

Taxonomic review of Western Indian Ocean goatfishes of the genus *Mulloidichthys* (Family Mullidae), with description of a new species and remarks on colour and body form variation in Indo-West Pacific species

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ABSTRACT. The taxonomy of the goatfish species of the genus *Mulloidichthys* from the Western Indian Ocean is reviewed. Four species are recognized: *M. ayliffe* sp. nov., *M. flavolineatus*, *M. pfluegeri* and *M. vanicolensis*. As colour may vary considerably in live fish and fades in preserved fish, and meristic characters are rather conservative in this genus, a large set of 41 morphometric characters was also examined. All seven valid *Mulloidichthys* species are included in the comparisons. The Western Indian Ocean *M. ayliffe* sp. nov. differs from its Pacific sister species *M. mimicus* in number of lateral-line scales, several morphometric features, the position of the conspicuous bluish dorso-mid-lateral body stripe in relation to the lateral line, and the width of the yellow mid-lateral body stripe. The new species can also be distinguished from the other congeners by colour, meristic and morphometric characters. A key is provided for the Western Indian Ocean species, which includes the South Pacific species, *M. mimicus*. The first evidence for geographic variation in body form among *Mulloidichthys* species with marked differences between the Pacific and Indian Ocean is presented. These results complement earlier findings of inter-oceanic divergence in the number of gill rakers in *M. vanicolensis*. The implications of these findings are discussed with respect to the need for DNA-based comparative studies on population differentiation and the ecological functions of colour patterns in *Mulloidichthys* species.

RÉSUMÉ. La taxonomie de l'espèce de rouget et du genre *Mulloidichthys* de l'ouest de l'Océan Indien est passée en revue. Quatre espèces sont reconnues : *M. ayliffe* sp. nov., *M. flavolineatus*, *M. pfluegeri* et *M. vanicolensis*. Étant donné que la couleur peut varier pour les poissons vivants et se détériorer pour les poissons conservés et que les caractéristiques meristiques de ce genre sont plutôt conservatives (minimales), un échantillon important de 41 caractéristiques morphométriques a été également analysé. Dans ces comparaisons on trouvera également toutes les 7 espèces vivantes de *Mulloidichthys*. L'espèce *M. ayliffe* de l'ouest de l'Océan Indien se distingue de sa sœur espèce du Pacifique *M. mimicus* par rapport au nombre d'écaillies en ligne latérale, plusieurs éléments morphométriques, la position de la ligne dorsale par rapport à la ligne latérale ainsi que la dimension du corps latéral du milieu. La nouvelle espèce peut également être identifiée par sa couleur et ses caractéristiques meristiques et morphométriques. Le moyen de comprendre les espèces de l'ouest de l'Océan Indien, y compris l'espèce Pacifique *M. mimicus*, est présenté dans cette analyse. La première preuve de la variation géographique dans la morphologie des espèces *Mulloidichthys* avec des différences importantes entre le Pacifique et l'Indien est présentée. Les résultats complètent les trouvailles antérieures sur les divergences interocéaniques spécialement en ce qui concerne la famille de *M. vanicolensis*.

KEY WORDS: morphology, colour patterns, new species, Mullidae, *Mulloidichthys*, Western Indian Ocean

INTRODUCTION

Recent reviews of the goatfish genera *Parupeneus* and *Upeneus* (Mullidae) from the Western Indian Ocean region have resulted in descriptions of ten new species, resurrection of two species, and several other novel insights into their diversity and distribution (Randall & Heemstra 2009; Randall & King 2009; Uiblein & Heemstra 2010; Uiblein & Heemstra 2011; Uiblein & Heemstra in press). These studies have highlighted the

obvious need for regional taxonomic reviews of goatfishes including the genus *Mulloidichthys* in which three species are known from the Western Indian Ocean, *M. flavolineatus* (Lacepède 1801, *M. pfluegeri* (Steindachner 1900), and *M. vanicolensis* (Valenciennes 1831) (Ben Tuvia, in Smith & Heemstra 1986; Myers 1989).

Earlier studies of *Mulloidichthys* found considerable variation in colour pattern, meristic or morphometric characters among species or populations, but found no evidence for the

Table 1. Abbreviation and description of morphometric and meristic characters

Morphometric characters	
SL	standard length, distance between snout tip and caudal fin base at mid-body
BODYDD	body depth at first dorsal-fin origin
BODYDA	body depth at anal-fin origin
HALFDD	half body depth (from lateral line downwards) at first dorsal fin origin
HALFDA	half body depth (from lateral line downwards) at anal fin origin
CPDD	caudal-peduncle depth, minimum depth anterior to caudal dorsal origin
CPDW	caudal-peduncle width at position of CPD measurement
HEAD1	maximum head depth, vertical distance at ventral edge of operculum
HEAD2	head depth across a vertical midline through eye
SUBORB	suborbital depth - distance between lower edge of orbit to ventral midline of head
INTORB	interorbital length - least distance between upper bony edges of orbits
HEADL	head length - distance between snout tip to posteriormost margin of operculum
SNOUTL	snout length - distance between snout tip to anterior margin of orbit
PORBL	postorbital length, distance between posterior edge of orbit and posterior margin of operculum
ORBTL	orbit length, horizontal fleshy orbit diameter
ORBITD	orbit depth, vertical fleshy orbit diameter
UJAWL	upper-jaw length - distance between symphysis and posterior end of upper jaw
LJAWL	lower-jaw length - distance between symphysis of lower jaw and posterior end of upper jaw
SNOUTW	snout width - least distance between hinder margins of upper jaw, with closed mouth
BARBL	barbel length
BARBW	maximum barbel width, horizontal width measured at base of soft part of barbell
SD1	first pre-dorsal length - distance between snout tip to origin of first dorsal fin
SD2	second pre-dorsal length - distance between snout tip to origin of second dorsal fin
D1D2	interdorsal distance - distance between last spine of first dorsal and first ray of second dorsal fin
CPDL	caudal-peduncle length - distance between last anal ray and ventral origin of caudal fin
SANL	pre-anal length - distance between snout tip to origin of anal fin
SPEL	pre-pelvic length - distance between snout tip to origin of pelvic fin
SPEC	pre-pectoral length - distance between snout tip to dorsal origin of pectoral fin
D2ANL	second dorsal-fin depth - distance between origin of second dorsal fin to origin of anal fin
D1PELV	pelvic-fin depth - distance between origin of first dorsal fin to origin of pelvic fin
D1PEC	pectoral-fin depth - distance between origin of first dorsal fin to dorsal origin of pectoral fin
D1B	length of first dorsal-fin base
D2B	length of second dorsal-fin base
CAUH	distance between dorsal caudal-fin origin and upper caudal-lobe tip
ANALB	length of anal-fin base
ANALH	distance between anal-fin origin and anal-fin anterior tip (= to tip of first anal ray)
PELVL	distance between pelvic-fin origin and pelvic-fin tip
PECTL	distance between pectoral-fin dorsal origin and pectoral-fin tip
PECTW	width of pectoral-fin base
D1H	first dorsal-fin height - distance between first dorsal-fin origin and first dorsal-fin anterior tip (= to tip of first long dorsal-fin spine)
D2H	second dorsal-fin height - distance between second dorsal-fin origin and second dorsal-fin anterior tip (= to tip of second dorsal-fin ray)
BMBS-LL	position (=distance from snout) of crossing point of blue dorso-mid-lateral body stripe and lateral line (<i>M. ayliffe</i> sp. nov. and <i>M. mimicus</i>)
Meristic characters	
P	pectoral-fin rays
GrUud	rudimentary (= width larger than its depth) gill rakers on upper limb
GrUd	developed gill rakers on upper limb
GrLd	developed gill rakers on lower limb (including gill raker in corner)
GrLud	rudimentary gill rakers on lower limb
GrU	total gill rakers on upper limb
GrL	total gill rakers on lower limb
Gr	total gill rakers
LLscal	scales along lateral line to caudal-fin base (excluding scales on caudal fin)

presence of a fourth species in the region. For example, in their description of *M. mimicus* from the South Pacific, Randall & Guézé (1980) noted that the species mimics the colour pattern of the blue-striped snapper *Lutjanus kasmira* (Forsskål 1775) that may reduce predation risk when the two species shoal together. In the Indian Ocean, off Tanzania, Kenya and Sri Lanka, a blue-striped colour variant of *M. vanicolensis* that appeared to resemble *M. mimicus* was observed (Randall & Guézé 1980). These authors further noted that *M. vanicolensis* forms shoals with *Lutjanus kasmira* and may be able to rapidly change between the 'typical' and the mimic colour pattern.

Stepien *et al.* (1994) found a divergence in the number of gill rakers between populations of *Mulloidichthys vanicolensis* in the Western Indian Ocean compared to those from the Pacific. Allozyme studies conducted in parallel to the morphological comparisons suggested, however, a close genetic relationship exists between the two populations.

Based on their findings these authors recognized three closely related species of the circumtropical 'martinicus' complex of *Mulloidichthys*: the Indo-West Pacific *M. vanicolensis*, the East Pacific *M. dentatus* (Gill 1862) and the West Atlantic *M. martinicus* (Cuvier 1829).

This study identifies a fourth, hitherto undescribed, species of *Mulloidichthys* from the Western Indian Ocean that can be clearly distinguished from the other six currently recognized species. A detailed comparison of colour patterns and 50 meristic and morphometric characters was made of a total of 118 specimens. Special emphasis was placed on the use of relatively quickly identifiable colour, meristic, and morphometric characters. The new species, *M. ayliffe* sp. nov. is described and a key to the Western Indian Ocean species that includes also the South Pacific sister species, *M. mimicus*, is provided, and can be used for both fresh and preserved fish. Comparisons of populations from different areas

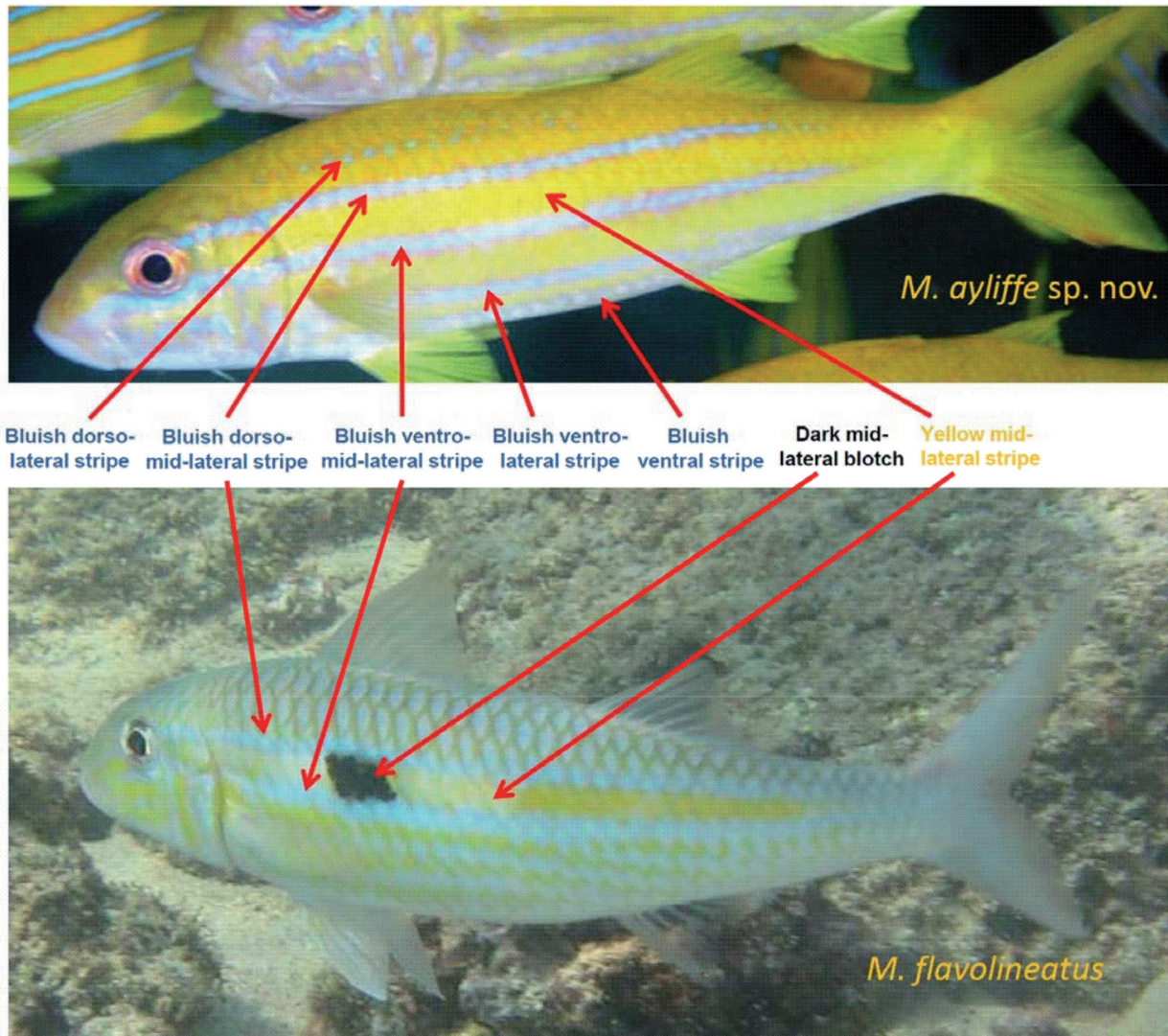


Fig. 1. Terminology for colour patterns in *Mulloidichthys* used in the current study (top: D. Pollack, from Plate 1A, bottom: F. Uiblein, off Kauai, Hawaii).

of the Indian Ocean and between the Indian Ocean and South Pacific are made to further understand the extent of geographical variation among the Western Indian Ocean *Mulloidichthys* species.

