The loaches of the genus *Nemacheilus* (Teleostei: Nemacheilidae) in Sunda Islands, with an identification key

[Ikan genus *Nemacheilus* (Teleostei: Nemacheilidae) di Kepulauan Sunda, berikut kunci identifikasinya]

Renny Kurnia Hadiaty[1,✉], Kazunori Yamahira[2]

[1]Ichthyology Laboratory, Museum Zoologicum Bogoriense (MZB),
Zoology Division of Research Center for Biology, Indonesian Institute of Sciences (LIPI)
Jln. Raya Bogor Km 46, Cibinong 16911, Indonesia.
[2]Tropical Biosphere Research Center, University of the Ryukyus, Okinawa, Japan.
Senbaru 1, Nishihara, Okinawa 903-0213, Japan.

Received: March 9, 2014; Accepted: April 22, 2014

Abstract

Loaches of the genus *Nemacheilus* are distributed in Southeast Asia from the mainland of Asia to Sunda Islands (Sumatra, Java, and Borneo). In this paper, the status of *Nemacheilus* in Sunda Islands is discussed base on the results of field trips in Indonesian waters, the fish collections in Museum Zoologicum Bogoriense, and published papers. There are 18 species in Sunda Islands, 8 species inhabit in Sumatra and 10 species in Kalimantan, and only 2 species inhabit in Java. An idetification key of the 18 species is also included.

Key words: Identification keys, *Nemacheilus,* Sunda Islands, Indonesia

Abstrak

Ikan genus *Nemacheilus* tersebar meliputi wilayah Asia Tenggara, dari daratan Asia sampai ke Kepulauan Sunda (Sumatra, Jawa, dan Kalimantan). Dalam tulisan ini dikemukakan status *Nemacheilus* di pulau-pulau tersebut berdasarkan hasil kegiatan lapangan di perairan Indonesia, koleksi di Museum Zoologicum Bogoriense (MZB), dan tulisan yang telah dipublikasi. Di Kepulauan Sunda dijumpai 18 species *Nemacheilus,* delapan spesies dijumpai di Sumatra, 10 spesies di Kalimantan dan hanya dua spesies di Jawa. Kunci identifikasi 18 spesies *Nemacheilus* disertakan.

Kata penting: Kepulauan Sunda, kunci identifikasi, *Nemacheilus,* Indonesia

Introduction

How many freshwater fish species live in Southeast Asia? Kottelat (2013) reported the biodiversity of freshwater fishes in Southeast Asia as follows: 3107 valid native species, in 707 valid genera and 137 families. In addition, there are about 300 species to be named or already on museum shelves, a fair number of synonyms to be revalidated, and about 500 species still awaiting discovery in the wild (Kottelat 2013).

One of the most diverse freshwater fish group in Southeast Asia is loaches, the suborder Cobitoidei. Indeed, the fishes reported from the highest altitude in Asia (at 5200 m above sea level) are loaches, and those reported from the lowest altitude (about 50 m below sea level) are also loaches. In a catalogue of Cobitoidei, Kottelat (2012) reviewed all 1499 recorded species-group names and 185 genus-group names and corrected spelling and types, based on about 1010 titles of bibliographies. He finally recognised 1043 valid species in 111 valid genera.

Nemacheilidae is a family of loaches, which live in the rivers of Eurasia and Ethiopia (Kottelat & Freyhof 2007 and Kottelat 2012). Nemacheilinae was a subfamily of Balitoridae for a long time, but since it was recognized to be a monophyletic lineage (Bohlen & Šlechtová 2009), Kottelat (2012) retain Nemacheilidae as a valid family. Based on his review, Nemacheilidae consists of 575 species in 46 genera.

✉ Corresponding author
E-mail address: renny_hadiaty@yahoo.com

The type genus of Nemacheilidae is *Nemacheilus*. The type species of the genus is *Nemacheilus fasciatus*, which was described as *Cobitis fasciata* by Valenciennes (in Cuvier & Valenciennes 1846). Bleeker in 1853 described the genus *Nemacheilus*. He reviewed the *C. fasciata* and put it in *Nemacheilus.*

The genus *Nemacheilus* comprise of 33 species, 6% of the total number of nemacheilid species (Kottelat 2012). All of the *Nemacheilus* species are endemic to Southeast Asia (the valid species, authors and type localities presented in Table 1). Among the 33 species, 16 species, about a half of them, have been described from Sunda Islands: Borneo (8 species), Sumatra (6 species), and Java (2 species). However, the diversity of this genus in Sunda Islands is still unclear, because of the lack of comprehensive field collections and taxonomic examinations of this group throughout the area.

Table 1. Valid species of *Nemacheilus*, their authors and type locality (from Kottelat 2012)

Species	Species Author(s)	Type locality
N. chrysolaimos	(Valenciennes, in C&V, 1846)	Indonesia: Java
N. fasciatus	(Valenciennes, in C&V, 1846)	Indonesia: Java, Buitenzorg (Bogor)
*N. jaklesii**	(Bleeker, 1852)	Indonesia: Sumatra: Pajakumbuh
N. kapuasensis	Kottelat, 1984	Indonesia: Borneo, Kalimantan Barat
N. longipectoralis	Popta, 1905	Indonesia: Borneo, Kalimantan Timur
N. longipinnis	Ahl, 1922	Indonesia: Sumatra, Riau, Siak drainage
N. marang	Hadiaty & Kottelat, 2010	Indonesia: Borneo, Kalimantan Timur
N. papillos	Tan & Kottelat, 2009	Indonesia: Sumatra Selatan
*N. papillosus**	(Perugia, 1893)	Indonesia: Sumatra, Balighe, Lake Toba
N. pfeifferae	(Bleeker, 1853)	Indonesia: Sumatra, Lake Maninjau
N. tebo	Hadiaty & Kottelat, 2009	Indonesia: Borneo, Kalimantan Timur
N. tuberigum	Hadiaty & Siebert, 2001	Indonesia: Sumatra, Aceh Selatan
N. elegantissimus	Chin & Samat, 1992	Malaysia: Borneo, Sabah, Lahad Datu
N. olivaceus	Boulenger, 1894	Malaysia: Borneo, Sabah, Bongon
N. paucimaculatus	Bohlen & Šlechtova, 2011	Malaysia: Johor, trib. of Segamat River
N. saravacensis	Boulenger, 1894	Malaysia: Borneo, Sarawak, Senah
N. selangoricus	Duncker, 1904	Malaysia: surrounding of Kuala Lumpur
N. spiniferus	Kottelat, 1984	Malaysia: Borneo, Sarawak
N. binotatus	Smith, 1933	Thailand: Chiang Mai Province
N. longistriatus	Kottelat, 1990	Thailand: Loei Province
N. masyae	Smith, 1933	Thailand: Nakhon Sritamarat
N. ornatus	Kottelat, 1990	Thailand: Surat Thani Province
N. pallidus	Kottelat, 1990	Thailand: Lampang Province
N. troglocataractus	Kottelat & Géry, 1989	Thailand: Kanchanaburi Province
N. anguilla	Annandale, 1919	India: Bombay Presidency
*N. corica**	(Hamilton, 1822)	India: Kosi River
*N. kaimurensis**	Husain & Tilak, 1998	India: Uttar Pradesh
*N. monilis**	Hora, 1921	India: Bhavani River
N. stigmofasciatus	Arunachalam & Muralidharan, 2009	India: Karnataka
N. banar	Freyhof & Serov, 2001	Vietnam: Kontum Province
N. cleopatra	Freyhof & Serov, 2001	Vietnam: Gia Lai Province
N. platiceps	Kottelat, 1990	Vietnam: Trang Bom
N. arenicolus	Kottelat, 1998	Laos: Khammouan Province

Note: * means the species is valid, but the author did not designate any holotype (Kottelat 2013).

