

## Review:

# A working checklist of the freshwater fish diversity for habitat management and conservation work in Sabah, Malaysia, North Borneo

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**Abstract.** Ng CKC, Abdullah F, Biun H, Ibrahim MK, Mustapha S, Sade A. 2017. Review: A working checklist of the freshwater fish diversity for habitat management and conservation work in Sabah, Malaysia, North Borneo. *Biodiversitas* 18: 560-574. Prioritization of freshwater habitat management and conservation is dependent on the availability of species baseline information at regional level. However, such information has not been updated since 2002 in Sabah. Thus the objective of this paper is to present the latest working checklist of freshwater ichthyofauna known so far in the state. A literature review of 68 studies was conducted focusing on the latest valid binomial nomenclature, locality and conservation status. A total of 166 valid species, namely 150 native species and 16 introduced species, were deduced from the literature. Native species comprised of 10 orders, 27 families and 75 genera while introduced species were from four orders, seven families and 14 genera. The review revealed 103 species (68.6% of native species) were yet to be assessed for the IUCN Red List and 11 species (7.3%) were identified as Data Deficient by IUCN. Some taxonomic discrepancies were also found and discussed. Many areas in Sabah remain poorly inventoried due to unequal sampling effort, biophysical and cultural challenges. The species list proposed herein is tentative at best and the number of species is expected to increase as more surveys are conducted in the near future.

**Keywords:** Borneo, checklist, freshwater fish, Sabah, taxonomy

## INTRODUCTION

Biological management and conservation demands precision. A species checklist reflects this precision by providing clarity at a glance, clearly and simply. In the context of ichthyology, a checklist is important for recording, analysing and assessing fish species diversity and distribution as biological units. It helps the ichthyologist, biologist and ecologist determine the likelihood of a species' presence or absence at a particular region. Moreover, a checklist is concise but dynamic enough to quickly indicate the various taxonomic changes over time. The changes may also encompass the establishment of introduced species, and whether native species have become threatened or extinct.

Unfortunately, in the case of Sabah in Malaysia, the discipline of ichthyology has somewhat stagnated. Due to a lack of local interest in fish taxonomy, species accounting in Sabah is still very much in discovery phase (Chong et al. 2010). The freshwater ichthyofauna of Sabah was first comprehensively enumerated by Inger and Chin (1962). Since then, an update was published (Inger and Chin 2002) to highlight some new and introduced species. Thereon, no author has made any further attempt to consolidate or update the inventory list although various taxonomic revisions have occurred from the latest morphological and

molecular studies.

This has arguably restrained the progress of sound conservation plans for freshwater fishes although their habitats are of grave concern. There were some ichthyofaunal studies in Sabah involving some particular rivers, streams and lakes. The most outstanding study done so far was in Danum Valley (Martin-Smith and Tan 1998) where 47 species in 12 families were revealed. However, none was focused on fish diversity of Sabah as a whole.

Many studies have suggested that Sabah shared a similar but less diverse ichthyofauna composition as Malaysian Sarawak, Indonesian Kalimantan and to a certain extent Indonesian Sumatra and Java island (Zakaria-Ismail 1994; Yap 2002; Lohman et al. 2011; Sulaiman and Mayden 2012). This is to be expected knowing that the Borneo island shares the Sundaic palaeoecological history with neighbouring land masses (Lohman et al. 2011; Sulaiman and Mayden 2012).

Since we know that the Borneo Island is considered one ichthyofauna biogeography, we can expect that the Sabah's fish diversity would be somewhat similar to other regions in the 745,567 km<sup>2</sup> island. Roberts (1989) reported a total of 263 species of 40 families and 120 genera were encountered in Kapuas watershed, West Kalimantan, and Atack (2006) suggested that Sarawak's species count stands at 254. Inger and Chin (2002) postulated that 168 species

can be found in Sabah. As Sabah is smaller in size than Sarawak and Kalimantan, thus we can assume that the species count may not be more than these regions.

Given more than a decade of scientific quiescence with regards to state-wide ichthyofaunal inventory, an up to date checklist is not only timely, but also necessary to revive the fish taxonomy and systematics discipline in the state. This is also in line with the Malaysian National Biodiversity Policy and Plan 2016-2025 and Sabah Biodiversity Strategy 2012-2022 in fulfilling pledges made to the Convention of Biological Diversity (CBD). A comprehensive study has explicitly stressed that "freshwater species have been poorly studied" as a key gap in establishing the appropriate Aichi Biodiversity Targets in most countries (Leadley et al. 2011). Without a reliable and updated species accounting foundation, any formal pledges to CBD may not be met. Correspondingly, the latest species taxonomic records and literature need critical re-examination. Therefore this study is aimed at generating an updated database of all possible valid species that may occur in Sabah as a basis to set the path for subsequent conservation work.

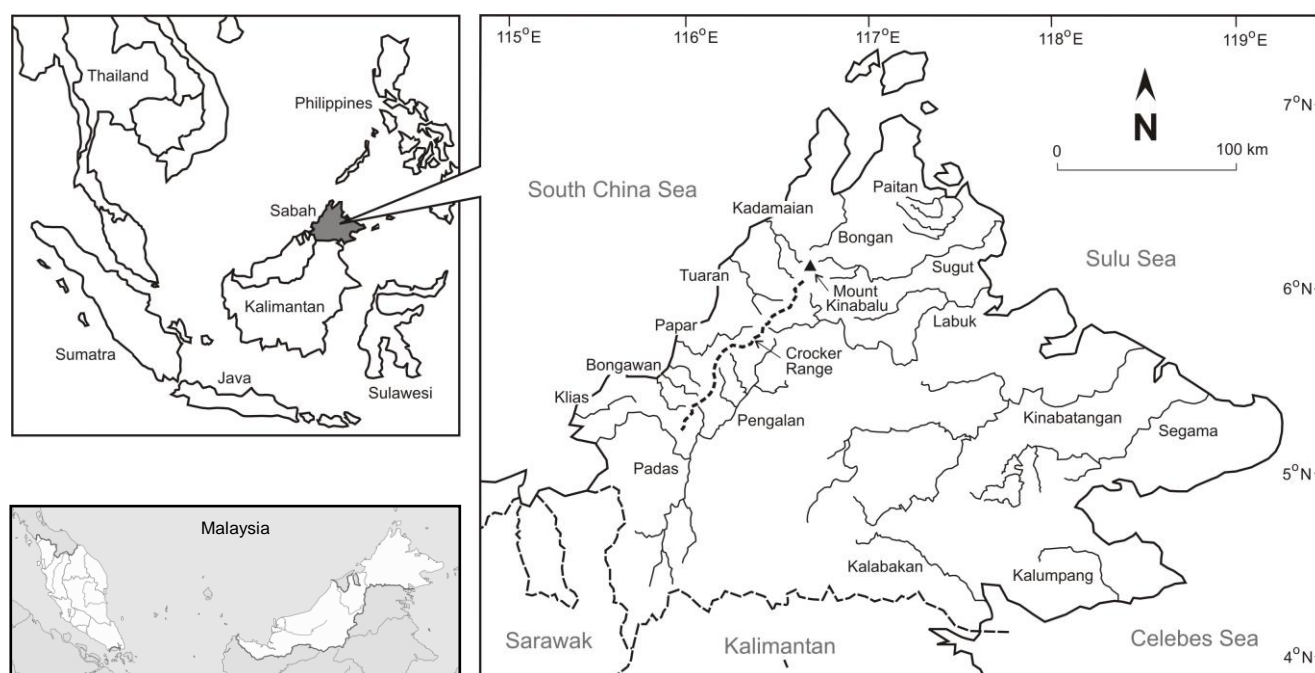
## MATERIALS AND METHODS

### Study area

Sabah is a state in the country of Malaysia located in the northeastern part of Borneo Island ( $5^{\circ} 25' 13''$  N,  $116^{\circ}$

$47' 48''$  E) and the state occupies a land size of 73,371 km<sup>2</sup>, or about 10% of Borneo island (Marsh and Greer 1992). The state shares its border with the Malaysian state of Sarawak in southwest and the Indonesian province of Kalimantan to the south. It has a 1,743km coastline that overlooks South China Sea in the west, the Sulu Sea in the northeast and Celebes Sea in the west. Sabah experiences monsoonal tropical climate with an average temperature of 32°C in lowland areas and 21°C in highland areas.

The state's freshwater habitats are typically affected by two monsoon seasons, namely the Northeast Monsoon that peaks between October to February and Southwest Monsoon that prevails from April to August. Rainfall is generally more frequent and intense during the Northeast Monsoon. Thus, the state's principle hydrologic interest can be divided into two areas, namely (i) rivers that are affected by the Southwest Monsoon and flowing toward the west coast (ii) rivers that are affected by the Northeast Monsoon and flowing toward the east coast (Figure 1). At peak monsoon period, most rivers are rendered café-au-lait brown and turbid from siltation. Many rivers in eastern Sabah possess the characteristics of geographically old rivers which are depicted by meandering flow paths and flanked by oxbow lakes. In contrast, the Crocker Range mountainous region is considered geologically young and thus correspondingly consists mostly of hill stream habitats that are typically less complex. Surface water temperature can range from 25°C in forest shaded rivers to 32°C in rivers fully exposed to sunlight.