MATERIALS AND METHODS

Abbreviations and descriptions of morphometric and meristic characters are provided in Table 1. Morphometric characters were measured with an electronic caliper and are expressed as % SL. For comparison with earlier studies – and in order to facilitate their application in the field – the diagnostically most important morphometric characters are provided as ratios of SL in the key and in Table 2c. Morphometric ratios less than 100 are given to two significant digits.

Only meristic characters that vary among species are referred to in the diagnoses and comparisons: the number of pectoral-fin rays, rudimentary and developed gill rakers on lower and upper limb, and lateral-line scales. In order to verify the presence of the first minute dorsal-fin spine, characteristic

for the genus, a stereomicroscope was used. In difficult cases the scales at the base of the second spine were moved or radiographs were examined. Gill rakers were identified as rudimentary if their length was less than their width. The gill raker in the angle between the upper and lower limbs of the first gill arch was included in the count for the lower limb. Lateral-line scale counts do not include scales on the caudal fin.

Measurements showing high overall intra-specific variation, e.g. fin distances from the snout, were not included in the diagnoses and only rarely in comparisons. Body depth measurements were only considered when there was consistent co-variation with other closely correlated measurements.

No juvenile or subadult *M. ayliffe* sp. nov. were available for comparative examinations. Because goatfishes vary significantly during ontogeny due to allometric changes in body form (Uiblein & Heemstra 2010), morphological comparisons need to be restricted to distinct life-history stages and size classes. In the current study only fish > 125

mm SL were examined, except for a single 79 mm *M. mimicus*.

To explore the inter- and intraspecific distinction among species, forms or populations, various statistical methods were used. Chi²-Test was used for comparing meristic characters in widely overlapping populations; Principal Component Analysis (PCA) with size-adjustment based on the residuals gained from log-log regressions of the morphometric variables with standard length was used to obtain information on optimal distinction

among species and/or deviating forms (e.g., Uiblein & Winkler 1992; Uiblein & Heemstra 2010). In order to facilitate correct identification and avoid terminological misunderstandings regarding the comparison of body stripes, the following schema was developed (Fig. 1). Generally, two types of body stripes can be distinguished by colour and width.

The first consists of bluish body stripes, with similar width to or narrower than the barbels, that vary in colour intensity between species (Table 2).

Table 2. Meristic and colour characters (a), morphometric characters in %SL (b), and morphometric character in times of SL (c) in five *Mulloidichthys* species.

		Pectoral-fin rays	Gill rakers on upper arch	Gill rakers on lower arch	Total gill rakers	Lateral-line scales	Yellow mid-lateral body stripe width *	Bluish body stripes (nr. **)	Dark oval or rectangular blotch mid-laterally below D1B ***										
(a)	<i>ayliffe</i> sp. nov.	16-17	7-8	19-23	27-31	35-37	> pupil > orbit Ø	conspicuous (2-5)	No										
	<i>flavolineatus</i>	16-18	7-10	19-22	26-31	34-38	≤ pupil Ø	weak (2)	Yes										
	<i>pfluegeri</i>	17-18	6-7	19-22	26-29	35-37	-	no	No										
	<i>vanicolensis</i>	15-17	7-10	23-26	31-35	36-38	≤ pupil Ø	weak (2)	No										
	<i>mimicus</i>	15-17	6-8	21-23	28-31	38-39	≥ orbit Ø	conspicuous (2-5)	No										
* not retained in preserved fish ** not or only weakly retained in preserved fish *** not always visible in live fish, weakly retained in preserved fish																			
		Body depth at first dorsal-fin origin	Body depth at anal-fin origin	Caudal-peduncle depth	Caudal-peduncle width	Maximum head depth	Head depth through eye	Head length	Snout length	Orbit length	Upper jaw length	Barbel length	Caudal-fin length	Anal-fin height	Pelvic-fin length	Pectoral-fin length	Pectoral width	First dorsal-fin height	Second dorsal-fin height
(b)	<i>ayliffe</i> sp. nov.	26-29	23-25	10-11	4.1-5.3	22-25	17-20	28-31	11-13	6.9-8.5	9.0-11	19-23	28-31	14-17	19-22	19-22	4.2-5.2	21-24	14-17
	<i>flavolineatus</i>	21-26	16-21	8.3-9.8	3.2-4.6	19-22	16-19	27-31	12-15	5.8-7.8	8.1-9.5	18-22	29-33	13-16	19-22	19-21	3.5-4.9	19-23	14-16
	<i>pfluegeri</i>	26-28	21-24	8.4-9.1	4.6-6.0	24-26	19-21	28-31	13-16	5.2-6.9	11-12	19-21	29-33	12-13	20-24	20-23	5.4-5.7	18-21	12-13
	<i>vanicolensis</i>	25-30	21-25	9.2-11	3.0-4.9	21-25	16-20	28-32	11-14	6.2-9.4	9.4-11	19-24	29-34	14-18	20-24	20-24	3.9-5.4	20-25	15-18
	<i>mimicus</i>	28-30	25-27	10-11	4.0-4.7	24-26	18-20	28-31	12-14	7.2-8.5	9.5-11	20-22	27-31	13-17	20-23	20-22	4.5-5.2	20-23	14-16
		Body depth at first dorsal-fin origin	Body depth at anal-fin origin	Caudal-peduncle depth	Caudal-peduncle width	Maximum head depth	Head depth through eye	Head length	Snout length	Orbit length	Upper jaw length	Barbel length	Caudal-fin length	Anal-fin height	Pelvic-fin length	Pectoral-fin length	Pectoral width	First dorsal-fin height	Second dorsal-fin height
(c)	<i>ayliffe</i> sp. nov.	3.4-3.9	3.9-4.4	9.3-10	19-25	4.0-4.5	5.1-5.8	3.2-3.6	7.6-8.9	12-14	8.8-11	4.4-5.2	3.2-3.6	5.8-7.1	4.5-5.1	4.5-5.2	19-24	4.2-4.8	5.8-7.2
	<i>flavolineatus</i>	3.9-4.8	4.7-5.6	10-12	22-31	4.5-5.2	5.2-6.4	3.2-3.6	6.8-8.2	13-17	10-12	4.4-5.7	3.0-3.5	6.4-7.7	4.5-5.4	4.7-5.3	20-26	4.4-5.3	6.1-7.4
	<i>pfluegeri</i>	3.5-3.9	4.2-4.7	11-12	17-22	3.9-4.1	4.9-5.3	3.2-3.6	6.4-7.6	15-19	8.2-9.2	4.9-5.2	3.1-3.4	7.5-8.6	4.1-4.9	4.3-4.9	18-19	4.7-5.6	7.1-8.2
	<i>vanicolensis</i>	3.3-4.1	4.0-4.8	9.2-11	20-33	4.0-4.8	4.9-5.1	3.2-3.5	7.2-9.1	11-16	9.0-11	4.2-5.2	3.0-3.5	5.5-7.0	4.2-5.0	4.1-5.0	19-25	4.0-5.0	5.6-6.5
	<i>mimicus</i>	3.3-3.6	3.7-4.0	9.2-9.6	21-25	3.9-4.1	5.0-5.6	3.3-3.6	7.1-8.5	12-14	8.9-11	4.5-5.0	3.2-3.7	6.0-7.4	4.4-4.9	4.5-5.1	19-22	4.3-5.0	6.3-7.2

The stripes are blue to pale blue in *Mulloidichthys ayliffe* sp.nov. and *M. mimicus*, and pale blue to whitish in *M. dentatus*, *M. flavolineatus*, *M. martinicus* and *M. vanicolensis*. The stripes may vary considerably in number, but the dorso-mid-lateral and the ventro-mid-lateral stripe are present in all six species, the latter stripe sometimes overlain by white-silvery body colour. In *M. mimicus* and *M. ayliffe* sp. nov. three additional bluish body stripes may occur, a ventro-lateral, a ventral, and a dorso-lateral stripe, the latter usually consisting of a series of blue dots.

The second type of stripes consists of wider, yellow stripes (Fig. 1), their width varying from pupil diameter to more than orbit diameter (Table 2a). The yellow, mid-lateral stripe occurs in fresh specimens of all striped species and is bordered by the bluish dorso-mid-lateral stripe above and the bluish ventro-mid-lateral stripe below. Yellow stripes may also be present more ventrally or dorsally, mostly in association with additional bluish body stripes. Due to the yellow 'background' body coloration in *M. ayliffe* sp. nov. and *M. mimicus* the yellow stripes appear to be less contrasting compared to those of *M. flavolineatus* and the 'martinicus' complex. The yellow body stripes fade in preserved fish and hence can be used only for field identification or freshly-caught fish. The bluish stripes and, in particular, the dorso-mid-lateral stripe are frequently retained in recently preserved *M. ayliffe* sp. nov. and *M. mimicus*.

Colour characters that fade in preserved fish were only included as supplementary information in the key and diagnoses along with comments on their restricted applicability. Colour photographs for each species were selected using primarily material that was also examined in the current study, or material that was identifiable (Plate 1).

Because *M. ayliffe* sp. nov. resembles *M. mimicus* considerably and misidentifications have been made to date, the latter is also included in the key and the species accounts.

Complementary information on species distributions was obtained from the literature.

TAXONOMY

Genus *Mulloidichthys* Whitley 1929

Mulloidichthys Whitley 1929: 122. Type species *Mullus flavolineatus* Lacepède 1801. Type by being a replacement name for *Mulloides* Bleeker 1849.

DIAGNOSIS. Dorsal fins VIII + 9; anal fin I, 6; pelvic fins I, 5; pectoral-fin rays 15–18; principal caudal-fin rays 7 + 8 (median 13 branched); gill rakers 6–10 + 19–27 = 26–35; lateral-line scales 33–39 (plus 3–4 on caudal base); lateral line complete; small conical teeth on both jaws; body oblong, slightly compressed; barbel length in adults (>125 mm SL) 4.2–5.7 times in SL, snout length 6.1–9.1 times in SL, larger than postorbital length (8.4–11 times in SL); fresh fish with either a rather uniformly red-coloured body or a silvery-white to yellow body with a yellow mid-lateral body stripe or band, bordered by two narrower bluish (blue to blue-white) stripes.

DISTRIBUTION. In all major oceans, tropical to subtropical, one species in the Atlantic.

REMARKS. Seven species are recognized as valid, *M. ayliffe* sp. nov. from the Western Indian Ocean, *M. flavolineatus*, *M. pfluegeri*, and *M. vanicolensis* from the Indo-Pacific, *M. mimicus* and *M. dentatus* from the Pacific, and *M. martinicus* from the subtropical and tropical Atlantic. No recent revision of the genus exists.

KEY TO THE WESTERN INDIAN OCEAN SPECIES OF *Mulloidichthys* AND *M. mimicus*

This key is based exclusively on adult fish (> 125 mm SL), see also Tables 2–6, Figs. 2, 3, Plates 1, 2.

