Notes on flyingfish diversity in Indonesia waters

A Syahailatua¹ and F Rijoly²
¹ Research Centre for Oceanography – Indonesian Institute of Sciences, Jalan Pasir Putih I, Jakarta 14430, Indonesia
² Faculty of Fisheries and Marine Science – University of Pattimura, Jalan Ir. Putuhena, Ambon 97233, Indonesia

E-mail: augy.syahailatua@lipi.go.id

Abstract. Flyingfish is a small pelagic commercial species caught by local fishermen in Indonesia waters which is an important fish by its roe (eggs) for export. Flyingfish diversity has been studied for almost a century since Weber and de Beaufort published their findings in 1922. In 1960, Parin extended this study, and after that, Hutomo et al. (1985) reviewed several flyingfish studies in Indonesia waters, especially on fishery aspects. Again, Parin (1999) revised the systematics of flyingfish in Indo-west Pacific, splitting the genus of Cypselurus Swainson 1838 into Cheilopogon Lowe 1841 and Hirundichthys Breeder 1928. In 2004-2010, we studied the diversity and distribution of flyingfish at 7 locations throughout Indonesia. We identified 14 species, and found that Parexocoetus mento was widely distributed. The Makassar Strait, Flores Sea and Ambon (central Maluku) are suggested as hotspots of flyingfish diversity in Indonesia waters.

1. Introduction
Flyingfish is well known as an important small pelagic commercial species caught by local fishermen throughout Indonesia, especially its roes or eggs used as an exported commodity to some countries, such as Japan and Taiwan [1],[2]. However, this fishery seems to have collapsed due to its production in south Sulawesi (as a central production of flyingfish) dropped dramatically from 11,000 ton in 1971 to 6,800 ton in 2000. This indicates the need for management of the flyingfish fishery in Indonesia [3]. In 2016, the Ministry of Marine Affairs and Fishery issued the management plan of flyingfish in Indonesia. Therefore, Indonesian government requires more data on this fishery to improve the management strategy for sustainable fishery of flyingfish.

In the world, the family of Exocoetidae consist of seven genera and 71 species have been recognized as valid species in published studies. These genera are Cheilopogon Lowe, 1841 (31 species), Cypselurus Swainson 1838 (12 species), Exocoetus Linnaeus, 1758 (5 species), Fodiator Jordan & Meek, 1885 (2 species), Hirundichthys Breder, 1928 (12 species), Parexocoetus Bleeker, 1865 (3 species) and Prognichthys Breder, 1928 (6 species) [4],[5],[2],[6],[7]. In the Indo-Pacific region, 6 genera have been described, including 31 species [6].
This study therefore aims to review and update information on the species diversity of flyingfish, and identify diversity hotspots in Indonesia waters. This information could be a key issue to develop a future management plan for the flyingfish fishery in Indonesia.

2. Methods
Flyingfish samples were collected from local fishermen catches during 2004-2010. Six locations throughout Indonesia were established as sampling sites, such as Padang (west Sumatera), Bintuang (west Jawa), Singaraja (north Bali), Makassar Strait and Flores Sea (south Sulawesi), Bitung (north Sulawesi), Ambon (central Maluku), and Kei Islands (southeast Maluku). The samples were preserved in formalin (10%), and transported to the Ichthyological Laboratory of the Research Centre for Oceanography - LIPI (Jakarta), and Faculty of Fisheries and Marine Sciences – University of Pattimura (Ambon) for species identification and biological observations. After identification, specimens were stored in 70% alcohol at the reference collections of LIPI in Jakarta and Ambon for permanent preservation.

Specimen identification of flyingfish was conducted following [6],[8],[9]. Morphometric measurement and meristic counts were taken based on [6],[8],[9],[10].

3. Results and Discussion

3.1. Study in the early 20th century
In 1922, Weber and Beaufort published an identification key for flyingfish in the western Pacific region, including Indonesia. They noted that flyingfish in this region consisted of 18 species belonging to 4 genera; Parexcoetus, Evolantia, Exocoetus, and Cypselurus. However, only 3 of the 18 described species still have a valid scientific name (table 1).

