm fin clip was obtained from two Mascarene specimens and three Hawaiian specimens. A single specimen of *Amblycirrhitus bimacula* (on display at the Waikiki Aquarium) was used as an outgroup. We were unable to obtain congeneric specimens of *Cirrhitops hubbardi,* due to its scarcity and remote distribution. Total genomic DNA was isolated by heating the fin clip in 50mM NaOH at 95° C for 20 minutes and neutralizing the solution with 10uL of 1M Tris, following the protocol devised by Meeker *et al.* (2007). We amplified a 750 base pair region of the mitochondrial cytochrome *b* gene using primer sequences designed by Song et al. (1998) and Taberlet et al. (1992), respectively: heavy strand 5'GTGACTTGAAAAACCACCGTTG and light strand 5'AATAGGAAGTATCATTCGGGTTTGATG. We also amplified a 650 base pair region of the mitochondrial cytochrome *c* oxidase I gene (also known as the DNA barcoding gene) using primer sequences described in Ward et al. (2005): FishF2 5'TCGACTAATCATAAAGATATCGGCAC and FishR2 5'ACTTCAGGGTGACCGAAGAATCAGAA. All reactions consisted of 0.26 µM each primer, 2 mM dNTPs, 3 mM $MgCl_2$, 0.5 units of polymerase, and 30–80ng extracted DNA in the following PCR protocol: an initial denaturation step at 94 °C for four minutes, followed by 35 cycles of 94°, 60 s; 50°, 30 s; 72° 45 s and a final extension at 72 °C for 10 minutes. The PCR product was prepared for automated sequencing using a 1:1 exonuclease: shrimp alkaline phosphatase mix (USB Corp., Cleveland OH). Sequencing in the forward and reverse direction was performed on an ABI 3730XL DNA Analyzer by the University of Hawaii Advanced Studies of Genomics, Proteomics and Bioinformatics Facility. DNA sequences were edited using Sequencher version 4.52b (Gene Codes Corporation, Ann Arbor, MI.) and are available in Genbank (accession nos. EU684131–EU684140). Pairwise sequence comparisons were used to calculate genetic distances as performed in PAUP version 4.0 (Swofford 2002). Phylogenetic trees were constructed in PAUP using maximum parsimony and maximum likelihood methods, via an exhaustive search. *Amblycirrhitus bimacula* sequences were used to root the tree. Confidence in tree topology was evaluated by bootstrapping over 1000 replicates (Felsenstein 1985).

***Cirrhitops mascarenensis* sp. nov.**
Figs. 2, 3; Table 1

Cirrhites cinctus (in part) Günther, 1860: 73 (Mauritius and Madagascar).
Cirrhitops fasciatus (non Bennett) Randall, 1963: 420 (Madagascar and Mauritius, after Günther, 1860).

Holotype. BPBM 20207, 59 mm, Mauritius, east coast, 100 m south of pass to Trou d'Eau Douce, fringing reef in 5 m, rotenone, J. E. Randall, 7 November 1973.

Paratypes. BPBM 20067, 2: 37–56 mm, Réunion, west coast, Cap la Houssaye, fringing reef, 12 m, rotenone, J. E. Randall, 23 October 1973; MNHN 2008-1189, 57 mm, and NSMT-P 79975, 56 mm, same data as preceding; USNM 349784, 56 mm, Mauritius, west coast, Baie de la Petite Riviere, off Albion Fisheries Research Center, 20°12′30″S, 57°23′E, 10–12 m, P. C. Heemstra, D. G. Smith, and A. C. Gill, 26 April 1995; USNM 349785, 55 mm, same locality, except 57°23′30″E, 4–8 m, A. C. Gill, D. G. Smith, M. J. Smale, B. Galil, and P. Clark, 4 May 1995; USNM 349786, 59 mm, Mauritius, west coast, Flic en Flac, 30 m north of pass, 20°16′ S, 57°22′E, 4–10 m, P. C. Heemstra, A. C. Gill, D. G. Smith, and M. J. Smale, 5 May 1995; USNM 349787, 2: 51–64 mm, Mauritius, southwest coast, Le Morne (Passe de l'Ambulante), 20°26″10″S, 57°17′36″E, 25–26 m, P. C. Heemstra, A. C. Gill, D. G. Smith, M. J. Smale, P. Clark, and B. Galil, 18 May 1995; BPBM 40889, 53 mm, Mauritius, Rampart Serpent, off Belle Ile, 25 m, D. Pelicier, hand net, 8 May 2007; BPBM 40890, 75 mm, Mauritius, off Womar, Chameau la Pirogue, 62 m, hand net, D. Pelicier, 15 January 2008.

Fig. 2. Holotype of *Cirrhitops mascarenensis*, BPBM 20207, 59 mm SL, Mauritius.