The aim of this study is to provide the status of the *Nemacheilus* species that inhabit Sunda Islands, i.e., Sumatra, Java, and Borneo (the four Indonesian provinces [Kalimantan Barat, Kalimantan Selatan, Kalimantan Tengah, Kalimantan Timur], the two Malaysian provinces [Sabah, Sarawak], and Brunei) and construct an identification key. Since we did not have the opportunity to collect fish in Malaysian Borneo, the information for species in that area are extracted from the literature (Kottelat 1984, 1990, 2012, 2013, and Chin & Samat 1992). This study will add to the data on fish biodiversity in Sunda Island, especially in Indonesian waters, and should help to recognise and identify these loaches.

Material and methods

Field collections

This study is based on the specimens collected by the first author during field trips in Sumatra, Java, and Kalimantan between 1997 and 2014. Collection sites were summarized in Table 2. Fish samples were collected with electricity, tray nets, and/or seines. Notes on habitats and surrounding environments were recorded. The live specimens of almost all species collected were photographed immediately after capture or later at the base camp. The fish were preserved in 10% formalin (4% formaldehyde).

The identifications were based on Alfred (1961), Chin & Samat (1992), Hadiaty & Siebert (2001), Hadiaty & Kottelat (2009, 2010), Kottelat (1984, 1990, 2012, 2013), Kottelat *et al*. (1993), Kottelat & Widjanarti (2005), Kottelat & Whitten (1996), Kottelat & Freyhof (2007), Martin-Smith & Tan (1998), Roberts (1989), and Tan & Kottelat (2009). All samples were registered at Museum Zoologicum Bogoriense (MZB), the Ichthyology Laboratory, Division of Zoology, Research Center for Biology, Indonesian Institutes of Sciences, Indonesia.

Some type specimens of *Nemacheilus* spp. were examined in five European museums: The Rijksmuseum van Natuurlijke Historie (RMNH), Leiden; The Natural History Museum (NHM), London; The National Museum of Natural History (MNHN), Paris; The Zoological Museum Amsterdam (ZMA), Amsterdam; Collections of Maurice Kottelat (CMK), Switzerland; and The Raffless Museum of Biodiversity Research (RMBR), Singapore. Some specimens were examined with scanning electron microscope in National Museum of Natural History (NMNH), Smithsonian Institution, Washington DC. In addition to the specimens collected during the field trips above, the *Nemacheilus* spp. collections of Museum Zoologicum Bogoriense (MZB), the Ichthyology Laboratory, Division of Zoology, Research Center for Biology, Indonesian Institutes of Sciences, were also examined.

Morphometry and meristics were examined for species which had not been described. Methods for morphometry and meristics follow Kottelat (1984; 1990) and Kottelat & Freyhof (2007). Measurements were taken using a digital caliper, from point to point; exceptions are explicitly signified.

Results

During the course of field trips, 10 species of *Nemacheilus* (in total 1533 individuals) were collected (Table 3); 2 species from Sumatra (*N. tuberigum* and *N. fasciatus*), 1 species from Bangka and Belitung (*N. selangoricus*), 2 species from Java (*N. fasciatus* and *N. chrysolaimos*) and 7 species from Kalimantan (*N. kapuasensis*, *N. longipectoralis*, *N. marang*, *N. spiniferus*, *N. selangoricus*, *N. tebo*, and *Nemacheilus* nsp.). *N. jacklesii, N. longipinnis, N. papillos*, *N.*

Table 2. Collection sites of *Nemacheilus* species and years of field trips

Collection sites	Province	Island	Year	Abbreviation
Suaq Balimbing Research Station	Aceh	North Sumatra	1997	NS1
Ketambe Research Station	Aceh	North Sumatra	1998	NS2
Bukit Barisan National Park	Lampung	South Sumatra	2005	SS1
Metro	Lampung	South Sumatra	2006	SS2
Lahat	Sumatra Selatan	South Sumatra	2006	SS3
Muara Enim	Sumatra Selatan	South Sumatra	2006	SS4
Pagar Alam	Sumatra Selatan	South Sumatra	2006	SS5
Muara Sabak	Jambi Province	South Sumatra	2011	SS6
Bangka Island	Bangka-Belitung	Bangka	2011	BB1
Belitung Island	Bangka-Belitung	Bangka	2011	BB2
Bogor	Jawa Barat	West Jawa	2009-2011	WJ1
Bandung	Jawa Barat	West Jawa	2011-2012	WJ2
Sukabumi	Jawa Barat	West Java	2012	WJ3
Banten	Jawa Barat	West Java	2013	WJ4
Gunung Sewu karst area	Yogyakarta	Central Java	2006-2009	CJ1
Purwokerto	Jawa Tengah	Central Java	2013	CJ2
Temanggung	Jawa Tengah	Central Java	2013	CJ3
Tuban karst area	Jawa Timur	East Java	2010	EJ1
Pacitan karst area	Jawa Timur	East Java	2013	EJ2
Blitar	Jawa Timur	East Java	2014	EJ3
Kediri	Jawa Timur	East Java	2014	EJ4
Lumajang	Jawa Timur	East Java	2014	EJ5
Mandor	Kalimantan Barat	West Borneo	2012	WB1
Banjarmasin	Kalimantan Selatan	South Borneo	2012	SB1
Kotawaringin Barat	Kalimantan Tengah	South Borneo	2012	SB2
Murung Raya	Kalimantan Tengah	Central Borneo	2006	CB1
Sukamara	Kalimantan Tengah	Central Borneo	2012	CB2
Sangkulirang karst area	Kalimantan Timur	East Borneo	2004	EB1
Kutai Barat	Kalimantan Timur	East Borneo	2006	EB2
Kutai Kartanegara	Kalimantan Timur	East Borneo	2008-2012	EB3

pfeifferae, *N. papillosa*, and *N. saravacensis* which had been described from Indonesian waters were not collected during the trips.