- 1a. Second dorsal-fin height 7.7–8.2 times in SL, caudal-peduncle depth 3.0–3.3 times or more in body depth at first dorsal-fin origin, caudal-peduncle width 1.5–1.8 times in caudal-peduncle depth; body reddish in fresh fish, lateral body stripes absent (Indo-Pacific) *M. pfluegeri*
- 1b. Second dorsal-fin height 5.5–7.5 times in SL, caudal-peduncle depth 2.4–2.9 times in body depth at first dorsal-fin origin, caudal-peduncle width 1.9–3.3 times in caudal-peduncle depth; wide yellow and narrow bluish (blue, pale blue or whitish) body stripes present in fresh fish 2
- 2a. Body and head depth shallow, body depth at anal-fin origin 4.7–5.6 times in SL, maximum head depth 4.5–5.2 times in SL, 19–22 gill rakers on lower limb, dark oval or rectangular blotch mid-laterally on body below first dorsal fin, sometimes weak or absent in fresh or preserved fish (Indo-Pacific)
..... *M. flavolineatus*
- 2. Body and head moderately deep, body depth at anal-fin origin 3.7–4.8 times in SL, maximum head depth 3.9–4.8 times in SL, 19–26 gill rakers on lower limb, no dark blotch on body 3

- 3a. Gill rakers on lower limb 23–26, body depth at anal-fin origin 4.0–4.8 times in SL, second dorsal-fin base 1.1–1.4 times in its height, yellow mid-lateral body stripe conspicuous, its width equal or less than pupil diameter, bluish (or whitish) body stripes weak, not retained in preserved fish (Indo-Pacific) *M. vanicolensis*
- 3b. Gill rakers on lower limb 19–23, body depth at anal-fin origin 3.7–4.4 times in SL, second dorsal-fin base 0.9–1.2 times in its height, yellow mid-lateral body stripe inconspicuous, its width larger than pupil diameter, bluish body stripes conspicuous, dorso-mid-lateral stripe frequently retained in freshly preserved fish 4
- 4a. Lateral-line scales 35–37, body depth at anal fin origin 3.9–4.4 times in SL, maximum head depth 4.0–4.5 times in SL, bluish dorso-mid-lateral body stripe crosses lateral line posterior to first dorsal-fin base (Indian Ocean) *M. ayliffe* sp. nov.
- 4b. Lateral-line scales 38–39, body depth at anal fin origin 3.7–4.0 times in SL, maximum head depth 3.0–4.1 times in SL, bluish dorso-mid-lateral body stripe crosses lateral line below first dorsal-fin base (Pacific) *M. mimicus*

***Mulloidichthys ayliffe* sp. nov.**

(Tables 2–3; Figs. 2, 3; Plates 1, 2)

Mulloidichthys mimicus: Taquet & Diring 2007: 260 (two photographs of live fish on pp. 258 and 260).

Mulloidichthys vanicolensis (in part): Randall 1995: 239, Fig. 621 (colour photograph showing a mixed school of *M. ayliffe* and *M. vanicolensis*).

Holotype. SAIAB 86367, 175 mm, KwaZulu-Natal, Sodwana Bay, Mellow Yellow Reef, South Africa, 27°31.863'S 32°42.48'E, 12–19 m, collected by Neville Ayliffe, Phillip C. Heemstra and Elaine Heemstra

Paratypes. Western Indian Ocean, South Africa: SAIAB 86368, 223–245 mm, KwaZulu-Natal, Coral Gardens, Sodwana Bay, 27°31.34'S, 32°41.15'E, 5–12 m; **Tanzania:** BPBM 17620, 155 mm, Mafia Island, Chole Island, Chole Bay, reef, 6 m; **Kenya:** SAIAB 18057, 190–194 mm, Shimoni, 4°39'S, 39°23'E; SAIAB 13907, 197–230 mm, Shimoni, 4°39'S, 39°23'E; **Seychelles:** SAIAB 18055, 210 mm, Amirante Islands, Poivre Island, 05°46'S, 53°19'E; **Oman:** BPBM 36010, 183–187 mm, Southern Oman, Kuria Muria Islands, Sawda Island, E end, 4–8 m; BPBM 36024, 6, 171–217 mm, Southern Oman, Kuria Muria Islands, Sawda Island, SW side, 10 m; BPBM 41008, 218 mm.

Non-Types. Western Indian Ocean, Sri Lanka: BPBM 18770, 154 mm, Trincomalee, Dutch Point, 5 m; BPBM 27749, 202 mm, Trincomalee, fish market; BPBM 31285, 152–192 mm, Trincomalee, Koddidiyar Patu, Foul Point, E side of lighthouse, 8°32'N, 81°19'E, 0–8 ft.

DIAGNOSIS. Pectoral fins 16 or 17; gill rakers 7–8 + 19–23 = 27–31; lateral-line scales 35–37; body depth at first dorsal-fin origin 26–29% SL; body depth at anus 23–25; caudal-peduncle depth 10–11; caudal-peduncle width 4.1–5.3; maximum head depth 22–25; head depth through eye 17–20; head length 28–31; snout length 11–13; orbit length 6.9–8.5; upper jaw length 9.0–11; barbel length 19–23; caudal-fin

length 28–31; anal-fin height 14–17; pelvic-fin length 19–22; pectoral-fin length 19–22; pectoral-fin width 4.2–5.2; first dorsal-fin height 21–24; second dorsal-fin height 14–17% SL; body, head and fins yellow in live fish, becoming orange dorsally and anteriorly in freshly collected fish; body and head with two to five straight bluish (blue or pale blue) lateral body stripes, with one to four yellow stripes between, bluish stripes approximately as wide as barbels; yellow mid-lateral stripe wider than pupil diameter; dorso-mid-lateral stripe most prominent, from behind upper orbit to behind end of second dorsal-fin base, crossing lateral line at 55–60% SL, well posterior to first dorsal fin base; head and body of preserved fish pale-brown to brown, lateral body stripes sometimes retained.

DESCRIPTION. Measurements in % SL and counts are given in Table 4; morphometric data as ratios of SL for holotype, data for paratypes in brackets. Body elongate, its depth at first dorsal-fin origin 3.6 [3.4–3.9], body depth at anal-fin origin 4.2 [4.0–4.4], maximum head depth 4.4 [4.0–4.5], head length 3.5 [3.2–3.6], snout length 8.5 [7.6–8.9], orbit length 13 [13–14], barbel length 4.8 [4.4–5.1], subequal to caudal-peduncle length (4.7 [4.7–5.3]), pelvic-fin length (4.7 [4.7–5.1]), and pectoral-fin length (4.6 [4.8–5.2]), anal-fin height 6.9 [6.0–7.1], first dorsal-fin height 4.3 [4.3–4.8], second dorsal-fin height 6.7 [6.5–7.2].

Mouth small, maxilla not reaching a vertical at front of orbit, upper jaw length 9.8 [8.8–11] in SL; small conical teeth on both jaws, placed in one outer row and more irregularly behind in the front of jaws, and in a single row more posteriorly; no teeth on roof of mouth; anterior nostril a small vertically elliptical opening about $\frac{2}{3}$ orbit diameter in front of eye; posterior nostril a narrow slit covered by a membrane next to edge of upper orbit; longest gill filaments on first gill arch about $\frac{2}{3}$ orbit diameter; longest gill raker on first arch about $\frac{2}{3}$ in longest gill filament; a single flat spine at posterior edge of operculum at level of about mid of eye.

Scales very finely ctenoid; head fully scaled; fins naked except base of caudal fin; dorsal fin

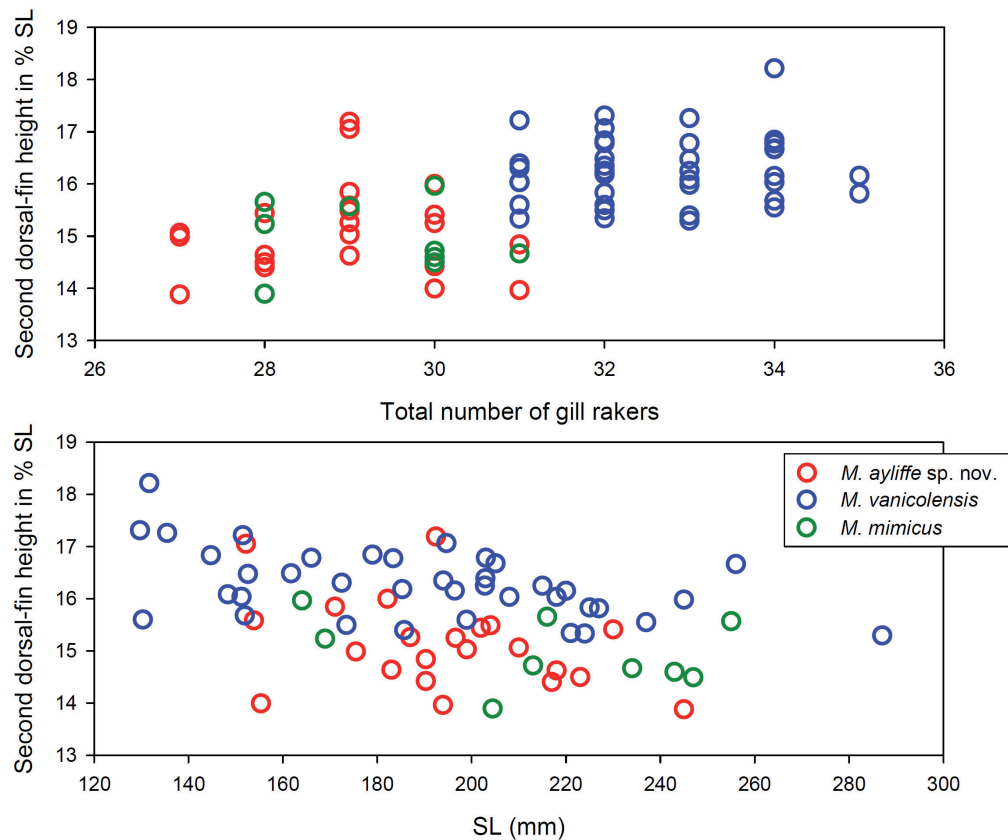


Fig. 2. Second dorsal-fin height against total number of gill rakers and SL in *Mulloidichthys ayliffe* sp. nov., *M. vanicolensis*, and *M. mimicus*.

of holotype behind 4th lateral line scale, origin of second dorsal above 18th scale, origin of anal fin below 19th scale origin; lateral line following contour of back; pored scales of lateral line with many branched tubules.

Fresh colour (based on holotype (HT), two paratypes, and underwater photographs) (Plates 1, 2). Body, head and fins mostly yellow in life, becoming slightly orange dorsally and anteriorly on in freshly collected fish; outer margins of jaws white to pale bluish; eyes with black pupils surrounded by red iris; iris at dorsal margin of orbit often bluish (see also description of upper-lateral stripe below).

Two to five straight, bluish body stripes (Fig. 2, Plate 1), their width about equal to barbel width, the dorso-mid-lateral stripe being the most prominent, reaching from behind the upper orbital margin to below rear end of soft dorsal-fin base, and continued anteriorly by a weak pigmentation of the iris along the dorsal orbital margin, and a tiny bluish patch (not always present) immediately in front of the upper edge of orbit; this stripe follows the lateral line for a distance from snout of 1.8 in SL (HT) [1.7–1.8 in PTs], crossing the lateral line well posterior to the first dorsal-fin base; the bluish ventro-mid-lateral stripe is the second-most conspicuous body stripe in this new species, consisting in a straight line from behind lower orbital margin to well behind anal-fin base, continuing below the

eye as a wave-like line, which at its anterior end points towards the snout tip or upper jaw, but not reaching them; the ventro-lateral body stripe, i.e., the bluish stripe below the ventro-mid-lateral body stripe, forms a straight line from head to caudal-fin base, passing ventral to pectoral fin base; this stripe is at a similar vertical distance from the mid-lateral stripe as the dorso-mid-lateral stripe, and sometimes continues anteriorly as a series of small bluish patches reaching from operculum to about the posterior margin of maxilla. Some specimens (e.g., the paratype in Plate 1) show an additional bluish, ventral stripe that extends close to the ventro-lateral body stripe, from behind operculum to anal-fin base, along the ventral body margin, and unites with the ventro-lateral stripe above the anal-fin base. Larger fish may also show a weak indication of a fifth bluish dorso-lateral body stripe as a series of close-set, small blue spots reaching from behind operculum to about end of first dorsal fin base or to half body at maximum, passing closely beneath the first dorsal-fin base.