Diagnosis. Dorsal rays X,14; anal rays III,6; pectoral rays 14 (rarely 15), the lower 6 unbranched and thickened; gill rakers 4–5 + 13–14; lateral-line scales 49–52; scales above lateral line to origin of dorsal fin 4; serrae on margin of preopercle 14–24 (increasing, in general, with growth); caudal fin slightly emarginate; red dorsally, white ventrally, with five slightly oblique, reddish brown bars on body below dorsal fin; a large oblong black spot anteriorly on caudal peduncle; a dark brown spot on opercle; ventral half of body with brownish red blotches of eye to pupil size; largest specimen, 75 mm SL.

Description. Dorsal-fin rays X,14, all soft rays branched; anal-fin rays III,6, the soft rays branched except first; pectoral-fin rays 14 (15 on one side of one paratype), the uppermost and lower 6 unbranched; pelvic-fin rays I,5; principal caudal-fin rays 15, the middle 13 branched; upper and lower procurrent caudal-fin rays 13 or 14, the posterior 2 segmented; lateral-line scales 50 (49–52); scales above lateral line to origin of dorsal fin 4; scales below lateral line to origin of anal fin 12; oblique rows of large scales on cheek 5; circumpeduncular scales 25; gill rakers 5 + 14 (4–5 + 13–14); pseudobranchial filaments 9; branchiostegal rays 6; vertebrae 26.

Body depth 2.95 (2.9–3.3) in SL; body compressed, the width 2.35 (1.95–2.3) in body depth; head length 2.7 (2.7–2.8) in SL; snout length 3.15 (3.1–3.3) in HL; orbit diameter 4.15 (3.4–4.35) in HL; interorbital space distinctly concave, the least width 7.2 (6.8–7.45) in HL; caudal-peduncle depth 2.7 (2.65–3.0) in HL; caudal-peduncle length 1.8 (1.75–1.9) in HL.

Mouth terminal and oblique, forming an angle of about 20° to horizontal axis of body; maxilla reaching between verticals at anterior edge of orbit and centre of eye, the upper-jaw length 2.65 (2.6–2.7) in HL; upper jaw with an outer row of stout conical teeth that curve slightly medially and posteriorly, the three at corner of jaw largest (about one-third pupil diameter in length), with a pair of smaller teeth in symphyseal gap; remaining teeth of outer row continuing progressively shorter to end of jaw; a broad band of villiform teeth behind anterior conical teeth, progressively narrower posteriorly; lower jaw with an outer row of stout conical teeth, four or five nearly half way back in jaw much larger (the largest as long as largest upper tooth); a broad band of villiform teeth anteriorly in lower jaw behind conical teeth, narrowing and ending medial to large conical teeth on side of jaw; vomer and palatines with incurving villiform teeth in two irregular rows, those on vomer in a broad V-shape. Tongue strongly pointed, the tip nearly reaching vomerine teeth when mouth closed. Gill rakers moderately long, the longest at angle as long as longest gill filament of first row.

Opercle ending posteriorly in a flat pointed spine, the tip forming an angle of about 70°; opercular membrane extending a pupil diameter posterior to spine; edge of preopercle broadly rounded, the upper half with 24 (14–24) coarse serrae, the number increasing, in general, with growth; scale-like free end of posttemporal with 5 (4–6) small serrae.

Anterior nostril before upper edge of pupil about one-third distance to base of upper lip, consisting of a short membranous tube with a posterior flap ending in about 8 long cirri that extend well beyond posterior nostril when laid back; posterior nostril oval, with a short rim, one nostril diameter behind and slightly

medial to anterior nostril.

Scales cycloid and adherent; scales on nape extending forward to above posterior margin of orbit; scales on cheek in straight oblique rows; scales on opercle embedded, small anteriorly, becoming as large as body scales posteriorly; scales ventrally on head small and embedded; no scales on snout or maxilla; small scales basally on fins, progressively smaller distally, those on caudal fin reaching at least two-thirds distance to posterior margin of fin (scales on fins easily lost).

Origin of dorsal fin above opercular spine, the predorsal length 2.8 (2.8–2.9) in SL; dorsal spines with a tuft of 7–9 slender cirri (as few as 4 on small paratype) extending dorsally from distal end of fin membrane behind spine tip; first dorsal spine 4.3 (4.2–4.65) in HL; sixth dorsal spine usually longest, but fifth and seventh spines subequal, 2.1 (2.0–2.2) in HL; first dorsal soft ray longest, 1.6 (1.65–1.85) in HL; origin of anal fin below base of second to third dorsal soft ray, the preanal length 1.45 (1.5–1.55) in SL; first anal spine 2.7 (2.7–3.0) in HL; second anal spine clearly longest, 1.85 (1.65–1.85) in HL; second anal soft ray longest, 1.7 (1.5–1.7) in HL; caudal-fin length (fin tips broken in holotype and largest paratype) 1.35–1.5 in HL; caudal concavity 9.0–13.7 in HL; lower five pectoral rays thickened, the tenth to twelfth abruptly longer, the tenth or eleventh longest, 2.95 (2.6–2.95) in SL; pelvic fins below base of fifth dorsal spine, the prepelvic length 2.3 (2.3–2.4) in SL; first pelvic soft ray longest, reaching or extending slightly posterior to anus, 1.65 (1.45–1.7) in HL.

