INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE
ISSN: 2067-533X Volume 16, Issue 1, 2025: 239-252 www. ijcs. ro
DOI: 10. 36868/IJCS.2025.01.16

SPECIES COMPOSITION AND SIZE STRUCTURE OF FLYING FISH AS A BASIS FOR CONSERVATION AND SUSTAINABLE MANAGEMENT IN THE WATERS OF WEST SULAWESI PROVINCE, INDONESIA

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Abstract

This research aimed to analyze the species composition and size structure of flying fish caught with drift gillnets in the waters of West Sulawesi Province from July to December 2023. The sampling was carried out at the Fish Landing Port (PPI) in the Rangas Village, West Sulawesi Province and the method included the random selection of three flying fish-catching vessels using drift gillnets. Meanwhile, the samples were randomly selected and taken to the Fisheries Laboratory of the University of West Sulawesi for analysis. The species measurement was carried out using a ruler with a precision of 1 mm. The results showed that the captured species were Hirundichthys oxycephalus, Cheilopogon abei, Cheilopogon spilopterus and Cheilopogon nigricans and the total number of samples was 820,232 individuals. The highest composition was observed in Hirundichthys oxycephalus, Cheilopogon abei, Cheilopogon spilopterus and Cheilopogon nigricans with a total of 702,461 (85.64%), 59,252 (7.22%), 53,448 (6.52%) and 5,071 (1.39%) individuals, respectively. According to the size structure, the largest number of Hirundichthys oxycephalus, Cheilopogon abei, Cheilopogon. spilopterus and Cheilopogon nigricans were captured in the length range of 243-262, 230-242, 264-281 and 204-211mm. Based on the size of flying fish that obtained, it was still foud that the size wat not suitable for catching. The flying fish capture that immature gonads can cause regeneration to be interrupted because the reproductive process does not occur. Recommendations for management and conservation effors of flying fish is need especially to pay attention in catchable size.

Keywords*: Flying fish; Species composition; Majene waters; Size structure; West Sulawesi*

Introduction

Flying fish are classified as a group of small pelagic or which is also commonly called surface-dwelling species inhabiting marine waters within the epipelagic zone [1, 2]. These species also belong to the into the category of fast-swimming fish and with the ability to glideor fly above the water surface and show an attraction to light during the night [3, 4]. In their habitat, flying fish have a wide distribution beyond the boundaries of a region and even across countries, even though this fish is not a long-range type of fish hunter [5], Besides that the distribution in various waters is often too found with other fish species such as *Carangidae* (jackfish), *Scombridae* (tuna, mackerel and bonito), *Engraulidae* (anchovies) and *Clupeidae*

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(sardines) [1, 6]. This makes flying fish a crucial component in the marine food chain [7]. Several species of flying fish are found to lay eggs in coastal waters and also require large amounts of floating bottom substrate to lay eggs and reproduce in the open sea [8], which is supported by climatic factors [9], including sea surface temperature [10].

The distribution can be found in tropical and subtropical seas [11]. Which includes inshore to offshore zones [12]. This extensive distribution is due to schooling behavior, migration and the ability to quickly adapt to the environment for survival. Generally, flying fish have a short lifespan of around 2 years [13]. Furthermore, oceanographic factors play an important role in distribution and abundance [13]. Adaptation to the aquatic environment [14]. The ability to respond to pressure including ocean currents and water depth [15] and diverse water conditions [16]. Some regions with significant potential for flying fish include is Seram Sea near Fak-Fak, Flores Sea and waters of the Makassar Strait [17].

Flying fish are among the economically important species, acting as the primary catch for fishermen in several regions [17]. In West Sulawesi, these species hold significant value because apart from the fish for local consumption needs of the community the eggs serve as an export commodity. The resource bears considerable socio-economic which importance, serving as an income for fishermen, a protein source and generating employment in the collection of eggs, fish catching by, drying and smoking fish businesses [6].

Majene waters are included in Makassar Strait with own the potential for very abundant marine resources including resource flying fish and the number of species in the Majene waters area that has been reported reported varies. According to [18], four types were found, namely *Cheilopogon spilopterus, Cheilopogon abeia, Cypselurus poecilopterus* and *Hirundichthys oxycephalus*. *M. Nur et al.* [19] reported eight types of the species, namely *Cheilopogon abei, Cheilopogon cyanopterus, Cheilopogon intermedius, Cheilopogon nigricans, Cheilopogon spilopterus, Hirundichthys oxycephalus* and *Parexocoetus mento*. The research was conducted in Mosso Village, Majene Regency, which is a landing area in West Sulawesi Province.