**Figure 1.** Major drainages that forms the hydrography of Sabah, Malaysia, North Borneo

## Method

We consulted the latest and previously published articles, records and books on ichthyological studies in Sabah. Species cited were also counter verified by voucher specimen examination in the collections of Likas Fisheries Research Center managed by the Department of Fisheries Sabah. The spelling of scientific names and species validity follows Kottelat (2013), Fishbase (Froese and Pauly 2016) and California Academy of Science's Catalog of Fishes (Eschmeyer et al. 2016). The family names, designation and rank follow Van der Laan et al. (2014).

As the checklist is intended to be a master reference for freshwater habitat conservation and management, we consulted the IUCN Red List website ([www.iucnredlist.org](http://www.iucnredlist.org)) to obtain the latest conservation status of each species. The latest literature was examined for identifying endemic and introduced species in Sabah. As one of the key purposes of this paper is to drive more inventory studies for place-based habitat management and conservation fieldwork, species distribution is presented by districts where the species were reportedly found by the respective authors. Species associated with brackish environment were excluded because the focus was on species that reside strictly in freshwater.

## RESULTS AND DISCUSSION

### Working checklist

Our finding registered 166 valid species, with 150 native species and 16 introduced species. Native species comprised of 10 orders, 27 families and 75 genera while introduced species were from four orders, seven families and 14 genera. A total of 36 species (24.0% of native species) are listed as endemic and with 15 species, *Gastromyzon* is evidently the most speciose genus. Table 1 and 2 outline the compilations of species occurrence in Sabah based on the literature examination of 68 studies listed under references. Species are presented by the latest order, family, valid binomial nomenclature, distribution and the corresponding IUCN status code at the time of this study.

### Conservation status

Based on IUCN categorization, a total of 103 species (68.6% of native species) are yet to be assessed and 11 species (7.3%) are identified as Data Deficient (DD). This implies that most species are poorly known or no data is available to assess their extinction risk. *Anguilla bicolor* is classified as Near Threatened (NT) while *A. borneensis*, *Acantopsis octoactinotos*, *Sundoreonectes sabanus* and *Betta chini* are identified as Vulnerable (VU). It is apparent that species distribution and diversity is geographically biased towards Kinabatangan (KI) and Lahad Datu (LD) as these districts have recorded higher number of species due to the exemplary work of Martin-Smith and Tan (1998) and

Inger and Chin (2002) while other districts remain relatively under-surveyed.

### Taxonomic issues

Some discrepancies among authorities were encountered during the production of the working checklist. At the time of this writing, Fishbase has placed *Parhomaloptera microstoma* (Boulenger, 1899), *Protomyzon aphelocheilus* Inger and Chin 1962, *Protomyzon borneensis* Hora and Jayaram, 1952, *Protomyzon grswoldi* (Hora and Jayaram, 1951) and *Protomyzon whiteheadi* (Vaillant, 1893) under the Balitoridae family. However, Kottelat (2013) has stated that these species to belong to the Gastromyzontidae family. As such we have applied the same treatment.

*Channa melasoma* (Bleeker 1851) which was initially recorded by Inger and Chin (2002) is not listed since Courtenay and Williams (2004) highlighted that records of this species in Sabah were misidentification of *C. baramensis*. *Crossocheilus cobitis* (Bleeker, 1854) recorded by Martin-Smith and Tan (1998) has been re-identified as *Cr. elegans*. *Lobocheilos bo* recorded by Martin-Smith and Tan (1998) and Inger and Chin (2002) has been resolved as Kottelat and Tan (2008) clarified that species recorded in Labuk, Segama and Danum were *L. unicornis* and *L. erinaceus*. Correspondingly, they highlighted that species recorded in western Sabah should be identified as *L. ovalis*. *Betta unimaculata* which was recorded by numerous studies in the past is recognised as *B. ocellata* (Tan and Ng, 2005).

*Tor tambra* (Valenciennes, 1842) itemized in our checklist is still marred by convoluted taxonomic problems. Currently, according to papers published by various researchers interested in the *Tor* genus of Borneo, they have treated *Tor tambra*, *T. tambroides*, *T. douronensis* and *T. soro* as valid species (Nyanti 1999; Desai 2003; Atack 2006; Esa et al. 2006; Haryono 2006; Ingram et al. 2007; Esa et al. 2008; Nguyen 2008; Esa et al. 2012). At time of this writing, Fishbase recognizes *Tor tambra*, *T. tambroides*, *T. douronensis* and *T. soro* while California Academy of Science's Catalog of Fishes website recognizes *Tor tambra*, *T. tambroides* and *T. douronensis* as valid species. Roberts (1999) has proposed that *T. soro* should be renamed to *Neolissochilus soro* and this is reflected in California Academy of Science's Catalog of Fishes but not Fishbase. Although sexually mature adults may display silvery orange, pink, red or yellow scales and fins, Roberts (1999) also suggested that only two species should be recognized, namely *T. tambra* (with a short mental lobe) and *T. tambroides* (with a long mental lobe). Correspondingly, he cautioned that there is also a possibility that they are both the same species. Moreover, Roberts (1999) and Kottelat (2013) have not been able to distinguish unique morphological markers between the two species. Hence, following Kottelat (2013), we have decided to only itemize one *Tor* species, *Tor tambra*.

**Table 1.** List of native species with known distribution in Sabah, North Borneo

Order/Family/Species	Authority	IUCN status	Common name/remarks	Locality	References
ORDER					
OSTEOGLOSSIFORMES					
<b>Family Notopteridae</b>					
<i>Chitala lopis</i>	(Bleeker, 1851)	LC	Giant featherback	BF	Inger and Chin 2002; Kottelat 2013
ORDER					
ANGUILLIFORMES					
<b>Family Anguillidae</b>					
<i>Anguilla bicolor</i>	McClelland, 1844	NT	Indonesian shortfin eel	TW	Inger and Chin 2002; Kottelat 2013
<i>Anguilla borneensis</i>	Popta, 1924	VU	n/a	BE, LD, KI, RA, SA, TO, TW	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Ahmad et al. 2006; Kottelat 2013
<i>Anguilla marmorata</i>	Quoy and Gaimard, 1824	LC	Giant mottled eel	KB, TE, TU, TW	Inger and Chin 2002; Kottelat 2013
ORDER CLUPEIFORMES					
<b>Family Sundasalangidae</b>					
<i>Sundasalanx microps</i>	Roberts, 1981	n/a	n/a	KI	Inger and Chin 2002; Kottelat 2013
ORDER CYPRINIFORMES					
<b>Family Cyprinidae</b>					
<i>Barbodes binotatus</i>	(Valenciennes, in Cuvier & Valenciennes, 1842)	LC	Spotted barb	BE, KB, KI, KK, TA, TU, TO, RA	Inger and Chin 2002; Sulaiman and Mayden 2012; Sade and Biun 2012; Kottelat 2013
<i>Barbodes sealei</i>	Herre, 1933	n/a	n/a/Endemic	BE, LD, KI, KM, RA, SA, TO, TW	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Sade and Biun 2012; Kottela, 2013; Tan 2013
<i>Barbodes strigatus</i>	(Boulenger, 1894)	n/a	n/a/Endemic	KU	Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013
<i>Barbonymus balleroides</i>	(Valenciennes, in Cuvier & Valenciennes, 1842)	n/a	n/a	LD, KI, TO, TW,	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat, 2013; Tan 2013
<i>Barbonymus collingwoodii</i>	(Günther, 1868)	n/a	n/a	LD, KB, RA	Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013
<i>Crossocheilus elegans</i>	Kottelat & Tan, 2011	n/a	n/a/Endemic	LD, KI	Kottelat and Tan 2011; Kottelat 2013
<i>Cyclocheilichthys apogon</i>	(Valenciennes, in Cuvier & Valenciennes, 1842)	LC	Beardless barb	SA, TW	Inger and Chin 2002; Kottelat 2013
<i>Cyclocheilichthys repasson</i>	(Bleeker, 1853)	LC	n/a	LD, KI, TO, TW	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat, 2013; Tan 2013
<i>Garra borneensis</i>	(Vaillant, 1902)	n/a	n/a	BE, KB, KI, KM, LD, TO	Martin-Smith and Tan 1998; Inger and Chin 2002; Sade and Biun 2012; Sulaiman and Mayden 2012; Kottelat 2013
<i>Garra robertsi</i>	Thoni & Mayden, 2015	n/a	n/a	KM	Thoni and Mayden 2015
<i>Hampala bimaculata</i>	(Popta, 1905)	n/a	n/a	KB	Kottelat et al. 1993; Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013