Table 1. Proportional measurement of type specimens of *Cirrhitops mascarenensis* as percentages of the standard length.

	Holotype	Paratypes					
	BPBM 20702	BPBM 20067	USNM 349787	BPBM 20067	MNHN 08-1189	USNM 349786	USNM 349787	BPBM 40890
Standard length (mm)	59	37	51	56	57	59	64	75
Body depth	33.7	30.2	32.4	33.3	31.7	32.5	32.3	34.7
Body width	14.3	13.8	15.5	14.3	15.7	15.6	15.3	15.4
Head length	36.7	36.7	36.9	37.2	36.8	37.1	37.2	35.9
Snout length	11.7	11.1	11.6	11.6	11.9	12.0	11.8	10.8
Orbit diameter	8.9	10.8	9.6	9.0	9.1	9.0	8.7	8.3
Interorbital width	5.1	5.4	5.1	5.3	5.1	5.0	5.4	5.3
Upper -jaw length	13.9	13.6	13.9	13.7	14.0	14.2	14.1	13.9
Caudal-peduncle depth	13.5	13.4	12.4	12.6	12.3	12.3	12.4	13.6
Caudal-peduncle length	20.3	21.2	20.7	20.5	19.3	20.2	19.3	19.4
Predorsal length	35.4	34.9	34.8	35.6	34.9	34.4	34.3	34.7
Preanal length	68.4	64.6	65.6	66.3	65.4	66.3	65.5	66.6
Prepelvic length	43.6	41.7	43.0	42.4	43.2	43.5	42.5	43.7
Dorsal-fin base	61.7	57.9	57.5	60.2	61.2	57.8	58.1	61.9
First dorsal spine	8.5	8.4	8.8	8.2	8.5	8.4	8.0	8.0
Longest dorsal spine	17.5	18.2	18.0	16.9	17.1	17.0	17.2	16.9
Longest dorsal ray	23.0	22.4	22.2	21.7	21.5	20.0	22.7	23.4
Anal-fin base	16.0	16.2	16.3	16.4	16.9	16.7	16.8	16.6
First anal spine	13.6	13.3	13.5	12.3	13.5	13.6	12.5	12.4
Second anal spine	20.1	20.9	22.1	21.5	19.9	22.0	21.8	20.0
Longest anal ray	21.4	23.1	23.5	21.7	23.2	21.9	22.3	23.9
Caudal-fin length	broken	27.1	27.0	24.7	26.3	27.3	24.4	broken
Pectoral-fin length	33.6	38.4	37.6	34.0	35.2	35.9	36.4	34.6
Pelvic spine	15.6	16.3	16.9	14.6	14.7	15.5	15.2	15.0
Pelvic-fin length	22.1	25.1	25.2	21.8	23.3	23.2	22.2	23.6

Colour of holotype in alcohol pale yellowish brown with five, slightly oblique, faint dark bars below dorsal fin that extend about half way down on body; first dark bar merging dorsally with dark area on nape; pale interspaces on body about half width of dark bars; a large oblique, oval, darker brown spot anteriorly on caudal peduncle; a dark brown spot nearly as large as eye posteriorly on opercle; fins pale yellowish.

Fig. 3. Underwater photograph of *Cirrhitops mascarenensis*, Mauritius.

Paratypes collected from below about 20 m have red bars in life that are lost in alcohol; however, the black spot on the caudal peduncle and the dark brown spot on opercle persist in preserved specimens. The paratypes of BPBM 40889, BPBM 40890, and USNM 349787 were collected deeper than 25 m, and all are uniformly pale in alcohol except for the opercular and peduncular black spots.

Colour of holotype when fresh as in Fig. 2. The underwater photograph of Fig. 3 shows the life colour.

We compared Mascarene and Hawaiian *Cirrhitops* specimens at two mitochondrial genes: a 741 base pair region of the cytochrome *b* gene and a 643 base pair region of the cytochrome *c* oxidase I gene.