One to several yellow bands are formed by the yellow ground colour of the body between the bluish body stripes; the width of the mid-lateral yellow stripe is between pupil and orbit diameter, the yellow ventro-lateral stripe below is about the same width; all other yellow stripes, if formed, are narrower.

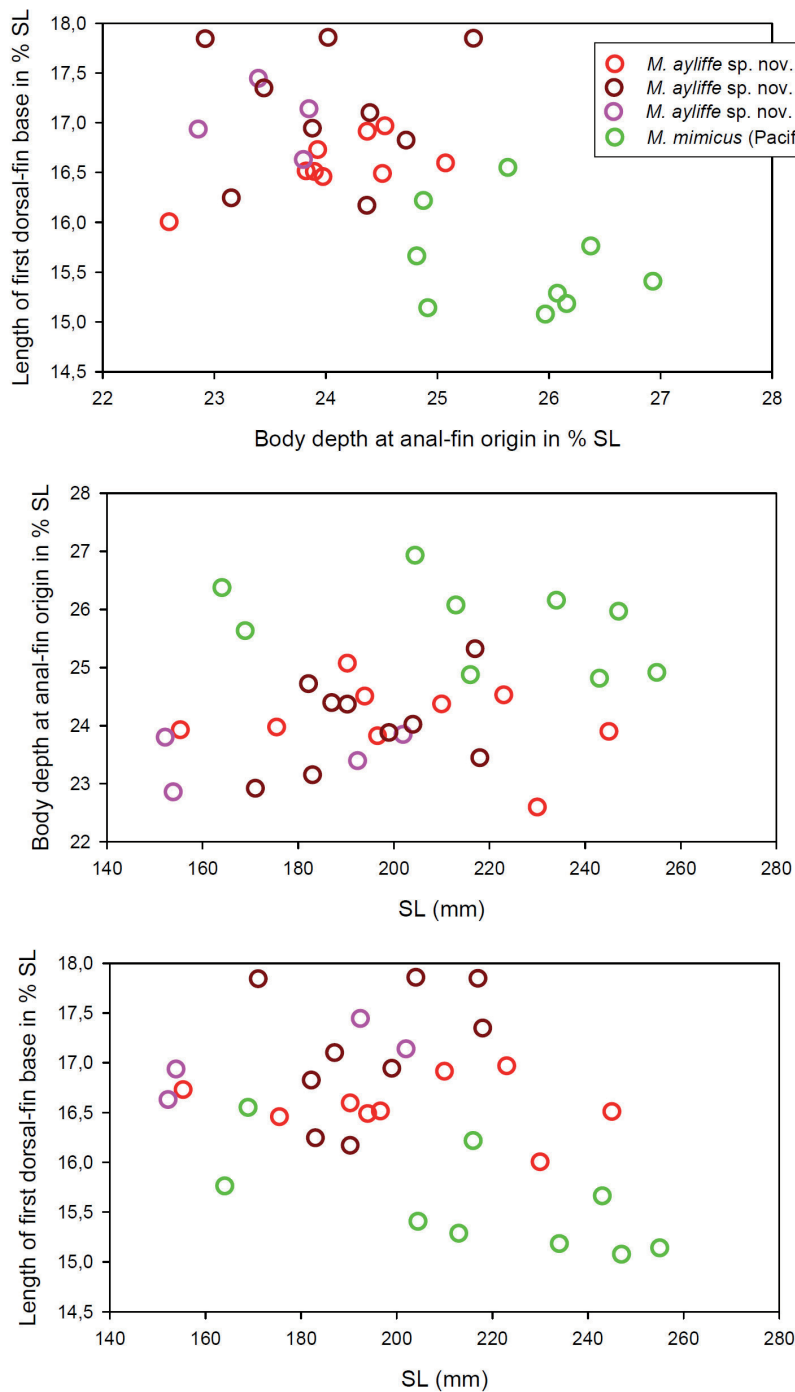


Fig. 3. Relationship between body depth at anal-fin origin, length of first dorsal-fin base and standard length for *Mulloidichthys ayliffe* sp.nov. (separated into three populations) and *M. mimicus*.

Pectoral fins hyaline, pelvic and anal fins sometimes whitish-yellow at bases and distal-most areas; caudal fins with some light red patches from origin to lobes, inner margins of caudal-fin lobes yellow-hyaline; dorsal fins slightly transparent in between posterior spines or rays; barbels white.

Preserved colour. Body and head of preserved fish pale-whitish to pale-brown, body of recently preserved fish dorsally darker with one to three dark body stripes in similar form and position to the bluish dorso-mid-, ventro-mid- and ventro-lateral stripes in fresh fish; all three stripes retained

in holotype, the dorso-mid-lateral stripe reaching from behind upper orbit to behind second dorsal-fin base, the ventro-mid-lateral stripe from behind operculum to caudal peduncle, and the ventro-lateral stripe from below pectoral-fin base to mid anal-fin base; pectoral fins hyaline; all other fins whitish-pale.

DISTRIBUTION. Western Indian Ocean: Natal, South Africa, Tanzania, Kenya, Oman, Seychelles, Sri Lanka, Andaman Islands.

ETYMOLOGY. The name 'ayliffe' is used as a noun in apposition; it honours Mr Neville Ayliffe, a former dive operator at Sodwana, who has assisted the South African Institute of Aquatic Biodiversity in acquiring important fish collections during many years. He collected the holotype and two paratypes with a speargun from shallow reefs in Sodwana Bay, KwaZulu-Natal, South Africa.

COMPARISONS. *Mulloidichthys ayliffe* differs from the Western Indian Ocean species as follows: from *M. flavolineatus* it differs in a deeper body and caudal peduncle, larger maximum head depth, longer dorsal-fin bases, frequent presence of more than two bluish body stripes, a wider yellow mid-lateral stripe, and absence of a mid-lateral dark oval or rectangular blotch below first dorsal-fin base; it differs from *M. pfluegeri* in a deeper caudal peduncle, shallower suborbital, shorter snout, larger eyes, shorter jaws, longer dorsal-fin bases, higher anal fin, smaller pectoral-fin width, higher dorsal fins, and presence of lateral body stripes; and it differs from *M. vanicolensis* in fewer gill rakers, modally fewer lateral-line scales, lower second dorsal fin, bluish body stripes darker and often more than two present, and wider yellow mid-lateral body stripe.

Non-Western Indian Ocean species: *Mulloidichthys ayliffe* differs from the Eastern Pacific *M. dentatus* in longer dorsal- and anal-fin bases, higher first dorsal fin, bluish body stripes darker and often more than two present, and wider yellow mid-lateral body stripe; it differs from the Western Atlantic *M. martinicus* in a longer caudal peduncle, longer second dorsal-fin base, shorter caudal fin, bluish body stripes darker and often more than two present, and wider yellow mid-lateral body stripe; and it differs from the Central Pacific *M. mimicus* in fewer lateral-line scales, shallower body at anal-fin origin, lower maximum head depth, shorter snout, longer first dorsal-fin base, bluish dorso-mid-lateral body stripe crossing lateral line further posteriorly, and yellow mid-lateral stripe narrower.

REMARKS. The use of colour patterns should allow easy field identification of *Mulloidichthys ayliffe* and distinction from co-occurring congeners. The main colour difference to *M. mimicus* is the position of the bluish dorso-mid-lateral body stripe in relation to the lateral line. While the yellow mid-lateral stripe and the bluish dorso- and ventro-mid-lateral body stripes of *M. ayliffe* have a similar vertical placement as in *M. dentatus*, *M. flavolineatus*, *M. martinicus*, and *M. vanicolensis*, the yellow mid-lateral stripe differs in width and is less conspicuous due to the lack of overall yellow ground body colouration in the latter four species. Field observations suggest that the bluish body stripes may vary in intensity and contrast in *M. ayliffe* (e.g., Randall & Guézé, 1980). No

information on night and resting colouration is currently available.

The combination of body depth at anal-fin origin and length of first dorsal-fin base allows clear separation between *M. ayliffe* from *M. mimicus* (Fig. 3). And, these two species can be separated from the closely related *M. vanicolensis* by combining second dorsal-fin height with total number of gill rakers (Fig. 2).

No significant differences in colour and morphological characters among populations from the southwestern Indian Ocean (East-Africa and Seychelles), Oman, and Sri Lanka were found (Table 4).

No juveniles or subadults were available for study.

Mulloidichthys ayliffe attains 25 cm SL; typical habitats of this species are shallow coral reef areas including submarine caves to 19 m depth.

Mulloidichthys flavolineatus (Lacepède 1801)

(Tables 2, 3; Figs. 4; Plates 1, 2)

Mullus flavolineatus Lacépède 1801: no locality stated. No types known (Eschmeyer 2010).

Mulloides flavolineatus: Ben-Tuvia, in Smith & Heemstra 1986: 610, Plate 69, colour photo.

Mulloidichthys flavolineatus: Randall 1995: 239, Fig. 621 (colour photo), Fricke 1999: 307–309; Heemstra & Heemstra 2004: 261, colour painting; Heemstra *et al.* 2004: 3322; Randall 2005: 292, 2 colour photos; Taquet & Diringer 2007: 260, colour photo.

DIAGNOSIS. Pectoral fins 15–18; gill rakers 7–10 + 19–22 = 26–31; lateral-line scales 34–38; body depth at first dorsal-fin origin 21–26% SL; body depth at anus 16–21; caudal-peduncle depth 8.3–9.8; caudal-peduncle width 3.2–4.6; maximum head depth 19–22; head depth through eye 16–19; head length 27–31; snout length 12–15; orbit length 5.8–7.8; upper jaw length 8.1–9.5; barbel length 18–22; caudal-fin length 29–33; anal-fin height 13–16; pelvic-fin length 19–22; pectoral-fin length 19–21; pectoral-fin width 3.5–4.9; first dorsal-fin height 19–23; second dorsal-fin height 14–16% SL; body silvery white, sometimes intermingled with yellow, darker above lateral line; head silvery white to yellowish, darker on dorsal part of snout and dorsally from mid-orbit; one straight yellow mid-lateral body stripe, its width subequal to pupil diameter, bordered by two pale bluish (sometimes whitish), narrow mid-lateral stripes; a dark oval to rectangular blotch at yellow mid-lateral body stripe below first dorsal-fin base, sometimes only faintly visible due to color changes, often retained in preserved fish; dorsal and caudal fins white to yellowish, partly hyaline, pectoral fins pale rose, partly transparent, pelvic and anal fins whitish and partly transparent;

