Rainbowfishes *(Melanotaenia:* Melanotaeniidae) of the Aru Islands, Indonesia with descriptions of five new species and redescription of *M. patoti* Weber and *M. senckenbergianus* Weber

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Abstract

The Aru Archipelago is a relict of the former land bridge connecting Australia and New Guinea and its freshwater *Melanotaenia* strongly reflect this past connection. Sea level changes over the past 2-3 million years have apparently provided sufficient isolation for the radiation of a mini-species flock consisting of at least seven species. *Melanotaenia patoti* and *M. senckenbergianus* were described from the islands by Weber in the early 1900s, but subsequently considered as junior synonyms of the New Guinea mainland species *M. rubrostriata* and *M. goldiei* respectively. Recent collections by the authors facilitated a reassessment of their status based on morphological and genetic investigations, consequently both are here recognised as valid and redescriptions are provided. In addition, the current study reveals the existence of five new taxa described herein. *M. albimarginata* n. sp. is described from 36 specimens, 35.3-90.9 mm SL, collected at Kobroor Island. It is allied to the "Australis" group of species of Australia and southern New Guinea. It differs from its closest Aru relatives, *M. patoti* and *M. aruensis,* on the basis of colour pattern, caudal peduncle depth, lateral scale counts and average number of cheek scales. *Melanotaenia aruensis* n. sp. is described from 19 specimens, 38.5-76.4 mm SL from Trangan and Kobroor islands. It is superficially similar to *M. albimarginata* and *M. patoti*, but exhibits marked genetic separation, unique colour pattern features, and several slight morphological differences. *Melanotaenia kolaensis, M. picta,* and *M. wokamensis* n. spp. are described from 95 (17.9-78.8 mm SL), 51 (17.2-93.2 mm SL), and 156 (14.1-75.6 mm SL) specimens respectively, collected at Kola, Kobroor, and Wokam islands. They comprise a close-knit group allied to the "Goldiei" group (along with *M. senckenbergianus),* but are differentiated on the basis of live colour patterns and various genetic, morphometric, and meristic features.

Zusammenfassung

Das Aru-Archipel ist ein Überbleibsel der früheren Landbrücke zwischen Australien und Neuguinea, die Süßwasser-*Melanotaenia* spiegeln das wider. Veränderungen des Meeresspiegels während der letzten 2-3 Millionen Jahre haben zu ausreichend Isolierung geführt, um eine Radiation einer kleinen Artengruppe von mindestens sieben Arten zu ermöglichen. *Melanotaenia patoti* und *M. senckenbergianus* waren Anfang der 1900er Jahre von dieser Inselgruppe durch Weber beschrieben worden, später aber als nachrangige Synonyme der Festlandarten Neuguineas *M. rubrostriata* bzw. *M. goldiei* aufgefasst worden. Neuere Funde der Autoren ermöglichten eine Neubewertung ihres Status auf der Grundlage von morphologischen und genetischen Daten; demnach können beide hier als gültige eigene Arten anerkannt werden, Neubeschreibungen werden vorgelegt. Außerdem wird in der vorliegenden Arbeit die Existenz von fünf weiteren Arten nachgewiesen, die hier zum ersten Mal beschrieben werden. *M. albimarginata* n. sp. wird auf der Grundlage von 36 Exemplaren beschrieben, 35,3-90,9 mm SL, die auf der Insel Kobroor gefangen wurden. Die neue Art wird mit der „Australis"-Gruppe von Arten in Verbindung gebracht, die in Australien und im

südlichen Neuguinea leben. Unterschiede zu den nächsten Aru-Verwandten, *M. patoti* und *M. aruensis,* lassen sich anhand von Farbmuster, Schwanzstieltiefe, seitlichen Schuppenzahlen und der durchschnittlichen Zahl von Wangenschuppen bestimmen. *Melanotaenia aruensis* n. sp.wird anhand von 19 Exemplaren, 38,5-76,4 mm SL, von den Inseln Trangan und Koobror beschrieben. Diese Art ist *M. albimarginata* und *M. patoti* ausgesprochen ähnlich, lässt sich aber durch deutliche genetische Unterschiede, unverkennbares Farbmuster und einige kleinere morphologische Merkmale erkennen. *Melanotaenia kolaensis, M. picta* und *M. wokamensis* n. spp. werden anhand von 95 (17,9-78,8 mm SL), 51 (17,2-93,2 mm SL) und 156 (14,1-75,6 mm SL) Exemplaren beschrieben, die auf den Inseln Kola, Kobroor und Wokam gefangen worden waren. Diese drei eng zusammengehörenden Arten bilden eine kleine Gruppe, die (ebenso wie *M. senckenbergianus)* mit der „Goldiei"-Gruppe in Verbindung gebracht wird, lassen sich aber durch Farbmuster (der lebenden Tiere) und verschiedene genetische, morphometrische und meristische Merkmale unterscheiden.

Résumé

L'archipel d'Aru est une relique de l'ancienne langue de terre qui reliait l'Australie à la Nouvelle-Guinée et ses *Melanotaenia* d'eau douce témoignent de cette connexion passée. Des changements du niveau de la mer dans les 2 ou 3 millions d'années passées ont apparemment provoqué une isolation d'un petit groupe d'au moins sept espèces. *Melanotaenia patoti* et *M. senckenbergianus* ont été décrits, en provenance de ces îles, par Weber au début des années 1900, mais considérés ensuite comme des synonymes plus récents d'espèces de Nouvelle-Guinée même, respectivement de *M. rubrostriata* et de *M. goldiei.* Des collectes récentes par les auteurs ont permis de réexaminer leur statut en se basant sur des données morphologiques et génétiques; en conséquence, ces deux espèces sont ici reconnues comme valides et de nouvelles descriptions sont fournies.. En outre, l'étude actuelle conclut à l'existence de cinq nouveaux taxons décrits ici. *M. albimarginata* n. sp. est décrit sur base de 36 spécimens, 35,3-90,9 mm de LS, collectés sur l'île de Kobroor. Elle est proche du groupe d'espèces « Australis » d'Australie et du sud de la Nouvelle-Guinée. Elle se distingue de ses parents d'Aru les plus proches, *M. patoti* et *M. aruensis,* par le patron de coloration, la hauteur du pédoncule caudal, le décompte des écailles latérales et le nombre moyen d'écailles sur la joue. *M. aruensis* n. sp. est décrit sur base de 19 spécimens, 38,5-76,4 mm de LS, venant des îles Trangan et Kobroor. L'espèce ressemble superficiellement à *M. albimarginata* et *M. patoti,* mais se signale par une nette distinction génétique, des caractéristiques uniques de coloration et plusieurs légères différences morphologiques. *Melanotaenia kolaensis, M. picta* et *M. wokamensis* n. spp. sont décrits sur base de 95 (17,9-78,8 mm LS), 51 (17,2-93,2 mm LS et 156 (14,1-75,6 mm LS) spécimens respectivement, collectés sur les îles Kola, Kobroor et Wokam. Ils forment un groupe très uni, voisin du groupe « Goldiei » (en compagnie de *M. senckenbergianus),* mais se distinguent sur base de la coloration in vivo et de caractéristiques variées de type génétique, morphométrique et méristique.

Sommario

L'arcipelago delle isole Aru è un relitto della primordiale lingua di terra che collegava l'Australia e la Nuova Guinea e le sue specie di *Melanotaenia* d'acqua dolce dimostrano chiaramente questa passata connessione. Variazioni del livello del mare nel corso degli ultimi 2-3 milioni di anni hanno apparentemente fornito un sufficiente isolamento per la radiazione di un piccolo sciame di specie costituito da almeno sette specie. *Melanotaenia patoti* e *M. senckenbergianus* sono state descritte da queste isole da Weber nel 1900, ma in seguito considerate come sinonimi delle specie continentali della Nuova Guinea *M. rubrostriata* e *M. goldiei,* rispettivamente. Collezioni recenti da parte degli autori hanno consentito una rivalutazione del loro status e, sulla base di evidenze morfologiche e genetiche, sono qui riconosciute entrambe come valide e sono ridescritte. Inoltre, lo studio rivela l'esistenza di cinque nuovi taxa qui descritti. *M. albimarginata* n. sp. è descritta da 36 esemplari di 35.3-90.9 mm SL, raccolti sull'isola di Kobroor. È vicina al gruppo di specie "Australis" presente in Australia e nel sud della Nuova Guinea. Si differenzia dai suoi parenti Aru più stretti, *M. patoti* e *M. aruensis,* sulla base della colorazione, dell'altezza del peduncolo caudale, del numero di scaglie laterali e del numero medio di scaglie sulla guancia. *Melanotaenia aruensis* n. sp. è descritta da 19 esemplari di 38.5-76.4 mm SL raccolti sulle isole Trangan e Kobroor. È superficialmente simile a *M. albimarginata* e *M. patoti,* ma mostra una marcata separazione genetica, caratteristiche uniche nella colorazione e alcune lievi differenze morfologiche. *Melanotaenia kolaensis, M. picta,* e *M. wokamensis* n. spp. sono descritti rispettivamente da 95 (17.9-78.8 mm SL), 51 (17.2-93.2 mm SL) e 156 (14.1-75.6 mm SL) esemplari raccolti alle isole Kola, Kobroor e Wokam. Esse costituiscono un gruppo omogeneo di specie alleato al gruppo "Goldiei" (con *M. senckenbergianus),* ma si differenziano sulla base della colorazione e varie caratteristiche genetiche, morfometriche e meristiche.

INTRODUCTION

Rainbowfishes of the family Melanotaeniidae are small (mainly < 100 mm SL), brightly coloured fishes endemic to fresh waters of New Guinea and Australia (mainly northern half). They are generally abundant in a wide variety of lotic and lentic habitats and are frequently one of the first fishes noticed, forming aggregations that swim in midwater or near the surface. Melanotaeniidae is one of the three dominant families (the other two being Eleotridae and Gobiidae) occurring in fresh waters of the combined Australia and New Guinea region with 93 described species (including those described herein) with many additional species still needing formal description (Unmack et al. 2013). The family was comprehensively treated by Allen

& Cross (1982) and Allen (1995), but numerous additional species have been described over the past two decades.

The former land bridge between Australia and New Guinea (the Arafura Plain) persisted throughout significant portions of the region's geologic history, and was certainly the dominant factor responsible for the remarkable faunal and floral similarities that continue to persist between northern Australia and alluvial lowlands of southern New Guinea (Spriggs et al. 2011). The Aru Archipelago (Fig. 1), now an isolated relict of the previous land bridge, is particularly interesting from an evolutionary and zoogeographic perspective. The present paper documents the melanotaeniid fauna of these islands, based largely on collections obtained during 2013 (Fig. 2).

Freshwater fishes of the Aru Islands were reported by Weber (1911) who listed 37 species, mainly collected by van Patot, van Kampen, and Lorentz in 1907 and 1909. These included two species of rainbowfishes, *Melanotaenia patoti* Weber 1907 and *Rhombatractus* (=*Melanotaenia) senckenbergianus* Weber 1911. These species were inadequately described and eventually recognised as synonyms (Allen & Cross 1982) of *M. rubrostriata* (Ramsay & Ogilby 1886) and *M. goldiei* (Macleay 1883) respectively, formerly considered as wide-ranging southern New Guinea species, but now divisible into several species based on DNA investigations (Unmack et al. 2013). The present paper provides evidence for the recognition of both *M. patoti* and *M. senckenbergianus*, as well as descriptions of five new species. We also discuss the unique circumstances of the Aru Islands, which has facilitated the evolution of these endemic rainbowfishes.

The Aru Islands

The Aru Archipelago (Fig. 1), at 6° S and 134° E, is located near the western edge of the extensive marine shallows (mostly about 20-50 m depth) linking northern Australia and the island of New Guinea, consisting of the Arafura Sea and Torres Strait. The islands, which form part of the Indonesian province of Maluku, are situated about 110 km south of New Guinea, 130 km east of the Kei

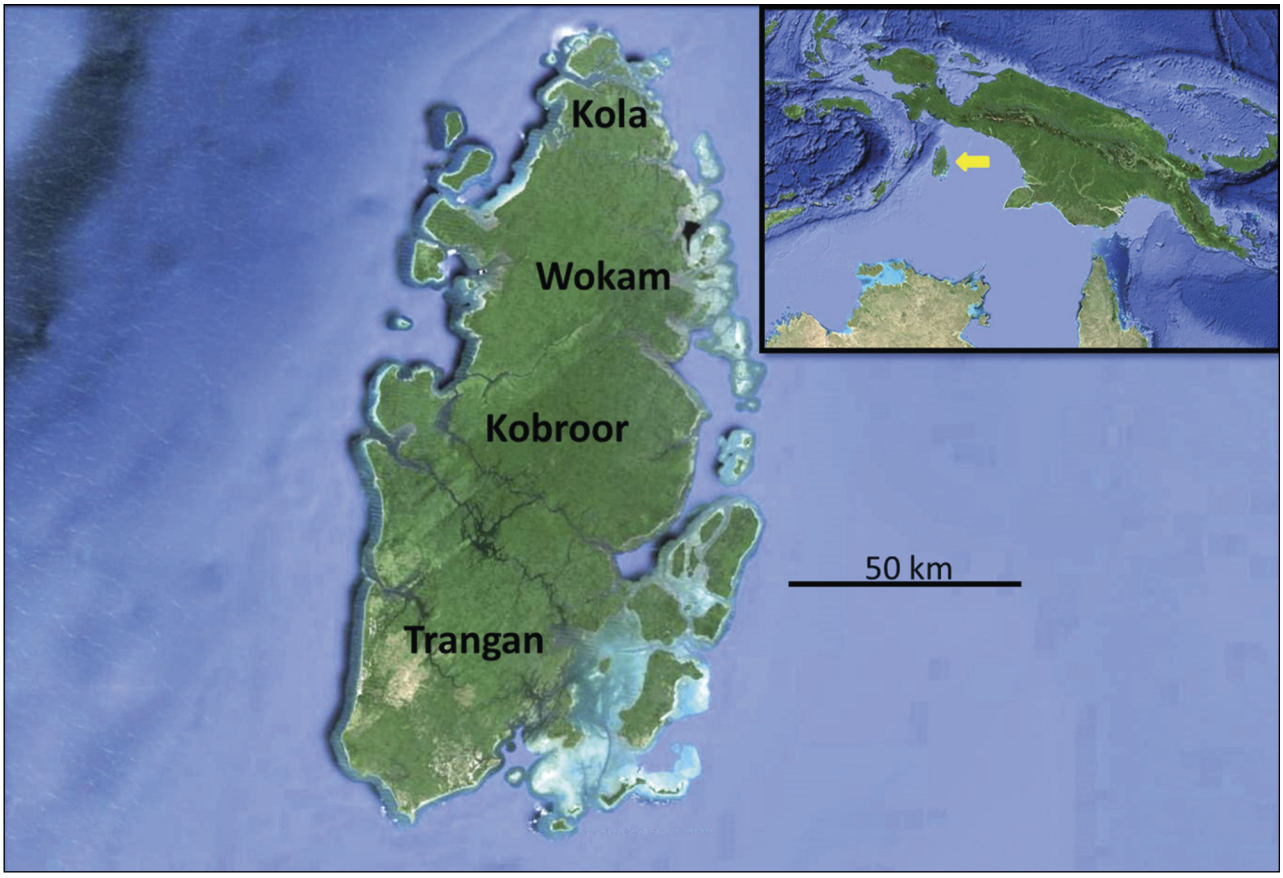

Fig. 1 Map of the Aru Islands, Maluku Province, Indonesia showing main islands sampled during the 2013 visits.

Islands, and 510 km north of Croker Island, Northern Territory, Australia. The archipelago contains about 80 islands greater than 40 ha in size, and another 80 smaller islands. The total land area is 8,225 km^2, with the six largest islands, Trangan, Kobroor, Maikoor, Koba, Wokam, and Kola, representing a combined land area of about 7,000 km^2 (van Balgooy 1996) and effectively forming a single large land mass dissected by numerous, relatively narrow (100-500 m) marine or brackish channels (known as "sungai") that have the appearance of large rivers. Most of the major "sungai" completely cross the island, connecting the east and west coasts. The entire archipelago extends about 180 km north to south and is about 80 km east to west at its widest point.

The islands are relatively low-lying, consisting of mangrove swamps along the coast and margins of the numerous marine sungai, giving way in the interior to low limestone hills with a maximum elevation of about 90 m (erroneously reported as 241 m on most maps). The average elevation is approximately 30 m with a general decrease in average proceeding southward. The islands are (in 2013) forest-covered over most of the interior with both primary rainforest and secondary forest as well as scattered gardens. Parts of Trangan, the largest and southernmost island, are covered with savannah grasslands and here *Pandanus* palms are also a common feature of the landscape.

The renowned British naturalist Sir Alfred Russell Wallace spent several months at the islands in 1857. His description of the landscape in *The Malay-Archipelago* (Wallace 1869), quoted in the following passage is still relevant and highly descriptive. *"The whole of the Aru is low, but by no means so flat as it has been represented, or as it appears from sea. Most of it is dry rocky ground with a*

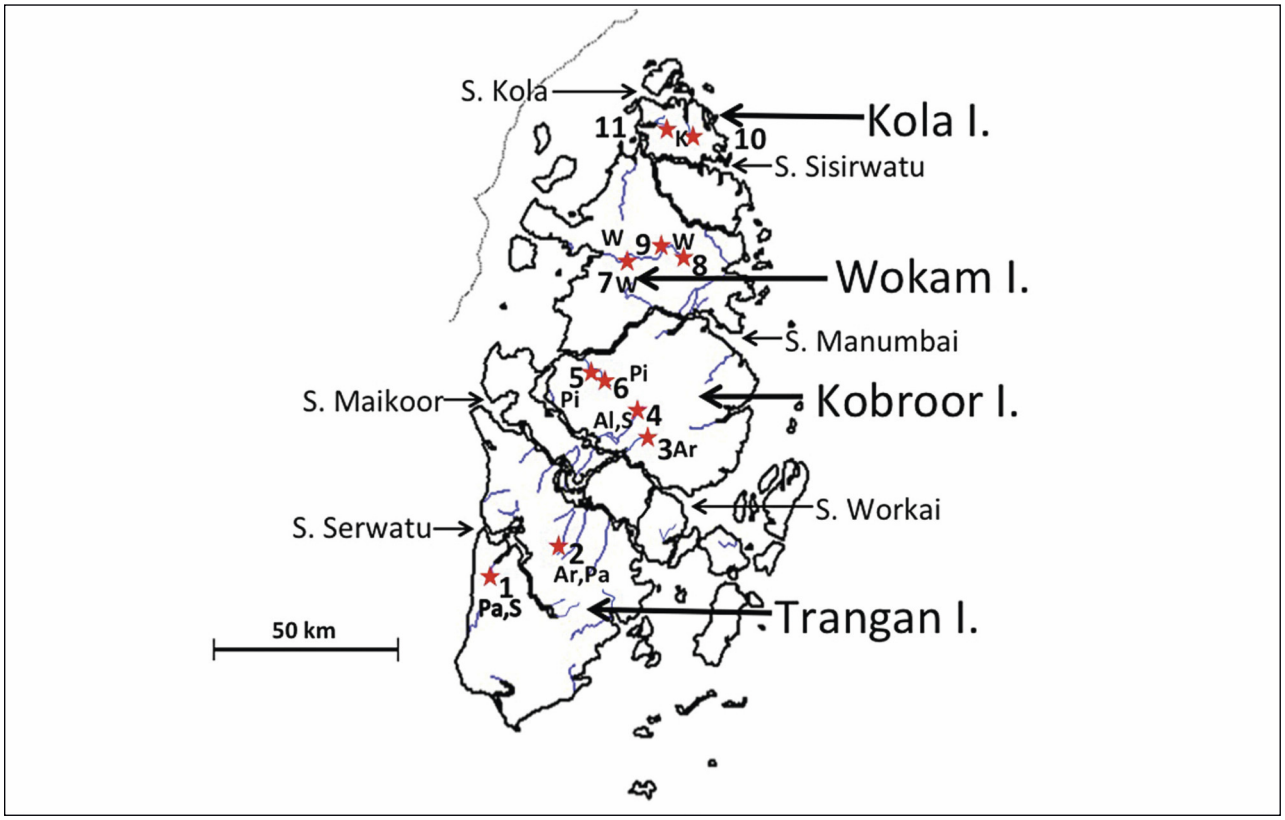

Fig. 2. Map of the Aru Islands, showing site of 2013 collections (red stars with numbers) and *Melanotaenia* species collected (abbreviations as follows: *M. albimarginata* = **Al**, *M. aruensis* = **Ar**, *M. kolaensis* = **K**, *M. patoti* = **Pa**, *M. picta* = **Pi**, *M. senckenbergianus* = S, *M. wokamensis* = **W**). Numbers for field sites as follows: 1) Sungai Galalou, Trangan Island, 26 January; 2) Sungai Sin, Trangan Island, 25 January; 3) un-named stream, Kobroor Island, 27 January; 4) Sungai Unmar, Kobroor Island, 27 January; 5) Sungai Gora, Kobroor Island, 4 December; 6) Sungai Kwamoli, Kobroor Island, 4 December; 7) Sungai Gaibel, Wokam Island, 5 December; 8) Sungai Torbol, Wokam Island, 5 December; 9) Sungai Gayarfafeimusin, Wokam Island, 5 December; 10) Sungai Marjina, Kola Island, 6 December; 11) Sungai Kofukim, Kola Island, 6 December.

somewhat undulating surface, rising here and there into abrupt hillocks, or cut into steep and narrow ravines. Except the patches of swamp which are found at the mouths of most of the small rivers, there is no absolutely level ground, although the greatest elevation is probably not more than two hundred feet. The rock which everywhere appears in the ravines and brooks is a coralline limestone, in some places soft and pliable, in others so hard and crystalline as to resemble our mountain limestone."