<i>Hampala macrolepidota</i>	Kuhl & Van Hasselt, 1823	LC	n/a/syn. <i>Hampala sabana</i> Inger & Chin, 1962	KI, LD	Inger and Chin 2002; Kottelat 2013
<i>Labiobarbus sabanus</i>	(Inger & Chin, 1962)	n/a	n/a/Endemic	KI, LD, RA	Martin-Smith and Tan 1998; Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013
<i>Leptobarbus hosii</i>	(Regan, 1906)	DD	n/a	BF, KI, TE	Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013
<i>Leptobarbus melanotaenia</i>	Boulenger, 1894	n/a	n/a	LD, KI, KU, TO, TW	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Ahmad et al. 2006; Sulaiman and Mayden 2012; Kottelat 2013; Tan 2013
<i>Lobocheilos erinaceus</i>	Kottelat & Tan, 2008	n/a	n/a	LD	Martin-Smith and Tan, 1998; Kottelat and Tan 2008; Kottelat 2013
<i>Lobocheilos ovalis</i>	Kottelat & Tan, 2008	n/a	n/a	BF	Kottelat and Tan 2008; Kottelat 2013
<i>Lobocheilos unicornis</i>	Kottelat & Tan, 2008	n/a	n/a	LD	Kottelat and Tan 2008; Kottelat 2013
<i>Lobocheilos terminalis</i>	Kottelat & Tan, 2008	n/a	n/a	KI	Kottelat and Tan, 2008; Kottelat 2013
<i>Luciosoma pellegrinii</i>	Popta, 1904	n/a	n/a	KI, LD	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat 2013
<i>Nematabramis borneensis</i>	Inger & Chin, 1962	n/a	n/a	KB, KI, LD, RA, SA,	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat 2013
<i>Nematabramis everetti</i>	Boulenger, 1894	n/a	n/a/Endemic	BE, BF, KI, KM, KU, LD, SA, TO, TW	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013; Tan 2013
<i>Nematabramis steindachnerii</i>	Popta, 1905	n/a	n/a/Endemic	KM, RA	Inger and Chin 2002; Kottelat 2013
<i>Osteochilus chini</i>	Karnasuta, 1993	n/a	n/a/Endemic	BE, KI, LD, TW	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013; Tan 2013
<i>Osteochilus ingeri</i>	Karnasuta, 1993	n/a	n/a	BE, KI, LD, TO	Inger and Chin 2002; Sade and Biun 2012; Kottelat 2013
<i>Osteochilus vittatus</i>	(Valenciennes, in Cuvier & Valenciennes, 1842)	LC	Bonylip barb	BE, KB, LD	Inger and Chin 2002; Kottelat 2013
<i>Osteochilus waandersii</i>	(Bleeker, 1853)	LC	n/a	KI, LD, TO	Martin-Smith and Tan 1998; Inger and Chin 2002; Ahmad et al. 2006; Kottelat 2013
<i>Parachela ingerkongi</i>	(Banareescu, 1969)	n/a	n/a	TW	Inger and Chin 2002; Kottelat 2013; Tan 2013
<i>Parachela oxygastroides</i>	(Bleeker, 1852)	LC		TW	Inger and Chin 2002; Kottelat 2013
<i>Paracrossochilus acerus</i>	Inger & Chin, 1962	n/a		BE, KB, KE, KI, LD, SI, TA	Martin-Smith 1998; Martin-Smith and Tan 1998; Nyanti, 1998; Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013
<i>Puntioplites bulu</i>	(Bleeker, 1851)	DD	Bulu barb	KI, LD	Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat 2013
<i>Rasbora argyrotaenia</i>	(Bleeker, 1849)	n/a	Silver rasbora	BE, KB, KI, KM, LD	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat 2013
<i>Rasbora einthovenii</i>	(Bleeker, 1851)	n/a	Brilliant rasbora	LA, SA	Inger and Chin 2002; Kottelat 2013
<i>Rasbora elegans</i>	Voltz, 1903	LC	Twospot rasbora	TW	Inger and Chin 2002; Kottelat 2013

<i>Rasbora hubbsi</i>	Brittan, 1954	n/a	n/a/Endemic	KI, KM, LD, TW	Kottelat et al. 1993; Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013; Tan 2013
<i>Rasbora myersi</i>	Brittan, 1954	n/a	n/a	KI	Inger and Chin 2002; Kottelat, 2013
<i>Rasbora rheophila</i>	Kottelat, 2012	n/a	n/a	KM, RA, SI	Kottelat, 2012; Kottelat 2013
<i>Rasbora ruttieni</i>	Weber & de Beaufort, 1916	n/a	n/a	LD, TW	Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013
<i>Rasbora semilineata</i>	Weber & de Beaufort, 1916	n/a	n/a	KI	Kottelat et al. 1993; Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013
<i>Rasbora sumatrana</i>	(Bleeker, 1852)	n/a	n/a	BE, KI, KK, LD, RA, SA, SE, TO, TU, TW, TU	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Sade and Biun 2012; Kottelat 2013; Tan 2013
<i>Schismatorhynchos holorrhynchos</i>	Siebert & Tjakrawidjaja, 1998	n/a	n/a	LD, KI, TO	Martin-Smith 1998; Inger and Chin 2002; Kottelat 2013
<i>Systemus rubripinnis</i>	(Valenciennes, in Cuvier & Valenciennes, 1842)	n/a	Javaen barb	SA	Inger and Chin 2002; Kottelat 2013
<i>Tor tambra</i>	(Valenciennes, in Cuvier & Valenciennes, 1842)	DD	n/a	KB, KE, KM, LD, RA, SI, TA, TE, TO	Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat 2013
<b>Family Cobitidae</b>					
<i>Acantopsis octoactinotos</i>	Siebert, 1991	VU	n/a/Endemic	KI, LD	Siebert 1991; Martin-Smith and Tan 1998; Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013
<i>Pangio anguillaris</i>	(Vaillant, 1902)	n/a	n/a	TW	Inger and Chin 2002; Kottelat 2013
<i>Pangio mariarum</i>	(Inger & Chin, 1962)	n/a	n/a	KI, LD	Martin-Smith and Tan 1998; Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013
<i>Theriodes sandakanensis</i>	(Inger & Chin, 1962)	n/a	n/a/Endemic	KI, SA	Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013
<b>Family Balitoridae</b>					
<i>Homalopteroides stephensoni</i>	(Hora, 1932)	n/a	n/a	LD, KI, TE, TO	Martin-Smith 1998; Martin-Smith and Tan 1998; Sulaiman and Mayden 2012; Kottelat 2013;
<b>Family Gastromyzontidae</b>					
<i>Gastromyzon aequabilis</i>	Tan, 2006	n/a	n/a/Endemic	LD	Tan 2006; Sulaiman and Mayden 2012; Kottelat 2013
<i>Gastromyzon aeroides</i>	Tan & Sulaiman, 2006	n/a	n/a	KE, SI, PE	Tan 2006; Sulaiman and Mayden 2012; Kottelat 2013
<i>Gastromyzon auronigrus</i>	Tan, 2006	n/a	n/a/Endemic	KM	Tan 2006; Sulaiman and Mayden 2012; Kottelat 2013
<i>Gastromyzon borneensis</i>	Günther, 1874	n/a	n/a/Endemic	KB, KI, KM, KU, RA, SI, TA	Inger and Chin 2002; Tan 2006; Sulaiman and Mayden 2012; Kottelat 2013
<i>Gastromyzon cornusaccus</i>	Tan, 2006	n/a	n/a/Endemic	KM	Tan 2006; Sulaiman and Mayden 2012; Kottelat 2013
<i>Gastromyzon danumensis</i>	Chin & Inger, 1989	n/a	n/a/Endemic	LD, TO	Martin-Smith and Tan 1998; Inger and Chin 2002; Ahmad et al. 2006; Tan 2006; Sulaiman and Mayden 2012; Kottelat 2013
<i>Gastromyzon extrorsus</i>	Tan, 2006	n/a	n/a/Endemic	PA, PE	Tan 2006; Sulaiman and Mayden 2012; Kottelat 2013