| No. | Species Name [8]                  | Valid Name [7]                  | Notes |
|-----|----------------------------------|--------------------------------|-------|
| 1.  | Parexcoetus brachypterus (Richardson, 1846) | Parexcoetus brachypterus (Richardson, 1846) |       |
| 2.  | Evolantia micropterus (Valenciennes, 1847) | Oxyporhamphus micropterus (Valenciennes, 1847) | a,b   |
| 3.  | Exocoetus volitans Linnaeus, 1758 | Exocoetus volitans Linnaeus, 1758 |       |
| 4.  | Cypselurus oxycephalus Bleeker, 1853 | Hirundichthys oxycephalus (Bleeker, 1853) |       |
| 5.  | Cypselurus speculiger (Valenciennes, 1847) | Hirundichthys speculiger (Valenciennes, 1847) | b     |
| 6.  | Cypselurus arcticeps (Günther, 1866) | Cheilopogon arcticeps (Günther, 1866) | b     |
| 7.  | Cypselurus nigricans (Bennett, 1840) | Cheilopogon nigricans (Bennett, 1840) | b     |
| 8.  | Cypselurus altipennis (Valenciennes, 1847) | Cheilopogon altipennis (Valenciennes, 1847) | b     |
| 9.  | Cypselurus hexazona (Bleeker, 1853) | Cypselurus hexazona (Bleeker, 1853) | b     |
| 10. | Cypselurus bilobatus Weber & de Beaufort, 1922 | Cheilopogon spilopterus (Valenciennes, 1847) | b     |
| 11. | Cypselurus poeciloterpus (Valenciennes, 1847) | Cypselurus poeciloterpus (Valenciennes, 1847) | b     |
| 12. | Cypselurus atrisignis Jenkins, 1903 | Cheilopogon atrisignis (Jenkins, 1903) | b     |

Tabel 1. List of the flyingfish species published on the fishes of the Indo-Australian Archipelago [8], and their valid name based on Fishbase [7].
13. *Cypselurus spilopterus* (Valenciennes, 1847)  
14. *Cypselurus bahiensis* Ranzani, 1842  
15. *Cypselurus opisthopus* (Bleeker, 1865)  
16. *Cypselurus nigrinennis* (Valenciennes, 1847)  
17. *Cypselurus brevis* Weber & de Beaufort, 1922  
18. *Cypselurus rondeletii* (Valenciennes, 1847)

|   | Scientific Name | Scientific Name |   |
|---|----------------|----------------|---|
| 1 | *Cheilopogon spilopterus* (Valenciennes, 1847) | *Cheilopogon cyanopterus* (Valenciennes, 1847) | b |
| 2 | *Cypselurus opisthopus* (Bleeker, 1865) | *Hirundichthys speculiger* (Valenciennes, 1847) | b |
| 3 | *Cypselurus hexazona* (Bleeker, 1853) | *Hirundichthys rondeletii* (Valenciennes, 1847) | b |

*a* belongs to the family of Hemiramphidae  
*b* name changed

According to the above information, Weber and de Beaufort had classified flyingfish from the Indo-Pacific region to include two families, Exocoetidae and Hemiramphidae, as *Oxyrhynchus micropterus* has since been described as belonging to the family Hemiramphidae [8]. The number of genera has since been increased from four to five; *Cheilopogon, Cypselurus, Exocoetus, Hirundichthys* and *Parexcoetus*. Several species of flyingfish from the previous description [8] then they categorized as similar species [7]. For example, *Cypselurus bilobatus* and *Cypselurus spilopterus* were identified as *Cheilopogon spilopterus*; *Cypselurus hexazona* and *Cypselurus brevis* were identified as *Cypselurus hexazona*; *Cypselurus speculiger* and *Cypselurus nigrinennis* were identified as *Hirundichthys speculiger*. Therefore, the 18 species of flyingfishes listed in table 1 changed in their classification as well as scientific names at the family and species levels to be only 14 species [7].

3.2. The late 20th Century

By the end of the 20th century, Hutomo et al. [2] identified 18 species from Indonesia waters, however there was no information on their distribution. In addition, in Makassar Strait and Flores Sea, Nessa et al. [1] identified 11 species, such as *Hirundichthys oxycephalus, Cypselurus altipennis, C. speculiger, C. oligolepis, C. ophisthopus, C. nigricans, C. poecilopterus, C. swainson, Cypselurus sp., Evolantia micropterus*, and *Prognichthys sealei*. The most abundant species in these waters was *Hirundichthys oxycephalus* (previous name: *Cypselurus oxycephalus*).