From those 10 species, three were designated as new species and described as *N. tuberigum* Hadiaty & Siebert 2001, *N. tebo* Hadiaty & Kottelat 2009, and *N. marang* Hadiaty & Kottelat 2010. One species from Kalimantan Tengah Province was also a new species but has not been described. These four species were examined as follows.

- ***Nemacheilus tuberigum* Hadiaty & Siebert, 2001**

Nemacheilus tuberigum is known from the area of Gunung Leuser National Park, Nangroe Aceh Darussalam Province, Indonesia.

Diagnosis. *Nemacheilus tuberigum* is distinguished from all other *Nemacheilus* by combination of a row of comparatively large tubercles present on enlarged, elongate scales in the scale rows immediately above and below the lateral line scale row on the anterior half of the caudal

Table 3. *Nemacheilus* species collected during the course of field trips. See Table 2 for abbreviations of collection sites

No.	Species	Collection sites
1.	*N. tuberigum*	NS1, NS2
2.	*N. fasciatus*	SS1-SS4, WJ1, WJ3, CJ1-CJ3, EJ1-EJ5
3.	*N. selangoricus*	BB1, BB2, WB1, SB1, SB2
4.	*N. chrysolaimos*	WJ1, WJ2
5.	*N. kapuasensis*	EB1
6.	*N. longipectoralis*	EB3
7.	*N. marang*	EB1
8.	*N. spiniferus*	CB1, EB1-EB3
9.	*N. tebo*	EB1
10.	*Nemacheilus* nsp.	SB2

Notes: NS= North Sumatra, SS=South Sumatra, WJ=West Java, CJ=Central Java, EJ=East Java, BB= Bangka-Belitung, WB=West Borneo, SB=South Borneo, EB= East Borneo, CB= Central Borneo

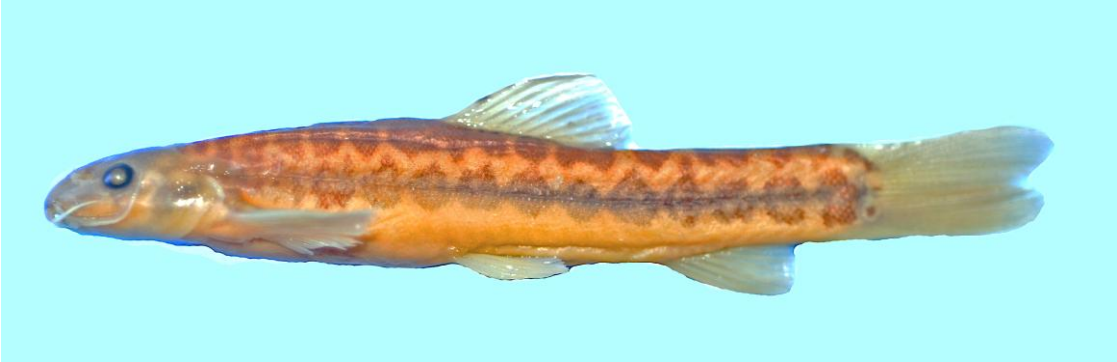

Figure 1. *Nemacheilus tuberigum*, MZB 14383, 48.7 mm SL; Nangroe Aceh Darussalam Province: Gunung Leuser National Park, Sumatra, Indonesia.

peduncle; colour pattern consisting of 11-15 dorsal saddles, a series of 8-13 lateral blotches centred along the lateral line and without a dark spot at anterior base of dorsal fin (Figure 1).

Sexual dimorphism. Male with suborbital flap and much more tubercles on flank than female.

- ***Nemacheilus tebo* Hadiaty & Kottelat, 2009**

Nemacheilus tebo is known from Danau Tebo area, an isolated hilly part of Sangkulirang Peninsula karstic area in Kalimantan Timur Province, Indonesia. This species was collected at 6 sites in the Danau Tebo drainage. The southern part of Tebo was burned once during the 1997 fires, but the area is so remote that other impacts (illegal logging and hunting) are minimal; it currently retains large patches of primary forest (Salas *et al*. 2005).

Diagnosis. *Nemacheilus tebo* is distinguished from all other species of the genus in Sunda Islands by its unique colour pattern: flank with 11-16 dark brown bars, those in front of the dorsal fin short, close together or fused, forming a kind of large elongate dark brown bar; those below and behind the dorsal fin distinct, continous across dorsum, irregularly shaped, usually wider along the dorsal midline and along lateral line, narrower in-between (Figure 2). It is also distinguished by the presence of longitudinal

rows of elongated scales on the caudal peduncle, each scale with a tubercle at posterior extremity. It is distinguished from the other species of the *N. selangoricus* group (*sensu* Hadiaty & Kottelat 2009) by having smaller tubercles, and by the presence of rows of tubercles on the lower half of the flank. Further, it is distinguished from *N. selangoricus* and *N. spiniferus* in missing the long, acuminate posterior projection on the caudal peduncle and by the absence of the black spot at the base of the anterior dorsal-fin rays and of the rows of black spot on the rays.

***Sexual dimorphism*.** Male with suborbital flap and much more tubercles on flank than female. The flap is smaller in the largest specimen.

Figure 2. *Nemacheilus tebo*, MZB 13367, holotype, 56.1 mm SL; Lake Tebo, Sangkulirang karst area, Kalimantan Timur Province, Indonesia.