<i>Gastromyzon ingeri</i>	Tan, 2006	n/a	n/a/Endemic	TW	Tan 2006; Sulaiman and Mayden 2012; Kottelat 2013; Tan 2013
<i>Gastromyzon introrsus</i>	Tan, 2006	n/a	n/a/Endemic	KE, TE	Tan 2006; Sulaiman and Mayden 2012; Kottelat 2013
<i>Gastromyzon lepidogaster</i>	Roberts, 1982	DD	n/a	BE, BF, KI, LD, PE, SI, TE, RA, TW	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Tan 2006; Sulaiman and Mayden 2012; Kottelat 2013; Tan 2013
<i>Gastromyzon monticola</i>	(Vaillant, 1889)	n/a	n/a/Endemic	KB, KM, RA, TE,	Inger and Chin 2002; Tan 2006; Sulaiman and Mayden 2012; Kottelat 2013
<i>Gastromyzon ornaticauda</i>	Tan & Martin-Smith, 1998	n/a		LD, SA	Martin-Smith and Tan 1998; Tan and Martin-Smith 1998; Tan, 2006; Sulaiman and Mayden 2012; Kottelat 2013
<i>Gastromyzon pariclavis</i>	Tan & Martin-Smith, 1998	n/a	n/a/Endemic	LD	Martin-Smith and Tan 1998; Tan and Martin-Smith 1998; Inger and Chin 2002; Tan 2006; Sulaiman and Mayden 2012; Kottelat 2013
<i>Gastromyzon spectabilis</i>	Tan, 2006	n/a	n/a/Endemic	LD	Martin-Smith and Tan 1998; Tan 2006; Sulaiman and Mayden 2012; Kottelat 2013
<i>Gastromyzon umbrus</i>	Tan, 2006	n/a	n/a	TW	Tan 2006; Sulaiman and Mayden 2012; Kottelat 2013
<i>Glaniopsis denudata</i>	Roberts, 1982	n/a	n/a	RA	Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013
<i>Glaniopsis gossei</i>	Roberts, 1982	n/a	n/a	SI	Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013
<i>Glaniopsis hanitschi</i>	Boulenger, 1899	n/a	n/a/Endemic	KE, RA	Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013
<i>Glaniopsis multiradiata</i>	Roberts, 1982	n/a	n/a	SI	Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013
<i>Neogastromyzon crassiobex</i>	Tan, 2006	n/a	n/a	LD, KI	Tan, 2006; Sulaiman and Mayden 2012
<i>Parhomaloptera microstoma</i>	(Boulenger, 1899)	n/a	n/a	LD, TA, TW	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat 2013; Tan 2013
<i>Protomyzon aphelocheilus</i>	Inger & Chin, 1962	n/a	n/a	KM, LD, RA, SI, TA	Martin-Smith and Tan 1998; Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013
<i>Protomyzon borneensis</i>	Hora & Jayaram, 1952	DD	n/a	KM, RA, TA, TE, TW	Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013; Tan 2013
<i>Protomyzon griswoldi</i>	(Hora & Jayaram, 1952)	n/a	n/a	RA, KE, KM, LD, SI, TW,	Martin-Smith and Tan 1998; Inger and Chin 2002; Tan 2006; Sulaiman and Mayden 2012; Kottelat 2013; Tan 2013
<i>Protomyzon whiteheadi</i>	(Vaillant, 1893)	n/a	n/a	KE, KI, LD, RA, SI, TE	Martin-Smith and Tan 1998; Inger and Chin 2002; Sulaiman and Mayden 2012; Kottelat 2013
<b>Family Nemacheilidae</b>					
<i>Nemacheilus elegantissimus</i>	Chin & Samat, 1992	n/a	n/a/Endemic	LD	Chin and Samat 1992; Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat 2013
<i>Nemacheilus olivaceus</i>	Boulenger, 1894	n/a	n/a/Endemic	KI, KM, KU, LD, RA, SA, TO, TW	Martin-Smith and Tan 1998; Inger and Chin 2002; Ahmad et al. 2006; Sulaiman and Mayden 2012; Kottelat 2013; Tan 2013
<i>Sundoreonectes sabanus</i>	(Chin, 1990)	VU	n/a	SI	Inger and Chin 2002; Kottelat 2013

## ORDER SILURIFORMES

**Family Akysidae**

<i>Acrochordonichthys falcifer</i>	Ng & Ng, 2001	n/a	n/a	LD	Ng and Ng 2001; Kottelat 2013;
<i>Acrochordonichthys pachyderma</i>	Vaillant, 1902	n/a	n/a	KI	Ng and Ng 2001; Inger and Chin 2002; Kottelat 2013

**Family Sisoridae**

<i>Glyptothorax major</i>	(Boulenger, 1894)	n/a	n/a	KB, KI, KM, LD, RA, TA, TE, TO, TW	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat 2013; Tan 2013; Ng & Kottelat 2016
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**Family Siluridae**

<i>Ompok sabanus</i>	Inger & Chin, 1959	n/a	n/a	KI, LD, TW	Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat 2013
<i>Phalacronotus parvanalis</i>	(Inger & Chin, 1959)	n/a	n/a	BE, KI, LD	Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat 2013
<i>Wallago maculatus</i>	Inger & Chin, 1959	n/a	n/a/Endemic, possible syn. of <i>Wallagonia leerii</i> (Bleeker 1851)	KI, LD	Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat 2013

**Family Clariidae**

<i>Clarias anfractus</i>	Ng, 1999	n/a	n/a/Endemic	LD, TW	Ng 1999; Inger and Chin 2002; Kottelat 2013
<i>Clarias leiacanthus</i>	Bleeker, 1851	n/a	n/a	KK, KE, KI, BE, SA, TW, LD, TO	Inger and Chin 2002; Sade and Biun 2012; Kottelat 2013; Tan 2013
<i>Clarias nieuhofii</i>	(Valenciennes, in Cuvier & Valenciennes, 1842)	LC	Slender Walking Catfish	BE, KK, SA, TU	Inger and Chin 2002; Kottelat 2013

**Family Pangasiidae**

<i>Pangasius kinabatanganensis</i>	Roberts & Vidthayanon, 1991	n/a	n/a/Endemic	KI	Roberts and Vidthayanon 1991; Inger and Chin 2002; Kottelat 2013;
<i>Pangasius macronema</i>	Bleeker, 1850	LC	n/a	BE	Inger and Chin 2002; Kottelat 2013
<i>Pangasius sabahensis</i>	Gustiano, Teugels & Pouyaud, 2003	n/a	n/a/Endemic	KI	Gustiano et al. 2002; Kottelat 2013
<i>Pseudolais micronemus</i>	(Bleeker, 1846)	DD	Shortbarbel pangasius	KI, LD, RA	Inger and Chin 2002; Kottelat 2013

**Family Bagridae**

<i>Hemibagrus baramensis</i>	(Regan, 1906)	n/a	n/a	LD, KI, RA, SA, TW, KI	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Ahmad et al. 2006; Kottelat 2013; Ng and Kottelat 2013
<i>Hemibagrus fortis</i>	(Popta, 1904)	n/a	n/a	BE, KB, KI, LD, KM, RA, SA, TA, TU, TW	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat 2013; Ng and Kottelat 2013
<i>Hemibagrus sabanus</i>	(Inger & Chin, 1959)	n/a	n/a/Endemic	KI, LD	Martin-Smith and Tan 1998; Kottelat 2013; Inger and Chin 2002
<i>Hemibagrus semotus</i>	Ng & Kottelat, 2013	n/a	n/a	KI, SI, TE	Kottelat, 2013; Ng and Kottelat 2013
<i>Leiocassis collina</i>	Ng & Lim, 2006	n/a	n/a	LD	Ng and Lim 2006; Kottelat 2013
<i>Leiocassis micropogon</i>	(Bleeker, 1852)	n/a	n/a	BF, TW	Inger and Chin 2002; Kottelat 2013
<i>Pseudomystus robustus</i>	(Inger and Chin, 1959)	n/a	n/a/Endemic	KI, LD	Martin-Smith 1998; Inger and Chin 2002; Kottelat 2013



## ORDER BELONIFORMES

**Family Zenarchopteridae**

<i>Dermogenys bispina</i>	Meisner & Collette, 1998	n/a	n/a	KI, LD	Meisner and Collette 1998; Kottelat 2013
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## ORDER

## GASTEROSTEIFORMES

**Family Syngnathidae**

<i>Oostethus brachyurus</i>	(Bleeker, 1854)	n/a	n/a	KI	Inger and Chin 2002; Kottelat 2013
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## ORDER

## SYNBRANCHIFORMES

**Family Synbranchidae**

<i>Monopterus javanensis</i>	La Cépède, 1800	n/a	Asian swamp eel	KI, SA	Inger and Chin 2002; Kottelat 2013
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**Family Mastacembelidae**

<i>Macrognathus keithi</i>	(Herre, 1940)	n/a	n/a/Endemic	KI, KM, LD, SA	Martin-Smith 1998; Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat 2013
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<i>Mastacembelus unicolor</i>	Cuvier, in Cuvier & Valenciennes, 1832	n/a	n/a	LD, TW	Inger and Chin 2002; Kottelat 2013
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## ORDER PERCIFORMES

**Family Toxotidae**

<i>Toxotes chatareus</i>	(Hamilton, 1822)	n/a	Spotted archerfish	KI, LD	Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat 2013
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**Family Nandidae**

<i>Nandus prolixus</i>	Chakrabarty, Oldfield & Ng, 2006	n/a	n/a/Endemic	SA	Inger and Chin 2002; Hossain and Sarker 2013; Kottelat 2013
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**Family Rhyacichthyidae**