The center for capture is centralized only in the region in the Majene Regency. Specifically in the region, the capture center is divided flying fish into two areas, namely Mosso and Rangas Villages. Mosso Village is predominantly inhabited by traditional fishermen with specifications (vessels used under 1 Gross Tonnage or GT), spending that is one day at sea, while Rangas Village is dominated by fishermen with fishing vessels of 5 GT capacity, spending up to one week at sea. The types of flying fish caught by fishermen in Rangas Village has not been reported.

Continuous awareness of the presence, types and population of flying fish in a particular water area is crucial. The diversity of species can decline over time when not regularly monitored and well-managed. The decline or extinction of the species may also occur, specifically without proper conservation efforts. Therefore, this research aims to analyze the species composition and size structure of flying fish caught using drift gillnets in the waters of West Sulawesi Province. The benefits include obtaining data as a scientific information source regarding the composition of species and size structure. This information is used as a foundational dataset in conservation and sustainable management efforts of flying fish resources in West Sulawesi Province.

Materials and Methods

Time and place

This research was conducted from July to December 2023 and sampling flying fish was carried out at Fish Landing Port (PPI) in Rangas Village, Banggae District, Majene Regency, West Sulawesi Province. The coordinates for the sampling flying fish point were (3°34'10.2"S 118°56'07.7" E) and random sampling was performed on vessels using drifting gill nets. A total of 3 vessels were sampled and flying fish were randomly selected, with one box of fish taken

from each vessel. Subsequently, the fish were analyzed at the Fisheries Laboratory of the University of West Sulawesi and the research location is shown in figure 1.

Fig. 1. Sampling location in Rangas Village, Majene Regency, West Sulawesi Province

Research procedure

The sampling method included the random selection of vessels using drifting gill nets for catching flying fish. A total of three vessels were sampled. The flying fish-catching vessels had specifications of 5 Gross Tonnage (GT) with length and width of 12 and 2 meters, respectively. The specifications of the drifting gill net used were length, width and mesh size of 50 meters, 1.50 meters and ¼ inches.

The capture of flying fish was conducted in Makassar Strait in areas presumed to be the habitat. This determination is based on characteristics of the location, distance, patterns of current flow and the appearance on the surface. The operation of capturing flying fish takes place while fishermen are at sea, lasting for 5-7 days. The deployment of drifting gill nets occurs after reaching the fishing ground. Subsequently, the captured fish are released from the nets and placed in a holding pen (hold) at the PPI in Rangas Village.

Fish samples were randomly taken, with one box per vessel selected as an example. Furthermore, the samples were transported to the Fisheries Laboratory, the Technical Implementation Unit (UPT) of the Integrated Laboratory and identified using a guidebook by [20-23]. The laboratory procedure for measuring the sample fish included placing on a slide. The total length of the samples was then measured using a ruler with a precision of 1.0mm from the tip of the snout to the rear end of the tail. Data analysis to determine the composition used the formula from Odum (1996):

$$P = \frac{ni}{N} x100\% \quad (1)$$

Description: P = Species composition; ni = Number of individuals of each type; N = Number of individuals of all species

The frequency distribution of lengths was obtained by determining class intervals, class mean values and frequencies within each length group. Subsequently, the length frequency distribution was plotted on a graph using MS Excel.

Results And Discussion

Diversity of Flying Fish Types

The flying fish found were four types consisting of one family and two genera. The complete diversity of the types reported can be seen in table 1 and figure 2.

Table 1. A diversity of fish species landed at the Rangas Village PPI, Majene

No	Genus	Species	Local name
1	Hirundicthys	*Hirundichthys oxycephalus*	*Tuing-tuing*
2	Cheilopogon	*Cheilopogon spilopterus*	*Ponggol-ponggol*
3	Cheilopogon	*Cheilopogon abei*	*Riripani*
4	Cheilopogon	*Cheilopogon nigricans*	*Ponggol-ponggol*