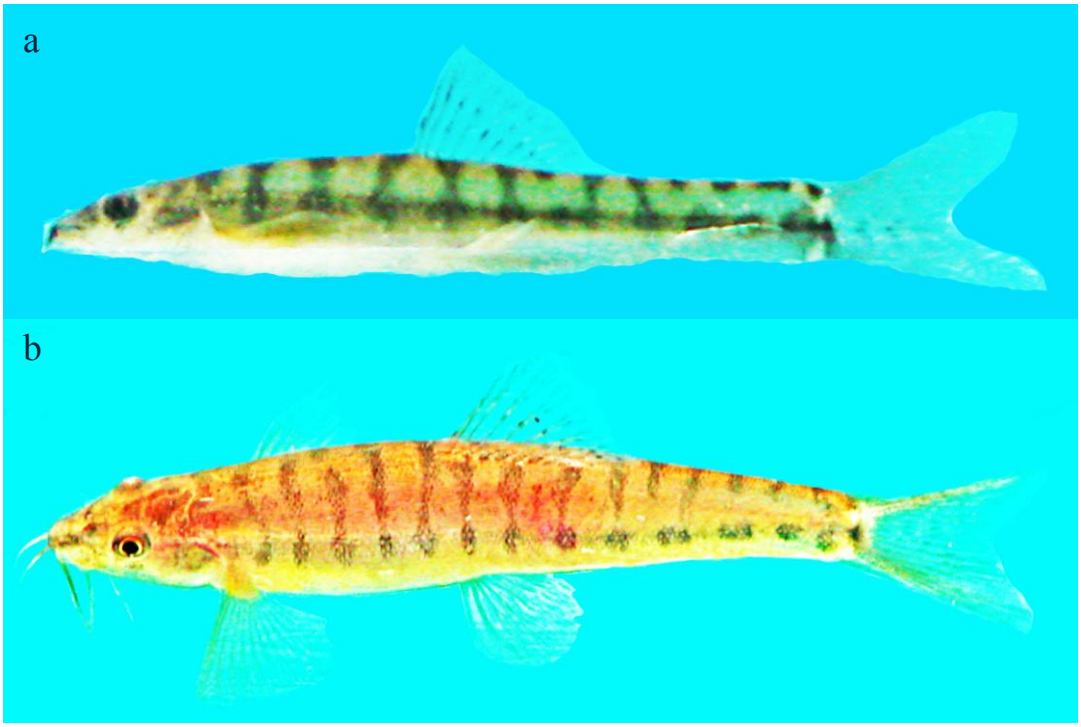

Figure 3. *Nemacheilus marang*: a. MZB 13301, holotype, 38.9 mm SL; b. MZB 13306, 55.9 mm SL, a gravid female, Marang River, Tepian Langsat, Sangkulirang karstic area, Kalimantan Timur Province, Indonesia.

- ***Nemacheilus marang* Hadiaty & Kottelat, 2010**

Nemacheilus marang is known from Sungai Marang, Bengalon drainage, Tepian Langsat Village, Kecamatan Kelai, Kabupaten Kutai Timur, Kalimantan Timur, Indonesia.

Diagnosis. *Nemacheilus marang* is distinguished from all other species of the genus in Sunda Islands by its colour pattern made of 10-18 dark brown bars on flank, extending from dorsal midline to just below lateral line, continous across back, not or only slightly wider on back and where crossing midlateral stripe; bars usually regular, straight, and width less than half that of interspaces (Figure 3).

Other diagnostic characters but not unique to the species are: scales of rows above and below lateral line row on caudal peduncle not elongate and without a tubercle at their posterior extremity; pectoral fin reaching only slightly beyond half of distance to pelvic-fin base; caudal fin forked, upper lobe 1.0-1.5 times longer than median rays; anus located behind middle of distance between pelvic-fin base and anal-fin origin; anterior nostril at the front side of a pointed flap; 17 branched caudal-fin rays: 8½ branched dorsal-fin rays; and 84-92 lateral line pores.

Sexual dimorphism. Male with suborbital flap.

- ***Nemacheilus* nsp.**

Nemacheilus nsp. were collected from Sei Samai drainage, Antakalang, Kotawaringin Barat, Kalimantan Tengah, Indonesia.

Diagnosis. *Nemacheilus* nsp. is distinguished from all other species of the genus in Sunda Islands by its colour pattern, all of the body colour is black, especially when alive, immediately after capture (Figure 4).

Sexual dimorphism. Male with suborbital flap.

Discussions

Diversity of the genus Nemacheilus in Indonesia

Throughout the field trips in Sunda Islands, three new *Nemacheilus* species have been described, and one more is waiting to be named. Considering that there are still many unexplored waters, it is very possible that there are more undescribed species of *Nemacheilus* in this area.

Figure 4. *Nemacheilus* nsp., MZB 21449, 42.7 mm SL; Sungai Batu Nyambil, Sei Samai drainage, Antakalang, Kotawaringin Barat, Kalimantan Tengah Province, Indonesia.

Table 4. The 18 *Nemacheilus* species in Sunda Islands and their distributions. Group indicates the groups estimated from the identification keys (see text for details).

Species	Distribution	Group
N. selangoricus	Malay Peninsula, Bangka, Belitung, Southeast Sumatra, Southwest Borneo	A
N. spiniferus	Northeast-Central Borneo	A
N. tebo	East Borneo	A
Nemacheilus nsp.	South Borneo	A
N. tuberigum	North Sumatra	A
N. pfeifferae	Central Sumatra	A
N. olivaceus	North Borneo	B
N. saravacensis	West Borneo	B
N. marang	East Borneo	B
N. longipectoralis	Central Borneo	B
N. longipinnis	Central Sumatra	B
N. papillos	South Sumatra	B
N. chrysolaimos	West Java	B
N. elegantissimus	North Borneo	C
N. kapuasensis	Southwest-Central Borneo	C
N. jaklesii	Central Sumatra	C
N. papillosus	North Sumatra	C
N. fasciatus	South Sumatra, Java	C

Including the undescribed species, in total, 18 species of *Nemacheilus*, more than half of the species of this genus, are found on Sunda Islands (Table 4). Especially, Borneo has 10 species, and Sumatra has 8 species, respectively, indicating that these two islands are the most diverse area of the genus. Among the 18 species, only *N. selangorius* inhabits both the Sunda (Sumatra, Bangka, Belitung, and Borneo) and the Asian mainland sides (Malay Peninsula). Besides, among the 18 species, *N. elegantissimus* and *N. olivaceus* inhabits only in Malaysian Borneo (Sabah) and has not been found from Indonesian waters. We provide identification keys for the 18 *Nemacheilus* species in Sunda Islands below.

Identification keys

This key is modified mainly from Kottelat (1984, 1990), with the additional information from Roberts (1989), Chin & Samat (1992), Kottelat *et al*. (1993), Hadiaty & Siebert (2001), Hadiaty & Kottelat (2009, 2010), Tan & Kottelat (2009), and van Oijen & Loots (2012).

1a. Acuminate or enlarged scales on rows above and below lateral line on caudal peduncle. 2

1b. No acuminate or enlarged scales on caudal peduncle 7

2a. 4-10 acuminate scales above and below lateral line on caudal peduncle 3

2b. Enlarged scales above and below lateral line on caudal peduncle 4

3a. Process of acuminate scales as long as rest of scale, its base width approximately one-half of scale width; colour pattern consisting of 10-13 dark bars, somewhat wider than interspaces, their middle area being sometimes lighter brown than the margin, these bars are not very regular, they usually are wider on dorsal mid-line than in bet-

ween; dorsal head length 21-23% SL; N.-C. Borneo ..... *N spiniferus*

3b. Process of acuminate scales shorter than rest of scale, its base width approximately one-fourth to one-third of scale width; colour pattern consisting of 8-12 dark bars, wider than interspaces, the middle area of the bars being often lighter brown than the margin or as light as the background, the bar then being vertically split into two thin bars, these bars are very regular; dorsal head length 18-22% SL; Malay Peninsula, Bangka, Belitung, S.E. Sumatra, W. Borneo ..... *N. selangoricus*

4a. Colour pattern consisting of 10-18 dorsal saddles with 8-15 blotches along lateral line 5

4b. Body with dark brown bars in some part fused forming a large elongate dark brown or body totally black 6

5a. Colour pattern consisting of 11-15 dorsal saddles, wider than interspaces, a series of 8-13 blotches along lateral line; dorsal head length 16.8-20.9 % SL; N. Sumatra ..... *N. tuberigum*

5b. Colour pattern consisting of 10-18 saddles on the back and 10-15 dark blotches along lateral line, alternating with the saddles, often fused to dorm a longitudinal stripe; C. Sumatra ..... *N. pfeifferae*

6a. Colour pattern consisting of 11-16 dark brown bars, those in front of dorsal fin short, close together or fused, forming a kind of large elongate dark brown bars, below and behind dorsal fin continuous across dorsum, irregularly shaped, wider along the dorsal midline and along lateral line, narrower in between; dorsal head length 17.1-21.1% SL; E. Borneo (Lake Tebo) ..... *N. tebo*

6b. Colour pattern consisting of all over of the body black, no bars, saddles or blotch; S. Borneo (Sei Samai) ..... *Nemacheilus* nsp.