<i>Rhyacichthys aspro</i>	(Valenciennes, in Cuvier & Valenciennes, 1837)	DD	Loach goby	PE	Inger and Chin 2002; Kottelat 2013
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**Family Eleotrididae**

<i>Bostrychus sinensis</i>	Lacépède, 1801	LC	Foureyed sleeper	SA	Inger and Chin 2002; Kottelat 2013
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<i>Butis butis</i>	(Hamilton, 1822)	LC	Duckbill sleeper	KI, SA	Inger and Chin 2002; Kottelat 2013
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<i>Butis gymnopomus</i>	(Bleeker, 1853)	n/a	n/a	KI, SA	Inger and Chin 2002; Kottelat 2013
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<i>Eleotris fusca</i>	(Bloch & Schneider, 1801)	LC	Dusky sleeper	KI, SA, TW	Inger and Chin 2002; Kottelat 2013
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<i>Eleotris melanosoma</i>	Bleeker, 1853	LC	Broadhead sleeper	BE, KI, SA	Inger and Chin 2002; Kottelat 2013
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<i>Giuris margaritaceus</i>	(Valenciennes, in Cuvier & Valenciennes, 1837)	n/a	Snakehead gudgeon	SA	Inger and Chin 2002; Larson 2012; Kottelat 2013
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<i>Ophiocara porocephala</i>	(Valenciennes, in Cuvier & Valenciennes, 1837)	LC	Northern mud gudgeon	KI, SA	Inger and Chin 2002; Larson 2013; Kottelat 2013
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<i>Oxyeleotris marmorata</i>	(Bleeker, 1852)	LC	Marble goby	KI	Inger and Chin 2002; Kottelat 2013
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<i>Oxyeleotris urophthalmoides</i>	(Bleeker, 1853)	DD	n/a	BE, KI	Inger and Chin 2002; Kottelat, 2013
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<i>Prionobutis dasyrhynchus</i>	(Gunther, 1868)	n/a	n/a	TW	Inger and Chin 2002; Kottelat 2013
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**Family Gobiidae**

<i>Brachygobius doriae</i>	(Günther 1868)	LC	n/a	KI	Inger and Chin 2002; Kottelat 2013
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<i>Brachygobius kabiliensis</i>	Inger, 1958	LC	Kabili bumblebee goby	SA	Kottelat et al. 1993; Inger and Chin 2002; Kottelat 2013
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<i>Brachygobius sabanus</i>	Inger, 1958	DD	Sabanus bumblebee goby	KI	Inger 1958; Kottelat et al. 1993; Inger and Chin 2002; Kottelat 2013
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<i>Eugnathogobius kabilia</i>	(Herre, 1940)	LC	n/a	SA	Herre, 1940; Inger and Chin 2002; Kottelat 2013
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<i>Eugnathogobius siamensis</i>	(Fowler, 1934)	LC	n/a	TW	Kottelat 2013
<i>Glossogobius celebius</i>	(Valenciennes, in Cuvier & Valenciennes, 1837)	DD	Celebes goby	KK, LD	Inger and Chin 2002; Kottelat 2013
<i>Glossogobius giuris</i>	(Hamilton, 1822)	LC	Tank goby	BE, KI, SA, TW	Inger and Chin 2002; Kottelat 2013
<i>Glossogobius sandakanensis</i>	Inger, 1957	n/a	n/a	SA	Inger 1957; Inger and Chin 2002; Kottelat 2013
<i>Pseudogobiopsis oligactis</i>	(Bleeker, 1875)	LC	n/a	TW	Inger and Chin 2002; Kottelat 2013
<i>Pseudogobius javanicus</i>	(Bleeker, 1856)	n/a	n/a	TW	Inger and Chin 2002; Kottelat 2013
<i>Redigobius bikolanus</i>	(Herre, 1927)	LC	Speckled goby	KI	Inger and Chin 2002; Kottelat 2013
<i>Redigobius chryosoma</i>	(Bleeker, 1875)	LC	n/a	KI	Inger and Chin 2002; Kottelat 2013
<i>Redigobius tambujon</i>	(Bleeker, 1854)	LC	n/a	KI	Inger and Chin 2002; Kottelat 2013
<i>Stenogobius gymnopomus</i>	(Bleeker, 1853)	LC	n/a	KI, TW	Inger and Chin 2002; Kottelat 2013
<i>Stenogobius ingeri</i>	Watson, 1991	n/a	n/a	TW	Watson 1991; Inger and Chin 2002; Kottelat 2013
<i>Stigmatogobius sadanundio</i>	(Hamilton, 1822)	n/a	n/a	SA	Inger and Chin 2002; Kottelat 2013
<b>Family Anabantidae</b>					
<i>Anabas testudineus</i>	(Bloch, 1792)	DD	Climbing perch	KB, KI, KK, RA, SA	Inger and Chin 2002; Kottelat 2013
<b>Family Osphronemidae</b>					
<i>Betta balunga</i>	Herre, 1940	n/a	n/a	TW	Herre 1940; Inger and Chin 2002; Kottelat 2013
<i>Betta chini</i>	Ng, 1993	VU	n/a/Endemic	BF	Ng 1993; Inger and Chin 2002; Kottelat 2013
<i>Betta gladiator</i>	Tan & Ng, 2005	n/a	n/a/Endemic	TO	Tan and Ng 2005; Sade and Biun 2012; Kottelat 2013
<i>Betta ocellata</i>	de Beaufort, 1933	n/a	n/a	KI, LD, SA, TW	Tan and Ng 2005; Kottelat 2013
<i>Osphronemus laticlavius</i>	Roberts, 1992	n/a	Giant red tail gourami	LD	Roberts 1992; Kottelat et al. 1993; Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat 2013
<i>Trichopodus trichopterus</i>	(Pallas, 1770)	LC	Three spot gourami	KB, KK, LD, TU	Inger and Chin 2002; Kottelat 2013
<b>Family Channidae</b>					
<i>Channa baramensis</i>	(Steindachner, 1901)	n/a	n/a	LD	Martin-Smith and Tan 1998; Kottelat 2013
<i>Channa striata</i>	(Bloch, 1793)	LC	Striped snakehead	KI, SA	Inger and Chin 2002; Kottelat 2013
ORDER					
TETRAODONTIFORMES					
<b>Family Tetraodontidae</b>					
<i>Auriglobus modestus</i>	(Bleeker, 1850)	LC	n/a	BE, KI, SA	Inger and Chin 2002; Kottelat 2013
<i>Auriglobus remotus</i>	(Roberts, 1982)	n/a	n/a	KI	Roberts 1982; Kottelat 2013
<i>Dichomyctere fluviatilis</i>	(Hamilton, 1822)	n/a	Green pufferfish	KI	Inger and Chin 2002; Kottelat 2013
<i>Dichomyctere kretamensis</i>	(Inger, 1953)	n/a	n/a/Endemic	KI	Inger 1953; Inger and Chin 2002; Kottelat 2013
<i>Dichomyctere sabahensis</i>	(Dekkers, 1975)	n/a	n/a/Endemic	KI	Dekkers 1975; Kottelat et al. 1993; Inger and Chin 2002; Kottelat 2013
<i>Pao leiurus</i>	(Bleeker, 1850)	n/a	n/a	TW	Inger and Chin 2002; Kottelat 2013

Note: Locality key Aq=Aquaculture; BE=Beluran; BF=Beaufort; KB=Kota Belud; KE=Keningau; KI=Kinabatangan; KK=Kota Kinabalu; KM=Kota Marudu; KU=Kudat; LA=Labuan Island; LD=Lahad Datu; PA=Papar; PE=Penampang; RA=Ranau; SA=Sandakan; SE=Semporna; SI=Sipitang; TA=Tambunan; TE=Tenom; TO=Tongod; TU=Tuaran; TW=Tawau. IUCN status key: CR=Critically Endangered; DD=Data Deficient; EN=Endangered; EW=Extinct in Wild; EX=Extinct; LC=Least Concerned; NE=Not Evaluated; NT=Near Threatened; VU=Vulnerable; n/a=Not available