Hutomo et al. [2] also noted 53 species of flyingfish globally, with 17 species distributed in the Atlantic Ocean, 11 species in the Indian Ocean, and 40 species were identified from the Pacific Ocean. However, Nelson [11] estimated that 50 – 60 species of flyingfish occur in the Pacific Ocean. In addition, in the Phillipines, especially in the western area of Luzon Island, *Hirundichthys oxycephalus* was the major species in flyingfish catch [12], and other flyingfish species such as *Cypselurus poecilopterus, Cheilopogon nigricans, Cheilopogon cyanopterus, Parexcoetus brachypterus*, and *Hirundichthys rondeletii*. Futhermore, in the equatorial region, the number of flyingfish species is more than in the southern or northern latitudes [2]. Parin [6] stated that there were 31 species in the Western Central Pacific; the genus Cheilopogon with 14 species, *Cypselurus* (7 spp.), *Exocoetus* (3 spp.), *Hirundichthys* (3 spp.), *Parexcoetus* (2 spp.) and *Prognichthys* (2 spp.).

Six of the eight genera of the Exocoetidae are found in the western Pacific, including Indonesia. However, two genera are not found, i.e. *Fodiator* and *Oxyrhynchus* [6],[7]. Of six genera in Indonesia waters, only two genera, *Cypselurus* and *Cheilopogon*, have a large number of species, i.e. *Cypselurus* with 6 species (*Cypselurus angusticeps, C. hexazona, C. naresii, C. oligolepis, C. ophisthopus, and C. Poecilopterus*), and *Cheilopogon* with 9 species (*Cheilopogon. abei, C. arcticeps, C. atrisignis, C. cyanopterus, C. intermedius, C. katoptron, C. pilonopterus, C. piloterus, and C. Suttoni*).

The genera *Cypselurus* and *Cheilopogon* have unique morphological characteristics. *Cypselurus* has a lower jaw shorter than the upper jaw, whereas *Cheilopogon* has relatively equal of jaw length, or a bit longer lower jaw than the upper jaw [6].
In the identification key of fishes in Indonesia, there were no species names under the genus of *Cheilopogon* [2],[5]. The genus *Cheilopogon* was similarly not recorded in Japanese waters [13]. Mostly, the species nowadays classified as *Cheilopogon* were previously classified as the species of *Cypselurus*. The split of these two genera was recognized in Indonesia following the FAO Living Marine Resources of the Western Central Pacific Publications [6]. Then, FishBase [7] and Kimura & Matsuura [14] accepted the new genus name of *Cheilopogon*.

### 3.3. Present Status (Based on the study results, 2004-2010)

The results of our flyingfish study in Indonesian waters from 2004 to 2010 were compiled, and we identified 14 species (table 2). Species of *Cheilopogon rapanouensis* was only 1 specimen of our collection. We found a similar species richness of flyingfish from the previous study [2] following validated names [6]. However, only 7 species were found and identified similarly with the previous study.

**Table 2.** Distribution of flyingfish in Indonesian waters based on the study results, 2004-2010.

| No. | Species                                | Padang | Binuangen | Makassar | Talaud | Ambon | Kei Is. | Singaraja |
|-----|----------------------------------------|--------|-----------|----------|--------|-------|---------|-----------|
| 1.  | *Cheilopogon abei* Parin, 1996          | •      | •         |          |        |       |         |           |
| 2.  | *Cheilopogon atrisignis* (Jenkins,1903) | •      |           |          |        |       |         |           |
| 3.  | *Cheilopogon cyanopterus* (Valenciennes, 1847) | • • | •         |          |        |       |         |           |
| 4.  | *Cheilopogon furcatus* (Mitchill, 1815) | •      |           |          |        |       |         |           |
| 5.  | *Cheilopogon katopron* (Bleeker, 1865) | •      | •         |          |        |       |         |           |
| 6.  | *Cheilopogon rapanouensis* Parin, 1961 |        |           |          |        |       |         |           |
| 7.  | *Cheilopogon spilonopterus* (Bleeker, 1865) | •      |           |          |        |       |         |           |
| 8.  | *Cheilopogon spilopterus* (Valenciennes, 1847) | • • • |           |          |        |       |         |           |
| 9.  | *Cheilopogon suttoni* (Whitley & Colefax, 1938) | • • • |           |          |        |       |         |           |
| 10. | *Cypselurus poecilopterus* (Valenciennes, 1847) | •      | •         |          |        |       |         |           |
| 11. | *Exocoetus volitans* Linnaeus, 1758      | •      |           |          |        |       |         |           |
| 12. | *Hirundichthys oxycephalus* (Bleeker, 1853) | •      | •         |          |        |       |         |           |
| 13. | *Parexocoetus brachypterus* (Richardson, 1846) | •      |           |          |        |       |         |           |
| 14. | *Parexocoetus mento* (Valenciennes, 1847) | • • • |           |          |        |       |         |           |