Freshwater habitat is abundant in the form of springs, creeks and small rivers, reflecting the relatively high rainfall. The annual average precipitation on the west coast of Trangan is about 2,000 mm with an increase eastward and northward to perhaps as much as 3,000 mm (Monk et al. 1997). During the northwest monsoon, from November to March, rainfall is heaviest with widespread afternoon thunderstorms. Although, there is little information available, our personal experience reveals that drainage patterns in the interior are frequently complex and unpredictable. The karst topography definitely exerts a "sponge" effect, with considerable runoff being absorbed by the porous rock, which is riddled with caves, sinkholes, and creeks that disappear underground and then reappear upstream. From our limited experience, streams of the northern half of the archipelago typically flow through narrow gullies or ravines, have solid limestone bottoms, and are frequently punctuated with cascades and small waterfalls. Local guides expressed concern about the possibility of afternoon flash floods, which must be a common phenomenon during the northwest monsoon. We witnessed streams that swelled to 2-3 times in size during a period of about one hour after the onset of heavy afternoon rains during December. On Trangan Island at least some streams and springs have a soft, silty bottom with more gentle gradients. Water throughout the archipelago is typically alkaline with pH values from 8.0-8.6 and January temperatures ranging from 26.5-28.1°C.

Palaeogeography: The Aru Islands and the nearby lowlands of southern New Guinea (Papua Province, Indonesia and Gulf and Western provinces, Papua New Guinea) are situated on the northern margin of the ancient Australian Plate, often referred to as the Sahul Shelf (Wilson 2013). Based on seismic refraction investigations (Curray et al. 1977; Jacobson et al. 1979; and Bowin et al. 1980), the Archipelago appears to be an old, peneplaned platform covered by Neogene to Recent sediments. Similarly, Verstappen (1959) suggested the islands are uplifted Pliocene and Quaternary marly limestone, siltstone, and sandstone sediments that are "domed", forming a high point on the shelf. Compared to the tectonically active regions to the north and west, the portion of the plate containing the Aru Islands has experienced remarkable stability (Polhemus 2007). For much of the past 150 million years the area has been submerged with the exception of the Eocene and Oligocene epochs or 53-24 Ma (millions of years ago) (Flannery 1995). The present geographic configuration of Australia and New Guinea has been in place for at least the last two million years (Hope 2007), and the last few million years are the most pertinent to Aru freshwater fish evolution. Although the northern margin of the Australian Plate is now covered by shallow waters of Torres Strait and the Arafura Sea, a land connection was a prominent feature of the landscape throughout most of the Quaternary. Consequently, the Aru Islands have been connected by dry land with southern New Guinea and Australia for over 80 % of the past million years, except during inter-glacial periods of higher sea level when most of the shelf was submerged (Hope & Aplin 2006). Data on global sea levels for the last 300,000 years obtained from oxygen isotope values indicate the Arus were a hilly promontory on the otherwise featureless Arafura Plain, becoming an island only during relatively brief interglacials (Hope 2007). Although these data only cover a small span of geological time, a similar scenario of cyclic sea level rises most likely persisted throughout the Quaternary glaciations, which started about 2.58 million years ago (Andersen & Borns, 1994) and during other periods of low sea levels over the past ~10 million years as suggested by Haq et al. (1987).

The Earth has experienced 17 periods of glaciation over the past few million years (Flannery 1995), including several major oscillations when sea-levels dropped by 120-135 m (Clark & Mix 2002), essentially exposing large tracts of land, including the Arafura Plain land-bridge (Hope 2007). In general, glacials have persisted about 100,000 years compared to the much shorter time span of 10,000 years for interglacials. This provided a conduit for the exchange of flora and fauna between the Aru Islands, New Guinea, and Australia. Wallace (1867) was the first to notice a strong faunal relationship between the Arus and southern New Guinea, correctly concluding the

Table I. Rainbowfish species from the Aru Islands used in the phylogenetic analysis including locality data, the number of individuals examined and the GenBank accession number for each unique haplotype with their respective labels on the phylogenetic tree.

Species	Locality (site #)	N	GenBank #	Tree label
M. albimarginata	Sungai Unmar (4)	3	= KC133542.1	I
M. aruensis	Sungai Sin (2)	3	KP345852.1	H1
M. aruensis	un-named trib, Kobroor Is (3)	2	KP345855-6.1	H3, H2
M. patoti	Sungai Galalou (1)	3	KP345853-4.1	H1, H2
M. kolaensis	Sungai Kofukim (11)	4	KP345839.1	
M. picta	Sungai Gora (5)	3	KP345842-3.1	H1, H2
M. senckenbergianus	Sungai Galalou (1)	4	KP345848-9.1	H5, H1
M. senckenbergianus	Sungai Sin (2)	4	KP345850-1.1	H3, H2
M. senckenbergianus	Sungai Unmar (4)	3	KP345846-7.1, KC133567.1	H6, H4, II H7
M. wokamensis	Sungai Gaibel (7)	4	KP345840-1.1	H1, H2
M. wokamensis	Sungai Torbol (8)	3	KP345844-5.1	H4, H3
M. wokamensis	Sungai Gayarfafeimusin (9)	2	= KP345840.1	

two areas were previously connected based on their very similar land-bird faunas. A similar correlation between these areas is documented for freshwater fishes (Weber 1911; Allen 1991), amphibians and reptiles (Allison 2007), and mammals (Aplin & Pasveer 2006). Freely mobile groups including Aru birds and mammals apparently maintained genetic continuity with their New Guinea mainland relatives, in contrast to fishes, which at least in melanotaeniids, have undergone speciation as a direct result of repeated long periods of isolation (this study). Similar to the situation with rainbowfishes, four of the six total species of amphibians and reptiles are endemic to the islands, which are considered a major area of endemism for this group (Allison 2007).

MATERIALS AND METHODS

Counts and measurements that appear in parentheses refer to the range for paratypes if different from the holotype. Type specimens are deposited at the Research Center for Biology, Indonesian Institute of Sciences, Cibinong, Indonesia (MZB), United States National Museum of Natural History, Washington, D.C. (USNM), and the Western Australian Museum, Perth (WAM).

Rather than following the usual alphabetical order for new taxa, the species accounts are presented according to their natural phylogenetic groupings, with the three members of the "Australis" group *(M. albimarginata*, *M. aruensis*, and *M. patoti),* treated first, followed by the four species belonging to the "Goldiei" group *(M. kolaensis*, *M. picta*, *M. senckenbergianus*, and *M. wokamensis).*

The methods of counting and measuring follow those of Allen & Cross (1982): dorsal and anal rays – the last ray of the anal and second dorsal fins is divided at the base and counted as a single ray; lateral scales – number of scales in horizontal row from upper edge of pectoral-fin base to caudal-fin base, excluding the small scales posterior to the hypural junction; transverse scales – number of scales in vertical row between anal fin origin and base of first dorsal fin; predorsal scales – number of scales along midline of nape in front of first dorsal fin; cheek scales – total number of scales covering the suborbital and preoperculum; total gill rakers includes all elements, including 2-3 small rakers on the upper arch, 1-2 of which are usually embedded in a protuberance of fatty tissue; standard length (SL) – measured from the tip of the upper lip to the caudal-fin base; head length (HL) – measured from the tip of the upper lip to the upper rear edge of the gill opening; caudal peduncle depth is the least depth and caudal peduncle length is measured between two vertical lines, one passing through the base of the last anal ray and the other through the caudal-fin base; caudal concavity is the horizontal distance between verticals at the tips of the shortest and longest rays.

All of the rainbowfish sequences from the monophyletic Southern lineage included by Unmack et al. (2013) were analysed, plus new sequences obtained from Aru Island species (Table I). We sequenced the mitochondrial cytochrome *b* (cyt*b)* gene and used GARLI 2.0 (Zwickl 2006) to obtain the best Maximum Likelihood tree and 1000 bootstrap replicates. Methods for obtaining and analysing DNA se-

Table II. Summary of counts for fin-rays, scales, and total gill rakers on first arch for *M. albimarginata, M. aruensis* and *M. patoti*.

	1st Dorsal Spines			2nd Dorsal Soft Rays				Anal Soft Rays				
	V	**VI**	**VII**	**10**	**11**	**12**	**13**	**19**	**20**	**21**	**22**	**23**
M. albimarginata	8	19			14	13		1	5	16	5	
M. aruensis	8	10	2	1	6	11	2		8	9	2	1
M. patoti	2	3			2	2	1		1	4		

	Pectoral Rays			Predorsal Scales				Lateral Scales			
	14	**15**	**16**	**15**	**16**	**17**	**18**	**33**	**34**	**35**	**36**
M. albimarginata	6	12	1		10	8	2			18	3
M. aruensis	18	2		1	2	13	4		5	14	2
M. patoti		5			3	2		1	4		

	Transverse Scales			Cheek Scales							
	10	**11**	**12**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
M. albimarginata		20		1	2	4	6	4	2	1	1
M. aruensis	1	1	18		5	2	6	5			2
M. patoti		5		2	2	1					

	Prepelvic Scales				Peduncle Scales		Gill Rakers		
	18	**19**	**20**	**21**	**12**	**13**	**16**	**17**	**18**
M. albimarginata	8	10	4		4	18		21	4
M. aruensis	2	6	8	2	2	17		1	18
M. patoti		5			5		1	3	1

quence data follows Allen & Unmack (2012) and Allen et al. (2014) except: the model of sequence evolution GTR+I+G was the best one identified by ModelTest 3.7 (Posada & Crandall 1998), we used attachmentspertaxon = 148 and trees were rooted with the "Goldiei" group species. GenBank accession numbers are provided in Table I for all new sequences obtained in this study.

Melanotaeniid taxonomic features: Allen (1980) provided a generic classification of rainbowfishes based largely on certain osteological structures, particularly those related to the jaw, pelvic and pectoral girdles, and caudal-fin skeleton. However, species-level differences are generally based on traditional morphometric and meristic data. Some of the most useful meristic features (Tables II and VI) include counts of dorsal, anal, and pectoral fin rays, as well as the number of lateral and transverse scale rows on the body and number of scales covering various regions of the head and body including the cheek (preopercle), predorsal and prepelvic midline, and around the caudal peduncle. Total number of gill rakers on the first branchial arch, although occasionally useful, is generally of lesser value. Closely related species, usually exhibit notable meristic and morphological differences, although discrepancies in modal or average values are also useful. Morphometric proportions are often useful, but like most fishes, melanotaeniids exhibit considerable allometric and sex-related variation. Therefore, it is especially important to make comparisons of similar sized individuals of the same sex when assessing interspecific differences. Adult males are usually deeper bodied than females and have a more elongate, pointed shape posteriorly on the soft dorsal and anal fins. The longest soft dorsal-fin rays of males are located in the posteriormost portion of the fin, and those of females are situated in the anterior half of the fin. The first dorsal fin of males is also much taller than that of females, the longest spine usually reaching well beyond the origin of the second dorsal fin when depressed. Although many species become sexually mature at sizes below 45 mm SL, adults of the Aru

species greater than about 60 mm SL were the most useful for showing differences in colour pattern and sex-related proportional differences.

SYSTEMATICS

Melanotaenia albimarginata, n. sp.
Whitetip Rainbowfish
(Figs 3-5, Tables II-III)

Holotype: MZB 22251, male, 90.9 mm SL, Alur Warnafa (site 4, Fig. 2), tributary of Sungai Unmar, near Algadang village, 6° 11.200'S, 134° 28.845'E, Kobroor Island, Aru Islands, Maluku Province, Indonesia, seine net, G. R. Allen, M. Erdmann & R. Hadiaty, 3 December 2013.
Paratypes: MZB 21667, 26 specimens, 35.3-71.0 mm SL, collected with holotype; MZB 21645, 4 specimens, 40.7-48.4 mm SL, ethanol collection, collected with holotype; WAM P.33834-002, 5 specimens, 59.4-71.1 mm SL, same locality as holotype, H. Bleher, M. Erdmann & M. Brooks, seine net, 27 January 2013.

Diagnosis: A species of melanotaeniid rainbowfish distinguished by the following combination of characters: dorsal rays V or VI-I,11 or 12; anal rays I,19-22; pectoral rays 14-15; lateral scales 35-36, predorsal scales 16-18; cheek scales 12-19; total gill rakers on first arch 16-18; greatest body depth of adult male 36.2 % SL; least depth of caudal peduncle 9.6-10.9 % SL; colour in life dappled grey on upper side, dark grey midlateral stripe (1-2 scales wide) with equally broad yellow stripe immediately below; dorsal and anal fins with greyish membranes and whitish to pale yellow fin rays; caudal semitranslucent grey with prominent white marking at tip of upper and lower lobes. Maximum size to 90.9 mm SL or 109.1 mm TL.

Description: Dorsal rays VI-I,12 (V or VI-I,11 or 12); anal rays I,22 (19-22); pectoral rays 16 (14-15); pelvic rays I,5; branched caudal rays 15; lateral scales 35 (35-36); transverse scales 11; predorsal scales 18 (16 -18); cheek scales 14 (12-19); total gill rakers on first arch 17 (16-18).

Body depth 2.8 (2.9-3.7) in SL; greatest body depth by sex and size class as follows: male – < 50 mm SL, 30.3 % SL (N = 1); *males* – 50-64 mm SL, 29.3-32.5 % SL ($\bar{x}$ = 30.6, N = 4); *males* – 65-79 mm SL, 31.9-34.6% SL ($\bar{x}$ = 33.3, N = 2); *male* – 90.9 mm SL (holotype), 36.2 % SL; *females* – < 50 mm SL, 27.2-30.1 % SL ($\bar{x}$ = 28.6, N = 5); *females* – 50-64 mm SL, 27.1-32.3% SL ($\bar{x}$ =29.2, N = 11); *female* – 71.1 mm SL, 32.2 % SL; head length 4.0 (3.5-4.0) in SL; greatest width of body 2.9 (2.1-2.8) in greatest body depth; snout length 3.1 (2.8-3.7) in HL; eye diameter 3.3 (2.7-3.1) in HL; interorbital width 2.7 (2.6-3.0) in HL; depth of caudal peduncle 2.3 (2.3-2.9) in HL; length of caudal peduncle 1.5 (1.4-1.7) in HL.

Jaws about equal, oblique, premaxilla with an abrupt bend between the anterior horizontal portion and lateral part; maxilla not reaching level of anterior edge of eye; maxillary length 3.9 (3.2-4.2) in HL; lips thin; teeth conical with slightly curved tips, extending on to outer surface of lips; teeth of upper jaw in 3-4 irregular rows anteriorly, reduced to a single row posteriorly, where they are exposed when mouth is closed; teeth in lower jaw in about 6-7 irregular rows anteriorly, reduced to 1 or 2 rows posteriorly; narrow row containing several small, conical teeth on vomer and palatines.

Scales of body cycloid, relatively large, and

Fig. 3. Underwater photograph of *Melanotaenia albimarginata*, male, approximately 70 mm SL, Sungai Unmar, Kobroor Island, Aru Islands. Photo by G. R. Allen.

arranged in regular horizontal rows; scale margins smooth to weakly crenulate; predorsal scales extending forward to about middle of interorbital space; preopercle with 2 scale rows between its posterior angle and eye.

Predorsal length 2.1 (2.0-2.1) in SL; preanal length 2.1 (1.9-2.1) in SL; prepelvic length 2.7 (2.5-2.8) in SL; length of second-dorsal fin base 4.0 (4.4-4.9); length of anal-fin base 2.5 (2.6-3.0).

First dorsal fin origin about level with or slightly anterior to anal fin origin; longest spine (usually third) of first dorsal fin 1.1 (1.3-2.3) in HL, its depressed tip reaching spine of second dorsal fin or slightly posterior in females and reaching to about base of third to fifth soft ray in mature males; longest rays (generally anterior ones in females and penultimate in males) of second dorsal fin 1.7 (1.6-2.3) in HL, the depressed posterior rays extending less than one half length of caudal peduncle in females and nearly full length of caudal peduncle in mature males; longest (middle rays in females and penultimate in males) anal rays 1.5 (1.5-2.7) in

Fig. 4. Aquarium photograph of freshly collected holotype of *Melanotaenia albimarginata*, male, 90.9 mm SL, Alur Warnafa, a triburary of Sungai Unmar, Kobroor Island, Aru Islands. Photo by G. R. Allen.

Fig. 5. *Melanotaenia albimarginata*, preserved male holotype, 90.9 mm SL, Alur Warnafa, a triburary of Sungai Unmar, Kobroor Island, Aru Islands. Photo by G. R. Allen.

Table III. Proportional measurements of selected type specimens of *Melanotaenia albimarginata* expressed as percentage of the standard length.