7a. Anterior naris of a short tube 8

7b. Anterior naris pierced on front side of a flap 14

8a. Anterior naris ending in a modified projection 9

8b. Anterior naris valve pierced at the tip of a tube 11

9a. Anterior naris ending in a filament at least as long as rest of valve; caudal fin rounded, truncate or forked, if forked, caudal lobes subequal, upper lobe less than 1.3 times of median caudal-fin rays; N. Borneo ..... *N. olivaceus*

9b. Anterior naris ending in a short projection; caudal fin forked, upper lobe 1.0-1.5 times longer than median caudal-fin rays .. 10

10a. 16 (17 in the Kapuas material) branched caudal-fin rays; 9-10 branched dorsal-fin rays; colour pattern consisting of 13-17 irregular dark blotches along lateral line; W. Borneo ..... *N. saravacensis*

10b. 17 branched caudal-fin rays; 8-9 branched dorsal-fin rays; colour pattern consisting of 10-18 dark brown bars, extending from the dorsal midline to just below lateral line, bars usually similarly shaped, straight, and narrower than interspaces; E. Borneo (Sangkulirang Karst area) ..... *N. marang*

11a. Long pectoral fins, pectoral fins reach farther than the base of pelvic fins; C. Borneo ..... *N. longipectoralis*

11b. Pectoral fins do not reach the base of pelvic fins 12

12a. Lips strongly papillated; colour pattern consisting of regular bar beginning on

dorsal profile with 10-11 bars, much wider than interspaces, no sexual dimorphism; S. Sumatra ..... *N. papillos*

12b. Lips not papillated; colour pattern irregular 13

13a. Big eyes, eye diameter 7% SL; a dark spot at the base of the anterior part of the dorsal fin; C. Sumatra (Siak River) ..... *N. longipinnis*

13b. Eye diameter 4-6% SL; body light brown with 9-18 dark bars of irregular shape, bars wider than interspaces; W. Java ..... *N. chrysolaimos*

14a. Colour pattern consisting of dark brown blotches and dorsal saddles 15

14b. Colour pattern consisting of dark bars 16

15a. Colour pattern consisting of 17-21 dark blotches which is some diamonds pattern along lateral line, dark saddles alternating with the blotches; N. Borneo (Danum Valley) ..... *N. elegantissimus*

15b. Colour pattern consisting of 14-18 dark blotches along lateral line with 11-12 dark saddles across the back; S. Sumatra, Java ..... *N. fasciatus*

16a. Colour pattern consisting of 10-12 dark bars, wider than interspaces; S.W.-C. Borneo ..... *N. kapuasensis*

16b. Colour pattern consisting of narrow dark bars, narrower than interspaces 17

17a. Colour pattern consisting of 10 narrow dark bars, much narrower than interspaces; C. Sumatra (Payakumbuh) ... *N. jaklesii*

17b. Colour pattern consisting of narrow dark bars with dorsal saddles; N. Sumatra (Baliage) ..... *N. papillosus*

Biogeography

The distribution of *Nemacheilus* species on the Great Sunda Islands is restricted to Sumatra, Java, Borneo, Bangka, and Belitung. They are not present in Sulawesi and Lesser Sunda Islands. The islands of Sumatra, Java, and Borneo, and mainland South-East Asia are on a shallow marine shelf, the Sunda shelf. Pleistocene glaciations caused sea level variation, exposing vast areas of the Sunda shelf and creating land bridges among the islands and mainlands (Voris 2000). Probably, the common ancestor of *Nemacheilus* in Sunda Island expand their geographic range from the mainland Asia to the islands during the Pleistocene glacial, when the shelf was exposed and drained by large river systems which connected many of today's rivers (Voris 2000). The striking faunal similarities between countries bordering the Sunda shelf have been attributed to faunal exchanges across the shelf (McConnel 2004).

The identification keys above indicates that *Nemacheilus* species in Sunda Islands are roughly classified into two groups; the group of species having acuminate or enlarged scales above and below the lateral line and that without acuminate or enlarged scales. The former group, Group A, includes 6 species on Sunda Islands (*N. tuberigum, N. pfeiffearae, N. tebo, Nemacheilus* nsp., *N. spiniferus*, and *N. selangoricus*) (Table 4). Interestingly, we observe that their geographic distributions are allopatric. For example, *N. tuberigum*, *N. pfeifferae*, and *N. selangoricus* live in Sumatra, but they separate their distributions in between the northern, central, and southeastern parts of the island. Similarly, *N. tebo*, *N. spiniferus*, *Nemacheilus* nsp., and *N. selangoricus* inhabit in Borneo, but their distributions also hardly overlap. Assuming that the species members of this group are phylogenetically close with each other, the non-overlap ping geographic pattern may suggest that physical isolations and

resultant allopatric speciation may have contributed to the diversification of this group. The fact that most of *Nemacheilus* species in Sunda Islands live in mountainous areas and have low dispersal ability may have facilitated physical isolations.

The other group is further divided into two subgroups by the shape of the anterior naris, one group having a tube-like naris, Group B, and the other having a non tube-like naris, Group C. We found that like Group A the species members of each of Group B and C also do not overlap their geographic distributions with each other or overlap only a little if any (Table 4). This suggests that allopatric speciations may have contributed to the diversifications also in Group B and Group C. It is presently unclear how the three groups (Group A-C) had diverged from a common ancestor in the first place, but it is likely that physical isolations are the primary conditions for the diversifications of this genus, considering their low dispersal ability.

Conservation status

According to the IUCN Red list of threatened fish species version 2013 (http: //www. iucnredlist/org/serch?page=2), *Nemacheilus selangoricus* is the only *Nemacheilus* in Sunda Islands included in the list. This species is listed as 'data deficient'. *Nemacheilus* species in Sunda Islands generally live in stream environments in the hilly part or mountainous area, with the clear water, stone or gravel substrate, and moderate to strong current. The water pollution, habitat degradation, and invasion by exotic species may easily affect the sustainability of the *Nemacheilus* species, and the freshwater stream biodiversity as well in general. It has been suggested that sustainable conservation strategies for freshwater biodiversity can be most effective, if they integrate multiple levels of biological organization (Geist 2011). However, their conservation in stream habitats are still poorly understood (Geist 2011), and thus may offer a great perspective for future researches.