**Table 2.** List of introduced species in Sabah, North Borneo

Order/Family/Species	Authority	IUCN status	Common Name/Remarks	References
ORDER CYPRINIFORMES				
<b>Family Cyprinidae</b>				
<i>Barbonymus gonionotus</i>	(Bleeker, 1849)	LC	Silver barb	Inger and Chin 2002; Kottelat 2013
<i>Carassius auratus</i>	(Linnaeus, 1758)	LC	Goldfish	Inger and Chin 2002; Kottelat 2013
<i>Cirrhinus molitorella</i>	(Valenciennes, in Cuvier & Valenciennes, 1844)	NT	Mud carp	Inger and Chin 2002; Kottelat 2013
<i>Ctenopharyngodon idella</i>	(Valenciennes, in Cuvier & Valenciennes, 1844)	n/a	Grass carp	Kottelat and Tan 2011; Kottelat 2013
<i>Cyprinus carpio</i>	Linnaeus, 1758	VU	Common carp	Inger and Chin 2002; Kottelat 2013
<i>Hypophthalmichthys molitrix</i>	(Valenciennes, in Cuvier & Valenciennes, 1844)	NT	Silver carp	Inger and Chin 2002; Kottelat 2013
<i>Hypophthalmichthys nobilis</i>	(Richardson, 1845)	DD	Bighead carp	Inger and Chin 2002; Kottelat 2013
<i>Leptobarbus rubripinna</i>	(Fowler, 1937)	LC	Red-finned Cigar Shark	Inger and Chin 2002; Kottelat 2013
ORDER SILURIFORMES				
<b>Family Clariidae</b>				
<i>Clarias gariepinus</i>	(Burchell, 1822)	LC	North African catfish	Inger and Chin 2002; Kottelat 2013
<b>Family Pangasiidae</b>				
<i>Pangasianodon hypophthalmus</i>	(Sauvage, 1878)	LC	Striped catfish	Inger and Chin 2002; Kottelat 2013
ORDER CYPRINODONTIFORMES				
<b>Family Poeciliidae</b>				
<i>Poecilia reticulata</i>	Peters, 1859	n/a	Guppy	Inger and Chin 2002; Kottelat 2013
ORDER PERCIFORMES				
<b>Family Cichlidae</b>				
<i>Oreochromis mossambicus</i>	(Peters, 1852)	NT	Mozambique tilapia	Martin-Smith and Tan 1998; Inger and Chin 2002; Kottelat 2013
<i>Oreochromis niloticus</i>	(Linnaeus, 1758)	n/a	Nile tilapia	Inger and Chin 2002; Kottelat 2013
<b>Family Helostomatidae</b>				
<i>Helostoma temminckii</i>	Cuvier, 1829	LC	Kissing gourami	Inger and Chin 2002; Kottelat 2013
<b>Family Osphronemidae</b>				
<i>Osphronemus goramy</i>	La Cèpède, 1801	LC	Giant Gouramy	Inger and Chin 2002; Kottelat 2013
<i>Trichopodus pectoralis</i>	Regan, 1910	LC	Snakeskin Gourami	Inger and Chin 2002; Kottelat 2013

Note: Locality key BE=Beluran; BF=Beaufort; KB=Kota Belud; KE=Keningau; KI=Kinabatangan; KK=Kota Kinabalu; KM=Kota Marudu; KU=Kudat; LA=Labuan Island; LD=Lahad Datu; PA=Papar; PE=Penampang; RA=Ranau; SA=Sandakan; SE=Semporna; SI=Sipitang; TA=Tambunan; TE=Tenom; TO=Tongod; TU=Tuaran; TW=Tawau. IUCN status key: CR=Critically Endangered; DD=Data Deficient; EN=Endangered; EW=Extinct in Wild; EX=Extinct; LC=Least Concerned; NE=Not Evaluated; NT=Near Threatened; VU=Vulnerable; n/a=Not available

### Field work challenges

At this point, we believe it would be helpful to discuss some background information on the pattern of diversity and field work challenges in Sabah for the benefit of future workers. Our analysis shows Kinabatangan and Lahad Datu

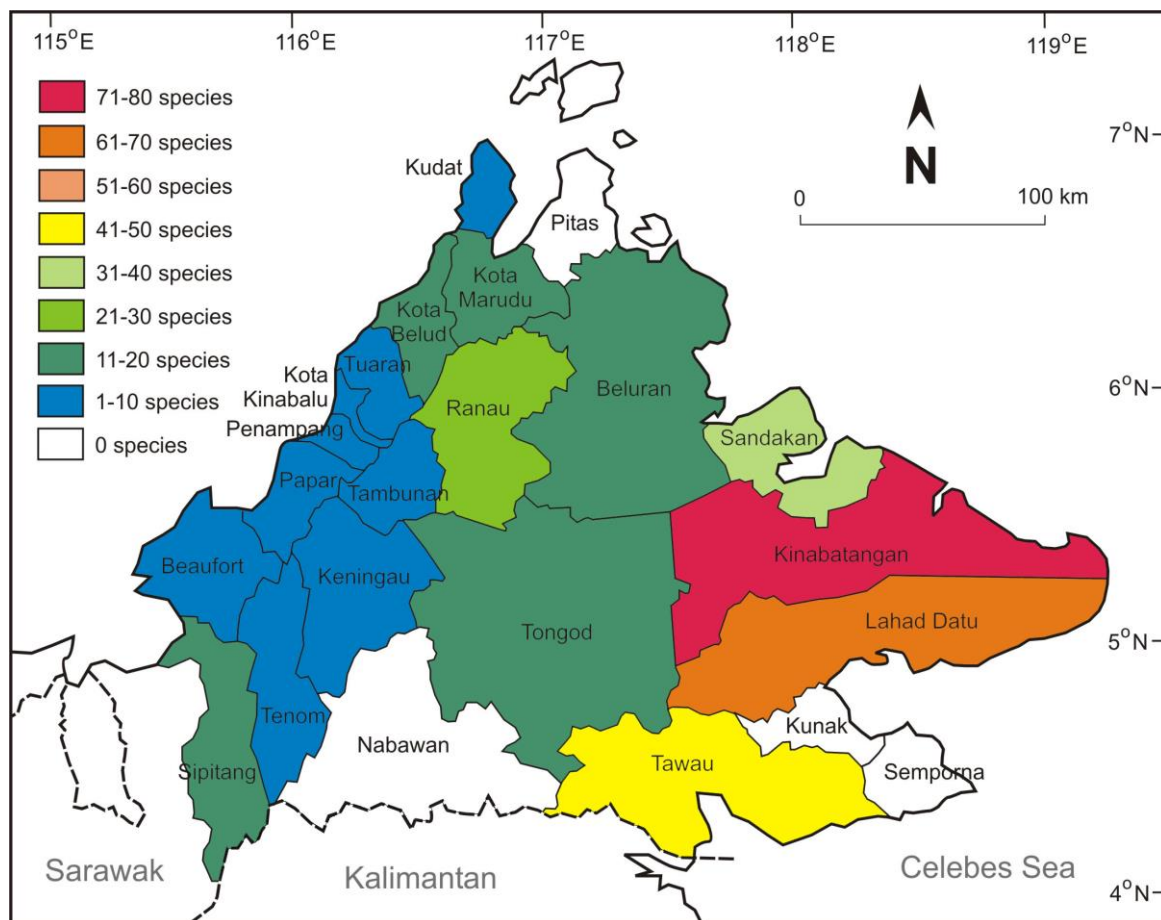
districts register the most species (Figure 2). However, we caution that this should not be construed as a lack of diversity in other districts, especially Beluran which has similar lowland geohydrology characteristics as Kinabatangan and Lahad Datu.

The Kinabatangan and Lahad Datu districts encompass some of the largest areas in the state and considering their low elevation and geological age as mentioned earlier, they are expected to host more species. But if we cast our sight on Tongod and Beluran, these districts are of considerable size too and yet not many species were recorded. We would like to stress that ichthyological study in Sabah is still at infancy stage and one should not attempt to correlate landscape sizes with species diversity yet. Existing data is inconclusive and biased towards localities which are most easy to access. Many parts of Sabah are still undeveloped and difficult to reach. The lack of interest in local fish taxonomy has also hindered robust data collection and checklists for some districts have yet to be produced.

Consequently, there are many other factors that caused species accounting to be under-represented in some districts. As highlighted earlier, river hydrological pattern and intensity in Sabah is affected by two monsoon seasons. This presents a challenge for field collections. Experience is crucial for capturing and collecting specimens in various stream/river orders, depth, turbidity, substrate and

hydrological conditions. Beginners or visiting researchers who are not familiar with species responses to the mentioned variances would find it frustrating to obtain a satisfactory collection result. Additionally, our own experiences have shown that many benthic species have burrowing habits or prefer to forage in crevices under rocks. These species are extremely difficult to find, much less capture. Some specialized species such as those from the *Gastromyzon* genus (Figure 3) inhabit turbulent waters that may be too dangerous for normal sampling exercise, while some species are probably nocturnal and night searches may be necessary.