	Holotype MZB 22251	Paratype MZB 21667	Paratype MZB 21667	Paratype MZB 21667	Paratype WAM P.33834	Paratype WAM P.33834	Paratype WAM P.33834	Paratype MZB 21667
Sex	male	male	male	male	female	female	female	female
Standard length (mm)	90.9	73.2	70.9	62.4	71.1	61.4	59.4	57.6
Body depth	36.2	34.6	31.9	32.5	32.2	30.0	32.3	28.6
Body width	12.3	12.4	13.1	13.6	13.5	12.2	13.5	12.5
Head length	25.1	26.0	26.0	26.3	25.3	26.9	28.6	28.8
Snout length	8.1	8.5	8.5	9.5	7.3	8.6	8.8	8.7
Maxillary length	6.4	7.0	6.8	7.4	6.5	8.3	7.7	6.9
Eye diameter	7.7	8.3	9.3	9.0	9.4	9.1	9.6	9.7
Bony interorbital width	9.1	9.8	9.2	9.9	9.0	9.1	9.6	9.7
Depth of caudal peduncle	10.9	10.7	10.6	10.3	10.8	10.4	10.3	10.1
Length of caudal peduncle	16.7	17.5	17.6	18.4	15.9	16.8	18.2	17.4
Predorsal distance	48.0	47.1	47.8	48.2	46.6	48.9	48.3	50.2
Preanal distance	48.7	48.9	48.7	48.9	52.0	52.9	51.3	51.7
Prepelvic distance	36.6	37.2	36.0	36.1	39.2	39.1	39.1	37.0
2nd dorsal fin base	24.8	22.8	22.3	22.0	22.4	20.5	21.7	20.7
Anal fin base	39.9	38.5	37.8	37.2	37.4	33.7	36.5	34.7
Pectoral fin length	17.8	18.7	18.3	18.8	18.6	17.6	19.5	18.9
Pelvic fin length	13.1	16.0	14.8	14.4	13.1	13.7	12.6	14.2
Longest ray 1st dorsal fin	22.3	20.1	19.2	17.9	12.8	13.7	13.6	12.5
Longest ray 2nd dorsal fin	15.2	15.0	15.2	16.2	13.8	13.5	14.5	12.7
Longest anal ray	17.2	16.4	16.4	17.1	11.3	13.5	11.1	10.9
Caudal fin length	20.0	16.4	20.9	20.8	20.8	19.5	20.9	19.8
Caudal concavity	6.6	5.6	5.4	5.3	4.9	5.2	5.6	8.0

HL; pelvic fin tips when depressed reaching nearly to origin of anal fin in females and to base second or third soft anal-fin ray in mature males; length of pelvic fins 1.9 (1.6-2.3) in HL; length of pectoral fins 1.4 (1.4-1.5) in HL; length of caudal fin 1.3 (1.2-1.6) in HL; caudal fin moderately forked, caudal concavity 3.8 (3.6-5.3) in HL.

Colour in life of male (from *in situ* underwater photographs, Fig. 3): brown dorsally on head, nape, and uppermost part of back; lower half of head pale grey with scaled area of preoperculum mainly yellow; middle of operculum yellow to pale reddish; iris yellow; upper half of side with dappled or variegated appearance due to presence of scattered pale bluish scales; also thin yellow stripes between each horizontal scale row on upper portion of side; midlateral dark grey stripe covering 1-2 horizontal scale rows from behind eye to caudal-fin base; an equally broad zone of yellow immediately below midlateral dark stripe, widest anteriorly; ventral portion of body (below yellow zone) pale grey; dorsal and anal fins with greyish membranes and whitish to pale yellow fin rays; first dorsal fin with small black spot at base of posteriormost portion of fin; caudal semitranslucent grey with prominent white area at tip of upper and lower lobes; pelvic fins dusky grey; pectoral fins translucent. Freshly collected live fish (Fig. 4) photographed in an aquarium were entirely blush with reddish margins on the scales of the upper side and the second dorsal fin was marked with 2-3 rows of dark spots. The only colour pattern features shared with the *in situ* fish are the white tips on the caudal fin and whitish rays on the anal fin.

Colour in life of female (from *in situ* underwater photographs): similar to male except no dark midlateral stripe and yellow stripes between horizontal scale rows of side are more obvious. Al-

so, the white tips on the caudal lobe are more diffuse and less obvious.

Colour of holotype in alcohol (Fig. 5): generally brown to tan except dark brown dorsally on head and midline of nape; scales of upper half of body with narrow brown or greyish margins; diffuse grey midlateral stripe from just above pectoral fin to caudal-fin base; fins generally semi-translucent greyish with 2-3 rows of brownish spots on basal half; small black spot on posterior-most portion of membrane of first dorsal fin.

Comparisons: *M. albimarginata* is closely related to another Aru endemic species, *M. patoti*. Although the known ranges of the two species are only about 35 km apart, they are well separated by two major saltwater channels (Sungai Workai and Sungai Maikoor) that completely bisect the southern Arus, forming a marine barrier between Kobroor *(M. albimarginata)* and Trangan *(M. patoti)* islands.

M. albimarginata and *M. patoti* are easily separated on the basis of live *in situ* colour patterns (compare Figs 3 and 11). Although intraspecific colour variation is well documented in rainbowfishes, there is mounting evidence that many so called geographic "variants" are actually genetically distinct valid taxa. *Melanotaenia trifasciata* (Rendahl 1922) of northern Australia and the related *M. goldiei* of southern New Guinea provide excellent examples of this phenomenon (Unmack et al. 2013). The adult male colour pattern of *M. albimarginata*, which incorporates prominent features including a dark midlateral stripe with a yellow stripe just below, and substantial white tips on the caudal-fin lobes is unique among the "Australis" group of *Melanotaenia*. The magnitude of the differences between *M. albimarginata* and *M. patoti* is certainly consistent with interspecific colour pattern differences within the family.

The two species share a wide range of morphological and meristic features as would be expected for closely related sister species. The only consistent difference involves the depth of the caudal peduncle, which is generally more slender in *M. albimarginata* (9.6-10.9 % of SL vs. 11.2-12.5 % SL for *M. patoti)*. There is also a slight difference in the number of lateral scales, usually 35 in *M. albimarginata* and 33 or 34 in *M. patoti*. Finally, there is a

Fig. 6. Type locality of *Melanotaenia albimarginata*, Alur Warnafa, a triburary of Sungai Unmar, Kobroor Island, Aru Islands (site 4). Photo by G. R. Allen.

tendency towards more cheek scales in *M. albimarginata* (average 15.1) compared with *M. patoti* (average 12.8). The reader is referred to the description of *M. aruensis* below for further comparisons with *M. albimarginata*.

Distribution and habitat: This species is known only from Alur Warnafa, a triburary of Sungai Unmar (Fig. 6), a small stream situated near the village of Algadang. The location is reached via Sungai Workai, a marine "river" that bisects the main island group. Sungai Unmar is reached via a 38 km transit from the west coast and then an additional 7 km upstream in fresh water. The lowermost km of the river is brackish and lined with mangrove. During the January 2013 visit to the type locality the water was very clear and slow flowing with depths ranging from about 1-3 m. Water levels were generally higher with stronger current, and reduced visibility during the December 2013 visit due to the onset of monsoonal rains. The bottom at this site consists of a relatively smooth limestone pavement with few aquatic plants *(Cryptocoryne cilliata),* littered with leaf and log debris. The new species repeatedly retreated among the dead branches of fallen trees when pursued. The stream formed a more or less open corridor lined with second growth forest and gardens. The pH and conductivity values for this site ranged from 8.04-8.64 (high tide) and 144-319 μS (high tide) respectively during the January visit. In addition, a water temperature of 27.4 °C was recorded. Although the site is purely a freshwater habitat, water levels are influenced by the tides. *Melanotaenia senckenbergianus* was also observed at this site, but generally in smaller numbers. Other species that were recorded include *Craterocephalus* cf. *randi* Nichols & Raven 1934, *Ambassis interrupta* Bleeker 1853, *Glossamia aprion* (Richardson 1842), *Awous acritosus* Watson 1994, *Glossogobius concavifrons* (Ramsay & Ogilby 1886), *Redigobius bikolanus* (Herre 1927), *Stiphodon atratus* (Watson 1996), *Eleotris fusca* (Forster 1801), and *Oxyeleotris mertoni* (Weber 1911).

Etymology: This species is named *albimarginata* (Latin: "white-margin") with reference to the prominent white markings on the caudal fin lobes.

Melanotaenia aruensis, n. sp.

Aru Rainbowfish

(Figs 7-9, Tables II & IV)

Holotype: MZB 22250, male, 76.4 mm SL, Sungai Sin (site 2, Fig. 2), 6° 30.125'S, 134° 20.227'E, Trangan Island, Aru Islands, Maluku Province, Indonesia, seine net, G. R. Allen, M. Erdmann, M. Brooks & H. Bleher, 25 January 2013.

Paratypes: MZB 22248, 3 specimens, 53.9-60.5 mm SL, collected with holotype; MZB 22249, 5 specimens, 47.4-68.8 mm SL, un-named creek (site 3, Fig. 2), 6° 14.114'S, 134° 29.751'E, Kobroor Island, Aru Islands, Maluku Province, Indonesia, seine net, G. R. Allen, M. Erdmann, M. Brooks & H. Bleher, 27 January 2013; WAM P.33831-002, 4 specimens, 49.5-61.0 mm SL, collected with holotype; WAM P.33833-001, 6 specimens, 38.5-66.7 mm SL, collected with MZB 22249.

Fig. 7. Underwater photograph of *Melanotaenia aruensis*, male, approximately 70 mm SL, Sungai Sin, Trangan Island, Aru Islands. Photo by G. R. Allen.

Diagnosis: A species of melanotaeniid rainbowfish distinguished by the following combination of characters: dorsal rays V to VII-I,10-13; anal rays I,20-23; pectoral rays 14-15; lateral scales 34-36, predorsal scales 15-18; cheek scales 13-19; total gill rakers on first arch 17-18; greatest body depth of adult male 35.1 % SL; least depth of caudal peduncle 9.5-11.1 % SL; colour in life grey-brown dorsally on head, nape, and adjacent anterodorsal portion of body; posterior two-thirds of upper half of body bluish grey with narrow bronze margin around each scale and bronze stripe between each horizontal scale row; dorsal and caudal fins semi-translucent grey, second dorsal fin with relatively broad whitish margin. Maximum size to 76.4 mm SL or 93 mm TL.

Description: Dorsal rays VI-I,12 (V to VII-I,10-13); anal rays I,23 (20-23); pectoral rays 14 (14-15); pelvic rays I,5; branched caudal rays 15; lateral scales 35 (34-36); transverse scales 10 (10-12); predorsal scales 18 (15-18); cheek scales 19 (13-19); total gill rakers on first arch 18 (17-18).

Body depth 2.9 (3.0-3.7) in SL; greatest body depth by sex and size class as follows: *males* –

Fig. 8. Aquarium photograph of freshly collected holotype of *Melanotaenia aruensis*, male, 76.4 mm SL, Sungai Sin, Trangan Island, Aru Islands. Photo by G. R. Allen.

Fig. 9. *Melanotaenia aruensis*, preserved male holotype, 76.4 mm SL, Sungai Sin, Trangan Island, Aru Islands. Photo by G. R. Allen.

Table IV. Proportional measurements of selected type specimens of *Melanotaenia aruensis* expressed as percentage of the standard length.

	Holotype MZB 22250	Paratype WAM P.33833	Paratype WAM P.33831	Paratype MZB 22249	Paratype MZB 22249	Paratype WAM P.33831	Paratype MZB 22249	Paratype WAM P.33833
Sex	male	male	male	male	female	female	female	female
Standard length (mm)	76.4	66.7	61.0	60.0	68.8	58.8	53.4	50.4
Body depth	35.1	31.8	33.1	33.0	28.5	31.1	30.1	29.8
Body width	12.7	13.6	13.1	12.5	12.9	12.6	12.9	13.9
Head length	27.7	26.5	28.4	26.7	24.9	28.7	27.7	28.8
Snout length	9.2	8.4	9.0	8.3	8.7	9.2	8.8	9.5
Maxillary length	7.2	7.5	8.5	7.5	6.7	8.0	7.5	8.3
Eye diameter	9.8	9.0	10.5	9.7	9.4	10.9	10.1	10.9
Bony interorbital width	10.1	8.7	10.2	9.8	9.4	10.4	10.5	10.1
Depth of caudal peduncle	11.1	10.3	10.3	10.8	10.0	10.0	10.3	9.9
Length of caudal peduncle	16.2	17.1	17.0	18.2	17.9	17.7	18.4	18.7
Predorsal distance	48.0	47.5	49.0	47.5	46.8	50.2	49.3	47.8
Preanal distance	50.1	49.9	51.1	51.3	48.8	55.1	52.2	52.6
Prepelvic distance	38.2	37.3	38.7	40.2	35.3	41.3	39.1	40.1
2nd dorsal fin base	24.5	23.2	22.5	24.2	20.8	21.4	18.7	21.2
Anal fin base	39.3	37.8	38.0	38.0	33.9	35.5	34.3	35.1
Pectoral fin length	19.0	16.8	18.9	19.8	16.1	19.6	18.5	18.7
Pelvic fin length	12.8	15.7	13.1	12.5	12.9	14.3	14.0	12.5
Longest ray 1st dorsal fin	22.0	22.0	17.5	21.0	15.0	12.1	13.3	14.1
Longest ray 2nd dorsal fin	13.4	18.3	12.3	16.8	11.9	14.3	13.5	12.3
Longest anal ray	13.0	17.7	13.9	16.0	12.5	11.6	10.9	11.9
Caudal fin length	21.6	22.0	23.4	20.2	19.6	24.1	19.9	19.4
Caudal concavity	6.4	6.0	6.4	3.3	5.1	8.7	6.2	3.8

50-64 mm SL, 30.2-33.4 % SL ($\bar{x}$ = 32.0, N = 6); *males* – 65-79 mm SL, 31.8-35.1 (holotype) % SL ($\bar{x}$ = 33.4, N = 2); *females* – < 50 mm SL, 27.2-30.1 % SL ($\bar{x}$ = 29.4, N = 3); *females* – 50-64 mm SL, 26.8-31.1 % SL ($\bar{x}$ =29.4, N = 8); *female* – 68.8 mm SL, 28.5 % SL; head length 3.6 (3.4-4.0) in SL; greatest width of body 2.8 (2.1-2.6) in greatest body depth; snout length 3.0 (2.9-3.3) in HL; eye diameter 2.8 (2.6-3.0) in HL; interorbital width 2.8 (2.6-3.1) in HL; depth of caudal peduncle 2.5 (2.5-3.1) in HL; length of caudal peduncle 1.7 (1.4-1.7) in HL.

Jaws about equal, oblique, premaxilla with an abrupt bend between the anterior horizontal portion and lateral part; maxilla not reaching level of anterior edge of eye; maxillary length 3.9 (3.3-3.8) in HL; lips thin; teeth conical with slightly curved tips, extending on to outer surface of lips; teeth of upper jaw in 3-4 irregular rows anteriorly, reduced to a single row posteriorly, where they are exposed when mouth is closed; teeth in lower jaw in about 5-7 irregular rows anteriorly, reduced to 1 or 2 rows posteriorly; narrow row containing small, conical teeth on vomer and palatines.

Scales of body cycloid, relatively large, and arranged in regular horizontal rows; scale margins smooth to weakly crenulate; predorsal scales extending forward to about middle of interorbital space; preopercle with 2-3 scale rows between its posterior angle and eye.

Predorsal length 2.1 (2.0-2.1) in SL; preanal length 2.0 (1.8-2.0) in SL; prepelvic length 2.6 (2.4-2.8) in SL; length of second-dorsal fin base 4.1 (4.1-5.3); length of anal-fin base 2.5 (2.6-3.0).

First dorsal fin origin about level with anal fin origin; longest spine (usually third) of first dorsal fin 1.3 (1.2-2.4) in HL, its depressed tip reaching spine of second dorsal fin or slightly posterior in fe-

males and reaching to about base of third to fifth soft ray in mature males; longest rays (generally anterior ones in females and penultimate in males) of second dorsal fin 2.1 (1.5-2.3) in HL, the depressed posterior rays extending less than one half length of caudal peduncle in females and two-thirds length to nearly full length of caudal peduncle in mature males; longest (middle rays in females and penultimate in males) anal rays 2.1 (1.5-2.6) in HL; pelvic fin tips when depressed reaching nearly to origin of anal fin in females and to base of first soft anal-fin ray in mature males; length of pelvic fins 2.2 (1.7-2.3) in HL; length of pectoral fins 1.5 (1.3-1.6) in HL; length of caudal fin 1.3 (1.2-1.5) in HL; caudal fin moderately forked, caudal concavity 4.3 (3.3-8.0) in HL.

Colour in life of male (from *in situ* underwater photograph, Fig. 7): grey-brown dorsally on head, nape, and adjacent anterodorsal portion of body; upper rear portion of cheek and adjacent portion of operculum pale yellow with metallic reflection; iris mostly pale yellow; posterior two-thirds of upper half of body bluish grey with narrow bronze margin around each scale and bronze stripe between each horizontal scale row; lower half of head and body white to pale grey; dorsal and caudal fins semitranslucent grey, second dorsal fin with relatively broad whitish margin; anal fin dusky grey with bronzy suffusion basally and broad white outer margin; pelvic fins greyish except white at base and near posterior tip; pectoral fins translucent. Freshly collected live fish (Fig. 8) photographed in an aquarium were similar in appearance except the membranous portion of the first dorsal fin is orange and orange colouration is present basally on the second dorsal fin and very prominent on the basal half of the anal fin. The female is similar to the male, except colours are less vivid, particularly the orange and bronzy hues. Individuals from Kobroor Island lack the broad white margins on the dorsal and anal fins.

Colour of holotype in alcohol (Fig. 9): generally brown dorsally on head and adjacent anterodorsal portion of body; remainder of upper side lighter brown with dark brown scale margins; side of head and lower half of body yellowish white with silvery reflections; dark grey mid-lateral stripe, about two scales wide, extending from above pectoral-fin to caudal-fin base; fins generally semitranslucent whitish to slightly grey.

Fig. 10. Type locality of *Melanotaenia aruensis*, Sungai Sin, Trangan Island, Aru Islands (site 2). Photo by H. Bleher.

Comparisons: *M. aruensis* is superficially similar in general appearance to the other two members of the "Australis" group of species that inhabit the Aru Islands. However, genetic results (see genetic discussion below) indicate a closer relationship with species from northern Australia. The general *in situ* colour pattern is particularly similar to *M. patoti* (compare Figs 8 and 12). Both species possess a large brownish zone that encompasses the anterodorsal portion of the body and upper head, giving way to conspicuous orange or bronze stripes on the posterior side. The species are separable on the basis of caudal peduncle depth (9.5-11.1 % SL vs. 11.2-12.5 % *for M. patoti)* and the maxillary of *M. aruensis* is generally longer than that of *M. patoti* (average length 6.8 vs. 7.7 % SL). The cheek is usually covered by more scales in *M. aruensis* (average 15.1 vs. 12.8) and this species usually has one more circumpeduncular scale (average 12.9 vs. 12.0). In addition, the eye of males in excess of 60 mm SL is larger *in M. aruensi*s (9.7-10.5 % SL vs. 7.5-8.0 % for *M. patoti).* However, these comparisons are based on only a few specimens and more data is needed to confirm the differences.

Despite a marked genetic separation there are few differences between *M. aruensis* and *M. albimarginata* besides their very different *in situ* colour patterns (compare Figs 3 and 7). These two species are geographically separated by a distance of only 5 km, but reside in different drainages that flow into the marine waters of Sungai Workai. The only morphometric feature of possible use in separating the two species is eye diameter, which tends to be slightly larger in *M. aruensis* (average 9.0 vs. 10.0 % SL), although there is some overlap in the range of the two species.

Distribution and habitat: This species is known from two locations, the type locality on Trangan Island and a small river on southern Kobroor Island. The two locations are separated by a distance of 34 km, and current day saltwater barriers in the form of Sungai Workai and Sungai Maikoor. The type locality (Fig. 10) is situated in luxuriant rainforest on the downstream side of a spectacular 75 m-long limestone tunnel. The stream was approximately 10-12 m wide with depths ranging from about 0.5-2.0 m. The water was relatively clear and slow-flowing with a rocky limestone bottom and abundant cover mainly in the form of submerged fallen tree limbs. The site on Kobroor Island, also lined by luxuriant forest was 15-20 m wide, 1-3 m deep, clear, and slow flowing. The margins of the channels were characterised by abundant, partially submerged terrestrial plants, which offered abundant shelter for small fishes. Temperature, pH, and conductivity values of 26.5 °C, 8.03, and 144 μS respectively were recorded in January 2013. The new species was common at both sites.

Etymology: This species is named *aruensis* with reference to the Aru Islands type locality.