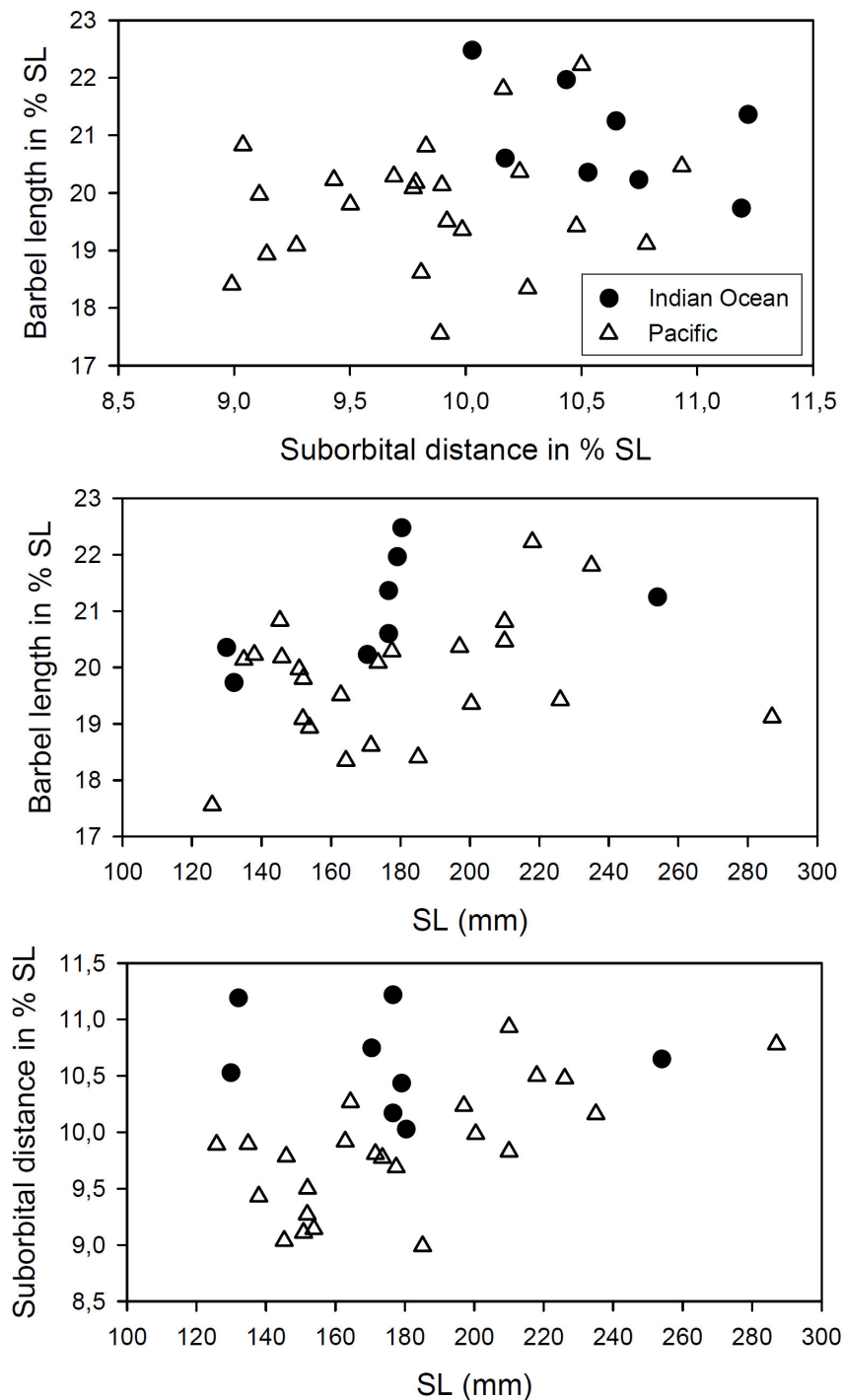


Fig. 4. Relationship between suborbital distance, barbel length, and size in *Mulloidichthys flavolineatus* from the Indian and Pacific Oceans.

barbels white; in preserved fish body generally pale brown or ventrally pale and dorsally darkened, head pale brown; recently collected material with a broad dark band laterally.

DISTRIBUTION. Indo-West Pacific: Red Sea, East and South Africa, Madagascar and Mascarenes east to Hawaiian Islands, Line Islands and Pitcairn Group, north to southern Japan, south to Joseph Bonaparte Gulf (northern in front of Western Australia), New South Wales (Australia) at 36°S, Lord Howe Island, New Caledonia and Rapa Island.

COMPARISONS. *Mulloidichthys flavolineatus* differs from the Western Indian Ocean species as follows: from *M. ayliffe* it differs in a shallower body and caudal-peduncle, smaller maximum head depth, shorter dorsal-fin bases, narrower yellow mid-lateral body stripe, and frequent presence of one mid-lateral dark oval or rectangular blotch below first dorsal-fin base; it differs from *M. pfluegeri* in a shallower body and head, thinner caudal peduncle, shorter jaws, smaller snout width, shorter first dorsal and anal-fin bases, smaller pectoral-fin width, higher second dorsal fin, presence of body stripes, and frequent presence of one mid-lateral

dark oval or rectangular blotch below first dorsal-fin base; it differs from *M. vanicolensis* in fewer gill rakers, modally more pectoral-fin rays and fewer lateral-line scales, shallower body, lower maximum head depth, shorter jaws, lower second dorsal fin, and frequent presence of one mid-lateral dark oval or rectangular blotch below first dorsal-fin base.

Non-Western Indian Ocean species: *Mulloidichthys flavolineatus* differs from the Pacific *M. dentatus* in a shallower body and caudal-peduncle, and frequent presence of one mid-lateral dark oval or rectangular blotch below first dorsal-fin base; it differs from the W-Atlantic *M. martinicus* in a shallower body and caudal-peduncle, lower maximum head depth, shorter first dorsal-fin base, and frequent presence of one mid-lateral dark oval or rectangular blotch below first dorsal-fin base; and it differs from the Pacific *M. mimicus* in fewer lateral line scales, shallower body, caudal

peduncle and head, shorter first dorsal-fin base, narrower yellow mid-lateral body stripe, and frequent presence of one mid-lateral dark oval or rectangular blotch below first dorsal-fin base.

REMARKS. This species varies considerably in body colouration with the yellow mid-lateral body stripe always present in diurnally active fish, but the dark mid-lateral oval or rectangular blotch being sometimes only faintly visible and the bluish mid-lateral body stripes sometimes changing to white and fading into the whitish-silvery or pale yellowish body colour in fresh fish.

In interspecific associations with *Mulloidichthys vanicolensis* the blotch may be completely 'switched off', thus making it considerably more difficult for an observer to distinguish between the two species. During a dive off Oahu, Hawaii, I observed a dense aggregation of both species close to a rocky

Table 3. Meristic counts of five *Mulloidichthys* species and populations of two oceans.

	Pectoral ray number			
	15	16	17	18
<i>M. ayliffe</i> sp. nov.		9	13	
<i>M. flavolineatus</i> Indian Ocean		3	5	
<i>M. flavolineatus</i> Pacific			18	1
<i>M. pfluegeri</i>			5	2
<i>M. vanicolensis</i> Indian Ocean	3	10	11	
<i>M. vanicolensis</i> Pacific		6	10	
<i>M. mimicus</i>	1	4	5	

	Gill raker number on:													
	upper limb					lower limb								
	6	7	8	9	10	19	20	21	22	23	24	25	26	27
<i>M. ayliffe</i> sp. nov.		8	14			1	4	6	9	2				
<i>M. flavolineatus</i> Indian Ocean			8			3	3	2						
<i>M. flavolineatus</i> Pacific		1	11	6	1	3	11	3	2					
<i>M. pfluegeri</i>	1	6				2	1	1	3					
<i>M. vanicolensis</i> Indian Ocean		1	9	14						9	7	8		
<i>M. vanicolensis</i> Pacific		1	6	6	3					5	4	5	2	
<i>M. mimicus</i>	1	3	6					3	5	2				

	Total number of gill rakers									
	26	27	28	29	30	31	32	33	34	35
<i>M. ayliffe</i> sp. nov.		3	4	8	5	2				
<i>M. flavolineatus</i> Indian Ocean		3	3	2						
<i>M. flavolineatus</i> Pacific		3	7	5	3	1				
<i>M. pfluegeri</i>	3		1	3						
<i>M. vanicolensis</i> Indian Ocean						5	8	5	6	
<i>M. vanicolensis</i> Pacific						2	5	3	4	2
<i>M. mimicus</i>			3	1	5	1				

	Lateral line scale number					
	34	35	36	37	38	39
<i>M. ayliffe</i> sp. nov.		3	11	8		
<i>M. flavolineatus</i> Indian Ocean	1		7			
<i>M. flavolineatus</i> Pacific		3	10	4	1	
<i>M. pfluegeri</i>		1	3	3		
<i>M. vanicolensis</i> Indian Ocean			5	12	4	
<i>M. vanicolensis</i> Pacific			7	6	3	
<i>M. mimicus</i>					9	1

wall above a sand bottom with both species showing identical coloration (the dark blotch in *M. flavolineatus* being absent or only very difficult to detect), and the species being only identifiable on body proportions (Plate 2b). Both species were mixed in a large shoal, *M. flavolineatus* appearing to be positioned slightly underneath *M. vanicolensis*. Resting or night colouration with dark-brown patches on pale body and the yellow stripe not visible (Plate 1F)

The Eastern Indian Ocean population of *M. vanicolensis* has a shorter caudal peduncle than populations in the Western Indian Ocean and Pacific. The Pacific Ocean population differs from Indian Ocean population in a higher pectoral-fin ray number (Table 3), a shorter suborbital distance, and shorter barbels (Fig. 4).

A comparison of juvenile and subadult (<125 mm SL) morphological characteristics between *M. flavolineatus* and *M. vanicolensis* is currently in preparation (Uiblein & Randall unpublished data).

Mulloidichthys flavolineatus attains 29 cm SL; it inhabits reef areas to 35 m depth.

Mulloidichthys pfluegeri
(Steindachner 1900)
(Tables 2, 3; Plate 1)

Mulloides pfluegeri Steindachner 1900: 485–486, Table III, Fig. 4; type locality Honolulu, Oahu, Hawaii.

Mulloidichthys:pfluegeri (non Steindachner): Myers 1989, 159, plate 74 I, colour photo.

Mulloidichthys:pfluegeri Fricke 1999: 309; Heemstra et al. 2004: 3322; Randall 2005: 293, 2 colour photos; Taquet & Diringer 2007: 261, colour photo.

DIAGNOSIS. Pectoral fins 17–18; gill rakers 6–7 + 19–22 = 26–29; lateral-line scales 35–37; body depth at first dorsal-fin origin 26–28% SL; body depth at anus 21–24; caudal-peduncle depth 8.4–9.1; caudal-peduncle width 4.6–6.0; maximum head depth 24–26; head depth through eye 19–21; head length 28–31; snout length 13–16; orbit length 5.2–6.9; upper jaw length 11–12; barbel length 19–21; caudal-fin length 29–33; anal-fin height 12–13; pelvic-fin length 20–24; pectoral-fin length 20–23; pectoral-fin width 5.4–5.7; first dorsal-fin height 18–21; second dorsal-fin height 12–13% SL; body ventrally white with rose flanks, ventral half of caudal peduncle white, dorsal half of body red becoming more intense further dorsally; head from eye dorsally and anteriorly to jaws red, inner jaw margins pale rose, operculum and posterior part of head from below eye and behind jaws whitish rose; dorsal fins rose with red base, caudal fin rose, white at inner margin of lobes; pectoral fins rose, slightly transparent; pelvic and anal fins rose; barbels whitish-rose.

DISTRIBUTION. Indo-West Pacific: Mascarenes, eastern Indonesia east to Hawaiian and Marquesas islands, north to Ryukyu Islands, south to Tonga.

COMPARISONS. *Mulloidichthys pfluegeri* differs from the Western Indian Ocean species as follows: from *M. ayliffe* in a shallower caudal peduncle, deeper suborbital, longer snout, smaller eyes, longer jaws, shorter dorsal-fin bases, lower anal fin, larger pectoral-fin width, lower dorsal fins, and absence of lateral body stripes; from *M. flavolineatus* it differs in a deeper body and head, thicker caudal peduncle, longer jaws, larger snout width, longer first dorsal- and anal-fin bases, larger pectoral-fin width, lower second dorsal fin, absence of body stripes and absence of mid-lateral dark oval or rectangular blotch; from *M. vanicolensis* it differs in fewer gill rakers, shallower and thicker caudal peduncle, deeper suborbital, longer snout and jaws, lower anal and dorsal fins, larger pectoral-fin width, and absence body stripes.

Non-Western Indian Ocean species: *Mulloidichthys pfluegeri* differs from the Pacific *M. dentatus* in a shallower and thicker caudal peduncle, deeper head and suborbital, longer jaws, longer second dorsal- and anal-fin bases, shorter anal and second dorsal fins, larger pectoral-fin width, and absence body stripes; it differs from the Atlantic *M. martinicus* in a shallower and thicker caudal peduncle, deeper head, deeper suborbital, smaller eyes, longer jaws, longer interdorsal distance, longer second dorsal-fin base, shorter anal and second dorsal fins, and absence body stripes; and it differs from the Pacific *M. mimicus* in fewer lateral-line scales, shallower body, shallower and thicker caudal peduncle, deeper suborbital, smaller eyes, longer jaws, larger interdorsal distance, lower anal fin, larger pectoral-fin width, lower second dorsal fin, and absence of body stripes.

REMARKS. The red body colour in *Mulloidichthys pfluegeri* may vary considerably in intensity with appearance of four broad vertical dark-red bars on pale-red ground colour as shown in photographs of fresh fish in Randall (2005: 293) and Taquet & Diringer (2007: 261). This pattern possibly represents the resting and/or night colour.