Besides sampling difficulties, there are some local cultural sensitivities to consider. The conventional electrofishing method and ichthyocide applied by researchers are not favoured because most locals regard such approaches as destructive. In Sabah, there is a traditional practice of *tagal* in many rural areas that forbids the collecting, injuring or killing of fishes. *Tagal* is a local tradition where fishes in the rivers are protected at various degrees by the local indigenous communities to increase



**Figure 2.** Locality and native species recorded: Beluran = 20; Beaufort = 7; Kota Belud = 16; Keningau = 8; Kinabatangan = 78; Kota Kinabalu = 7; Kota Marudu = 20; Kudat = 5; Labuan Island = 1; Lahad Datu = 67; Papar = 1; Penampang = 3; Ranau = 25; Sandakan = 35; Sipitang = 13; Tambunan = 9; Tenom = 10; Tongod = 20; Tuaran = 6; Tawau = 42. So far, no survey was carried out in Semporna, Nabawan, Kunak and Pitas district



**Figure 3.** Species from the *Gastromyzon* genus (ventral view) have specialized pectoral fin, suprapelvic flap and fused pelvic fin that have evolved to function as suction cups to adhere to rocks in torrent rivers



**Figure 4.** Indigenous people are typically skilful fishermen and it is advisable to collaborate with them in collection exercises for satisfactory results

the population of usually larger food species. The rule is strictly enforced and there have been cases when even conservation organizations were penalized for collecting specimens in the rivers! *Tagal* is a commendable practice for habitat conservation and we advise researchers to obtain the necessary "free, prior and informed consent" (FPIC) (Buppert and McKeehan 2013) from the local community prior to initiating any field work. Moreover, collaboration with the local community is advisable for detecting as many species as possible because they possess the site-specific fish collection skills and traditional ecological knowledge (Figure 4).

In conclusion, we present a list of 150 native species and 16 introduced species recorded in Sabah so far. Because Sabah remains largely unexplored and there are some challenges in conducting ichthyofaunal surveys, the accuracy of the checklist is expected to fall short. Clearly, fish taxonomic and ecology studies must be prioritized in these less assessed districts as a matter of urgency. Even though incomplete, it is hoped that the working checklist may set the foundation for driving progress in species-level research and habitat conservation. We expect the checklist to be in flux and needs to be updated periodically.

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#### REFERENCES

- Ahmad A, Tn Nek, SAR, Ambak MA. 2006. Preliminary study on fish diversity of Ulu Tungud Meliau Range Sandakan Sabah. *J Sustain Sci Manag* 1 (2): 21-26.
- Ambak MA, Mat Isa MM, Zakaria MZ, Ghaffar MA. 2012. *Fishes of Malaysia*, 2nd ed. Penerbit UMT, Terengganu.
- Atack K. 2006. *The Fishes of Kuching Rivers, Sarawak, Malaysian Borneo*. Natural History Publication (Borneo), Kota Kinabalu.
- Buppert T, McKeehan A. 2013. *Guidelines for Applying Free, Prior and Informed Consent: A Manual for Conservation International*. Conservation International, Arlington.
- Chakrabarty P, Oldfield RG, Ng HH. 2006. *Nandus prolixus*, a new species of leaf fish from northeastern Borneo (Teleostei: Perciformes: Nandidae). *Zootaxa* 1328: 51-61.
- Chin PK, Samat A. 1992. A new species of loach, *Nemacheilus elegantissimus*, (Family Balitoridae, subfamily Nemacheilinae) from Danum Valley, Sabah, Malaysia. *Malay Nat J* 46 (1): 25-33.
- Chin PK. 1990. A new Bornean species of loach, *Elxis sabanus* (Cobitidae) from Mendolong, Sabah. *Malay Nat J* 43 (2): 72-76.
- Chong VC., Lee PKY, Lau CM. 2010. Diversity, extinction risk and conservation of Malaysian fishes. *J Fish Biol* 76: 2009-2066.
- Courtenay WR and Williams JD. 2004. *Snakeheads (Pisces, Channidae): A biological synopsis and risk assessment*. USGS Circular 1251. US Geological Survey, Gainesville.
- Dekkers WJ. 1975. Review of the Asiatic freshwater puffers of the genus *Tetraodon* Linnaeus, 1758 (Pisces, Tetraodontiformes, Tetraodontidae). *Bijdragen tot de Dierkunde* 45 (1): 87-142.
- Desai VR. 2003. Synopsis of biological data on the tor mahseer *Tor tor* (Hamilton, 1822). *FAO Fisheries Synopsis No.158*. FAO, Rome.
- Esa YB, Siraj SS, Daud SK, Rahim A, Adha K. 2006. Mitochondrial DNA Diversity of *Tor douronensis* Valenciennes (Cyprinidae) in Malaysian Borneo. *Pertanika J Trop Agric Sci* 29: 47-55.
- Esa YB, Siraj SS, Daud SK, Ryan JJR, Rahim KAA, Tan SG. 2008. Molecular systematics of mahseers (Cyprinidae) in Malaysia inferred from sequencing of a mitochondrial Cytochrome C Oxidase I (COI) Gene. *Pertanika J Trop Agric Sci* 31 (2): 263-269.
- Esa YB, Siraj SS, Rahim KAA, Daud SK, Ho GC, Tan SG, Syukri MF. 2012. Genetic characterization of two mahseer species (*Tor douronensis* and *Tor tambroides*) using microsatellite markers from other Cyprinids. *Sains Malaysiana* 40 (10) 1087-1095.