Melanotaenia patoti Weber 1907

Patoti's Rainbowfish

(Figs 11-13, Tables II & V)

Melanotaenia patoti Weber 1907: 403 (rivulet at Nigri Lama, west coast Terangan Island, Aru Islands).

Melanotaenia patoti Weber & deBeaufort 1922: 291, Fig. 77 (Aru Islands).

Material examined (6 specimens, 54.6-87.9 mm SL): ZMA 103199, 77.0 mm SL (lecto-holotype), Terangan (now spelled Trangan) Island, Aru Islands; WAM P.33832-002, 5 specimens, 54.6-87.9 mm SL, Trangan Island, Aru Islands (site 1, Fig. 2).

Diagnosis: A species of melanotaeniid rainbowfish distinguished by the following combination of characters: dorsal rays V-VI-I,11-12; anal rays I,20-21; pectoral rays 15; lateral scales 33-34, predorsal scales 16-17; cheek scales 12-14; total gill rakers on first arch 16-18; greatest body depth of adult male 36.9 % SL; colour in life generally greenish brown to bluish, grading to silvery white ventrally with series of orange-red stripes on side of body. Maximum size to 87.9 mm SL or 108 mm TL.

Redescription: Dorsal rays V-VI-I,11-12; anal rays I,20-21; pectoral rays 15; pelvic rays I,5; branched caudal rays 15; lateral scales 33-34; transverse scales 11; predorsal scales 16-17; cheek scales 12-14; total gill rakers on first arch 16-18.

Body depth 2.7-3.1 in SL; head length 3.5-4.1 in SL; greatest width of body 2.3-2.9 in greatest body depth; snout length 3.0-3.7 in HL; eye diameter 2.9-3.5 in HL; interorbital width 2.7-3.1 in HL; depth of caudal peduncle 2.0-2.5 in HL; length of caudal peduncle 1.6-1.9 in HL.

Jaws about equal, oblique, premaxilla with an abrupt bend between the anterior horizontal portion and lateral part; maxilla ends before anterior edge of eye; maxillary length 3.7-3.9 in HL; lips thin; teeth conical with slightly curved tips, extending on to outer surface of lips; teeth of upper jaw in 3-4 irregular rows anteriorly, reduced to a

single row posteriorly, where they are exposed when mouth is closed; teeth in lower jaw in about 6-7 irregular rows anteriorly, reduced to 1 or 2 rows posteriorly; narrow row containing several small, conical teeth on vomer and palatines.

Scales of body cycloid, relatively large, and arranged in regular horizontal rows; scale margins smooth to weakly crenulate; predorsal scales extending forward to about middle of interorbital space; preopercle with 2 scale rows between its posterior angle and eye.

Predorsal length 2.0-2.2 in SL; preanal length 1.9-2.1 in SL; prepelvic length 2.6-2.8 in SL; length of second-dorsal fin base 3.6-4.8; length of anal-fin base 2.4-2.6.

First dorsal fin origin about level with or slightly anterior to anal fin origin; longest spine (usually third) of first dorsal fin 1.4-2.1 in HL, its depressed tip reaching spine of second dorsal fin or slightly posterior in females and reaching to about base of third to fifth soft ray in mature males; longest rays (generally anterior ones in females and penultimate in males) of second dorsal fin 1.6-2.2 in HL, the depressed posterior rays extending about one half length of caudal peduncle in females and nearly full length of caudal peduncle in

Fig. 11. Underwater photograph of *Melanotaenia patoti*, male, approximately 80 mm SL, Sungai Galalou, Trangan Island, Aru Islands. Photo by G. R. Allen.

Fig. 12. Aquarium photograph of freshly collected specimen (WAM P.33832-002) of *Melanotaenia patoti*, male, 87.9 mm SL, Sungai Galalou, Trangan Island, Aru Islands. Photo by G. R. Allen.

mature males; longest (middle rays in females and penultimate in males) anal rays 1.3-2.4 in HL; pelvic fin tips when depressed reaching nearly to origin of anal fin in females and to base second or third soft anal-fin ray in mature males; length of pelvic fins 1.4-2.0 in HL; length of pectoral fins 1.4-1.5 in HL; length of caudal fin 1.1-1.5 in HL; caudal fin moderately forked, caudal concavity 4.0-6.2 in HL.

Colour in life (from *in situ* underwater photograph, Fig. 11): greenish brown on top of head, nape, and anterior back; lower half of head silvery white; 4-5 alternating greenish brown and orange-red stripes on upper half of sides, darker stripes covering about one-half of each horizontal scale row with slightly narrower reddish stripes between, stripe pattern most conspicuous on rear half of body; lower half of body silvery white with hint of pale orange stripes between horizontal scale rows; dorsal fins greyish with narrow white outer margin on second dorsal; anal fin white to orange basally, grading to greyish on outer half; caudal fin semi-translucent grey; pelvic fins greyish brown; pectoral fins translucent. Freshly collected live fish (Fig. 12) photographed in an aquarium with similar pattern except overall pale bluish with orange-red stripes on side between each horizontal scale row.

Colour in alcohol (Fig. 13): generally brown on dorsal half of body and pale yellow with silvery reflections on lower half; diffuse grey mid-lateral stripe along middle of side, occupying about two horizontal scale rows; faint indication of orange-red (now tan) stripes on upper side described under live colouration; fins generally greyish; small black spot on posteriormost portion of membrane of first dorsal fin of males.

Comparisons: Based on morphology, *M. patoti* is similar to *M. rubrostriata*, which is widespread in southern New Guinea, particularly in alluvial lowlands. Allen & Cross (1982) regarded *M. patoti* as a junior synonym of *M. splendida rubrostriata* (now regarded as a valid species, distinct from *M. splendida* (Peters 1866) of Australia). Genetic data presented here indicates that these species belong to the "Australis" group, forming a subclade with *M. albimarginata* as its nearest relative along with several Australian species (including *M. australis* (Castelnau 1875), *M. eachamensis* Allen & Cross 1982 and introgressed Leichhardt Springs *M. trifasciata* I), despite its close physical resemblance to *M. rubrostriata*. The closest relative based on morphology is *M. aruensis*, which is described above and the reader is referred to the comparisons section for that species.

Fig. 13. *Melanotaenia patoti*, preserved male specimen (WAM P.33832-002), 87.9 mm SL, Sungai Galalou, Trangan Island, Aru Islands. Photo by G. R. Allen.

Table V. Proportional measurements for specimens of *Melanotaenia patoti* expressed as percentage of the standard length.

	WAM P.33832	WAM P.33832	WAM P.33832	WAM P.33832	WAM P.33832
Sex	male	male	female	female	female
Standard length (mm)	87.9	78.5	81.3	69.8	54.6
Body depth	36.9	35.9	35.1	35.5	32.2
Body width	12.7	13.5	13.2	14.0	14.1
Head length	26.3	24.3	25.0	26.5	28.6
Snout length	8.0	7.3	8.4	8.0	7.7
Maxillary length	6.8	6.6	6.4	6.9	7.3
Eye diameter	7.5	8.0	8.6	8.5	9.5
Bony interorbital width	9.2	8.3	9.2	9.2	9.3
Depth of caudal peduncle	12.5	12.0	11.2	11.5	11.4
Length of caudal peduncle	13.9	15.2	15.3	16.8	17.2
Predorsal distance	47.2	45.4	48.6	49.1	49.8
Preanal distance	48.1	50.3	52.0	51.7	52.2
Prepelvic distance	36.3	36.6	38.1	37.2	38.8
2nd dorsal fin base	27.8	25.0	24.2	24.6	20.9
Anal fin base	42.0	40.0	38.4	39.3	38.3
Pectoral fin length	19.5	16.1	17.7	17.8	19.8
Pelvic fin length	18.2	14.4	12.4	13.8	14.1
Longest ray 1st dorsal fin	19.2	17.6	14.6	13.2	13.9
Longest ray 2nd dorsal fin	16.0	12.4	13.0	13.0	13.0
Longest anal ray	19.8	10.7	12.4	12.2	11.9
Caudal fin length	23.1	19.1	17.1	21.3	24.7
Caudal concavity	6.5	5.1	4.8	4.3	7.1

Similar to most *Melanotaenia,* males are deeper bodied than females and have a more elongate, pointed shape posteriorly on the soft dorsal and anal fins. The body depth (as % of SL) of two males, 78.5-87.9 mm SL, ranged from 35.9-36.9 with an average of 36.4; that of 3 females, 54.6-81.3 mm SL, was 32.2-35.5 with an average of 34.3 mm SL.

Distribution and habitat: This species is known only from the vicinity of the type locality on Trangan Island, the southernmost large island in the main Aru Group (Figs 1-2). The type specimens were collected from a small creek close to the coast. Recent specimens (forming most of the basis of this redescription) were collected by the first author and M. Erdmann in January 2013 from within 5 km of the type locality. The habitat consisted of a creek adjacent to a foot-bridge crossing, about 0.25 km from a small village. The stream was slow flowing with a soft, muddy bottom with abundant aquatic vegetation and leaf and log litter. There was also considerable trash in the creek, owing to its proximity to the village. Nevertheless, *M. patoti* was relatively abundant, as was another rainbowfish, *M. senckenbergianus*. Values for pH, conductivity, and temperature of 8.0, 98 μS, and 28.1 °C respectively were recorded.

Etymology: This species was named *patoti* in recognition of its first collector W. F. Tissot van Patot who visited the islands in 1907.

Melanotaenia kolaensis, n. sp.

Kola Rainbowfish

(Figs 14-16, Tables VI & VII)

Holotype: MZB 22252, male, 78.8 mm SL, Sungai Marjina (site 10, Fig. 2), 5° 30.745'S, 134° 37.250'E, tributary of Sungai Tasinwalas, Kola Island, Aru Islands, Maluku Province, Indonesia, seine net, R. Hadiaty and party, 6 December 2013.

Paratypes: MZB 21719, 45 specimens, 25.7-65.2 mm SL, collected with holotype; MZB 21720, 6 specimens, 51.6-78.4 mm SL, collected with holotype; MZB 21717, 9 specimens, 17.9-29.1 mm SL, ethanol collection, collected with holotype. MZB 21737, 9 specimens, 32.6-44.4 mm SL, Sungai Kofukim (site 11, Fig. 2), 5° 029.358'S, 134° 33.115'E, tributary of Sungai Batu Putih,

Kolas Island, Aru Islands, Maluku Province, Indonesia, seine net, R. Hadiaty and party, 7 December 2013; MZB 21746, 6 specimens, 22.6-29.5 mm SL, same data as MZB 21737; MZB 21730, 7 specimens, 17.5-33.4 mm SL, ethanol collection, same data as MZB 21737; USNM 32450, 5 specimens, 33.4-44.0 mm SL, same data as MZB 21737; WAM P.34297-001, 7 specimens, 32.8-44.7 mm SL, same data as MZB 21737.

Diagnosis: A species of melanotaeniid rainbowfish distinguished by the following combination of characters: dorsal rays IV-VI-I,12-13; anal rays I,18-21; pectoral rays 13-14 (most frequently13); lateral scales 33-34 (rarely 34), predorsal scales 14-16; cheek scales 17-23; total gill rakers on first arch 16-18; greatest body depth of adult male 36.2 % SL; colour in life generally light blue to blue-green on back; dark blue midlateral stripe (1-2 scales wide), especially conspicuous on posterior third of body, edged below with prominent white to pale blue stripe that occupies lowermost part of caudal peduncle, extending forward to middle of sides; ventral portion of body greyish-white to pale blue except pair of dark blue, irregular stripes often present above anal fin and large, bright blue patch just behind and below pectoral-fin base; second dorsal, anal and caudal fins with reddish suffusion. Maximum size to 78.8 mm SL or 94 mm TL.

Description: Dorsal rays VI-I,13 (IV-VI-I,12-13); anal rays I,20 (18-21); pectoral rays 13 (13-14); pelvic rays I,5; branched caudal rays 15; lateral scales 33 (33-34); transverse scales 10 (10-11); predorsal scales 15 (14-16); cheek scales 23 (17-21); total gill rakers on first arch 16 (17-18).

Body depth 2.8 (3.0-3.6) in SL; greatest body depth by sex and size class as follows: *males* – < 50 mm SL, 31.4-31.6 % SL ($\bar{x}$ = 31.5, N = 2); *males* - 50-64 mm SL, 28.9-33.6 % SL ($\bar{x}$ = 31.7, N = 10); *male* – 78.8 mm SL (holotype), 36.8 % SL; *female* – 45.7 mm SL, 30.0 % SL; *females* – 50-64 mm SL, 28.1-28.7 % SL ($\bar{x}$ = 28.4, N = 2); *female* – 65.2 mm SL, 32.2 % SL; head length 3.6 (3.4-3.7) in SL; greatest width of body 2.3 (2.1-2.5) in greatest body depth; snout length 2.5 (2.8-3.0) in HL; eye diameter 3.5 (2.9-3.3) in HL; interorbital width 2.5 (2.5-2.9) in HL; depth of caudal peduncle 2.3 (2.4-2.9) in HL; length of caudal peduncle 1.9 (1.6-1.8) in HL.

Jaws about equal, oblique, premaxilla with an abrupt bend between the anterior horizontal portion and lateral part; maxilla reaching level of anterior edge of eye; maxillary length 2.5 (2.5-2.9) in HL; lips thin; teeth conical with slightly curved tips, extending on to outer surface of lips; teeth of upper jaw in 4-5 irregular rows anteriorly, reduced to a single row posteriorly, where they are exposed when mouth is closed; teeth in lower jaw in about 6-8 irregular rows anteriorly, reduced to 1 or 2 rows posteriorly; narrow row containing several small, conical teeth on vomer and palatines.

Scales of body cycloid, relatively large, and arranged in regular horizontal rows; scale margins smooth to weakly crenulate; predorsal scales extending forward to about middle of interorbital

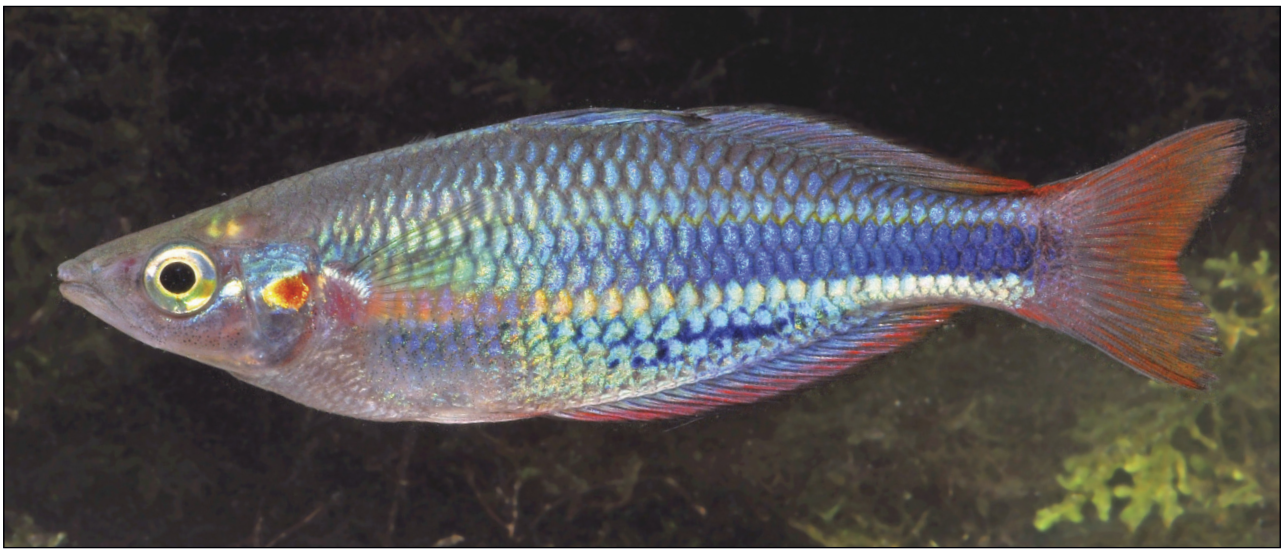

Fig. 14. Aquarium photograph of freshly collected holotype of *Melanotaenia kolaensis*, male, 78.8 mm SL, Sungai Marjina, Kola Island, Aru Islands. Photo by G. R. Allen.

Table VI. Summary of counts for fin-rays, scales, and total gill rakers on first arch for *Melanotaenia kolaensis, M. picta* and *M. senkenbergianus,* and *M. wokamensis.*

	1st Dorsal Spines				2nd Dorsal Soft Rays						Anal Soft Rays				
	IV	**V**	**VI**		**11**	**12**	**13**	**14**	**15**		**12**	**13**	**14**	**15**	**16**
M. kolaensis	1	15	14			14	16					20	10		
M. picta		20	7		2	8	13	4				2	21	3	1
M. senckenberg.	1	22	16		1	7	29	21	1		4	22	6		
M. wokamensis	1	23	7		6	15	9	1			3	25	3		

	Anal Soft Rays						Lateral Scales			
	18	**19**	**20**	**21**	**22**	**23**	**33**	**34**	**35**	**36**
M. kolaensis	1	4	8	2			5	5		
M. picta		1	5	16	2	3			11	17
M. senckenberg.			8	22	9	1	1	2	12	5
M. wokamensis	2	7	15	6	1		3	15	3	

	Transverse Scales				Predorsal Scales					
	9	**10**	**11**	**12**	**14**	**15**	**16**	**17**	**18**	**19**
M. kolaensis			5	6	2	3	1			
M. picta				18			18	6	2	1
M. senckenberg.	2	8	17	5			7	16	6	1
M. wokamensis	2	16			8	13	5			

	Prepelvic Scales							Peduncle Scales		
	15	**16**	**17**	**18**	**19**	**20**	**21**	**12**	**13**	**14**
M. kolaensis	2	16	4					11	13	
M. picta				1	9	6	2	4	16	
M. senckenberg.			2	18	7	2		2	14	14
M. wokamensis		8	12	8					18	3

	Gill Rakers				
	15	**16**	**17**	**18**	**19**
M. kolaensis		5	12	12	
M. picta	1	4	6	12	6
M. senckenberg.			15	12	
M. wokamensis	3	15	3		

	Cheek Scales												
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23+**
M. kolaensis							5	9	7	3	1	1	1
M. picta						1			2	4	10	10	
M. senckenberg.					2	2	4	6	6	8	4	3	6
M. wokamensis	2	2	6	6	5	1	1						

space; preopercle with 2-3 scale rows between posterior angle and eye.

Predorsal length 2.0 (2.0-2.2) in SL; preanal length 2.1 (1.8-2.1) in SL; prepelvic length 2.7 (2.4-2.8) in SL; length of second-dorsal fin base 3.5 (3.5-4.4); length of anal-fin base 2.4 (2.6-3.1).

First dorsal fin origin slightly anterior to level of anal fin origin; longest spine (usually third) of first dorsal fin 1.2 (1.4-2.3) in HL, its depressed tip reaching spine of second dorsal fin or slightly posterior in females and reaching to about base of second to fourth soft ray in mature males; longest rays (generally anterior ones in females and penultimate in males) of second dorsal fin 1.3 (1.4-2.3) in HL,

the depressed posterior rays extending about one half length of caudal peduncle in females and nearly full length of caudal peduncle in mature males; longest (middle rays in females and penultimate in males) anal rays 1.8 (1.8-2.7) in HL; pelvic fin tips when depressed reaching nearly to origin of anal fin in females and to base of first or second soft anal-fin ray in mature males; length of pelvic fins 1.7 (1.5-2.1) in HL; length of pectoral fins 1.4 (1.4-1.6) in HL; length of caudal fin 1.5 (1.4-1.5) in HL; caudal fin moderately forked, caudal concavity 4.9 (4.7-5.7) in HL.