The Pacific Ocean specimens of *M. pfluegeri* have a deeper body and head, a longer caudal fin and a lower first dorsal fin than those from the Indian Ocean; the sample size from both areas would have to be larger to investigate these differences in more detail.

No information on juvenile morphological characteristics is currently available.

The distribution of *Mulloidichthys pfluegeri* appears to be restricted to oceanic islands, similar to *Upeneus taeniopterus* Cuvier, 1829 (Uiblein & Heemstra 2010); *M. pfluegeri* attains 40 cm SL;

largest species of the genus; it occurs on shallow bottoms to 110 m depth.

***Mulloidichthys vanicolensis*
(Valenciennes 1831)**

(Tables 2, 3; Figs. 2, 5; Plates 1, 2)

Upeneus vanicolensis Valenciennes, in Cuvier & Valenciennes 1831: 521; type locality: Vanicolo Island, Santa Cruz Islands, Solomon Islands, Southwestern Pacific, 11°37'S, 166°58'E.

Mulloides vanicolensis Ben-Tuvia, in Smith & Heemstra 1986: 611, Plate 69, colour painting.

Mulloidichthys vanicolensis Randall 1995 (in part): 239, Fig. 621 (colour photo showing a mixed school of *M. ayliffe* and *M. vanicolensis*), Fricke 1999: 309-310; Heemstra & Heemstra 2004: 261; Heemstra *et al.* 2004: 3322; Randall 2005: 293, 2 colour photos; Taquet & Diringer 2007: 261, colour photo.

DIAGNOSIS. Pectoral fins 15-17; gill rakers 7-10 + 23-26 = 31-35; lateral-line scales 36-38; body depth

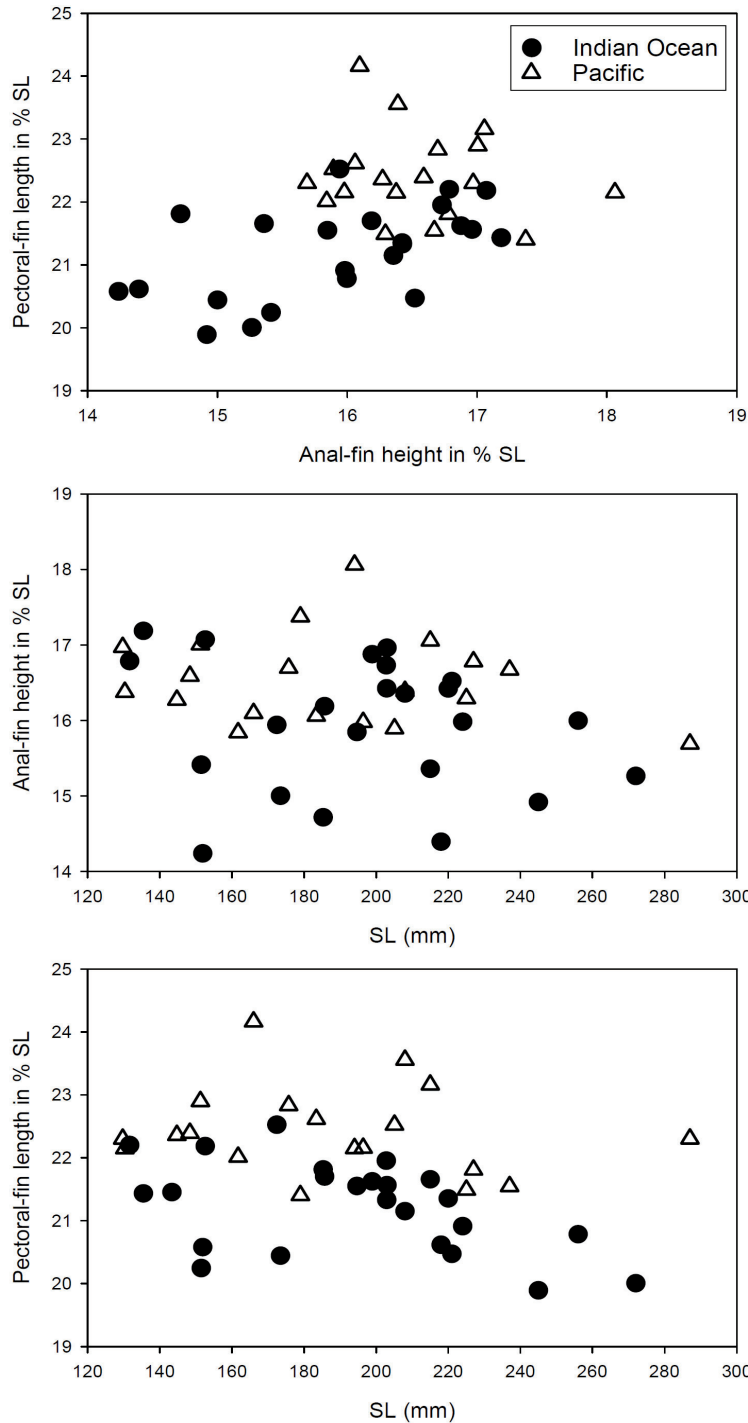


Fig. 5. Relationship between anal-fin height, pectoral-fin length, and size in *Mulloidichthys vanicolensis* from the Indian and Pacific Oceans.

at first dorsal-fin origin 25–30% SL; body depth at anus 21–25; caudal-peduncle depth 9.2–11; caudal-peduncle width 3.0–4.9; maximum head depth 21–25; head depth through eye 16–20; head length 28–32; snout length 11–14; orbit length 6.2–9.4; upper jaw length 9.4–11; barbel length 19–24; caudal-fin length 29–34; anal-fin height 14–18; pelvic-fin length 20–24; pectoral-fin length 20–24; pectoral-fin width 3.9–5.4; first dorsal-fin height 20–25; second dorsal-fin height 15–18 %SL; body silvery white ventrally, yellow above lateral line; head silvery white to pale rose below eye and behind jaws, with some yellowish patches, darker rose on snout and yellowish above mid eye; one straight yellow mid-lateral body stripe from eye to caudal-fin base, its width subequal to pupil diameter, becoming wider on posterior part of caudal peduncle, bordered by two narrow pale bluish (sometimes whitish) mid-lateral stripes from eye to behind anal fin-base; dorsal caudal, pelvic and anal fins yellow, pectoral fin hyaline; barbels white; in preserved fish body pale brown or ventrally pale and dorsally darkened, head pale brown; recently collected material with a broad dark band mid-laterally.

DISTRIBUTION. Indo-West Pacific: Red Sea, East Africa, Comoro Islands and Mascarenes, east to the Hawaiian Islands, Line Islands and Pitcairn Group, north to southern Japan, south to Joseph Bonaparte Gulf (northern in front of Western Australia), New South Wales (Australia), Lord Howe, Norfolk, Kermadec Islands, New Caledonia, Tonga and Gambier Islands.

COMPARISONS. *Mulloidichthys vanicolensis* differs from the Western Indian Ocean species as follows: from *M. ayliffe* it differs in more gill rakers, more lateral-line scales, higher second dorsal fin, bluish body stripes weaker (sometimes whitish), and yellow mid-lateral body stripe narrower; it differs from *M. flavolineatus* in more gill rakers, modally fewer pectoral-fin rays and more lateral-line scales, a deeper body, larger maximum head depth, longer jaws, higher second dorsal fin, and absence of one mid-lateral dark oval or rectangular blotch below first dorsal-fin base; and it differs from *M. pfluegeri* in more gill rakers, deeper and thinner caudal peduncle, shallower suborbital, shorter snout and jaws, higher anal and dorsal fins, larger pectoral-fin width, and presence of a yellow mid-lateral body stripe.

Non-Western Indian Ocean species: *Mulloidichthys vanicolensis* differs from the Pacific *M. dentatus* in more gill rakers, longer anal-fin base, and lower dorsal fins; it differs from the Atlantic *M. martinicus* in more gill rakers and shorter snout; and from the Pacific *M. mimicus* it differs in more gill rakers, modally fewer lateral-line scales, shallower body at anal-fin origin, higher second dorsal fin,

bluish body stripes weaker (sometimes whitish), and yellow mid-lateral body stripe narrower.

REMARKS. *Mulloidichthys vanicolensis* varies considerably in body coloration with the yellow mid-lateral body stripe always present in active fish, but the bluish mid-lateral body stripes sometimes changing to white due to blending with the general whitish-silvery or pale yellowish body colour in fresh fish. Resting or night colouration with patches of red on pale body and yellow stripes only faintly visible (Randall 2005: 293).

The southwestern Indian Ocean specimens of *M. vanicolensis* have a thinner caudal peduncle than the populations from Oman and the Eastern Indian Ocean and the latter differs from the Western Indian Ocean specimens in having a longer caudal peduncle. The main differences between the Indian Ocean and Pacific populations are a higher anal fin and a longer pectoral fin in the latter (Fig. 5).

Mulloidichthys vanicolensis attains 31 cm SL; it occurs on shallow bottoms to 113 m depth.

Mulloidichthys mimicus Randall & Guézé 1980

(Tables 2–3; Figs. 2, 3; Plate 1)

Mulloidichthys mimicus Randall & Guézé 1980: 603–609, 2 figs. (colour photos); type locality: west side of Sentinelle de l'Est, Nuku Hiva, Marquesas Islands, South Pacific; Randall 2005: 292, 2 colour photos.

DIAGNOSIS. Pectoral fins 15–17; gill rakers 6–8 + 21–23 = 28–31; lateral-line scales 38–39; body depth at first dorsal-fin origin 28–30% SL; body depth at anus 25–27; caudal-peduncle depth 10–11; caudal-peduncle width 4.0–4.7; maximum head depth 24–26; head depth through eye 18–20; head length 28–31; snout length 12–14; orbit length 7.2–8.5; upper jaw length 9.5–11; barbel length 20–22; caudal-fin length 27–31; anal-fin height 13–17; pelvic-fin length 20–23; pectoral-fin length 20–22; pectoral-fin width 4.5–5.2; first dorsal-fin height 20–23; second dorsal-fin height 14–16% SL; head, body and fins yellow in live fish, blending dorsally and anteriorly into orange after collection; body and head covered by two to five straight bluish (blue or pale blue) body stripes, with one to four yellow stripes in between; bluish stripes approximately as wide as barbel, yellow mid-lateral body stripe wider than orbit diameter; bluish dorso-mid-lateral stripe most prominent, from above orbit to behind end of second dorsal-fin base, crossing lateral line at 44–48% SL, below posterior end of first dorsal-fin base; head and body of preserved fish pale-brown to brown, bluish lateral body stripes sometimes retained.

DISTRIBUTION. South Pacific Islands, a single record from Kauai, Hawaiian Islands.

COMPARISONS. The Pacific *Mulloidichthys mimicus* differs from the Indian Ocean *M. ayliffe* sp. nov. in more lateral-line scales, a deeper body at anal-fin origin, higher maximum head depth, longer snout, shorter first dorsal-fin base, bluish dorso-mid-lateral body stripe crossing lateral line farther anterior, and wider yellow mid-lateral body stripe; it differs from *M. flavolineatus* in more lateral-line scales, a deeper body, caudal peduncle and head, longer first dorsal-fin base, wider yellow mid-lateral body stripe, and absence of one mid-lateral dark oval or rectangular blotch below first dorsal fin; it differs from *M. pfluegeri* in more lateral-line scales, a deeper body, deeper and thinner caudal peduncle, shallower suborbital, larger eyes, shorter jaws, smaller interdorsal distance, higher anal fin, smaller pectoral-fin width, higher second dorsal fin, and presence of body stripes; and it differs from *M. vanicolensis* in fewer gill rakers, modally more lateral-line scales, a deeper body at anal-fin origin, lower second dorsal fin, bluish body stripes more conspicuous and wider yellow mid-lateral body stripe.

Non-Western Indian Ocean species: *Mulloidichthys mimicus* differs from the Pacific *M. dentatus* in more lateral-line scales, a deeper body, higher maximum head depth, longer second dorsal- and anal-fin bases, bluish body stripes more conspicuous and wider yellow mid-lateral body stripe; and it differs from the Atlantic *M. martinicus* in more lateral-line scales, a deeper body at anal-fin origin, higher maximum head depth, longer anal-fin base, shorter caudal fin, bluish body stripes more conspicuous, and wider yellow mid-lateral body stripe.