Conclusions

Eighteen species of the genus *Nemacheilus* inhabit Sunda Islands, including one undescribed species. Among the 18 species, 11 and 9 species live in Borneo and Sumatra, respectively, indicating that these two islands are the most diverse area of the genus. Only one species, *N. selangoricus*, is distributed both on Sunda Islands and the mainland Asia. Identification keys suggest that the 18 species in Sunda Islands are classified into three subgroups.

Materials examined

Nemacheilus chrysolaimos: MNHN 3961, lectotype, 1 ex., 46.7 mm SL; Java, Indonesia; Kuhl & van Hasselt, no date. MNHN B 2972, paralectotype, 1, 46.7 mm SL; Java, Indonesia; Kuhl & van Hasselt, no date. MZB 1374b, 10 ex., 43.0-47.3 mm SL; Cisarua, Bogor, Java, Indonesia; Yachya, 5 April 1970. MZB 1366, 9 ex., 27.9-41.6 mm SL; Ciapus, Gadog, Bogor, Java, Indonesia; Minin, 25 December 1969. MZB 6, 3 ex., 48.8-67.7 mm SL; Sungai Cigundul, West Java, Indonesia; Hardenberg, 15 August 1930.

Nemacheilus elegantissimus: CMK 7937, paratype, 1 ex., 46.0 mm SL; Sungai Lonpodas, Danum Valley, Lahad Datu District, Sabah, Borneo, Malaysia; A. Samat, 7 December 1990. ZRC 40381, 1 ex., 47.8 mm SL; Sungai Lonpodas, Danum Valley, Lahad Datu District, Sabah, Borneo, Malaysia; K. Martin-Smith, 4 June 1996.

Nemacheilus fasciatus: MNHN B 2798, holotype, 1 ex., 54.1 mm SL; Java, Indonesia; Kuhl & van Hasselt. MZB 1372b, 3 ex., 55.3-57.6 mm SL; Cikaniki, Cipaku, Bogor, Java, Indonesia; S. Wargasasmita, 25 March 1970. MZB 1372c, 6 ex., 56.7-69.2 mm SL; Cikaniki, Cipaku, Bogor, Java, Indonesia; S. Wargasasmita, 25 March 1970. MZB 2010, 7 ex., 56.3-68.6 mm SL, Sangharus, Airnaningan, Pulau Panggung, Lampung Selatan, Sumatra, Indonesia; D. Hardjono & F. Sabar, 26 February 1975. ZMA 109.262, 2 ex., 41.9 mm SL, 1 specimen without head; stream in Gremeng cave, Gunung Sewu, Yogya, Java, Indonesia; E. Jacobson, Feburary 1911.

Nemacheilus jaklesii: BMNH 1866.5.2.60, paralectotype, 1 ex., 49.1 mm SL, male; Paya Kumbuh, Sumatra, Indonesia; no collector and date.

Nemacheilus kapuasensis: ZRC 44047, 1 ex., 60 mm SL; Bau area, Sarawak, Malaysia; H. H. Tan, 24 April 2004. ZRC 38823, 2 ex., 51.4–52.9 mm SL, Sungai Lanjak in Lanjak and Sungai Lanjak Deras, 1 km east of Lanjak, Kapuas drainage, Kalimantan Barat, Borneo, Indonesia; M. Kottelat, 11 June 1995. CMK 3187, 3 ex., 41.2-54.0 mm SL; Sungai Pinoh at Nangu Saian, 45 km S of Nangapinoh, Kapuas drainage, Kalimantan Barat, Borneo, Indonesia; T.R. Roberts, 26 July 1976.

Nemacheilus longipectoralis: RMNH 7641, lectotype, 1 ex., 34.4 mm SL; upper Mahakam, Kalimantan Timur, Borneo, Indonesia; A.W. Nieuwenhuis, November 1898. RMNH 27350, paralectotypes, 2 ex., 28.9-36.7 mm SL, Mahakam, Borneo, Indonesia; A.W. Nieuwenhuis, November 1898. MZB 16479, 1 ex., 39.4 mm SL; Sungai Pleo, Sungai Senget Kiri, Mahakam drainage, Kalimantan Timur, Borneo, Indonesia; R.. Hadiaty *et al*., 6 June 2008. ZRC 40383, 3 ex., 33.7–38.3 mm SL; Sungai Lonpodas, Danum Valley, Lahad Datu District, Sabah, Malaysia; H.H. Tan & Y.Y. Goh, 3 October 1996.

Nemacheilus longipinnis: ZMB 20547, holotype, 1 ex, broken tail; upper & middle sections of Rokan Kanan, Rokan Kiri and Siak drainages, Riau, Sumatra, Indonesia.

Nemacheilus marang: MZB 13301, holotype, 1 ex., 38.9 mm SL; Sungai Marang, Bengalon drainage, Tepian Langsat village, Kecamatan Kelai, Kabupaten Kutai Timur, Kalimantan Timur, Borneo, Indonesia; R. K. Hadiaty, Sugeng & July, 25 August 2004. Paratypes: ANSP 187007, 1 ex., 43.0 mm SL; BMNH 2006.3.20.2, 2 ex., 38.5-40.7 mm SL; UF 165708, 2 ex., 39.6-43.8 mm SL; USNM 388745, 2 ex., 38.7-40.9 mm SL; ZRC 50729, 2 ex., 34.9-36.4 mm SL; CMK 20314, 2 ex., 40.1-44.2 mm SL; CMK 18908, 2 ex., 41.9-49.6 mm SL; same data as holotype. MZB 13321, 4 ex., 37-51.6 mm SL; Sungai Jelai; Bengalon drainage, Tepian Langsat village, Kecamatan Kelai, Kabupaten Kutai Timur, Kalimantan Timur, Borneo, Indonesia; R. K. Hadiaty, Sugeng & July, 26 August 2004. Additional material (non types): MZB 13295, 1 ex., 41.5 mm SL; Sungai Marang; Bengalon drainage, Tepian Langsat village, Kecamatan Kelai, Kabupaten Kutai Timur, Kalimantan Timur, Borneo, Indonesia; Daeng, 21 August 2004. MZB 13302, 1 ex., 39.6 mm SL; Sungai Marang; Indonesia: Kalimantan Timur: Kabupaten Kutai Timur: Kecamatan Kelai: Tepian Langsat village; Daeng, 23 August 2004. MZB 13304, 3 ex.,

41.7–45.8 mm SL; Mouth of Sungai Marang, Indonesia: Kalimantan Timur: Kabupaten Kutai Timur: Kecamatan Kelai: Tepian Langsat village; R. K. Hadiaty, Oman & Sugeng, 24 August 2004. MZB 13306, 10 ex., 37.5-54.7 mm SL; Mouth of Sungai Marang, Indonesia: Kalimantan Timur: Kabupaten Kutai Timur: Kecamatan Kelai: Tepian Langsat village; R. K. Hadiaty, Oman & Sugeng, 25 August 2004.