Colour in life of male holotype (from aquarium photograph of freshly captured specimen, Fig. 14): grey-brown dorsally on head, nape, and predorsal region; cheek and side of snout blue grey, cheek usually with silvery reflections; operculum blue-grey with prominent pale-edged, red spot (about two-thirds pupil size); iris pale yellow to silvery-white with tan patch at lower rear corner; scales of upper back blue with narrow brown margins; dark blue to blackish midlateral stripe (1-2 scales wide), especially conspicuous on posterior third of body, edged below with prominent white to pale blue stripe that occupies lowermost part of caudal peduncle, extending forward to middle of

Fig. 15. Aquarium photograph of freshly collected paratype (MZB 21719) of *Melanotaenia kolaensis*, juvenile, 35.0 mm SL, Sungai Marjina, Kola Island, Aru Islands. Photo by G. R. Allen.

Fig. 16. *Melanotaenia kolaensis*, preserved male holotype, 78.8 mm SL, Sungai Marjina, Kola Island, Aru Islands. Photo by G. R. Allen.

Table VII. Proportional measurements of selected type specimens of *Melanotaenia kolaensis* expressed as percentage of the standard length.

	Holotype MZB 22252	Paratype MZB 21719	Paratype MZB 21719	Paratype MZB 21719	Paratype MZB 21719	Paratype MZB 21719	Paratype MZB 21719
Sex	male	male	male	male	female	female	female
Standard length (mm)	78.8	63.6	63.1	59.3	65.2	62.4	51.3
Body depth	36.2	32.7	33.6	32.4	32.2	28.7	28.1
Body width	15.5	13.1	13.9	13.8	15.0	13.6	13.5
Head length	27.8	26.7	28.2	29.3	28.7	28.7	29.8
Snout length	11.0	9.1	9.5	9.9	8.9	9.6	10.7
Maxillary length	10.9	10.7	10.8	10.5	10.0	11.4	11.9
Eye diameter	8.0	9.0	9.2	9.4	9.4	8.8	10.1
Bony interorbital width	10.9	10.2	11.1	10.3	10.7	10.6	10.9
Depth of caudal peduncle	12.1	11.3	11.4	11.1	10.9	10.1	10.1
Length of caudal peduncle	15.0	14.5	16.0	17.9	17.9	17.3	17.9
Predorsal distance	46.3	45.8	47.5	48.9	46.9	49.2	47.2
Preanal distance	47.7	47.8	51.2	50.8	51.7	53.4	54.4
Prepelvic distance	37.1	36.2	38.2	38.3	39.0	40.1	40.9
2nd dorsal fin base	28.8	28.5	27.1	24.8	25.5	22.8	24.2
Anal fin base	41.6	38.8	37.6	37.1	33.0	33.0	32.6
Pectoral fin length	20.2	18.7	18.1	19.9	18.1	19.7	18.9
Pelvic fin length	16.1	16.7	15.2	17.0	13.7	15.4	19.9
Longest ray 1st dorsal fin	22.5	17.9	20.8	20.4	11.8	12.7	13.8
Longest ray 2nd dorsal fin	22.0	18.7	18.7	19.6	11.3	12.0	11.3
Longest anal ray	15.9	15.7	15.4	15.5	10.6	12.2	10.9
Caudal fin length	19.2	18.4	19.8	21.4	18.3	19.9	21.1
Caudal concavity	5.7	5.7	4.9	5.6	4.3	5.8	6.0

sides; ventral portion of body greyish-white to pale blue except pair of dark blue, irregular stripes between scale rows, often present above anal fin and large, bright blue patch just behind and below pectoral-fin base; first dorsal fin bluish; second dorsal fin blue, grading to red posteriorly and on outer edge of fin; anal fin blue basally and broadly red on outer portion; caudal fin red; pelvic fins white; pectoral fins semitranslucent. Paratypes were generally similar, although there is some variation in the intensity of the pale stripe on the lower caudal peduncle, which varies from brilliant white to pale blue. Females are generally similar to males, but with slightly less vivid colours. Juveniles (Fig. 15) conform to the general *M. senckenbergianus* pattern except for an irregular dark blue strip on the ventral side, diffuse anteriorly and becoming more vivid above the anal fin.

Colour of holotype in alcohol (Fig. 16): generally brown dorsally on head and upper half of body, tan to whitish on lower half with diffuse blackish midlateral stripe (1-2 scales wide), except diffuse and conspicuous on caudal peduncle and adjacent posterior body; white stripe immediately below dark midlateral stripe evident on ventral portion of caudal peduncle, extending forward to middle of side; several scales of lower side, above posterior half of anal fin, with blackish margins; fins generally semitranslucent pale grey.

Comparisons: Based on morphology *M. kolaensis* is closely allied to *M. picta* n. sp., *M. wokamensis* n. sp. and *M. senckenbergianus*. It is most similar to *M. wokamensis*. The two species inhabit the adjacent islands of Kola and Wokam in the northern Aru Group. The populations are separated by a major saltwater barrier, Sungai Sisirwatu, which varies in width from 100-500 m. The two species exhibit similar colour patterns (Figs 14 and 28-29)

with notable exceptions in the form of a pair of brilliant red-orange stripes on either side of the dark midlateral stripe in *M. wokamensis*, and the lack of these stripes in *M. kolaensis*, which instead has a broad white or pale blue stripe immediately below the dark midlateral stripe. Features that unite this species pairing, which differ from *M. senckenbergianus* and *M. picta* include usual counts of 13 pectoral rays, 33-34 longitudinal scales, 10 horizontal scale rows, and 14-16 predorsal scales (vs. 14, 35-36, 11-12, and 16-19, respectively). The bony interorbital width generally exceeds the snout length in both *M. kolaensis* and *M. wokamensis*, but for adults (> 60 mm SL) of *M. picta* and *M. senckenbergianus* the interobital width is either equal to or less than the snout length. However, *M. kolaensis* and *M. wokamensis* consistently differ from each other in counts for cheek scales (17-23 for *M. kolaensis* vs. 11-16). Although sample size is small (n = 4-5) and more specimens are required to confirm the use of this character, males of *M. kolaensis* appear to have longer rays in the first dorsal, second dorsal, and anal fins (17.9-22.5, 18.7-22.0, and 15.4-15.9 % SL respectively) compared to males of *M. wokamensis* (14.0-17.4, 15.4-18.6, and 12.7-15.3 % SL respectively).

Unfortunately, only one relatively large male, 78.8 mm SL (holotype), was captured, but it has a body depth of 36.2 % SL, which is the highest value recorded for members of the Aru Islands "Goldiei" group and is possibly a useful feature for distinguishing this species. Like *M. wokamensis*, adult males (>59 mm SL) at least, have a relatively deep caudal peduncle, which usually exceeds 11 % SL.

The reader is referred to the comparisons sections below for *M. picta* and *M. wokamensis* for additional discussion of the differences between these species and *M. kolaensis*.

Distribution and habitat: This species is currently known only from two drainages separated by about 7-8 km on Kola, the northernmost large is-

Fig. 17. Type locality of *Melanotaenia kolaensis*, Sungai Marjina, Kola Island, Aru Islands (site 10). Photo by R. Hadiaty.

land of the main Aru Group. The island has an area of about 300 km² and judging from Google Earth images has approximately 10-12 freshwater drainage systems, of which the one (Sungai Tasinwalas) where the type locality is situated penetrates the farthest inland. The type locality (Fig. 17) is situated approximately 11 km upstream from the sea. The main river makes a gradual transition from a broad, mangrove-lined tidal stream with brackish conditions to an exceptionally narrow and steep-walled, limestone channel in woodland habitat with pure fresh water. The fish was located about 100 m beyond the navigable (via small outboard boat) limit of the stream.

Etymology: This species is named *kolaensis* with reference to the Kola Island type locality.

Melanotaenia picta n. sp.
Painted Rainbowfish
(Figs 18-22, Tables VI & VIII)

Holotype: MZB 22253 male, 93.2 mm SL, Sungai Gora (site 5, Fig. 2), 6° 03.058'S, 134° 24.032'E, tributary of Sungai Mareremar, Kobroor Island, Aru Islands, Maluku Province, Indonesia, seine net, R. Hadiaty and party, 4 December 2013.
Paratypes: MZB 21669, 19 specimens, 25.1-84.4 mm SL, collected with holotype ; MZB 21670, 4 specimens, 64.0-90.9 mm SL, collected with holotype; MZB 21687, 9 specimens, 17.2-70.3 mm SL, Sungai Kwamoli (site 6, Fig. 2), 6° 03.362'S, 134° 25.668'E, tributary of Sungai Mareremar, Kobroor Island, Aru Islands, Maluku Province, Indonesia, seine net, R. Hadiaty and party, 4 December 2013; MZB 21688, 5 specimens, 52.0-77.8 mm SL, collected with MZB 21687; USNM 432451, 5 specimens, 34.4-55.1 mm SL, collected with MZB 21687; WAM P.34298-001, 8 specimens, 36.2-59.9 mm SL, collected with MZB 21687.

Diagnosis: A species of melanotaeniid rainbowfish distinguished by the following combination of characters: dorsal rays V-VI-I,11-14; anal rays I,19-23; pectoral rays 13-16 (usually 14); lateral scales 35-36, predorsal scales 16-19; cheek scales 16-22 (usually > 20); total gill rakers on first arch 15-19; greatest body depth of adult male 33.9 % SL; colour in life generally shades of blue green to blue with metallic reflections and indication of darker blue mid-lateral stripe, most prominent on caudal peduncle where edged below with relatively broad white stripe; *in situ* colour pattern features brilliant golden reflections especially conspicuous on each side of midlateral region on side of body and caudal peduncle; dorsal, anal, and caudal fins with reddish to yellow highlights. Maximum size to 93.2 mm SL or 110.2 mm TL.

Description: Dorsal rays VI-I,13 (V-VI-I,11-14); anal rays I,21 (19-23); pectoral rays 14 (13-16);

Fig. 18. Underwater photograph of *Melanotaenia picta*, male, approximately 70 mm SL, Sungai Gora, Kobroor Island, Aru Islands. Photo by G. R. Allen.

Table VIII. Proportional measurements of selected type specimens of *Melanotaenia picta* expressed as percentage of the standard length.

	Holotype MZB 22253	Paratype MZB 21699	Paratype MZB 21699	Paratype MZB 21699	Paratype MZB 21699	Paratype MZB 21699	Paratype MZB 21699	Paratype MZB 21699
Sex	male	male	male	male	female	female	female	female
Standard length (mm)	93.2	84.4	76.4	63.9	79.1	70.0	56.3	51.1
Body depth	33.9	29.5	27.6	26.4	26.4	25.3	23.6	27.8
Body width	13.5	11.7	12.8	13.8	14.3	12.9	12.8	14.5
Head length	26.8	27.4	26.2	27.7	27.9	29.3	28.8	29.7
Snout length	9.3	9.0	9.6	10.2	9.7	10.7	9.4	10.2
Maxillary length	9.2	9.5	9.4	10.2	9.9	10.7	10.1	10.6
Eye diameter	8.0	7.6	8.1	8.6	8.5	8.0	10.3	9.6
Bony interorbital width	9.4	9.0	8.9	9.5	10.2	9.0	9.2	10.4
Depth of caudal peduncle	10.7	9.8	9.3	10.0	10.2	9.3	9.6	9.8
Length of caudal peduncle	16.7	17.9	16.8	17.5	19.5	17.7	17.9	19.6
Predorsal distance	49.8	49.1	46.5	47.6	48.8	50.4	50.1	48.5
Preanal distance	47.3	47.9	47.6	49.1	49.6	51.1	52.0	52.1
Prepelvic distance	34.4	34.5	35.3	35.8	37.7	39.0	37.5	39.1
2nd dorsal fin base	27.1	27.0	25.0	23.6	22.9	22.4	21.5	22.3
Anal fin base	38.6	39.1	38.4	36.9	33.0	34.1	31.6	33.3
Pectoral fin length	17.0	16.5	19.0	19.6	18.8	17.0	16.9	19.0
Pelvic fin length	16.1	14.3	16.4	16.7	17.4	15.1	15.1	15.9
Longest ray 1st dorsal fin	15.7	17.2	17.4	19.9	11.9	14.3	12.6	11.5
Longest ray 2nd dorsal fin	18.1	16.5	15.2	16.9	13.1	13.0	11.5	14.3
Longest anal ray	16.5	14.1	12.4	14.7	12.6	12.1	11.5	11.9
Caudal fin length	18.2	17.7	22.1	22.5	21.5	21.0	20.6	23.9
Caudal concavity	4.8	3.6	7.6	5.5	6.2	5.9	5.2	6.8

Fig. 19. Aquarium photograph of freshly collected paratype (MZB 21669) of *Melanotaenia picta*, male, 76.4 mm SL, Sungai Gora, Kobroor Island, Aru Islands. Photo by G. R. Allen.

pelvic rays I,5; branched caudal rays 15; lateral scales 35 (35-36); transverse scales 12; predorsal scales 16 (16-19); cheek scales 22 (16-22); total gill rakers on first arch 19 (15-19).

Body depth 2.9 (3.3-4.2) in SL; greatest body depth by sex and size class as follows: *males* – < 50 mm SL, 25.2 % SL (N = 1); *males* – 50-64 mm SL, 26.0-30.4 % SL ($\bar{x}$ = 27.6, N = 6); *males* – 65-79 mm SL, 27.6-31.4 % SL ($\bar{x}$ = 29.8, N = 5); *males* – . 80 mm SL, 30.3-33.9 (holotype) % SL ($\bar{x}$ = 31.2, N = 3); *females* – < 50 mm SL, 24.1-27.8 % SL ($\bar{x}$ = 25.7, N = 3); *females* – 50-64 mm SL, 23.6-26.7 % SL ($\bar{x}$ =24.8, N = 7); *females* – 65-79 mm SL, 25.9 % SL ($\bar{x}$ = 25.9, N = 2); head length 3.7 (3.4-3.7) in SL; greatest width of body 2.5 (1.8-2.5) in greatest body depth; snout length 2.9 (2.7-3.2) in HL; eye diameter 3.3 (2.8-3.7) in HL; interorbital width 2.8 (2.7-3.3) in HL; depth of caudal peduncle 2.5 (2.5-3.2) in HL; length of caudal peduncle 1.6 (1.3-1.7) in HL.

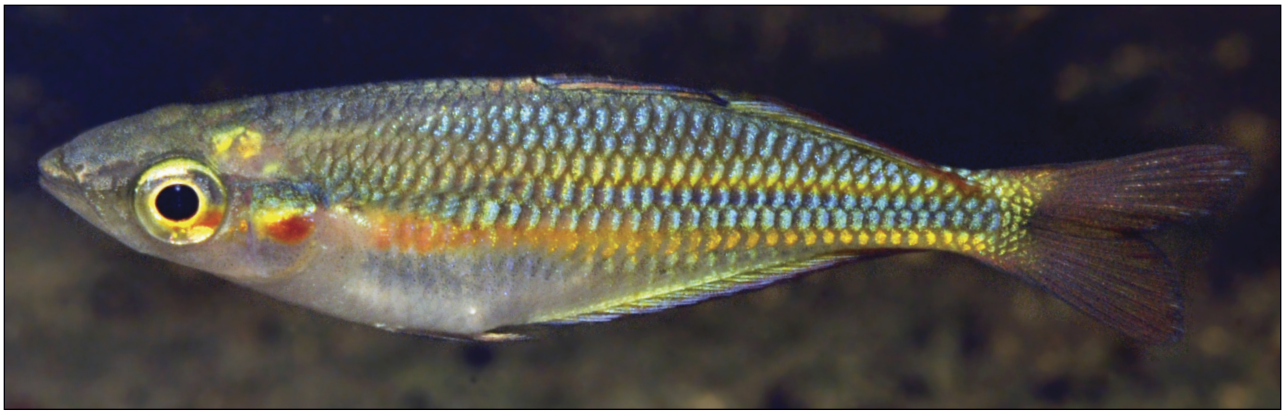

Fig. 20. Underwater photograph of *Melanotaenia picta*, juvenile, approximately 30 mm SL, Sungai Gora, Kobroor Island, Aru Islands. Photo by G. R. Allen.

Fig. 21. *Melanotaenia picta,* discovered in 2007 by H. Bleher in the Sungai Mareremar, Kobroor Island, Aru Islands, and here a aquarium photograph of wild males with approximately 80 cm in SL after long period in captivity. Photo by J. Felix.

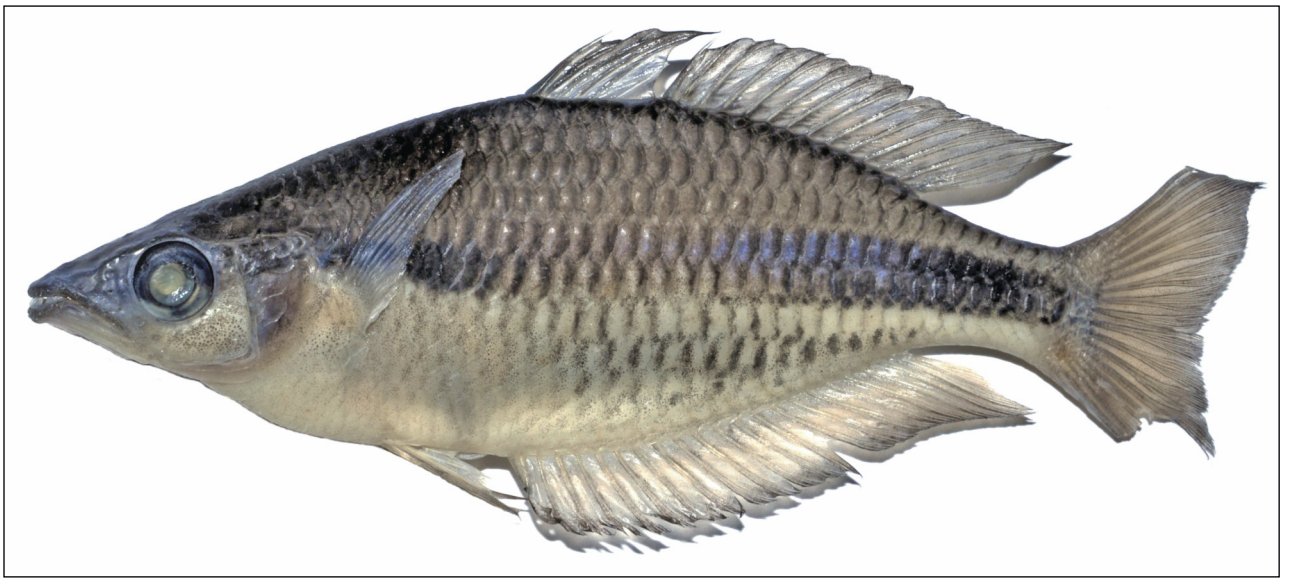

Fig. 22. *Melanotaenia picta*, preserved male holotype, 93.2 mm SL, Sungai Gora, Kobroor Island, Aru Islands. Photo by G. R. Allen.

Fig. 23. Typical habitat (tributary of Sungai Mareremar near site 3) of *Melanotaenia picta* near the type locality, Kobroor Island, Aru Islands Photo by G. R. Allen.

Jaws about equal, oblique, premaxilla with an abrupt bend between the anterior horizontal portion and lateral part; maxilla nearly reaching level of anterior edge of eye; maxillary length 2.9 (2.7-3.1) in HL; lips thin; teeth conical with slightly curved tips, extending on to outer surface of lips; teeth of upper jaw in 3-5 irregular rows anteriorly, reduced to a single row posteriorly, where they are exposed when mouth is closed; teeth in lower jaw in about 7-8 irregular rows anteriorly, reduced to 1 or 2 rows posteriorly; narrow row containing several small, conical teeth on vomer and palatines.