REMARKS. The use of colour patterns should allow easy field identification of *Mulloidichthys mimicus* and distinction from co-occurring congeners, as has been noted for *M. ayliffe*.

No information on night and resting colour, and on population differences is currently available.

The single juvenile measured clearly differs in a shallower body, caudal peduncle and head, shorter snout and jaws, longer orbit, shorter barbels and longer caudal peduncle compared with the adult specimens.

A single record of this species from Kauai, Hawaiian Islands, is based on a photograph from a local fisherman. It is unclear, however, if this record represents a naturally occurring population in the area or is derived from accidental introduction.

Mulloidichthys mimicus attains 26 cm SL; it occurs in shallow reef habitats to 15 m depth

DISCUSSION AND CONCLUSIONS

The present account is the first comprehensive review of the goatfish genus *Mulloidichthys* in the Western Indian Ocean. Apart from the description of a new species for this region, detailed comparisons between all known species of this genus and an identification key, data on morphological differentiation among populations from the Indian Ocean and between the Indian and Pacific Oceans are also presented.

A diagnosis of *Mulloidichthys* species has to be based on a combination of colour, meristic and morphometric characters with special emphasis on the latter. Bluish and yellow body stripes and overall body coloration are to some extent useful for the distinction between species. But colour patterns do change considerably, e.g. during resting, at night, or in interspecific aggregations. Preserved fishes are often monochromatic (i.e., pale-brown or brownish). Meristic characters behave rather conservatively in this genus and show relatively little variation. By including a large dataset of morphometric variables in the description, diagnosis and comparisons it was possible to clearly distinguish all species.

This study is the first to provide clear evidence for geographic variation in body form among *Mulloidichthys* species with marked differences between the Pacific and Indian Oceans. These results complement earlier findings of inter-oceanic divergence in the number of gill rakers reported for *M. vanicolensis* by Stepien *et al.* (1994). A re-examination of their allozyme-based findings by using modern DNA techniques might prove a valuable approach towards a better understanding of the extent of geographic differentiation and isolation among *Mulloidichthys* populations.

As also observed in other goatfish genera (e.g., *Upeneus*, Uiblein & Heemstra 2010), considerable allometric changes in body form occur in *Mulloidichthys* species. An example is the comparison of a single juvenile with adult *M. mimicus*. A detailed comparison among life-history stages and species with more information on phenotypic diversity among Pacific populations and forms of *M. flavolineatus* and *M. vanicolensis* is currently in preparation (Uiblein & Randall unpublished data).

Another rewarding future area of research would be to study the relationship between colour patterns in *Mulloidichthys* species and their possible functions with regard to mimicry and inter- or intraspecific communication. Our observation of the close colour resemblance in *M. flavolineatus* and *M. vanicolensis* (Plate 2) indicates that colour mimicry may also occur among those species. The advantages for either species are however unclear. Possibly the relatively smaller and more elongated *M. flavolineatus* hides among *M. vanicolensis* to

reduce predation risk. To go any further with such an assumption it will be necessary to understand both the costs and benefits of colour changes in *M. flavolineatus*, as 'switching off' the species-specific dark lateral blotch may increase the confusion among the two species, which – at least during the reproductive period – may entail an increased risk of hybridization.

ACKNOWLEDGMENTS

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MATERIAL EXAMINED

Mulloidichthys dentatus: **East Pacific, Mexico**: USNM 65581, 165 mm, Acapulco, Albatross Expedition, 1904-1905; RMNH 5145, 226 mm, Las Tres Marias; USNM 43241, 156 mm, Sonora, Bay of Guaymas.

Mulloidichthys flavolineatus: **Western Indian Ocean, South Africa**: SAIAB 86370, 254 mm, KwaZulu-Natal, Ribbon Reef, Sodwana Bay, 27°29.37'S, 32°41.38'E, 12-18 m; **Chagos**: SAIAB 15361, 170-179 mm, NW corner of Isle Boddam on ocean side; **Mascarenes**: SAIAB 68799, 5: 130-132 mm, Rodrigues, off Port Mathurin, Ile Hollandaise; SAIAB 70580, 180 mm, Rodrigues, north of Grand Bay; **Eastern Indian Ocean, Indonesia**: RMNH 13299, 2: 177 mm, Sumatra, Sabang Bay, Pulu Weh; **West Pacific, Guam**: BPBM 77, 235 mm, **Mariana Islands**; **Vanuatu**: BPBM 962, 178 mm, Efate Island; **Hawaii**: BPBM 1749, 185 mm, Oahu, Honolulu; BPBM 1750, 172 mm, Oahu, Honolulu; BPBM 25457, 126 mm, Oahu, Waianae coast; BPBM 25674, 174 mm, Oahu, Honolulu market; BPBM 4087, 287 mm, Laysan; BPBM 4088, 138-226 mm, Lisianski; **Marcos Island**: BPBM 7087, 210 mm, N end; reef flat, 3 ft; BPBM 7088,

197 mm, reef flat, 3 ft; **Rapa Island**: BPBM 12937, 164 mm, E side of Akatamiro Bay, 8 ft; **Phoenix Islands**: BPBM 15299, 3: 146-154 mm, Hull Island, Orona Atoll; Midway Atoll: BPBM 15308, 152 mm, reef; **Caroline Islands**: BPBM 24628, 163 mm, Puluwat Atoll, lagoon side, 07°20'N, 149°11'E, at surface; **Marquesas Islands**: BPBM 2140, 200 mm, Nukuhiva; **New Zealand**: RMNH 11308, 210 mm; **Indonesia**: RMNH 29720, 135-151 mm, Java Sea, Selat Linta, E of Komodo, Indonesian-Dutch Snellis II Exp., 1984, 8°30'S, 119°34.6'E; RMNH 29994, 218 mm, Bay of Sanggar, N of Sumbawa, near edge of coastal reef flat, Indonesian-Dutch Snellius II exp. 1984; RMNH 13300, 145 mm, Jakarta, Bay of Batavia.

Mulloidichthys martinicus: **West Atlantic, Ascension Island**: USNM 267497, 270 mm, Northeast Bay; **Netherlands Antilles**: RMNH 22268, 165-179 mm, Curacao, Bullenbaai; **Antigua**: USNM 170110, 181 mm, Atlantic, Barbados.

Mulloidichthys mimicus: **Holotype**: BPBM 12638, 204 mm, Pacific, Marquesas Islands, Nukuhiva, Taiohae Bay; W side of Sentinelle de l'Est, 15 m; **Paratypes, West Pacific, Line Islands**: BPBM 4079, 183 mm, Palmyra Atoll (head broken); BPBM 31897, 164 mm, Kiritimati Atoll, Bay of Wrecks, N end; reef, coral and rubble drop-off, 11 m; BPBM 7738, 6: 213-255 mm, Teraina Island, W end; wreck of the 'Southbank', 6-7.5 m; **Marquesas Islands**: BPBM 12135, 169 mm, Uapou, Hakahetau; S side of bay, 6-11 m; BPBM 11901, 79 mm, Tahuata Island, off point at S end of Vaitahu Bay, 18 m.

Mulloidichthys pfluegeri: **Western Indian Ocean, Mascarenes**: MNHN 1965-23, 273 mm, Réunion, 21°7'1"S, 55°34'59"E; MNHN 1965-29, 188 mm, Réunion, 21°7'1"S, 55°34'59"E; SAIAB 70557, 333 mm, Rodrigues, north of Grand Bay; **West Pacific, Hawaii**: BPBM 8479, 258 mm, Oahu, Honolulu fish market; USNM 55516, 208 mm, Maui, Lahui; **Marquesas Islands**: BPBM 11057, 355 mm, Fatuhiva, off point at N end of Hanauu Bay, 60-75 ft; USNM 267494, 247 mm, Tahiti, Papeete market.

Mulloidichthys vanicolensis: **Western Indian Ocean, South Africa**: SAIAB 46235, 185 mm, Aliwal Shoal southern ledges; SAIAB 86369, 215 mm, KwaZulu-Natal, Coral Gardens, Sodwana Bay, 27°31.34'S, 34°41.15'E, 5-12 m; **Mozambique**: SAIAB 51025, 152 mm, Pinda Island, 14°13'S, 40°46'E; SAIAB 60425, 172 mm, Baixo Sao Joan, 26°24'S, 32°55'E; **Tanzania**: SAIAB 18056, 143-152 mm, Pemba Island, 05°08'S, 39°40'E; **Oman**: BPBM 36011, 208-220 mm, Southern Oman, Kuria Muria Islands, Sawda Island, E end, 4-8 m; BPBM 36023, 6: 195-224 mm, Kuria Muria Islands, Southern Oman, Sawda Island, SW side, 10 m; BPBM 39473, 4: 173-256 mm; **Mauritius**: SAIAB 1338, 3: 132-272 mm; SAIAB 5672, 135 mm; **Eastern Indian Ocean,**

- Indonesia:** RMNH 25449, 153–199 mm, Sumatra, Sabang Bay, Pulu Weh; **West Pacific, Hawaii:** BPBM 1715, 179 mm, Oahu, Honolulu; BPBM 4082, 225 mm, Oahu, Honolulu; BPBM 4083, 194 mm, Oahu, Honolulu; BPBM 8804, 196–205 mm, Oahu, Honolulu fish market; BPBM 25675, 162 mm, Oahu, Honolulu market; **Marcus Island:** BPBM 2412, 287 mm; **Pitcairn Group:** BPBM 13266, 166 mm, Pitcairn Island, off Bounty Bay, reef, 80 ft; BPBM 16576, 227–237 mm, Oeno Atoll, N side of atoll; off small boat passage, 40–60 ft; **Johnston Atoll:** BPBM 29587, 151 mm, Johnston Island; under concrete ramp, 1–3 m; **Samoa:** RMNH, 11245, 183 mm, Savaii; French Polynesia: RMNH, 11297, 148 mm, Tahiti; **Netherlands New Guinea:** RMNH 25446, 144 mm, Hollandia, Landingstage, Viss. Onderz. Holl. Exp. Brongersma, cs. 1954/55; **Indonesia:** RMNH 31737, 130 mm, Java Sea, Selat Linta, E of Komodo, Indonesian-Dutch Snellius II Exp. 1984, 8°30'S, 119°34.6'E; RMNH, 25451, 130 mm, Jakarta, Bay of Batavia.
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A. *M. ayliffe* sp. nov., SAIAB 86367, holotype, 175 mm SL, Sodwana Bay, KwaZulu-Natal, South Africa (P.C. Heemstra).



B. *M. ayliffe* sp. nov., SAIAB 86368, paratype, 245 mm SL, Sodwana Bay, KwaZulu-Natal, South Africa (P.C. Heemstra).



C. *M. ayliffe* sp. nov., BPBM 17620, paratype, 155 mm SL, Mafia Island, Tanzania (J.E. Randall).



D. *M. flavolineatus*, SAIAB 86370, 254 mm SL, Sodwana Bay, KwaZulu-Natal, South Africa (P.C. Heemstra).



E. *M. flavolineatus*, SAIAB 68799, 120 mm SL, Rodrigues, Mascarenes (P.C. Heemstra).



F. *M. flavolineatus*, ca. 220 mm SL, Maldives, at night (J.E. Randall).



G. *M. pfluegeri*, SAIAB 70557, 333 mm SL, Rodrigues, Mascarenes (P.C. Heemstra).



H. *M. vanicolensis*, SAIAB 86369, 215 mm SL, Sodwana Bay, KwaZulu-Natal, South Africa (P.C. Heemstra).



I. *M. vanicolensis*, ca. 175 mm SL, Praslin, Seychelles (J.E. Randall).



J. *M. mimicus*, paratype, BPBM 7738, 234 mm SL, Washington Island, Line Islands, Pacific Ocean (J.E. Randall).



A. *Mulloidichthys ayliffe* sp. nov. with *M. vanicolensis* (at lower right) and several *Lutjanus kasmira* (at mid-left), at Sodwana Bay, KwaZulu-Natal (D. Polack).



B. A mixed shoal of *Mulloidichthys flavolineatus* (dark mid-lateral blotch below first dorsal fin not visible in most individuals) and *M. vanicolensis*, Oahu, Hawai'i (F. Uiblein).