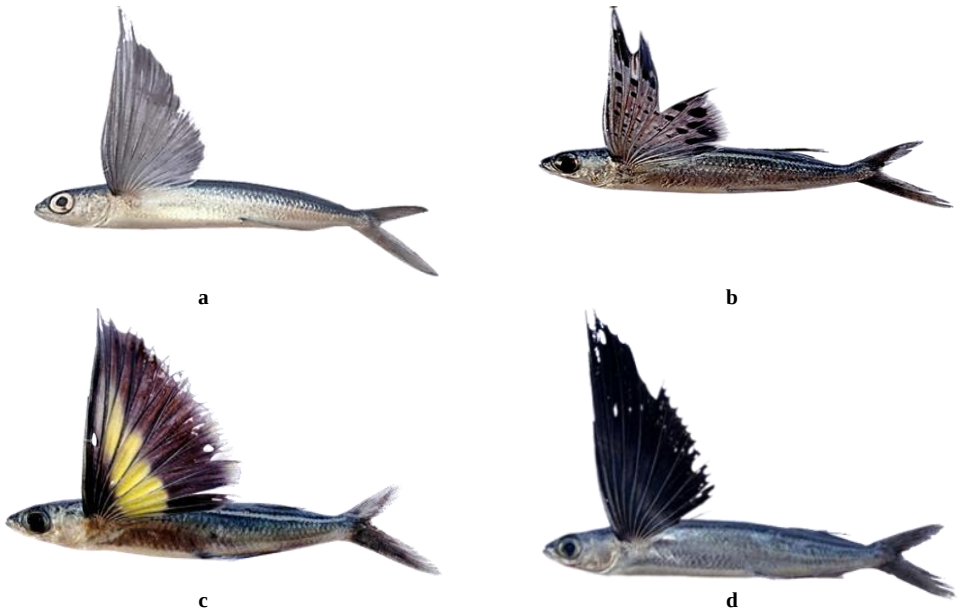

Fig. 2. Types of flying fish landed at the Rangas Village PPI, West Sulawesi Waters. Description: a *(Hirundichthys oxycephalus)*, b *(Cheilopogon spilopterus)*, c (*Cheilopogon abei)*, d *(Cheilopogon nigricans)*

Based on figure 2 and Table 1, there are four species of flying fish belonging to two genera, namely the Genus *Hirundichthys* and *Cheilopogon*. The difference between *Hirundichthys* and *Cheilopogon* is in the characteristics of the jaws. In the genus *Cheilopogon*, the upper and lower jaws are of the same length and the young individuals possess paired barbels. In contrast, genus *Hirundichthys* has a slightly longer lower jaw than the upper part. In *Hirundichthys*, the anal fin is positioned in front or not more than two fingers from the dorsal fin. The number of dorsal fin rays is slightly or equal to the anal and young individuals lack barbels [18, 19].

Hirundichthys oxycephalus is the only species found in genus *Hirundichthys*. This species has distinctive anal and dorsal fins with a small number of rays. Furthermore, it is distributed across the West Indo-Pacific region, from the Arabian Sea to southern Japan, New Guinea, New South Wales and Australia [24]. The fish is frequently caught and is a key component of the population in the waters of Majene [19]. Reproductive aspects include spawning from February to October, occurring 3-4 times during the season. Mature individuals show spawning behavior by attaching eggs to substrates, primarily feeding on zooplankton,

specifically copepods. After spawning, the life cycle is continued offshore [3]. Flying fish eggs of high economic value are produced by the *Hirundichthys oxycephalus* species, known as native torani or smooth eggs [2]. Research conducted by *A.B. Sambah et al.* [25] in West Papua's waters reported that the flying fish egg-laying season occurred from May to September, with peak spawning.

Cheilopogon has distinctive features that differentiate the species from other flying fish. The name comes from Greek, where cheilos means lips and pogon means bearded [24]. *Cheilopogon abei* is characterized by large and yellow pectoral fins, earning the name yellow-winged flying fish [26]. This species has large yellow pectoral fins that cross visibly, black or gray spots on the dorsal fins and gray-colored tail fins. Meanwhile, the dorsal, anal and vertebral fins have 13-14, 9-10 and 41-43 rays [24, 27]. Researching *Cheilopogon abei* in the waters of Eastern Seram Strait, Maluku, found that the first gonad maturation of male and female fish occurred at sizes of 210.5 mm and 214.1 mm, with spawning peaks in June and August.

Cheilopogon nigricans (Bennett, 1840) also belongs to the genus *Cheilopogon*. The species has a dark blue upper body and a whitish lower body, pale black pectoral fins with a central yellowish line narrowing towards the front edge and black spots on the pelvic fins [19]. *Cheilopogon nigricans* can reach a maximum size of 25cm, with 0 dorsal and Hard anal fin rays, as well as 13-15 and 8-11 Weak dorsal and anal fin rays, respectively [24]. According [24], the distribution covers the West Indo-Pacific, Mascarenes, Aldabra, Natal, South Africa, Japan, Caroline Islands, Solomon Islands and Brazil. Furthermore, *Cheilopogon spilopterus* (Valenciennes, 1846) belongs to genus *Cheilopogon*. The species reach a maximum size of 25 cm, with the first gonad maturation (Lm) at 28.5 cm, ranging from 28-29.2cm. The distribution extends beyond the Indo-Pacific to the East Indian Ocean and the Western Pacific, from the Andaman Sea to Samoa. The spawning season is between May and September, with a peak from June to August [26].