- Eschmeyer WN, Fricke R, Van der Laan R (eds.). 2016. Catalogue of Fishes: Genera, Species, References. [version 10/2016] <http://www.calacademy.org/scientists/projects/catalog-of-fishes>
- Froese R, Pauly D. (eds.) 2016. FishBase. [version 10/2016] <http://www.fishbase.org>.
- Gustiano R, Teugels GG, Pouyaud L. 2002. Revision of the *Pangasius kunyit* catfish complex, with description of two new species from South-East Asia (Siluriformes; Pangasiidae). *J Nat Hist* 37 (3): 357-376.
- Haryono AHT. 2006. Morphological study for identification improvement of *Tambra* fish (*Tor* spp.: Cyprinidae) from Indonesia. *Biodiversitas* 7: 59-62.
- Herre AWCT. 1940. New species of fishes from the Malay Peninsula and Borneo. *Bull Raffles Mus* 16: 5-26.
- Herre AWCT. 1939. The genera of Phallostethidae. *Proc Biol Soc Washington* 52: 139-144.
- Herre AWCT. 1940. Additions to the fish fauna of Malaya and notes on rare or little known Malayan and Bornean fishes. *Bull Raffles Mus* 16: 27-61.
- Herre AWCT. 1933. A checklist of fishes from Sandakan, British North Borneo. *Journal of Pan-Pacific Research Institute* 8: 2-5.
- Hossain MS, Sarker S. 2013. New species of leaf fish *Nandus meni* (Perciformes: Nandidae) from Noakhali, Bangladesh. *Zoology and Ecology* 23 (3): 191-197.
- Inger RF. 1953. A new fish from north Borneo. *Fieldiana Zoology* 34 (11): 149-152.
- Inger RF. 1957. Report on a collection of marine fishes from North Borneo. *Fieldiana Zoology* 36 (3): 341-405.
- Inger RF. 1958. Notes on the fishes of the genus *Brachyobius*. *Fieldiana Zoology* 39 (14): 107-117.
- Inger RF, Chin PK. 1962. The freshwater fishes of North Borneo. *Fieldiana: Zoology* 45: 1-268.
- Inger RF, Chin PK. 2002. The freshwater fishes of North Borneo, with a revised supplementary chapter. Natural History Publications (Borneo), Kota Kinabalu.
- Ingram B, Sungan S, Tinggi D, Sim SY, De Silva SS. 2007. Breeding performance of Malaysian Mahseer, *Tor tambroides* and *T. douronensis* broodfish in captivity. *Aquacult Res* 38: 809-818.
- Kottelat M. 2012. *Rasbora rheophila*, a new species of fish from northern Borneo (Teleostei: Cyprinidae). *Revue Suisse de Zoologie* 119 (1): 77-87.
- Kottelat M. 2013. The fishes of the inland waters of Southeast Asia: A catalogue and core bibliography of the fishes known to occur in freshwaters, mangroves and estuaries. *Raffles Bull Zool* 27: 1-663.
- Kottelat M, Lim KKP. 1995. Freshwater fishes of Sarawak and Brunei Darussalam: a preliminary annotated checklist. *Sarawak Mus J* 48: 227-256.
- Kottelat M, Tan HH. 2008. A synopsis of the genus *Lobocheilus* in Java, Sumatra and Borneo, with descriptions of six new species (Teleostei: Cyprinidae). *Ichthyol Explor Freshw* 19 (1): 27-58.
- Kottelat M, Tan HH. 2011. *Crossocheilus elegans*, a new species of fish from northern Borneo (Teleostei: Cyprinidae). *Raffles Bull Zool* 59 (2): 195-199.
- Kottelat M, Whitten AJ., Kartikasari SN, Wirjoatmodjo S. 1993. Freshwater fishes of Western Indonesia and Sulawesi. Periplus Editions, Hong Kong.
- Larson H. 2012. *Hypseleotris cyprinoide*: The IUCN Red List of Threatened Species 2012 [version 10/2016] <http://dx.doi.org/10.2305/IUCN.UK.2012.RLTS.T63355A3124969.en>.
- Larson H. 2012. *Ophiocara porocephala*: The IUCN Red List of Threatened Species 2012 [version 10/2016] <http://dx.doi.org/10.2305/IUCN.UK.2012-1.RLTS.T188101A1854106.en>.
- Leadley PW, Krug CB, Alkemade R, Pereira HM, Sumaila UR, Walpole M, Marques A, Newbold T, Teh LSL, van Kolck J, Bellard C, Januchowski-Hartley SR, Mumby PJ. 2014. Progress towards the Aichi Biodiversity Targets: An Assessment of Biodiversity Trends, Policy Scenarios and Key Actions. Secretariat of the Convention on Biological Diversity, Montreal.
- Lohman DJ, Bruyn MD, Page T, Rintelen KV, Hall R., Ng PKL, Shih HT., Carvalho GR, Rintelen TV. 2011. Biogeography of the Indo-Australian Archipelago. *Ann Rev Ecol Evol Syst* 42: 205-226.
- Marsh CW, Greer AG. 1992. Forest land use in Sabah, Malaysia: An introduction to Danum Valley. *Phil Trans R Soc London* 335: 331-339.
- Martin-Smith KM. 1998. Biodiversity patterns of tropical freshwater fish following selective timber extraction: A case study from Sabah, Malaysia. *Italian J Zool* 65: 363-368.
- Martin-Smith KM, Tan HH. 1998. Diversity of freshwater fishes from Eastern Sabah: Annotated checklist for Danum Valley and a consideration of inter- and intra-catchment variability. *Raffles Bull Zool* 46 (2): 573-604.
- Meisner AD, Collette BB. 1998. A new species of viviparous halfbeak, *Dermogenys bispina* (Teleostei: Hemiramphidae) from Sabah (North Borneo). *Raffles Bull Zool* 46 (2): 373-380.
- Nelson G, Platnick N. 1981. Systematics and Biogeography: Cladistics and Vicariance. Colombian University Press, New York.
- Nelson JS. 2006. Fishes of the World, 4th edn. John Wiley & Sons Inc., New Jersey.
- Ng HH, Ng PKL. 2001. A revision of the akysid catfish genus *Acrodonichthys* Bleeker. *J Fish Biol* 58 (2): 386-418.
- Ng HH, Kottelat M. 2013. Revision of the Asian catfish genus *Hemibagrus* Bleeker, 1862 (Teleostei: Siluriformes: Bagridae). *Raffles Bull Zool* 61 (1): 205-291.
- Ng HH, Kottelat M. 2016. The *Glyptothorax* of Sundaland: A revisionary study (Teleostei: Sisoridae). *Zootaxa* 4188 (1): 001-092.
- Ng HH, Lim KKP. 2006. Two new species of *Leiocassis* (Teleostei: Bagridae), riverine catfishes from northeast Borneo. *Ichthyol Explor Freshw* 17 (2): 165-172.
- Ng HH, Lim KKP. 2008. Catalogue of the siluriform (Teleostei: Ostariophysi) types in the Raffles Museum of Biodiversity Research. National University of Singapore, Raffles Museum of Biodiversity Research, Singapore.
- Ng HH. 1999. Two new species of catfishes of the genus *Clarias* from Borneo (Teleostei: Clariidae). *Raffles Bull Zool* 47 (1): 17-32.
- Ng HH, Martin-Smith KM, Ng PKL. 2000. *Hemibagrus furcatus*, a new species of bagrid catfish (Teleostei: Siluriformes) from Sabah, East Malaysia. *Raffles Bull Zool* 48 (1): 65-69.
- Ng PKL. 1993. On a new species of *Betta* (Teleostei: Belontiidae) from peat swamps in Sabah, East Malaysia, Borneo. *Ichthyol Explor Freshw* 4 (4): 289-294.
- Nguyen TTT. 2008. Population structure in the highly fragmented range of *Tor douronensis* (Cyprinidae) in Sarawak, Malaysia revealed by microsatellite DNA markers. *Freshw Biol* 53: 924-934.
- Nyanti L. 1998. Fish fauna of Sayap-Kinabalu Park, Sabah. ASEAN Review of Biodiversity and Environmental Conservation (ARBEC), The Philippines.
- Nyanti L, Yee, LT, Adha K. 1999. Freshwater fishes from Bario, Kelabit Highlands, Sarawak. ASEAN Review of Biodiversity and Environmental Conservation 4: 1-6.
- Parenti LR. 1996. Phylogenetic systematics and biogeography of phallostethid fishes (Atherinomorpha, Phallostethidae) of northwestern Borneo, with description of new species. *Copeia* 3: 703-712.
- Parenti LR. 2014. A new species of *Neostethus* (Teleostei: Atherinomorpha; Phallostethidae) from Brunei Darussalam, with comments on northwestern Borneo as an area of endemism. *Raffles Bull Zool* 62: 175-187.
- Randall JE, Lim KKP. 2000. A Checklist Of The Fishes Of The South China Sea. *Raffles Bull Zool* 8: 569-667.
- Roberts TR. 1982. The southeast Asian freshwater pufferfish genus *Chonerhinus* (Tetraodontidae), with descriptions of new species. *Proc Calif Acad Sci* 43 (1): 1-16.
- Roberts TR. 1989. The freshwater fishes of Western Borneo (Kalimantan Barat, Indonesia). *Proc Calif Acad Sci* 14: 1-210.
- Roberts TR. 1992. Systematic revision of the southeast Asian anabantoid fish genus *Osphronemus*, with descriptions of two new species. *Ichthyol Explor Freshw* 2 (4): 351-360.
- Roberts TR. 1999. Fishes of the Cyprinid Genus *Tor* in the Nam Theun watershed (Mekong Basin) of Laos, with description of a new species. *Raffles Bull Zool* 47 (1): 225-236.
- Roberts TR, Vidhayanon C. 1991. Systematic revision of the Asian catfish family Pangasiidae, with biological observations and descriptions of three new species. *Proc Acad Nat Sci Philadelphia* 143: 97-143.
- Sabah State Government. 2012. Sabah Biodiversity Strategy 2012-2022. Bornean Biodiversity & Ecosystems Conservation Programme Phase II (BBECII) joint programme of the Sabah State Government, Universiti Malaysia Sabah, Kota Kinabalu, and Japan International Cooperation Agency.

- Sade A, Biun H. 2012. The ichthyofauna of Maliau Basin buffer zone at Maliau Basin Conservation Area, Sabah, Malaysia. *J Trop Biol Conserv* 9 (1): 105-113.
- Siebert DJ. 1991. *Acantopsis octoactinotos*, a new species of horse-faced loach (Cypriniformes: Cobitidae) from Sabah, Malaysia. *Copeia* 4 : 910-915.
- Sulaiman ZH, Mayden RL. 2012. Cypriniformes of Borneo (Actinopterygii, Otophysi): An extraordinary fauna for integrated studies on diversity, systematics, evolution, ecology, and conservation. *Zootaxa* 3586: 359-376.
- Tan HH. 2006. *The Borneo Suckers*. Natural History Publications (Borneo), Kota Kinabalu.
- Tan HH. 2013. SAFE Project - Sabah: Kalabakan. Freshwater fish list with pictures (based on October 2011 survey). Raffles Museum of Biodiversity Research, Department of Biological Science, National University of Singapore, Singapore.
- Tan HH., Martin-Smith KM. 1998. Two new species of *Gastromyzon* (Teleostei: Balitoridae) from the Kuamut headwaters, Kinabatangan basin, Sabah, Malaysia. *Raffles Bull Zool* 46 (2): 361-371.
- Tan HH, Ng PKL. 2005. The fighting fishes (Teleostei: Osphronemidae: genus *Betta*) of Singapore, Malaysia and Brunei. *Raffles Bull Zool* 13: 43-99.
- Thoni RJ, Mayden RL. 2015. *Garra robertsi*, a new cyprinid (Cypriniformes: Cyprinidae) fish species from Borneo. *Zootaxa* 3985 (2): 284-290.
- Van der Laan R, Eschmeyer WN, Fricke R. 2014. Family-group names of Recent fishes. *Zootaxa* 3882 (2): 1-230.
- Watson RE. 1991. A provisional review of the genus *Stenogobius* with descriptions of a new subgenus and thirteen new species. (Pisces: Teleostei: Gobiidae). *Rec Western Austr Mus* 15 (3): 571-654.
- Wiley EO. 1988. Vicariance Biogeography. *Ann Rev Ecol Syst* 19: 513-542.
- Yap SY. 2002. On the distributional patterns of Southeast-East Asian freshwater fish and their history. *J Biogeogr* 29: 1187-1199.
- Zakaria-Ismail M. 1994. Zoogeography and biodiversity of the freshwater fishes of Southeast Asia. *Hydrobiologia* 285 (1-3): 41-48.