Scales of body cycloid, relatively large, and arranged in regular horizontal rows; scale margins smooth to weakly crenulate; predorsal scales extending forward to about middle of interorbital space; preopercle with 2-3 scale rows between its posterior angle and eye.

Predorsal length 2.0 (2.0-2.2) in SL; preanal length 2.1 (1.9-2.2) in SL; prepelvic length 2.9 (2.6-2.9) in SL; length of second-dorsal fin base 3.7 (3.7-5.1); length of anal-fin base 2.5 (2.6-3.2).

First dorsal fin origin about level with anal fin origin; longest spine (usually third) of first dorsal fin 1.7 (1.3-2.6) in HL, its depressed tip reaching spine of second dorsal fin or slightly posterior in females and reaching to about base of third or fourth soft ray in mature males; longest rays (generally anterior ones in females and penultimate in males) of second dorsal fin 1.5 (1.3-2.5) in HL, the depressed posterior rays extending about one half length of caudal peduncle in females and nearly full length of caudal peduncle in mature males; longest (middle rays in females and penultimate in males) anal rays 1.6 (1.7-2.5) in HL; pelvic fin tips when depressed reaching nearly to origin of anal fin in females and to base of first or second soft anal-fin ray in mature males; length of pelvic fins 1.7(1.5-2.0) in HL; length of pectoral fins 1.6 (1.4-1.7) in HL; length of caudal fin 1.5 (1.2-1.5) in HL; caudal fin moderately forked, caudal concavity 5.6 (3.4-7.7) in HL.

Colour in life of male (from *in situ* underwater photograph, Fig. 18): blue-grey dorsally on head, nape, and two uppermost, horizontal scale rows of back; cheek and operculum silver to grey with blood-red spot (about one-half pupil size) on upper part of operculum; iris mostly pale yellow; side of body blue to pale grey with most scales broadly to narrowly edged with golden yellow; large patch of golden yellow on anterior body, just behind and above pectoral fin; golden yellow hues also evident along base of dorsal and caudal fins, and on membranous portion of dorsal and anal fins; fins otherwise blue greyish except semitranslucent pectoral fins. Freshly collected live fish (Fig. 19) photographed in an aquarium generally blue green to blue with metallic reflections and indication of darker blue mid-lateral stripe, most prominent on caudal peduncle where edged below with relatively broad white stripe. Juvenile (Fig. 20) with brown on back with pale green scale margins; sky blue midlateral stripe edged above and below with yellow to orange stripe (one scale wide); median fins largely bluish. Male aquarium specimens (Fig. 21) kept in Germany for several years are largely various shades of blue with darker scale edges (especially bold on ventral side above the anal fin), a black stripe through the eye to just above the pectoral region, midlateral black stripe (about 2 scales wide) on the posterior body/caudal peduncle, and reddish dorsal, anal, and caudal fins.

Colour of holotype in alcohol (Fig. 22): generally brown dorsally on head and upper half of body, grading to greyish white or tan on lower half with blackish midlateral stripe (1-2 scales wide), most conspicuous on posterior body (including caudal peduncle) and just behind head; fins generally semitranslucent whitish to slightly grey.

Comparisons: Morphologically, *M. picta*, *M. kolaensis*, and *M. wokamensis*, as well as *M. senckenbergianus* comprise a group of closely related species belonging to the "Goldiei" group of Australia and southern New Guinea. *Melanotaenia picta* is especially separable on the basis of its *in situ* colour pattern (Fig. 18), especially the overall bluish or blue-green colouration with extensive golden yellow highlights. It differs to a slightly lesser degree in the pattern exhibited by freshly collected specimens, which exhibit an inordinate amount of bright blue with a subdued dark midlateral stripe. It also exhibits an exceptionally slender body shape with adult males rarely exceeding 30 % SL. Although *M. senckenbergianus* is also relatively slender, males may reach 36 % SL. The body shape discrepancy is particularly noticeable in the size range of 50-64 mm SL. The average body depth of *M. picta* males in this group is 27.6 (n = 6) compared with much higher values of 31.7 (N = 10) for *M. kolaensis*, 31.4 (n = 12) for *M. senckenbergianus* and 31.3 (N = 10) for *M. wokamensis;* likewise, the depth of similar-sized *M. picta* females is 24.8 (n = 7) compared with 28.6 (n = 9) for *M. senckenbergianus,* 29.7 (N = 10) for *M. wokamensis*, and 32.2 (N = 2) for *M. kolaensis*. *M. picta* also

has a slightly shorter prepelvic length in males larger than 55 mm SL. Its values range from 34.4-37.7 % SL (average 35.8, N = 10) compared with 38.0-40.7 (average 38.8, N = 10) for *M. senckenbergianus*, 37.5-38.7 (average 38.0, N = 5) for *M. wokamensis*, and 36.2-38.3 (average 37.4, N = 4) for *M. kolaensis*. Similarly, there is a tendency for adult males > 60 mm SL of *M. picta* to have a slightly shorter preanal length (45.9-50.5 % SL, average 48.1, N = 8) compared with similar-sized *M. senckenbergianus* (49.5-54.5 % SL, average 51.9, N = 10), *M. wokamensis* (49.3-52.3, average 50.6, N = 5), and *M. kolaensis* (47.7-51.2, average 49.4, N = 4).

Distribution and habitat: This species is known from two locations, both situated in the Marere-mar River system of northwestern Kobroor Island and separated by a distance of about 3 km. The habitat for this species (Fig. 19) is among the most scenic freshwater environments found at the Aru Islands, consisting of small, rainforest brooks with quiet pools interspersed with cascades to 3-4 m high. Water clarity was excellent, offering good conditions for underwater photography. Stream channels were composed of relatively smooth limestone with minimal aquatic vegetation, but abundant shelter for fishes in the form of log snags.

Etymology: This species is named *picta* (Latin: painted) with reference to its beautiful colour pattern.

Melanotaenia senckenbergianus Weber, 1911
Senckenberg Rainbowfish
(Figs 24-27, Tables VI & IX)

Melanotaenia senckenbergianus Weber 1911: 25, Pl. 1, fig 2 (Trangan and Kobroor islands, Aru Islands).

Material examined (79 specimens, 24.6-68.1 mm SL): ZMA 103168, 57.0 mm SL (holotype), near Popdjetur, Terangan (now spelled Trangan) Island, Aru Islands; MZB 21648, 44 specimens, 24.6-58.0 mm SL, Sungai Unmar (site 4, Fig. 2), Kobroor Island; MZB 21646, 2 specimens, 42.7-44.9 mm SL Sungai Unmar, Kobroor Island, Aru Islands; WAM P.33831-001, 11 specimens, 33.4-53.1 mm SL, Sungai Sin (site 2, Fig. 2), Trangan Island, Aru Islands; WAM P.33832-001, 13 specimens, 38.8-68.1 mm SL, Sungai Galalou (about 10 km northwest of type locality; site 1, Fig. 2), Trangan Island, Aru Islands; WAM P.33834-001, 8 specimens, 43.0-63.5 mm SL, Sungai Unmar, Kobroor Island, Aru Islands.

Diagnosis: A species of melanotaeniid rainbowfish distinguished by the following combination of characters: dorsal rays IV-VI-I,11-15 (usually V-VI-I,12-13); anal rays I,20-23 (rarely 23); pectoral rays 13-15 (usually 14); lateral scales 34-36; predorsal scales 16-19 (rarely 19); cheek scales 15-24 (average 19.6); total gill rakers on first arch 17-18;

Fig. 24. Underwater photograph of *Melanotaenia senckenbergianus*, male, approximately 70 mm SL, Sungai Galalou, Trangan Island, Aru Islands. Photo by G. R. Allen.

Table IX. Proportional measurements for specimens of *Melanotaenia senckenbergianus* expressed as percentage of the standard length.

	WAM P.33834	WAM P.33832	WAM P.33832	WAM P.33832	WAM P.33832	WAM P.33832	WAM P.33831	MZB 21648
Sex	male	male	male	male	female	female	female	female
Standard length (mm)	63.5	59.2	55.8	51.7	68.1	61.2	53.1	48.8
Body depth	28.3	34.6	34.4	28.8	30.8	31.9	24.9	28.7
Body width	12.6	14.5	13.3	12.8	13.5	13.9	13.7	13.5
Head length	27.6	29.6	28.3	28.0	29.4	29.4	29.4	24.1
Snout length	8.8	10.5	10.2	9.7	10.3	10.3	10.2	10.0
Maxillary length	9.8	11.0	10.6	10.4	10.9	10.3	10.2	10.9
Eye diameter	8.5	8.8	8.8	8.3	9.4	9.5	9.2	10.9
Bony interorbital width	8.8	10.5	8.6	9.3	10.1	9.8	9.2	10.2
Depth of caudal peduncle	9.8	11.5	11.5	10.1	10.4	10.9	9.2	9.8
Length of caudal peduncle	16.7	13.0	14.5	18.2	15.6	14.9	14.9	17.4
Predorsal distance	48.5	48.6	47.3	48.0	47.3	51.3	48.4	48.8
Preanal distance	51.0	51.5	49.5	52.0	54.5	53.3	52.5	50.8
Prepelvic distance	37.6	40.7	36.9	38.9	39.8	39.1	39.0	37.5
2nd dorsal fin base	22.5	26.7	26.5	23.2	23.3	23.7	23.7	24.6
Anal fin base	35.3	41.7	40.9	34.0	37.3	36.8	32.8	35.2
Pectoral fin length	18.4	17.2	15.9	18.0	17.2	17.2	18.8	20.1
Pelvic fin length	15.3	15.9	14.3	14.5	15.9	13.9	16.2	16.0
Longest ray 1st dorsal fin	16.7	16.9	18.1	13.9	13.4	13.9	14.3	13.9
Longest ray 2nd dorsal fin	12.8	14.9	15.9	12.6	10.9	10.8	13.2	12.3
Longest anal ray	11.2	13.5	13.4	10.8	11.3	11.9	13.0	11.7
Caudal fin length	20.5	21.1	18.8	22.4	19.1	19.3	23.4	19.1
Caudal concavity	4.7	4.2	3.6	7.0	4.4	5.9	7.2	5.7

Fig. 25. Aquarium photograph of freshly collected specimens (MZB 21648) of *Melanotaenia senckenbergianus*, female in foreground and male in background, approximately 50 mm SL, Sungai Unmar, Kobroor Island, Aru Islands. Photo by G. R. Allen.

greatest body depth of adult male 35.9 % SL; colour in life generally greenish brown dorsally, grading to silvery white to pale yellow ventrally with midlateral, dark blue stripe, 1-2 scale rows wide, extending from rear margin of eye to caudal-fin base, usually faint or interrupted on middle of side; operculum with prominent red spot, smaller than pupil. Maximum size to 68.1 mm SL or 83 mm TL.

Redescription: Dorsal rays IV-VI-I,11-15 (usually V-VI-I,12-13); anal rays I,20-23 (rarely 23); pectoral rays 13-15 (usually 14); pelvic rays I,5; branched caudal rays 15; lateral scales 34-36; transverse scales 9-12; predorsal scales 16 to 19 (rarely 19); cheek scales 15-24 (average 19.6); total gill rakers on first arch 17-18.

Body depth 2.9-4.0 in SL; head length 3.4-3.6 in SL; greatest width of body 1.8-2.6 in greatest body depth; snout length 2.8-3.3 in HL; eye diameter 2.7-3.4 in HL; interorbital width 2.7-3.4 in HL; depth of caudal peduncle 2.5-3.2 in HL; length of caudal peduncle 1.5-2.3 in HL.

Jaws about equal, oblique, premaxilla with an abrupt bend between the anterior horizontal portion and lateral part; maxilla ends below anterior edge of eye or slightly anterior to this level; maxil-

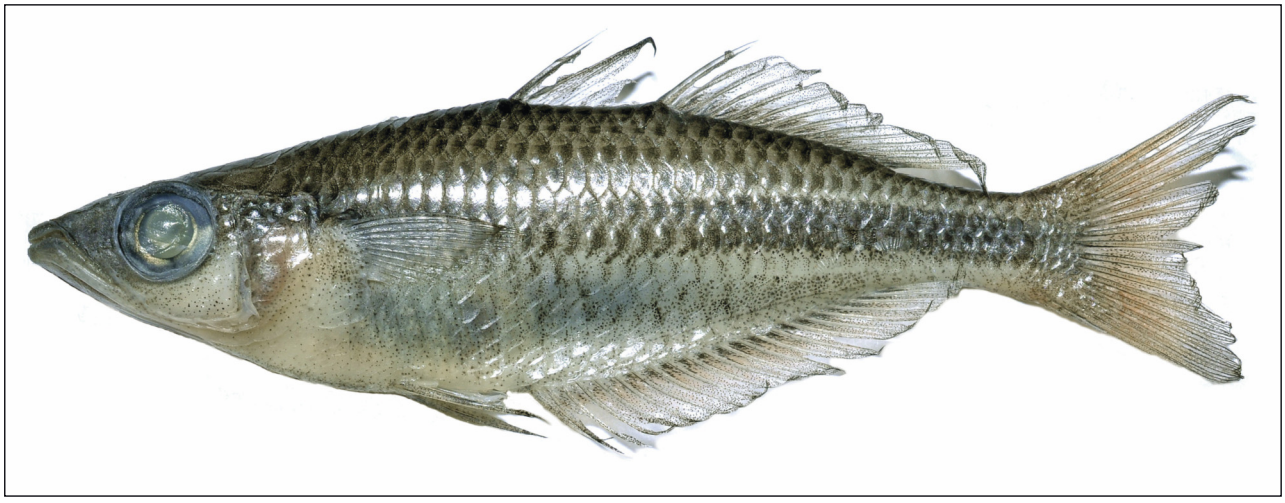

Fig. 26. *Melanotaenia senckenbergianus*, preserved female specimen (MZB 21648), 58.0 mm SL, Sungai Unmar, Kobroor Island, Aru Islands. Photo by G. R. Allen.

Fig. 27. *Melanotaenia senckenbergianus*, preserved male specimen (WAM P.33832-001), 59.2 mm SL, Sungai Galalou, Trangan Island, Aru Islands. Photo by G. R. Allen.

lary length 2.6-2.9 in HL; lips thin; teeth conical with slightly curved tips, extending on to outer surface of lips; teeth of upper jaw in 3-5 irregular rows anteriorly, reduced to a single row posteriorly, where they are exposed when mouth is closed; teeth in lower jaw in about 7-8 irregular rows anteriorly, reduced to 1 or 2 rows posteriorly; narrow row containing several small, conical teeth on vomer and palatines.

Scales of body cycloid, relatively large, and arranged in regular horizontal rows; scale margins weakly crenulate; predorsal scales extending forward to about middle of interorbital space; preopercle with 2-3 scale rows between its posterior angle and eye.

Predorsal length 1.9-2.1 in SL; preanal length 1.8-2.6 in SL; prepelvic length 2.5-2.7 in SL; length of second-dorsal fin base 3.6-4.6; length of anal-fin base 2.4-3.1.

First dorsal fin origin about level with anal-fin origin; longest spine (usually third) of first dorsal fin 1.6-2.4 in HL, its depressed tip reaching spine of second dorsal fin or slightly posterior in females and reaching to about base of second or third soft ray in mature males; longest rays (generally anterior ones in females and penultimate in males) of second dorsal fin 1.7-2.7 in HL, the depressed posterior rays extending about one half length of caudal peduncle or less in females and nearly full length of caudal peduncle in mature males; longest (middle rays in females and penultimate in males) anal rays 2.1-2.6 in HL; pelvic fin tips when depressed not reaching origin of anal fin in females and to of first or second soft anal-fin ray in mature males; length of pelvic fins 1.7-2.0 in HL; length of pectoral fins 1.5-1.8 in HL; length of caudal fin 1.2-1.7 in HL; caudal fin moderately forked, caudal concavity 3.0-8.6 in HL.

Colour in life (from *in situ* underwater photograph, Fig. 24): greenish brown on top of head, nape, and uppermost part of back; lower half of head grey to slightly yellow; operculum silvery or metallic yellow with red spot about one-half pupil size; iris mainly yellow; side of body generally yellow with dark grey to blue midlateral stripe (1-2 scales wide) and large patch of light blue just behind and mainly below pectoral-fin base; faint reddish stripe usually evident between each scale row of side; median fins generally semitranslucent, but frequently with yellow to red suffusion (especially caudal); pelvic fins white to yellowish; pectoral fins translucent. Freshly collected live fish (Fig. 25) photographed in an aquarium with similar pattern except dark midlateral stripe often edged with more prominent red stripes and/or with relatively broad, pale yellow to whitish stripe above and below, especially noticeable on rear portion of body, including caudal peduncle.

Colour in alcohol (Fig. 26): generally brown (often with each individual scale with lighter centre) on dorsal half of body and pale yellow or tan on lower half with blackish midlateral stripe between the two areas; fins generally semitranslucent greyish. The midlateral stripe is usually more distinct on the posterior half of the body. Specimens from Sungai Galalou (Fig. 27 WAM P. 33832-001) are characterised by broad dark scale margins, contrasting sharply with the otherwise pale background, on the lower half of the middle section of the body.

Comparisons: Morphologically, *M. senckenbergianus* and its relatives from the Aru Islands, in-

Fig. 28. Comparison of male members of the *senckenbergianus* species complex from the Aru Islands (top to bottom): *M. senckenbergianus, M. picta, M. wokamensis,* and *M. kolaensis*. Photo by G. R. Allen.

cluding *M. kolaensis, M. picta,* and *M. wokamensis*, belong to the "Goldiei" group of southern New Guinea and northern Australia (Unmack et al. 2013). Allen and Cross (1982) considered *M. senckenbergianus* as a junior synonym of *M. goldiei*. Recent genetic and morphological investigations (unpublished data and Unmack et al. 2013) indicate that *M. goldiei* as presently recognised is divisible into several taxa. The various members of this complex are very similar and difficult to separate using traditional taxonomic characters as nearly all included taxa exhibit broadly overlapping counts and measurements. Aside from genetic differences, colour pattern and geography are the best means of separating the various species. Although possessing similar colour patterns, the Aru members of this complex can be differentiated by consistent colour pattern differences (Fig. 28). Additional comparisons are given in the descriptions for *M. kolaensis, M. picta,* and *M. wokamensis*.

Both males and females are relatively slender, although adult males are generally deeper bodied and have a more elongate, pointed shape posteriorly on the soft dorsal and anal fins as in most *Melanotaenia*. Most of our adult specimens are in the 50-65 mm SL range. The body depth of 12 males in this category ranged from 28.3-35.9 % SL (average 31.4) and that of 9 females from 24.9-32.6 % SL (average 28.6). The depth of three males under 50 mm SL ranged from 25.3-27.2 % SL (average 26.2) and that of 13 females from 25.4-28.7 % SL (average 26.9). Large specimens were poorly represented with the longest male 63.5 mm SL and only one female, 68.1 mm SL (body depth 30.8 % SL) in excess of 65 mm.

Distribution and habitat: This species appears to be widespread on southern Aru, occurring in nearly all freshwater streams sampled to date on Trangan and southern Kobroor, which are the largest islands in the main Aru Group. The habitat consists of creeks and small rivers flowing through primary rainforest and second growth forest and gardens, as well as tree-lined creeks in relatively open savannah. In streams of Trangan and two sites sampled on southern Kobroor it co-occurs with species of the "Australis" group, either *M. albimarginata*, *M. aruensis*, or *M. patoti* as well as other fishes such as *Craterocephalus*, *Mogurnda*, *Glossamia*, and *Glossogobius*. The reader is referred to the above descriptions of *M. albimarginata*, *M. aruensis*, and *M. patoti* for additional habitat information.

Etymology: This species was named *senckenbergianus*, presumably after the Senckenberg Museum of Frankfurt, Germany, publisher of the journal where the original description of this fish first appeared.