Total number of species 1 3 11 2 10 4 3
According to this study results from 7 sites in Indonesian waters (figure 1), we identified 14 species, and the species *Parexocoetus mento* had a wide-ranging distribution from west to east Indonesia. Eleven species were discovered from Makassar Strait and Flores Sea (southern Sulawesi), and 10 species from Ambon (central Maluku). These two areas had 66.7% similarity in species composition, and are probably to be proposed as genetic conservation zones for flyingfish species, because all flyingfish species from Indonesian waters were present there. If we compared the updated information of flyingfish species from the western central Pacific [6], there are more than 45% of the total species numbers found in the Indonesian waters. In addition, *Cheilopogon rapanouensis*, might be noted as a new record from Indonesian waters. In the previous studies on flyingfish e.g. [2],[8],[15], no specimens of this species were recorded. During our study, we collected a single specimen of this species, from Ambon waters.

Figure 2. The number of flyingfish species discovered at 7 sampling sites in Indonesia waters, 2004-2010.

Previous publications suggest that the number of flyingfish species found in Indonesia waters are actually more than we discovered during our study in 2004-2010. For example, Parin [15] reported 27 species found from Indonesia and Papua New Guinea (PNG), including one species from the family of Hemiramphidae (see table 3). Several species listed by Parin [15] were not discovered during our study, such as *Cheilopogon exsileiens*, *Cypselurus comatus*, *Cypselurus hexazona*, *Cypselurus* sp1., *Cypselurus* sp2., *Cypselurus* sp3., *Excoetus monocirrhus*, *Hirundichthys speculiger*, *Prognichthys brevipinnis*, and *Prognichthys sealei*. Moreover, from other studies in Indonesia waters, *Cheilopogon antoncichi*, *Cypselurus oligolepis* and *Cypselurus opisthopus* were identified [2],[16],[17]. According to this information, flyingfish species in Indonesia waters could be estimated at more than 25 species.

The information from several studies on flyingfish in the Indo-Pacific region shows variety in species composition (table 3), and the waters of the Philippines, Indonesia and PNG contributed a large number of flyingfish species [15].
Table 3. Results of flyingfish identification and collection from the Indo-Pacific region.