Nemacheilus olivaceus: ZRC 43986, 1 ex, 49.8 mm SL; small tributary to Sungai Bole, ca. 500 m into coupe 93, Danum Valley, Sabah, Borneo, Malaysia; H.H. Tan & Y.Y. Goh, 2 October 1996. ZRC 45411, 1 ex., 43.9 mm SL; Danum Valley, Sabah, Borneo, Malaysia; H.H. Tan & Y.Y. Goh, 1 October 1996. ZRC 45453, 5 of 7 ex., 36.3-50.9 mm SL; Danum, Lahad Datu, Sabah, Borneo, Malaysia; H.H. Tan & Y.Y. Goh, 2 October 1996. ZRC 45485, 5 ex., 40.6-48.5 mm SL; a tributary of Segama, Sabah, Borneo, Malaysia; Y.Y. Goh, 23 September 1998.

Nemacheilus papillos: MZB 10994, holotype, 1 ex., 55.3 mm SL; Sumatra: Sumatera Selatan: Sungai Sentang near Desa Sukajaya, about 5 km from road (turn-off at about 12 km on road from Bayung Lencir to Jambi; H. H. Tan, 27 July 1997.

Nemacheilus papillosus: ZMA 112.874, 2 syntypes, 48.0 mm SL, male with subocular flap obvious, 56.3 mm SL, female with eggs apparent; Lake Toba, Balige, Sumatra, Indonesia; no collector and date.

Nemacheilus pfeifferae: MZB 4710, 2 ex., 37.1-40.9 mm SL; Sungai Batang Kalu, Kayu Tanam, Padang, Sumatra Barat, Indone-sia; I. Rachmatika & F. Sabar; 2 October 1982. MZB 4968, 22 ex., 33.3-63.3 mm SL, Sungai Anai, Agam, Padang, Sumatra Barat, Indonesia; M. Siluba, 23 December 1984. MZB 4977, 17 ex., 34.7-60.5 mm SL ; Sungai Anai, Agam, Padang, Sumatra Barat, Indonesia; M. Siluba & M. Toha, 22 December 1983. MZB 4981, 12 ex., 41.7-64.4 mm SL; Sungai Anai, Agam, Padang, Sumatra Barat, Indonesia; M. Siluba & M. Toha, 22 December 1983.

Nemacheilus saravacensis: BMNH 1893.3.2.277, lectotype, 42.1 mm SL; Senah, Sarawak, Borneo, Malaysia; Everett, no date. ZRC 39851, 10 of 18 ex., 29.5-40.4 mm SL; Tributary of Sungai Kahat, Serian, Sarawak; HH Tan et al.; 14 January 1996.

Nemacheilus selangoricus: MZB 3551, 3 ex., 28.3-29.4 mm SL; small forested stream where it flows into Sungai Mandai, an upstream from its confluence with Kapuas mainstream, Sungai Kapuas basin, Kalimantan Barat, Indonesia; T.R. Roberts, 10 August 1976. MZB 2395b, 3 ex., 29.3-41.4 mm SL; Tanah merah, Lempake, Kalimantan, Indonesia; M. Siluba, 27 February 1978. RMNH 28879, 5 ex., 41.1–44.1 mm SL; Sungai Mandai Kecil, 18 km south west of Putussibau, Borneo, Indonesia; T.R. Roberts, 11 August 1975. RMNH 24995, 1, 47.1 mm SL; north of Seletar reservoir, Sungei Seletar, Singapore; E.R. Alfred, 4 April 1963.

Nemacheilus spiniferus: MZB 6807, 6 ex., 32.2-37.5 mm SL; Sungai Tarusan, a tributary of Sungai Laung, a tributary of Sungai Barito, Kalimantan Tengah, Borneo, Indonesia; D.J. Siebert, A.H. Tjakrawidjaja & O. Crimmen, 16 July 1992. MZB 6877, 11 ex., 29.5-38.0 mm SL; Sungai Karingian, a tributary of Sungai Laung, a tributary of Sungai Barito, Kalimantan Tengah, Borneo,

Indonesia; D.J. Siebert, A. H. Tjakrawidjaja & O. Crimmen, 7 July 1992. MZB 6928, 2 ex., 38.7-40.0 mm SL; Sungai Laung, a tributary of Sungai Barito, Laung Tuhup, Barito Utara, Kalimantan Tengah, Borneo, Indonesia; D.J. Siebert, A.H. Tjakrawidjaja & O. Crimmen, 15-18 July 1992. MZB 6948, 2 ex., 34.1-34.5 mm SL; Sungai Mata, a tributary of Sungai Barito below Muara Laung, Laung Tuhup, Barito Utara, Kalimantan Tengah, Borneo, Indonesia; D.J. Siebert, A.H. Tjakrawidjaja & O. Crimmen, 8 July 1992.

Nemacheilus tebo: MZB 13367, holotype, 1 ex., 56.1 mm SL; Indonesia: Kalimantan Timur: Berau Regency, Kelai District, Merapun Village, Lake Tebo area, a pond at mouth of west cave, site 2; coll. R. Hadiaty, Sokir & Cai, 31 Aug.2004. Paratypes: All from Indonesia: Kalimantan Timur: Berau Regency, Kelai District, Merapun Village, Lake Tebo area; BMNH 2007.11.30.1, 1 ex., 43.8 mm SL (58.4 mm TL); CMK 18909, 3 ex., 35.9-45.0 mm SL; MZB 13380, 2 ex., 37.5-41.1 mm; UF 165707, 1 ex., 38.6 mm SL; USNM 388744, 2 ex., 40.4-40.4 mm SL; ANSP 187006, 1 ex., 42 mm SL; same data as holotype. - MZB 13359, 3 ex., 36.-40.7 mm SL; cave behind camp, site 3; coll. R. Hadiaty, Sokir & Cai, 30 Aug. 2004. - MZB 13360, 4 ex., 37.1–44.9 mm SL; ZRC 50728, 1 ex., 40.6 mm SL; entrance of cave northwest of camp, site 1; coll. R. Hadiaty, Sokir & Cai, 31 Aug. 2004. Additional material (non types): MZB 13341, 43 ex., 18.8–48.2 mm SL: Tuba-tubaan river, site 6; coll. R. Hadiaty, Sokir & Cai, 30 Aug.2004. - MZB 13346, 2 ex., 37.5–41.6 mm SL; Gua Keluar, site 4; coll. R. Hadiaty, Sokir & Cai, 30 Aug. 2004. - MZB 13379, 1 ex., 31.8 mm SL; Lake Tebo; coll. R. Hadiaty, 28 Aug. 2004.