Melanotaenia wokamensis n. sp.
Wokam Rainbowfish
(Figs 29-30, Tables VI & X)

Holotype: MZB 22254, male, 75.6 mm SL, Sungai Torbol (site 8, Fig. 2), 5° 47.945'S, 134° 30.365'E, tributary of Sungai Tunguwatu, Wokam Island, Aru Islands, Maluku Province, Indonesia, seine net, R. Hadiaty, U. Nurhaman & A. Sianipar, 5 December 2013.
Paratypes: MZB 21702, 47 specimens, 17.1-61.2 mm SL, collected with holotype; MZB 21696, 33 specimens, 30.2-62.2 mm SL, Sungai Gaibel (site 7, Fig. 2), 5° 048.673'S, 134° 27.409'E, tributary of Sungai Tunguwatu, Wokam Island, Aru Islands, Maluku Province, Indonesia, seine net, R. Hadiaty, U. Nurhaman & A. Sianipar,, 5 December 2013; MZB 21695, 37 specimens, 17.2-47.0 mm SL, ethanol collections, collected with MZB 21696; MZB 21700, 9 specimens, 14.1-25.7 mm SL, collected with holotype; MZB 21706, 10 specimens, 22.6-70.9mm SL, Sungai Gayarfafeimusin (site 9, Fig. 2), 5° 047.228'S, 134° 28.481'E, tributary of Sungai Tunguwatu, Wokam Island, Aru Islands, Maluku Province, Indonesia, seine net, R. Hadiaty, U. Nurhaman & A. Sianipar, 5 December 2013; MZB 21705, 5 specimens, 17.7-29.0 mm SL, ethanol collection, collected with MZB 21706; USNM 432452, 4 specimens, 39.2-49.8 mm SL, collected with MZB 21706; WAM P.34299-001, 10 specimens, 35.8-58.4 mm SL, collected with MZB 21706.

Diagnosis: A species of melanotaeniid rainbowfish distinguished by the following combination of characters: dorsal rays IV-VI-I,11-14; anal rays I,18-22; pectoral rays 12-14 (usually 13); lateral scales 33-35 (rarely 35), predorsal scales 14-16; cheek scales 11-17; total gill rakers on first arch 15-17; greatest body depth of adult male 34.4 % SL; colour in life generally light blue on back with metallic reflections; dark blue midlateral stripe (1-2 scales wide), bordered with bold, relatively broad reddish to orange stripes; ventral portion of body greyish-white except bold dark-blue margins on scales above anal fin and large, bright blue patch just behind and below pectoral-fin base; second

dorsal and anal fins bluish with broad, reddish outer margin; caudal fin semitranslucent reddish. Maximum size to 75.6 mm SL or 95.6 mm TL.

Description: Dorsal rays V-I,12 (IV-VI-I,11-14); anal rays I,21 (18-22); pectoral rays 13 (12-14); pelvic rays I,5; branched caudal rays 15; lateral scales 33 (33-35); transverse scales 9 (9-10); predorsal scales 14 (14-16); cheek scales 15 (11-17); total gill rakers on first arch 16 (15-17).

Body depth 3.1 (2.9-3.5) in SL; greatest body depth by sex and size class as follows: *males* – < 50 mm SL, 28.8-35.3 % SL ($\bar{x}$ = 32.7, N = 11); *males* – 50-64 mm SL, 28.0-34.4 % SL ($\bar{x}$ = 31.3, N = 13); *males* – 65-79 mm SL, 30.6-32.3 % SL ($\bar{x}$ = 33.4, N = 2); *females* – < 50 mm SL, 26.3-31.6 % SL ($\bar{x}$ = 29.2, N = 7); *females* – 50-64 mm SL, 27.1-31.7 % SL ($\bar{x}$ = 29.7, N = 10); head length 3.6 (3.3-3.7) in SL; greatest width of body 2.4 (2.1-2.6) in greatest body depth; snout length 2.9 (2.8-3.1) in HL; eye diameter 3.7 (3.1-3.7) in HL; interorbital width 2.8 (2.6-3.1) in HL; depth of caudal peduncle 2.4 (2.3-2.8) in HL; length of caudal peduncle 1.6 (1.3-1.8) in HL.

Jaws about equal, oblique, premaxilla with an

Fig. 29. Aquarium photograph of freshly collected holotype of *Melanotaenia wokamensis*, male, 75.6 mm SL, Sungai Torbol, Wokam Island, Aru Islands. Photo by G. R. Allen.

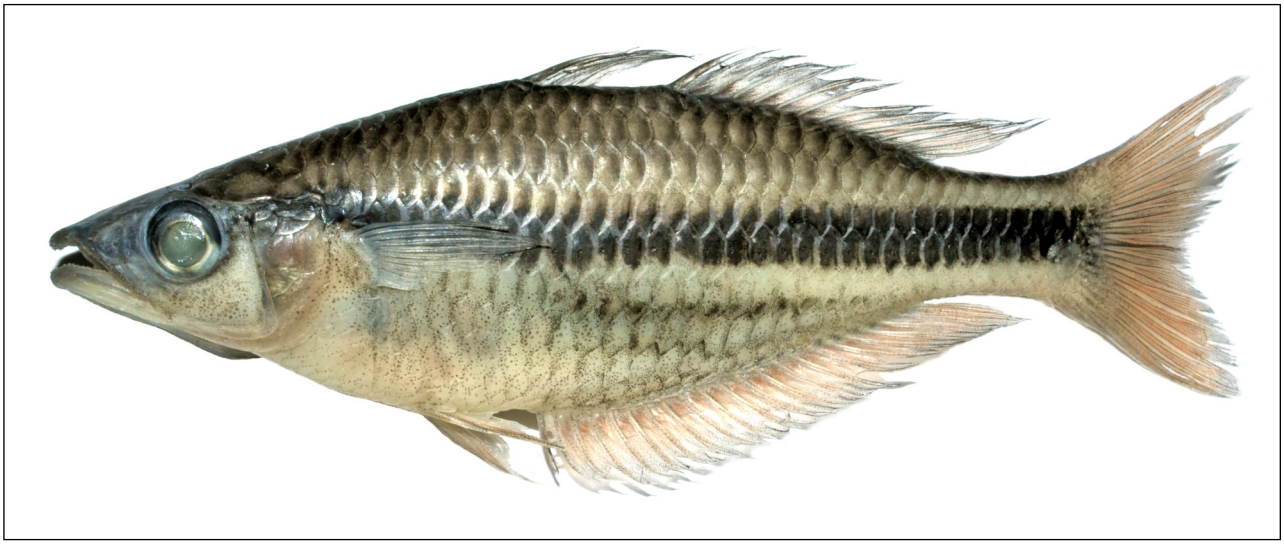

Fig. 30. *Melanotaenia wokamensis*, preserved male holotype, 75.6 mm SL, Sungai Torbol, Wokam Island, Aru Islands. Photo by G. R. Allen.

Table X. Proportional measurements of selected type specimens of *Melanotaenia wokamensis* expressed as percentage of the standard length.

	Holotype MZB 22254	Parataype MZB 21702	Paratype MZB 21702	Paratype MZB 21702	Paratype MZB 21702	Paratype MZB 21702	Paratype MZB 21702	Paratype MZB 21702
Sex	male	male	male	male	female	female	female	female
Standard length (mm)	75.6	70.0	62.2	60.2	59.2	58.4	55.5	47.6
Body depth	32.3	34.4	32.0	32.4	28.9	31.7	31.5	29.6
Body width	13.5	13.4	14.3	13.0	14.0	14.9	14.4	13.4
Head length	27.5	27.1	28.6	28.2	28.5	27.1	27.0	30.3
Snout length	9.5	9.6	9.3	9.0	9.5	8.7	9.0	9.9
Maxillary length	11.0	10.6	10.1	10.8	11.1	10.1	9.4	11.3
Eye diameter	7.4	7.3	8.2	8.1	9.1	8.0	8.3	9.5
Bony interorbital width	9.8	8.9	10.0	9.5	10.0	9.6	9.7	10.5
Depth of caudal peduncle	11.6	11.4	12.2	10.3	11.0	11.6	11.7	10.7
Length of caudal peduncle	17.6	18.3	17.2	15.6	16.9	20.5	18.7	17.2
Predorsal distance	46.4	46.3	47.4	47.2	49.8	48.1	47.0	49.2
Preanal distance	49.3	51.3	51.3	51.5	52.2	51.7	52.3	51.5
Prepelvic distance	37.7	38.6	37.5	38.7	38.0	38.4	38.0	38.7
2nd dorsal fin base	25.0	26.3	24.0	22.6	20.3	23.1	23.2	21.6
Anal fin base	39.7	37.6	37.1	36.5	31.6	36.5	34.2	32.4
Pectoral fin length	19.6	17.6	18.8	17.4	18.8	18.3	19.5	19.3
Pelvic fin length	14.0	15.6	15.8	15.9	15.4	15.1	15.3	16.6
Longest ray 1st dorsal fin	14.0	17.4	16.2	15.9	10.5	14.0	14.8	12.6
Longest ray 2nd dorsal fin	16.1	15.7	15.4	18.6	12.8	13.4	11.0	12.8
Longest anal ray	13.9	13.6	12.7	15.3	12.2	11.0	10.1	11.6
Caudal fin length	20.0	19.3	18.2	21.6	21.1	18.0	20.7	23.3
Caudal concavity	5.0	3.6	4.2	5.3	7.1	3.4	5.4	5.9

abrupt bend between the anterior horizontal portion and lateral part; maxilla reaching level of anterior edge of eye; maxillary length 2.5 (2.5-2.9) in HL; lips thin; teeth conical with slightly curved tips, extending on to outer surface of lips; teeth of upper jaw in 4-5 irregular rows anteriorly, reduced to a single row posteriorly, where they are exposed when mouth is closed; teeth in lower jaw in about 6-8 irregular rows anteriorly, reduced to 1 or 2 rows posteriorly; narrow row containing several small, conical teeth on vomer and palatines.

Scales of body cycloid, relatively large, and arranged in regular horizontal rows; scale margins smooth to weakly crenulate; predorsal scales extending forward to about middle of interorbital space; preopercle with 2 scale rows between its posterior angle and eye.

Predorsal length 2.2 (2.0-2.2) in SL; preanal length 2.0 (1.9-2.0) in SL; prepelvic length 2.7 (2.6-2.7) in SL; length of second-dorsal fin base 4.0 (3.8-4.9); length of anal-fin base 2.5 (2.5-3.2).

First dorsal fin origin about level with anal fin origin; longest spine (usually third) of first dorsal fin 2.0 (1.6-2.7) in HL, its depressed tip reaching spine of second dorsal fin or slightly posterior in females and reaching to about base of second to fourth soft ray in mature males; longest rays (generally anterior ones in females and penultimate in males) of second dorsal fin 1.7 (1.5-2.5) in HL, the depressed posterior rays extending about one half length of caudal peduncle in females and nearly full length of caudal peduncle in mature males; longest (middle rays in females and penultimate in males) anal rays 1.6 (1.7-2.5) in HL; pelvic fin tips when depressed reaching nearly to origin of anal fin in females and to base of first or second soft anal-fin ray in mature males; length of pelvic fins 2.0 (1.8-2.6) in HL; length of pectoral fins 1.4 (1.4-1.6) in HL; length of caudal fin 1.4 (1.2-1.6) in HL; caudal fin moderately forked, caudal concavity 5.5 (4.0-7.9) in HL.

Colour in life of male holotype (from

aquarium photograph of freshly captured specimen, Fig. 29): grey-brown dorsally on head, nape, and predorsal region; cheek and side of snout blue grey; operculum blue with silvery stripe across level of lower eye, interrupted by small (about one-half pupil size) red spot; iris silvery-white with tan and blackish patches (entirely silvery-white in most other paratypes); scales of upper back sky blue with metallic reflections, and narrow bronze to red-orange stripe between each horizontal row, lowermost (at level of upper eye) widest and brilliant red-orange; dark blue midlateral stripe, most vivid from behind eye to above pectoral fin and on posterior half of body, edged below for most its length (except anteriormost part of body) with orange stripe; ventral portion of body, including breast greyish-white except bold, dark-blue margins on scales above anal fin and large, bright blue patch just behind and below pectoral-fin base; first dorsal fin bluish; second dorsal and anal fins blue basally with broad reddish outer margin; caudal fin semitranslucent reddish; pelvic fins white; pectoral fins semitranslucent. Paratypes were generally similar, although there is considerable variation in the intensity of the dark-blue scale margins ventrally on the side of the body, above the anal fin. Also the red-orange stripe in the largest males from Sungai Gayarfafeimusin is particularly intense and slightly wider than fish from the other two sites. Females of this species are generally similar to males, but with slightly less vivid colours.

Colour of holotype in alcohol (Fig. 30): generally light brown dorsally on head and upper half of body, whitish on lower half with blackish midlateral stripe (1-2 scales wide); fins generally semitranslucent whitish to slightly grey.

Comparisons: Morphologically, *M. wokamensis* is a member of the Aru "Goldiei" group of species, which includes *M. kolaensis*, *M. picta* and *M. senckenbergianus*. The general colour pattern of member species is similar, consisting of a bluish ground colour, narrow red-orange stripes between horizontal scale rows on the upper half of the body, dark blue to nearly black midlateral stripe on the side of the body, and vivid red spot on the upper operculum. However, both *M. picta* and *M. wokamensis* exhibit unique variations of this general theme. In contrast to the other two species, *M. wokamensis* has more brightly coloured and much wider red-orange stripes immediately above and below the dark mid-lateral stripe. Furthermore, it lacks the

Fig. 31. Habitat of *Melanotaenia wokamensis*, Sungai Gaibel, Wokam Island, Aru Islands (site 7). Photo by R. Hadiaty.

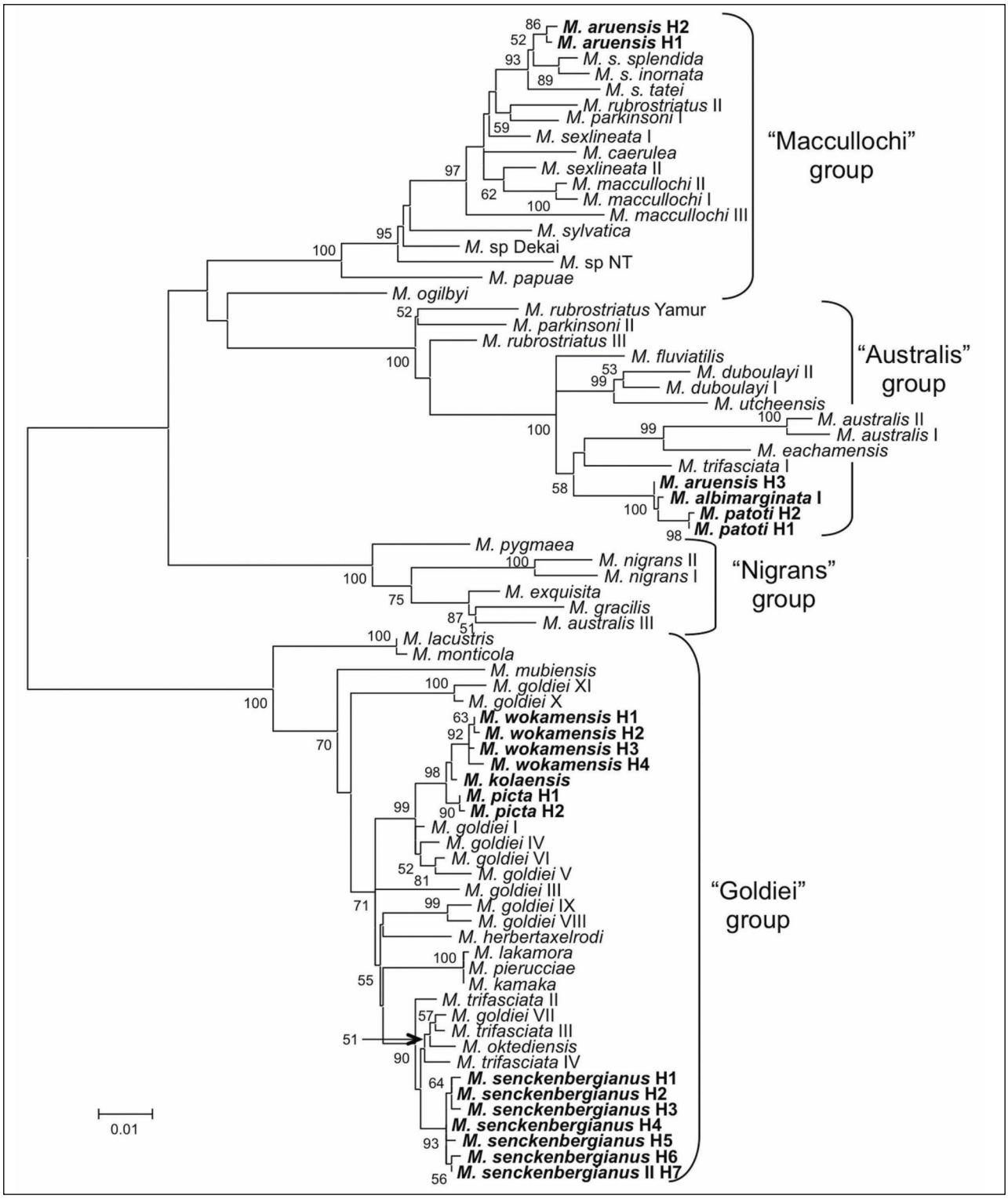

Fig. 32. Maximum likelihood tree for *Melanotaenia* species based on analysis of cytochrome *b* sequences (1,141 bp). Bootstrap values were obtained from 1,000 replicates. New sequences obtained for Aru rainbowfishes (shown in bold) are followed by their haplotype numbers (Table I). All other species names and codes can be found in Unmack et al. (2013), except *Melanotaenia rubrostriata* I and *Melanotaenia goldiei* II which have been reidentified and labelled in the tree as *M. albimarginata* I H2 and *M. senckenbergianus* II H7 respectively.

golden yellow hues seen on the body of *M. picta* when viewed *in situ*.

The new species generally has larger and fewer scales as reflected by several scale counts. It normally has 10 transverse scale rows (vs. 11-12 in the other two species), 33-34 longitudinal scales (vs. usual counts of 35-36), 14-16 predorsal scales (vs. 16-19, but frequently >16), and 11-16 cheek scales (vs. almost always > 16).

Although all members of the Aru "Goldiei" group of species are relatively slender, *M. wokamensis* differs in having deeper-bodied young (< 50 mm SL). The average depth for 11 males is 32.7 % SL and 29.2 % SL for seven females, compared with values of less than 27% SL for the other two species. In addition, the caudal peduncle for all size groups is usually deeper for *M. wokamensis*, ranging from 10.2-12.2 % SL, with values rarely less than 11 %. In contrast, the range for *M. picta* is 9.3-10.9 % SL, and that of *M. senckenbergianus* 9.2-11.5 %, with values infrequently exceeding 11 %. In *M. kolaensis*, only adults males (>59 mm SL) have values greater than 11 % SL.

Distribution and habitat: This species is currently known only from three tributaries of Sungai Tunguwatu on the western side of Wokam Island (Fig. 31). The streams were typically narrow (average width about 3-5 m) limestone channels flowing through rainforest. The species was most common in deeper pools (to 1.5-2.0 m depth) below the numerous cascades and small waterfalls. These streams are prone to flash-flooding during heavy afternoon showers in the rainy season.

Etymology: This species is named *wokamensis* with reference to the Wokam Island type locality.