| No. | Species                                                                 | Indo-West Pacific | Philippines | Indonesia & PNG | Australia  | Indonesia  |
|-----|-------------------------------------------------------------------------|-------------------|-------------|-----------------|------------|------------|
| 1   | Cheilopogon abei Parin, 1996                                           | •                 |             |                 |            |            |
| 2   | Cheilopogon antonicichi (Woods & Schultz, 1953)                         | •                 |             |                 |            |            |
| 3   | Cheilopogon arcticeps (Günther, 1866)                                  | • • • • • •      |             |                 |            |            |
| 4   | Cheilopogon atrisignis (Jenkins, 1903)                                  | • • • • • •      |             |                 |            |            |
| 5   | Cheilopogon cyanopterus (Valenciennes, 1847)                           | • • • • • •      |             |                 |            |            |
| 6   | Cheilopogon exsiliens (Linneaus, 1771)                                 | •                 |             |                 |            |            |
| 7   | Cheilopogon furcatus (Mitchill, 1815)                                   | • • • • • •      |             |                 |            |            |
| 8   | Cheilopogon katopron (Bleeker, 1865)                                   | •                 |             |                 |            |            |
| 9   | Cheilopogon nigricans (Bennett, 1840)                                   | •                 |             |                 |            |            |
| 10  | Cheilopogon pinnatibarbus altipennis (Valenciennes, 1847)               | •                 |             |                 |            |            |
| 11  | Cheilopogon rapanouensis Parin, 1961                                   | •                 |             |                 |            |            |
| 12  | Cheilopogon simus (Valenciennes, 1847)                                 | •                 |             |                 |            |            |
| 13  | Cheilopogon spilonopterus (Bleeker, 1865)                               | • • • • • •      |             |                 |            |            |
| 14  | Cheilopogon spilopterus (Valenciennes, 1847)                            | • • • • • •      |             |                 |            |            |
| 15  | Cheilopogon suttoni (Whitley & Colefax, 1938)                           | • • • • • •      |             |                 |            |            |
| 16  | Cheilopogon unicolor (Valenciennes, 1847)                               | •                 |             |                 |            |            |
| 17  | Cypselurus comatus (Mitchill, 1815)                                     | •                 |             |                 |            |            |
| 18  | Cypselurus hexazona (Bleeker, 1853)                                     | • • • • • •      |             |                 |            |            |
| 19  | Cypselurus naresii (Günther, 1889)                                     | •                 |             |                 |            |            |
| 20  | Cypselurus oligoplepis (Bleeker, 1853)                                  | • • • • • •      |             |                 |            |            |
| 21  | Cypselurus opisthopus (Bleeker, 1865)                                   | • • • • • •      |             |                 |            |            |
| 22  | Cypselurus poecilopterus (Valenciennes, 1847)                           | • • • • • •      |             |                 |            |            |
| 23  | Cypselurus sp1                                                          | •                 |             |                 |            |            |
| 24  | Cypselurus sp2                                                          | •                 |             |                 |            |            |
| 25  | Cypselurus sp3                                                          | •                 |             |                 |            |            |
| 26  | Exocoetus monocirrhus Richardson, 1846                                  | • • • • • •      |             |                 |            |            |
| 27  | Exocoetus volitans Linneaus, 1758                                       | • • • • • •      |             |                 |            |            |
| 28  | Hirundichthys albiculatus (Fowler, 1934)                               | •                 |             |                 |            |            |
| 29  | Hirundichthys oxycephalus (Bleeker, 1853)                               | • • • • • •      |             |                 |            |            |
| 30  | Hirundichthys rondeletii (Valenciennes, 1847)                           | •                 |             |                 |            |            |
| 31  | Hirundichthys speculiger (Valenciennes, 1847)                           | • • • • • •      |             |                 |            |            |
| 32  | Oxyphorhamphus micropterus (Valenciennes, 1847)                         | • • • • • •      |             |                 |            |            |
| 33  | Parexocoetus brachypterus (Richardson, 1846)                            | • • • • • •      |             |                 |            |            |
| 34  | Parexocoetus mento (Valenciennes, 1847)                                 | • • • • • •      |             |                 |            |            |
| 35  | Prognichthys brevipinguis (Valenciennes, 1847)                          | • • • • • •      |             |                 |            |            |
| 36  | Prognichthys sealei Abe, 1955                                          | • • • • • •      |             |                 |            |            |

| Total | 15 | 23 | 27 | 21 | 16 |

a [8]  
b [15]  
c Specimen Catalog of the Australian Museum (Sydney) and Museum and Art Gallery of the Northern Territory (Darwin)  
d Specimen Catalog of Research Centre for Oceanography - LIPI and Faculty of Fishery and Marine Science - University of Pattimura (Indonesia)
4. Conclusion

The classification of flyingfish changed quite dramatically after Parin [6]. Some species in the genus of *Cypselurus* were divided into the genus of *Cheilopogon* and *Hirundichthys*. In addition, several species have also been changed in their scientific names due to misidentifications in several previous studies. Limited availability of information on specimen collection of flyingfish from Indonesia waters has slowed efforts to account for the total number of 14 flyingfish species already recorded in Indonesia, although there have been several contributions to the literature on this topic.

Knowing the diversity and distribution of flyingfish in Indonesia is very important for the conservation and management of this taxon. So far, flyingfish’s roe or eggs are in high demand as a fishery commodity for domestic and international markets. Thus, protection from overexploited of the flyingfish is a serious issue to be addressed at the national and local levels. By understanding the diversity and distribution of flyingfish, we could suggest significant areas to be managed for sustainable fishery purposes.

We clearly identify Makassar Strait, Flores Sea and Ambon waters as (potential) hotspots of flyingfish diversity in Indonesia. Future studies on the flyingfish fishery should be concerned in these areas. Although the south Sulawesi region contributed almost 30% of flyingfish catch in Indonesia, production has dropped significantly over the last 30 years [6],[18]. The abundance of flyingfish in the region could be due to enhanced nutrients periodically following the upwelling event during the southeast monsoon [19]. Therefore, Makassar Strait and Flores Sea need more attention to be protected related to flyingfish diversity and fishery.

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