Nemacheilus tuberigum: MZB 9356, holotype, 48.5 mm SL; MZB 10565, 1 paratype, 43.0 mm SL; MZB 9357, 12 paratypes, 39.6–53.2 mm SL; BMNH 2000.4.10.1–5, 5 paratypes, 42.2–50.5 mm SL; a tributary of Sungai Lembang, Gunung Leuser National Park, Desa Pucuk Lembang, Kecamatan Kluet Selatan, Aceh, Sumatra, Indonesia; R.K. Hadiaty & A. Mun'im, 2 September 1997. MZB 9358, 4 paratypes, 44.8-53.4 mm SL; same data as holotype; 31 August 1997. MZB 9359, 1 paratypes, 42.6 mm SL; same data as holotype, 1 September 1997. MZB 9360, 4 paratypes, 42.6-49.2 mm SL; a tributary of Sungai Lembang, Alur Betung, Desa Pucuk Lembang, Kecamatan Kluet Selatan, Aceh, Sumatra, Indonesia; R.K. Hadiaty & A. Mun'im, 2 September 1997. MZB 9361, 2 paratypes, 31.9-37.2 mm SL; a tributary of Sungai Lembang, a muddy forest stream, Suaq Balimbing Research Station, Kecamatan Kluet Selatan, Aceh, Sumatra, Indonesia; R.K. Hadiaty & A. Mun'im, 4 September 1997. Non type materials: MZB 9351, 10 ex., (38.0-53.0 mm SL); data as for holotype. MZB 9362, 28 ex., (33.2-45.9 mm SL); location as for holotype; R.K. Hadiaty and A. Mun'im; 31 August 1997. MZB 9363. 27 ex.. (34.7-52.2 mm SL); location as for holotype; R.K. Hadiaty and A. Mun'im; 1 September 1997. MZB 9364, 11 ex., (33.2-52.3 mm SL); a tributary of Sungai Lembang, Alur Betung, Desa Pucuk Lembang, Aceh Selatan, Sumatra, Indonesia; R.K. Hadiaty and A. Mun'im; 2 September 1997. MZB 10566, 2 ex., (47.2-48.2 mm SL); unnamed tributary of S. Alas,

behind the camp at Ketambe Research Station, Aceh, Sumatra, Indonesia; R.K. Hadiaty & A. Mun'im: 21 June 1998. MZB 10567, 3 ex., (38.6-52.9 mm SL); unnamed tributary of S. Alas, Ketambe Research Station, Aceh, Sumatra, Indonesia; R.K. Hadiaty & A. Mun'im; 20 June 1998. MZB 10568, 5 ex., (41.2-52.8 mm SL); unnamed tributary of S. Alas, in front of the National Park camp ground, Ketambe, Aceh, Sumatra, Indonesia; R.K. Hadiaty & A. Mun'im; 23 June 1998. MZB 10569, 2 ex., (39.8^4.9 mm SL); mouth of S. Sukarimbun, Ketambe, Aceh, Sumatra, Indonesia; R.K. Hadiaty & A. Mun'im; 20 June 1998. MZB 10570, 15 ex., (28.2-59.6 mm SL), unnamed tributary of S. Alas, behind the camp of the Ketambe Research Station, Sumatra, Indonesia; R.K. Hadiaty & A. Mun'im; 21 June 1998. MZB 14383, 8 ex., 46.9-54.9 mm SL; a tributary of Sungai Alas, Ketambe Research Center, Gunung Leuser National Park, Ketambe, Aceh, Sumatra, Indonesia; R.K. Hadiaty & A. Mun'im, 21 June 1998. ZMA 112.875, 1, 49.1 mm SL; ZMA 113.744, 4, 34.3–48.7 mm SL; Pageralem; P.A. Ouwens, 22 November 1918. ZMA 116.645, 1, 46.7 mm SL; no collector and date.

Nemacheilus nsp. MZB 21450, 1, 49.8 mm SL, Sungai Mawai, a tributary of Sungai Samai, Antakalang, Kalimantan Tengah, Indonesia; R.K. Hadiaty, X. Giam, & D. Wowor, 25 June 2012. MZB 2145, 1, 38.2 mm SL, Sungai Tangoi, a tributary of Sungai Samai, Antakalang, Kalimantan Tengah, Indonesia; R.K. Hadiaty, X. Giam, & D. Wowor, 25 June 2012. MZB 21449, 4, 35.9-45.9 mm SL, Sungai Batu Nyambil, a tributary of Sungai Samai, Antakalang, Kalimantan Tengah, Indonesia; R.K. Hadiaty, X. Giam, & D. Wowor, 15 June 2012. MZB 21452, 2, 43.6-45.6 mm SL; Sungai Batu Nyambil, a tributary of Sungai Samai, Antakalang, Kalimantan Tengah, Indonesia; R.K. Hadiaty, X. Giam, & D. Wowor, 15 June 2012. MZB 21121, 6 ex., 43.3-52.4 mm SL, Sungai Batu Nyambil, a tributary of Sungai Samai, Antakalang, Kalimantan Tengah, Indonesia; R.K. Hadiaty, X. Giam, & D. Wowor, 26 June 2012.

Acknowledgements

We thank to Research Center for Biology, Indonesian Institute of Sciences for the support of the research activities in Indonesian waters, especially for the research funds to the Gunung Leuser National Parks in 1997 & 1998 and to Gunung Sewu karst area in 2006-2010. The first author thanks Darrell J. Siebert, who introduced her to the taxonomical work, and Maurice Kottelat for the nice work on *Nemacheilus* informations and also for the references. Our gratitude acknowledge to Robert Stuebing who invited the MZB aquatic team researchers in the REA KALTIM palm oil concession, also to the manager and staffs of REAKON: Monica Kusneti, Kahang, Ingan, Daud, Lamber, and Jacob who helped us during the field trips in Kalimantan Timur. Thanks are to the Nature Conservancy, the coordinator of Sangkulirang karst expeditions Leo Salas, to the Zoological Society London (ZSL) and the coordinator, Anhar for organising and supporting the work in Sumatra and Kalimantan Selatan. Thanks are also to Larry Page, Lukas Ruber, Heok Hui Tan and Xingli for the research collaborators in Indonesian waters, to Lynne Parenti for giving the opportunity to use the SEM facilities at the Smithsonian Museums, and to Peter Ng for the invitation to NUS,

Singapore. Martien van Oijen and Ronald de Ruiter from Naturalis Museum, Leiden provided references and the pictures of *N. jaklesii* and *N papillosus.* Last but not least, it is a great pleasure to thank Pak Abdul Mun'im and Sopian Sauri, technicians at the MZB Ichthyology Laboratory who accompanied and help during the field trips, and to Yayat who for help in the fish collections. Thanks are also to my colleague, Daisy Wowor who coordinated the field trips to Kalimantan Timur. We thank to Seiji Arakaki and Maurice Kottelat for giving useful comments on the manuscript. All photos took by RKH.

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