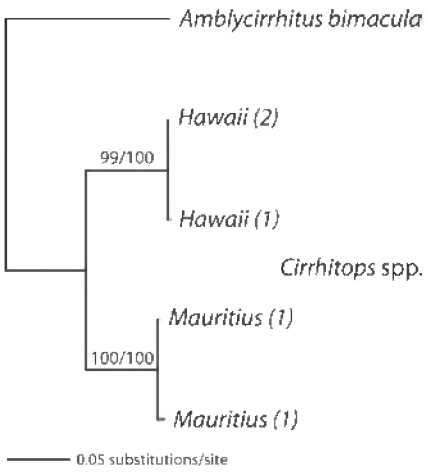

Fig. 5. Maximum likelihood phylogenetic tree of the cytochrome *b* gene. Number of specimens in parentheses. Numbers on branches reflect bootstrap support for maximum parsimony/ maximum likelihood analyses.

Cytochrome *b* analyses revealed 86 variable nucleotide sites of which 80 were parsimony informative, with a transition: transversion ratio of 5:1. There were two haplotypes in three Hawaiian specimens and two Mascarene haplotypes. Pairwise genetic distances between locations (d = 0.11) were 15 to 100 times greater than within location distances (d = 0.001, 0.007 Hawai'i and Mauritius respectively). Cytochrome *c* oxidase I analyses were similarly robust. Of 41 variable nucleotide sites, 39 were parsimony informative, with a transition: transversion ratio of 12:1. There were two haplotypes in three individuals collected from Hawai'i and two Mascarene haplotypes. Pairwise genetic distances between locations (d = 0.06) were lower than observed at the cytochrome *b* gene, but at least an order of magnitude greater than within location distances (d = 0.0016).

Genetic distances between *Cirrhitops* and the outgroup, *Amblycirrhitus bimacula* (cytochrome *b*, d = 0.20; cytochrome oxidase, d = 0.18, 0.21 Hawaii and Mauritius, respectively) were high. Phylogenetic analyses converged on a single tree topology for both mitochondrial markers and using two methods of analysis (Fig. 5). High bootstrap values (99–100) reflect strong differentiation between Mascarene and Hawaiian specimens.

Fig. 4. Underwater photograph of *Cirrhitops fasciatus*, O'ahu, Hawaiian Islands.

Material of *Cirritops fasciatus* examined. Hawaiian Islands, O'ahu: BPBM 349, 87 mm; BPBM 1806–1808, 3: 70–80 mm; BPBM 2111–2113, 3: 74-80 mm; BPBM 4128, 5: 77–91 mm; BPBM 6348, 6: 33–78 mm; BPBM 6454, 69 mm; BPBM 8899, 2: 33–35 mm; BPBM 40485. 81 mm. Hawai'i: BPBM 25913, 31 mm. Nehoa: BPBM 9163, 33 mm. Midway: BPBM 34818, 2: 56–81 mm.

Etymology. This species is named *Cirrhitops mascarenensis* for its occurrence in the Mascarene islands of Mauritius and Réunion.

Remarks. Our record of *Cirrhitops mascarenensis* from Madagascar is the listing by Günther (1860:73) as *Cirrhites cinctus*, an unnecessary replacement name. Günther's specimen, 71 mm SL, collected by J. E. Gray, was found unregistered by James Maclaine in the Natural History Museum, London. It was assigned the number BMNH 2008.4.14.1. A photograph of the specimen was readily

identified by us as *C. mascarenensis*.

This species was not reported from Rodrigues, the most eastern of the Mascarene Islands, in a preliminary checklist of the fishes of the island (Heemstra et al., 2004), but it might be expected from there.

Günther regarded his specimens from the Madagascar and Mauritius as the same species as Bennett's holotype of *Cirrhitops fasciatus* from the Hawaiian Islands, and he was followed by Randall (1963) in a review of the family. Although we later noticed a difference in life colour in the two widely separated populations, no morphological differences were found, and the ranges in lateral-line scale and gill-raker counts are the same. However, the DNA results are unequivocal as two species.

There is reciprocal monophyly and high sequence divergence between the Mascarene and Hawaiian specimens. Eleven percent divergence at the mitochondrial cytochrome *b* gene, which has a divergence rate of 2% per million years as calibrated in multiple fish species (Bowen et al., 2001), constitutes approximately 5.5 million years of reproductive isolation. A barcoding survey of 200 fish species performed by Ward et al. (2005) reports an average of 0.39% divergence within species and 9.9% divergence within genera. We find 0.16% divergence within species and 6.2% divergence between Mascarene and Hawaiian specimens at the barcoding gene (cytochrome *c* oxidase I). Therefore, genetic analyses support species-level differentiation.

Based on existing museum material, the Hawaiian species is larger. The largest of our 14 type specimens of *Cirrhitops mascarenensis* measures 75 mm SL. Twelve of our 26 Bishop Museum specimens of *C. fasciatus* are larger than 75 mm, the largest 91 mm SL.

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