MOLECULAR GENETICS & BIOGEOGRAPHY

A total of 38 individuals were included from the Aru Islands (Table I) along with 56 sequences for the mtDNA cyt *b* gene from Unmack et al. (2013) for a total of 94 sequences. Once individuals with identical haplotypes were removed, the final analysis contained 74 unique haplotypes which yielded 792 invariant characters, 74 variable but parsimony uninformative characters, and 275 parsimony informative characters. ML analysis recovered one tree with a likelihood score of -6849.360852 (Fig. 32). The relationships recovered were broadly congruent with the larger sequence dataset in Unmack et al. (2013), albeit with reduced support for some nodes and slightly different relationships due to only having 1141 characters vs. 6827 in Unmack et al. (2013). The new species descriptions now mean that samples *Melanotaenia rubrostriata* I (isolate MAru2.1.exHB) and *Melanotaenia goldiei* II (isolate MAru2.2.exHB) from Unmack et al. (2013) have been reidentified as *M. albimarginata* and *M. senckenbergianus* respectively (shown in the tree with their respective Roman numerals after the species names). The sample *Melanotaenia goldiei* I (isolate MAru1.1.exHB) represents a likely additional as yet undescribed species from Sungai Loramar, Kobroor Island, Aru Islands which we are yet to recollect for morphological examination. Within species genetic diversity was generally low, with most Aru species having between one and four different haplotypes except *M. senckenbergianus* which had seven (it also had the most diverse geographic sampling too). However, most species were only sampled from one or two sites and only small numbers were included, thus our results likely underestimate within species diversity.

Aru Island rainbowfishes were recovered from three of the four species groups, with presence of haplotypes in the "Maccullochi" group due to old introgression (Unmack et al. 2013). *Melanotaenia aruensis*, based on colour patterns and morphology resembles *M. splendida* from northern Australia and was genetically most closely related to haplotypes from that region consistent with some historical faunal connections within the last few hundred thousand years or less. One individual *M. aruensis* (haplotype 3) was closely related to *M. albimarginata* suggesting some secondary contact and potential introgression between these two otherwise quite distinct species. Individuals within *M. albimarginata* and *M. patoti* were nested within Australian members of the "Australis" group rather than any species from southern New Guinea. Bootstrap support for their relationships within the "Australis" group was low (58), however they were sister to other northern Australian species *(M. australis*, *M. eachamensis* and introgressed Leichhardt Springs *M. trifasciata* I) rather than those from eastern Australia *(M. fluviatilis* (Castelnau 1878), *M. duboulayi* (Castelnau 1878), and *M. utcheensis* McGuigan 2001), or southern New Guinea *(M.* cf. *rubrostriata),* but with a large genetic divergence indicative of separation likely prior to the Pleistocene.

Within the "Goldiei" group Aru rainbowfishes occurred in two distinct portions of the tree. *Melanotaenia senckenbergianus* had close relation-

ships within the *M. trifasciata* complex which is primarily found across northern Australia and the Fly River in southern central New Guinea. The remaining three new species, *M. kolaensis*, *M. picta*, and *M. wokamensis* were most closely related to forms from the *M. goldiei* complex from western New Guinea. All three new species were closely related to each other, with p-distances of between 0.4-0.9 %.

Molecular data indicate the Aru Islands were colonised by four separate rainbowfish ancestors, three with strong connections to northern Australia which led to the species *M. aruensis*, *M. albimarginata*, *M. patoti*, and *M. senckenbergianus* and one from southern New Guinea which led to *M. kolaensis*, *M. picta*, and *M. wokamensis*. While we don't specifically estimate their ages here, results from molecular clock estimates in Unmack et al. (2013) included *M. albimarginata* and *M. senckenbergianus* (under their previous identities) and provided mean ages of 4.7 Ma (95% highest posterior density (HPD) of 3.9-5.5 Ma) and 1.7 Ma (95% HPD of 1.3-2.1 Ma) respectively for the divergence of these species from their sister groups. Divergence of the three Aru rainbowfishes to those from southern New Guinea would be similar to the estimates for *M. senckenbergianus*. The divergences of *M. aruensis* and other closely related rainbowfishes on the Aru Islands are likely to be in the order of 1 Ma or less. These results suggest that at least some rainbowfish lineages colonised the Aru Islands between the Late Miocene and Early Pleistocene, with one *(M. aruensis)* arriving later in the Mid Pleistocene. Diversification within the two Aru lineages with multiple species primarily occurred during the Mid Pleistocene which suggests that at least the most recent major glacial cycle (and probably the one or two before it) had little direct influence on species diversification.

DISCUSSION

Freshwater Fishes of the Aru Islands: Our 2013 field investigations in combination with historic records reveal a freshwater fish fauna consisting of at least 52 species (Allen et al. in progress). However, only 21 fishes are considered obligate freshwater species, spending their entire life cycle in this environment. The others, including a variety of gobioid fishes, are characterised by marine larval stages. The first category, containing species that lack marine dispersal and are "anchored" to fresh waters of the Aru Islands is especially interesting from a zoogeographic perspective. It includes members of the following genera: *Neosilurus* (Plotosidae), *Melanotaenia* (Melanotaeniidae), *Pseudomugil* (Pseudomugilidae), *Craterocephalus* (Atherinidae), *Glossamia* (Apogonidae), *Bostrichthys*, *Hypseleotris*, *Mogurnda*, and *Oxyeleotris* (Eleotridae), and *Glossogobius* (Gobiidae). Without exception, these are groups equally well represented in the Northern Territory of Australia and southern New Guinea. Until now, the various Aru species in these genera were thought to be the same as those found in Australia/New Guinea, but more detailed genetic and morphological studies are required to properly evaluate their true status. One certainty is that the close affinity of the fishes of northern Australia and southern New Guinea corroborates the influence of the Arafura Plain land connection between these two regions. During lengthy intervals when the shelf was emergent, a complex pattern of low lying drainage basins covered the area (Harris et al. 2005), which during flood periods offered excellent opportunities for broad dispersal across the Arafura Plain, probably similar to those that exist today in the Trans-Fly region of Papua New Guinea or around Australia's Gulf of Carpentaria.

Although more survey effort is required, it is our impression that the southern half of the main archipelago has a significantly richer freshwater fauna compared to the northern islands. For example, the following genera have been captured exclusively in the south: *Neosilurus* (Plotosidae), *Craterocephalus* (Atherinidae), *Iriatherina* (Melanotaeniidae), *Pseudomugil* (except the estuarine species *P. inconspicuous), Glossamia* (Apogonidae), and *Oxyeleotris* (Eleotridae). In contrast, northern streams are relatively impoverished, dominated chiefly by *Melanotaenia* and various gobioid fishes. The reason for this discrepancy is possibly associated with the more hilly terrain in the north and the common occurrence of waterfalls and seawater barriers as opposed to lower elevations in the south, which presumably may have been more conducive to colonisation by lowland fishes that were distributed widely over the Arafura Plain during prolonged periods of low sea levels. Moreover, it appears that the savannah habitat on Trangan Island is a remnant of more widespread grasslands typical of former times. Several lines of evidence suggest that during glacial periods, conditions on the Arafura Plain were much drier and slightly cooler than present (Walker, 1972). Savannah habitat is still well represented in the Trans-Fly of New Guinea

and the assemblage of fishes found there is very similar to that of southern Aru. For example many streams are characterised by the presence of both *Melanotaenia rubrostriata* and the species complex currently called *Melanotaenia goldiei*, a situation paralleled by that of southern Aru where relatives of these two species frequently co-occur. However, northern Aru streams are invariably inhabited by a single *Melanotaenia* species, always a member of the *M. goldiei* complex, which has also successfully invaded hill stream habitat on the mainland.

Rainbowfishes of the Aru Islands: The present study indicates that regional and local isolating factors, fuelled by dynamic sea level fluctuations, have created a unique situation for melanotaeniid evolution. This family is particularly prone to speciation events when populations are fragmented by marine incursions or various geological processes such as stream capture, lake formation, and tectonic plate movements. The Kikori River system of Papua New Guinea provides a good example of this phenomenon. Four species of closely related rainbowfishes occur within this single drainage basin, *Melanotaenia* n. sp. (formerly identified as *M. goldiei*) is found in downstream sections, including the alluvial floodplain and is also found in adjacent lowland systems. Further upstream it is replaced by *M. mubiensis* Allen 1996, which appears to be isolated by major waterfalls. The mountainous upper tributaries are inhabited by *M. monticola* Allen 1980 with the exception of Lake Kutubu, which is home to *M. lacustris* Munro 1964. The melanotaeniid fauna of the Aru Islands, consisting of seven species, five of which are described herein as new, provides yet another example of the evolution of close-knit species complexes within a restricted area, in this case a group of highly fragmented islands that have been subject to numerous isolating events over the past few million years. Although reproductive isolation may not be generated during short inter-glacial periods, alternate genotypes between temporally separated groups can become fixed, which may lead to accumulated genetic differences even with ongoing gene flow (Rocha & Bowen 2008). These processes are often invoked to explain, at least in part, the high biodiversity within the Indo-Malay-Philippines region (Woodland 1983; Bellwood & Wainwright 2002; Gaither & Rocha 2013).

Rainbowfishes of the Aru Islands belong to two distinct lineages, the "Goldiei" and "Australis" groups. Widespread species within these groups, (e.g., *M. goldiei*, *M. trifasciata*, *M. rubrostriata* and *M. splendida),* are typical representatives of multispecies complexes (Unmack et al. 2013). The presence of at least one member from each of these groups is a typical component of most river systems of southern New Guinea and parts of Australia (Northern Territory, and Cape York Peninsula). Ancestral populations of the two lineages were apparently widespread on the Arafura Plain and able to gain access to the ancient "Aru Hills" during periods of low sea level. During intervening periods of raised sea levels, as seen in current times, the Aru populations of the two lineages would have been effectively isolated and although these episodes were relatively short in terms of geologic time (about 10,000 years on average) they were of sufficient duration for morphological/genetic divergence.

Further divergence on a more localised scale within the Aru Islands was apparently facilitated by its highly unusual topography, essentially consisting of highly fragmented, short drainage systems on each island and the major marine sungai separating the larger islands. Trangan Island and the adjacent section of Kobroor Island, which collectively account for about one-half the land area of the main Aru Group, must have maintained a degree of freshwater habitat continuity, judging from the current distribution of *M. senckenbergianus* and *M. aruensis*. Most likely, during lowered sea levels, the more widespread distribution of these species was facilitated by the now marine channels of Sungai Workai and Sungai Maikoor (Fig. 2), which would likely have contained freshwater streams, providing a major conduit for dispersal. Isolation of rainbowfish populations on the larger islands of northern Aru was apparently more absolute, possibly because the small independent drainages where rainbowfishes are currently known, flow directly out to sea rather than into communal sungai. However, more sampling is required to test this hypothesis, particularly in streams of Kola and Wokam islands draining into Sungai Sisirwatu and Sungai Manumbai. Interestingly, the three new species from northern Aru are all members of the "Goldiei" group, which more than any other group of rainbowfishes studied to date, has a propensity for speciation (Unmack et al. 2013).

The exceptionally diverse melanotaeniid fauna of the Aru Islands, as revealed by the current study, is indicative of future trends for the taxonomy of this family. Indeed, our genetic results to date (Unmack

et al. 2013) clearly reveals a need for major revision in this family, both at the genus and species level. The species *M. goldiei*, *M. trifasciata* and *M. rubostriata* should all be considered species complexes as they are clearly divisible into numerous undescribed taxa. This proliferation of species, largely based on genetic evidence, appears to be the general trend for freshwater fishes of the Australia-New Guinea region. For example, Raadik (2014) has shown that the *Galaxias olidus* (Galaxiidae) complex of south-eastern Australia is divisible into three previously described species and 12 new species. These findings have important conservation value, creating an urgent need to reassess freshwater management strategies. The present study highlights the unique freshwater fish fauna of the Aru Islands and the need for protective measures to insure its survival.

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REFERENCES

Allen, G. R. 1980. A generic classification of the rainbowfishes (family Melanotaeniidae). *Records of the Western Australian Museum* **8** (3): 449-490.

Allen, G. R. 1991. *Field Guide to the Freshwater Fishes of New Guinea*. Publication No. 9, Christensen Research Institute, Madang, Papua New Guinea. 268 pp.

Allen, G. R. 1995. *Rainbowfishes in Nature and in the Aquarium*. Tetra Verlag, Melle, Germany. 180 pp.

Allen, G. R. & Cross, N. J. 1982. *Rainbowfishes of Australia and Papua New Guinea*. Angus & Robertson, Sydney. 141 pp.

Allen, G. R. & Unmack, P. J. 2012. A new species of rainbowfish *(Chilatherina:* Melanotaeniidae), from the Sepik River System of Papua New Guinea. *aqua, International Journal of Ichthyology* **18** (4): 227-237.

Allen, G. R., Hadiaty, R. K. & Unmack, P. J. 2014. *Melanotaenia flavipinnis*, a new species of rainbowfish (Melanotaeniidae) from Misool Island, West Papua Province, Indonesia. *aqua, International Journal of Ichthyology* **20** (1): 35-48.

Allison, A. 2007. Section 4.6. Herpetofauna of Papua. In: *The Ecology of Papua, Part One* (Eds. M. J. Marshall & B. M. Beehler.): 564-616. Periplus Edition, Hong Kong.

Andersen, B. G. & Borns, H. W. Jr. 1994. *The Ice Age World: an Introduction to Quaternary History and Research with Emphasis on North America and Northern Europe During the Last 2.5 Million Years*. Oxford University Press, USA. 208 pp.

Aplin, K. & Pasveer, J. 2006. Chapter 3. Mammals and other vertebrates from late Quaternary archaeological sites on Pulau Kobroor, Aru Islands, eastern Indonesia. In: *The Archaeology of the Aru Islands* (Eds. S. O'Conner, M. Spriggs & P. Veth.): 25-39. *Terra Australis* 22. Australian National University Press, Canberra.

Bellwood, D. R. & Wainwright, P. C. 2002. Chapter 1. The history and biogeography of fishes on coral reefs. In: *Coral Reef Fishes: Dynamics and Diversity in a Complex Ecosystem* (Ed. P. S. Sale): 5-32. Academic Press, San Diego, USA.

Bowin, C., Purdy, G. Johnston, C., Shor, G., Lawver, L., Hartono, H. & Jezek, P. 1980. Arc-continent collision in Banda Sea region. *American Association of Petroleum Geologists Bulletin* 64 (6): 868-915.

Clark, P. U. & Mix, A. C. 2002. Ice sheets and sea level of the Last Glacial Maximum. *Quaternary Science Reviews* **21** (1): 1-7.

Curray, J. R., Shor, G. G. Jr., Raitt, R. W. & Henry, M. 1977. Seismic refraction and reflection studies of crustal structure of the Eastern Sunda and Western Banda Arcs. *Journal of Geophysical Research* **82** (17): 2479-2489.

Flannery, T. 1995. *Mammals of New Guinea*. Reed Books, Sydney. 568 pp.

Gaither, M. R., & Rocha, L. A. 2013. Origins of species richness in the Indo-Malay-Philippine biodiversity hotspot: evidence for the centre of overlap hypothesis. *Journal of Biogeography* **40** (9): 1638-1648.

Haq, B. U., Hardenbol, J. & Vail, P. R. 1987. Chronology of fluctuating sea levels since the Triassic. *Science*, **235** (4793): 1156-1167.

Harris, P., Heap, A., Passlow, V., Sbaffi, L. Fellows, M., Porter-Smith, R., Buchanan, C. & Daniell, J. 2005. *Geomorphic Features of the Continental Margin of Australia*. Geoscience Australia, Record 2003/30, 142 pp.

Hope, G. S. 2007. Section 2.7. Paleoecology and paleoenvironments of Papua. In: *The Ecology of Papua, Part One* (Eds. M. J. Marshall & B. M. Beehler.): 255-266. Periplus Edition, Hong Kong.

HOPE, G. & APLIN, K. 2006. Chapter 2. Environmental change in the Aru Islands. In: *The Archaeology of the Aru Islands* (Eds. S. O'Conner, M. Spriggs & P. Veth.): 25-39. *Terra Australis* 22. Australian National University Press, Canberra.

JACOBSON, R., SHOR, G., KIECKHAFER, R. & PURDY, G. 1979. Seismic refraction and reflection studies in the Timor-Aru Trough system and Australian continental shelf. *Memoirs of the American Association of Petroleum Geologists* **29**: 209-222.

MONK, K. A., DE FRETES, Y. & REKSODIHARJO-LILLEY, G. 1997. *The Ecology of Nusa Tenggara and Maluku*. Hong Kong & Cambridge: Periplus and Cambridge University Press. *Ecology of Indonesia Series* 5.

POLHEMUS, D. A. 2007. Section 2.1. Tectonic geology of Papua. In: *The Ecology of Papua, Part One* (Eds. M. J. Marshall & B. M. Beehler.): 137-164. Periplus Edition, Hong Kong.

POSADA, D. & CRANDALL, K. A. 1998. ModelTest: testing the model of DNA substitution. *Bioinformatics* **14**: 817-818.

RAADIK, T. A. 2014. Fifteen from one: a revision of the *Galaxias olidus* Gunther, 1866 complex (Teleostei, Galaxiidae) in south-eastern Australia recognises three previously described taxa and describes 12 new species. *Zootaxa* **3898**: 1-198.

ROCHA, L. A., & BOWEN, B. W. 2008. Speciation in coral-reef fishes. *Journal of Fish Biology* **72** (5): 1101-1121.

SPRIGGS, M., O'CONNOR, S. & VETH, P. 2006. Chapter 1. The Aru Islands in perspective: a general introduction. In: *The Archaeology of the Aru Islands* (Eds. S. O'Conner, M. Spriggs & P. Veth.): 1-23. *Terra Australis* 22. Australian National University Press, Canberra.

UNMACK, P. J., ALLEN, G. R. & JOHNSON, J. B. 2013. Phylogeny and biogeography of rainbowfishes (Melanotaeniidae) from Australia and New Guinea. *Molecular Phylogenetics and Evolution* **67** (1): 15-27.

VAN BALGOOY, M. M. J. 1996. Vegetation sketch of the Aru Islands. In: *The Aru Archipelago: Plants, Animals, People and Conservation* (Ed. H. P. Nooteboomed.): 1-14. *Mededelingan* **30**. Nederlandse Commissie Voor Internationale Natuurbescherming, Amsterdam.

VERSTAPPEN, H. TH. 1959. Geomorphology and crustal movements of the Aru Islands in relation to the Pleistocene drainage of the Sahul shelf. *American Journal of Science* **257**: 491-502.

WALKER, D. (Ed.). 1972. *Bridge and Barrier: the Natural and Cultural History of Torres Strait.* Department of Biogeography and Geomorphology, Research School of Pacific Studies, the Australian National University, Canberra.

WALLACE, A. R. 1869. *The Malay Archipelago: The Land of the Orang-utan and the Bird of Paradise. A Narrative of Travel with Studies of Man and Nature*. MacMillan, London.

WEBER, M. 1907. Eine zoogeographische Prophezeiung. *Zoologischer Anzeiger* **32** (14): 401-404.

WEBER, M. 1911. Die Fische der Aru- und Kei-Inseln. Ein Beitrag zur Zoolographie dieser Inseln. *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft Frankfurt-a.-M.* **34** (1): 1-49.

WEBER, M. & DE BEAUFORT, L. F. 1922. *The Fishes of the Indo-Australian Archipelago. IV. Heteromi, Solenichthyes, Synentognathi, Percesoces, Labyrinthici, Microcyprini*. E. J. Brill, Leiden. 410 pp.

WILSON, B. 2013. *The Biogeography of the Australian North West Shelf: Environmental Change and Life's Response*. Elsevier, San Diego, USA. 413 pp.

WOODLAND, D. J. 1983. Zoogeography of the Siganidae (Pisces): an interpretation of distribution and richness patterns. *Bulletin of Marine Science* **33** (3): 713-717.

ZWICKL, D. J. 2006. Genetic algorithm approaches for the phylogenetic analysis of large biological sequence datasets under the maximum likelihood criterion. Ph.D. dissertation, The University of Texas at Austin.