Plate 2

Appendix
Table 4. Measurements and counts for *Mulloidichthys ayiliffe* sp.nov. and *M. mimicus* (HT Holotype, PT Paratype)

SL (mm)	<i>M. ayiliffe</i> sp. nov.		<i>M. mimicus</i>		PT (juvenile)	
	HT	PT's (E-Africa)	All	Non-type		
BODYDD	175	155-245	152-245	164	169-255	79
BODYDA	27	26-29	26-29	30	28-30	24
HALFDD	24	23-25	23-25	26	25-27	22
HALFDA	21	20-24	20-24	24	21-24	19
CPDD	18	16-18	16-18	19	18-20	15
CPDW	10	10-11	10-11	11	10-11	9
HEAD1	5.1	4.2-4.8	4.1-5.3	4.1	4.0-4.7	3.3
HEAD2	23	22-25	22-25	26	24-26	19
SUBORB	18	17-20	17-20	19	18-20	16
INTORB	9.4	9.5-11	9.0-10	10	9.9-11	9
HEADL	29	28-31	28-31	30	28-31	28
SNOUTL	12	11-13	11-13	13	12-14	9.6
PORBL	9.9	9.6-11	9.8-11	11	9.6-11	10
ORBITL	8.0	6.9-7.8	6.9-8.5	8.5	7.2-8.5	9
ORBITD	7.1	6.4-7.4	6.4-7.5	7.8	6.2-7.8	7.5
UJAWL	10	8.6-11	8.6-11	10	9.5-11	9.3
SNOUTW	9.8	8.7-10	8.6-11	9.9	9.0-11	8.6
BARBL	7.8	8.1-10	7.3-10	9.0	7.5-9.6	7.9
BARBW	21	20-23	19-23	22	20-22	9
SD1	0.8	0.7-0.9	0.6-1.0	0.9	0.7-1.0	0.7
SD2	38	37-40	37-41	41	39-42	36
D1D2	67	65-68	66-68	68	64-68	64
CPDL	14	12-16	12-16	14	12-15	12
SANL	21	19-21	19-22	21	18-22	23
SPEL	67	64-68	63-66	65	63-69	66
SPEC	34	32-35	30-36	34	32-36	33
D2ANL	32	30-33	30-34	32	29-33	32
D1PELV	24	24-26	24-26	27	25-28	22
D1PEC	27	26-29	27-29	30	28-30	24
D1B	19	18-20	18-21	21	20-22	17
D2B	16	16-17	16-18	16	15-17	15
CAUH	15	14-15	14-15	15	13-15	16
ANALB	31	28-31	29-31	30	27-31	31
ANALH	12	10-12	10-13	12	10-12	12
PELVL	14	14-17	14-17	16	13-17	17
PECTL	21	20-21	19-22	23	20-23	21
PECTW	22	19-21	19-22	22	20-22	20
D1H	4.7	4.2-5.2	4.2-5.2	5.0	4.5-5.2	3.9
D2H	23	21-23	21-24	23	20-23	23
BMB5-LL	15	14-15	14-17	16	14-16	16
P	55	58-59	55-60	48	44-48	-
GrUud	17	16-17	16-17	16	15-17	10
GrUd	1	0-2	0-2	2	1-4	2
GrLd	6	5-8	5-8	6	3-7	5
GrLud	15	14-18	14-19	16	15-18	17
GrU	5	4-7	3-7	6	4-6	4
GrL	7	7-8	7-8	8	6-8	8
Gr	20	19-23	19-23	22	21-23	21
LLscal	27	27-31	27-31	30	28-31	29
	36	35-37	35-37	38	38	38

Table 5. Measurements and counts for *Mulloidichthys flavolineatus* and *M. pfluegeri* (WIO/EIO Western/Eastern Indian Ocean)

SL (mm)	WIO		EIO		<i>M. flavolineatus</i>		WIO		<i>M. pfluegeri</i>		Indo-Pacific	
	n	n	n	n	Pacific	Indo-Pacific	n	n	Pacific	Indo-Pacific	n	n
BODYDD	130-254	6	177	2	126-287	23	126-287	31	188-333	4	188-355	7
BODYDA	23-25	6	24	2	21-26	23	21-26	31	26-27	4	26-28	7
HALFDD	19-20	6	20-21	2	18-21	23	18-21	31	21-23	4	21-24	5
HALFDA	18-21	6	19	2	16-21	23	16-21	31	21	2	21-24	3
CPDD	13-16	6	15	2	13-16	23	13-16	31	16	2	16-18	3
CPDW	8.3-9.5	6	9.2	2	8.6-9.8	23	8.3-9.8	31	8.4-8.5	2	8.4-9.1	5
HEAD1	3.3-3.9	6	4.3	2	3.2-4.6	23	3.2-4.6	31	4.6-5.0	2	4.6-6.0	5
HEAD2	21-22	6	19-21	2	19-22	23	19-22	31	24-25	2	24-26	5
HEAD3	17-19	6	17-18	2	16-18	23	16-19	31	20-21	2	19-21	4
SUBORB	10-11	6	10-11	2	9.0-11	23	9.0-11	31	13	2	12-14	3
INTORB	8.4-9.8	6	8.6-8.8	2	7.7-9.3	23	7.7-9.8	31	9.8	2	9.4-10	3
HEADL	29-31	6	30-31	2	27-31	23	27-31	31	28-30	2	28-31	7
SNOUTL	13-14	6	13-15	2	12-14	23	12-15	31	13-14	4	13-16	7
PORB	10-11	6	9.9-11	2	9.3-11	23	9.3-11	31	11	2	10-12	3
ORBTL	6.5-7.6	6	7.1-7.4	2	5.8-7.8	23	5.8-7.8	31	5.2-6.8	4	5.2-6.9	7
ORBITD	5.8-6.3	6	6.0-6.5	2	5.1-6.8	23	5.1-6.8	31	4.5-6.1	2	4.5-6.1	5
UJAWL	8.6-9.4	6	8.3-9.5	2	8.1-9.3	23	8.1-9.5	31	11-12	4	11-12	7
LJAWL	8.1-9.1	6	8.1-8.7	2	7.8-9.0	23	7.8-9.1	31	11	2	11-12	3
SNOUTW	7.2-8.9	6	6.2-7.1	2	5.9-7.6	23	5.9-8.9	31	8.8	2	8.8-11	3
BARBL	20-22	6	21	2	18-22	23	18-22	31	19-20	4	19-21	7
BARBW	0.7-1.0	6	0.7	2	0.5-0.9	23	0.5-1.0	31	1.0	2	0.7-1.0	3
SD1	38-42	6	39-41	2	37-41	23	37-42	31	39	2	39-40	3
SD2	65-68	6	67-69	2	64-68	23	64-69	31	64	2	64-68	3
D1D2	13-16	6	14-15	2	12-17	23	12-17	31	15	2	15-16	3
CPDL	21-24	6	20-21	2	21-24	23	20-24	31	23	2	21-23	3
SANL	65-69	6	67	2	65-70	23	65-70	31	67	1	65-66	3
SPEL	32-38	6	33-34	2	31-35	23	31-38	31	29	2	30-32	3
SPEC	30-34	6	31-33	2	30-34	23	30-34	31	29	2	29-32	3
D2ANL	19-21	6	21	2	19-22	23	19-22	31	27	2	23-25	3
D1PELV	23-25	6	24	2	22-26	23	22-26	31	24	2	27-28	3
D1PEC	17-19	6	18	2	16-19	23	16-19	31	19	2	19	3
D1B	13-15	6	15	2	13-16	23	13-16	31	15	2	15	3
D2B	11-13	6	12-13	2	11-14	23	11-14	31	13	2	13-14	3
CAUH	29-31	6	-	0	29-33	16	29-33	22	29	1	29-33	3
ANALB	9.1-9.8	6	9.4-11	2	8.5-11	23	8.5-11	31	11	2	11-12	3
ANALH	13-15	6	14-15	2	13-16	22	13-16	30	12-13	2	12-13	5
PELVL	19-22	6	20-21	2	19-22	23	19-22	31	23-24	4	20-24	7
PECTL	19-21	6	19-20	2	19-21	23	19-21	31	20-23	4	20-23	7
PECTW	3.8-4.9	6	4.6-4.7	2	3.9-4.8	22	3.8-4.9	30	5.5	2	5.4-5.7	3
D1H	20-22	6	22	2	19-23	23	19-23	31	20-21	4	18-21	7
D2H	14-17	6	14	2	14-16	23	14-16	31	12-13	2	12-13	5
P	16-17	6	16	2	16-18	23	16-18	31	17	4	17-18	7
GrUud	1-4	6	5	2	1-4	23	1-5	31	2	2	2-5	3
GrUd	4-7	6	3	2	4-8	23	3-8	31	4	2	2-4	3
GrLud	16-18	6	13	2	13-18	23	13-18	31	14	2	12-15	3
GrLud	3-5	6	6	2	2-7	23	2-7	31	6	2	6-7	3
GrU	8	6	8	2	7-10	23	7-10	31	7	4	6-7	7
GrL	19-21	6	19	2	19-22	23	19-22	31	6-7	4	6-7	7
Gr	27-29	6	27	2	26-31	23	26-31	31	19-21	4	19-22	7
LLscal	34-36	6	36	2	35-38	22	34-38	30	26-28	4	26-29	7
									35-36	4	35-37	7

Table 6. Measurements and counts for *Mulloidichthys vanicolensis*, *M. dentatus*, and *M. martinicus* (EIO Eastern Indian Ocean)

SL (mm)	East-Africa		Oman		EIO		M. vanicolensis Indian Ocean		Pacific		Indo-Pacific		M. dentatus E Pacific		M. martinicus W Atlantic	
	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
BODYDD	10	12	2	24	16	40	3	4								
BODYDA	10	11	2	23	16	39	3	4								
HALFDD	10	11	2	23	16	39	3	4								
HALFDA	10	11	2	23	16	39	3	4								
CPDD	10	12	2	24	16	40	3	4								
CPDW	10	12	2	24	16	40	3	4								
HEAD1	10	12	2	24	16	40	3	4								
HEAD2	10	12	2	24	16	40	3	4								
SUBORB	10	12	2	24	16	40	3	4								
INTORB	10	12	2	24	16	40	3	4								
HEADL	10	12	2	24	16	40	3	4								
SNOUTL	10	12	2	24	16	40	3	4								
PORBL	10	12	2	24	16	40	3	4								
ORBITL	10	12	2	24	16	40	3	4								
ORBITD	10	12	2	24	16	40	3	4								
UJAWL	10	12	2	24	16	40	3	4								
LJAWL	10	11	2	23	16	39	3	4								
SNOUTW	10	11	2	23	16	39	3	4								
BARBL	10	12	2	24	16	40	3	4								
BARBW	10	12	2	24	16	40	3	4								
SD1	10	12	2	24	16	40	3	4								
SD2	10	12	2	24	16	40	3	4								
D1D2	10	12	2	24	16	40	3	4								
CPDL	10	12	2	24	16	40	3	4								
SANL	10	12	2	24	16	40	3	4								
SPEL	10	12	2	24	16	40	3	4								
SPEC	10	12	2	24	16	40	3	4								
D2ANL	10	12	2	24	16	40	3	4								
D1PELV	10	11	2	23	16	39	3	4								
D1PEC	10	12	2	24	16	40	3	4								
D1B	10	12	2	24	16	40	3	4								
D2B	10	12	2	24	16	40	3	4								
CAUH	8	10	2	20	14	34	1	3								
ANALB	10	12	2	24	16	40	3	4								
ANALH	9	12	2	23	16	39	3	4								
PELVL	10	12	2	24	16	40	3	4								
PECTL	10	12	2	24	16	40	3	4								
PECTW	10	12	2	24	16	40	3	4								
D1H	10	12	2	24	16	40	3	4								
D2H	8	12	2	22	15	38	1	3								
P	10	12	2	24	16	40	3	4								
GrUud	10	12	2	24	16	40	3	4								
GrUd	10	12	2	24	16	40	3	4								
GrLd	10	12	2	24	16	40	3	4								
GrLud	10	12	2	24	16	40	3	4								
GrU	10	12	2	24	16	40	3	4								
GrL	10	12	2	24	16	40	3	4								
Gr	10	12	2	24	16	40	3	4								
LLscal	8	11	2	21	16	37	3	4								