The number of species is consistent with the report of *Indrayani et al.* [17], who found *Cheilopogon spilopterus, Cheilopogon abeia, Cypselurus poecilopterus* and *Hirundichthys oxycephalus* in the waters of Majene. Meanwhile, *M. Nur et al.* [19] found eight species, including *Cheilopogon abei, Cheilopogon cyanopterus, Cheilopogon intermedius, Cheilopogon nigricans, Cheilopogon spilopterus, Cypselurus poecilopterus, Hirundichthys oxycephalus* and *Parexocoetus mento*. The variation in the number of captured species is due to differences in locations and timing. *M. Nur et al.* [6] research was conducted in Mosso Village, dominated by traditional fishermen, with fishing grounds less than 5 miles and one-day fishing trips. In contrast, sampling was conducted in Rangas Village, a community predominantly inhabited by fishermen operating vessels with a capacity of 5GT. These fishermen engage in fishing activities at locations situated beyond 5 nautical miles and the fishing trips extend up to one week. Additionally, research by *M. Nur et al.* [6] spanned one year and lasted for six months. In the waters of Malacca, *M.W. Nahak et al.* [28] found six different species, including *Cypselurus callopterus, Cypselurus spilonopterus, Cheilopogon arcticeps, Cheilopogon doederleinii* and *Cheilopogon abei.* According to *M. Mirnawati et al.* [29], flying fish resources are multispecies in Indonesian waters and several species can be caught in one fishing trip. The variability in distribution patterns is dependent on the specific environmental conditions, influencing divergent fishing areas among different regions.

The composition of species is presented in figure 3, where the highest is from *Hirundichthys oxycephalus* at 85.64%, followed by *Cheilopogon abei* and *Cheilopogon spilopterus* at 7.22% and 6.52%, while the lowest is *Cheilopogon nigricans* at 1.39%. *Hirundichthys oxycephalus* is the most abundant and captured species in the waters of Rangas Majene. The species is the primary target for fishermen, with high abundance and distribution

in Makassar Strait waters. Furthermore, flying fish is a highly economical fish traded in fresh and dried form. The eggs are exported including countries such as China, Korea, Russia and Japan [30] and the composition of the species caught is presented in figure 3.

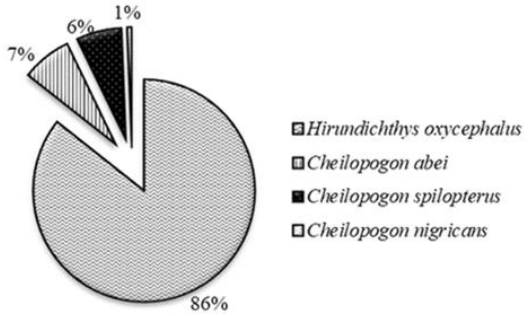

Figure 3. Composition of flying fish species caught landed at the Rangas Village PPI, West Sulawesi Waters

The composition of flying fish species captured based on the sampling time can be observed in figure 3. In July, the highest and lowest composition of species was found in *Hirundichthys oxycephalus* and *Cheilopogon nigricans* at 80% and 3%. In August, the highest and lowest composition of species was in *Hirundichthys oxycephalus* and *Cheilopogon nigricans* at 94% and 2%. In September, the highest and lowest composition was in *Hirundichthys oxycephalus* and *Cheilopogon spilopterus* at 82% and 4%. In October, the highest and lowest composition was in *Hirundichthys oxycephalus* and *Cheilopogon spilopterus* at 76% and 7%. In November, the highest and lowest composition was found in *Hirundichthys oxycephalus* and *Cheilopogon spilopterus* at 66% and 5%. In December, the highest and lowest composition was also found in *Hirundichthys oxycephalus* and *Cheilopogon spilopterus* at 78% and 3%, respectively.

There is variation in the composition of the captured flying fish species. According to *A.H. Arthington et al.* [31], the differences in the number of species and catch are influenced by the preferences of the species for the aquatic environment as a habitat for life and growth. The abundance is influenced by oceanographic conditions, such as sea surface temperature, chlorophyll, currents and waves [32]. Additionally, the abundance and distribution are affected by upwelling activities in the waters. According to *S. Lie et al.* [33], the occurrence of fish in a particular area is correlated with the presence of upwelling, characterized by the upward movement of cold. This proves advantageous for the proliferation of phytoplankton, rendering upwelling areas exceptionally fertile and productive.

The dominant species found in the waters of Majene is *Hirundichthys oxycephalus*, with the largest population. Therefore, the distribution is widespread due to favorable environmental factors and the species prefer deep waters [35]. According to *C.W. Chang et al.* [34], *Hirundichthys oxycephalus* has a wide distribution in the waters of West Indo-Pacific, Arabian Sea, Sea of Japan, New Guinea, New South Wales and Australia, as seen in figure 4.

The composition of fish species varies significantly each month and is subject to fluctuations. According to *M. Mirnawati et al.* [29], fish resources in Indonesian waters are multi-species and depend on the environment, leading to different patterns of distribution and abundance, as well as the number caught in each fishing season.

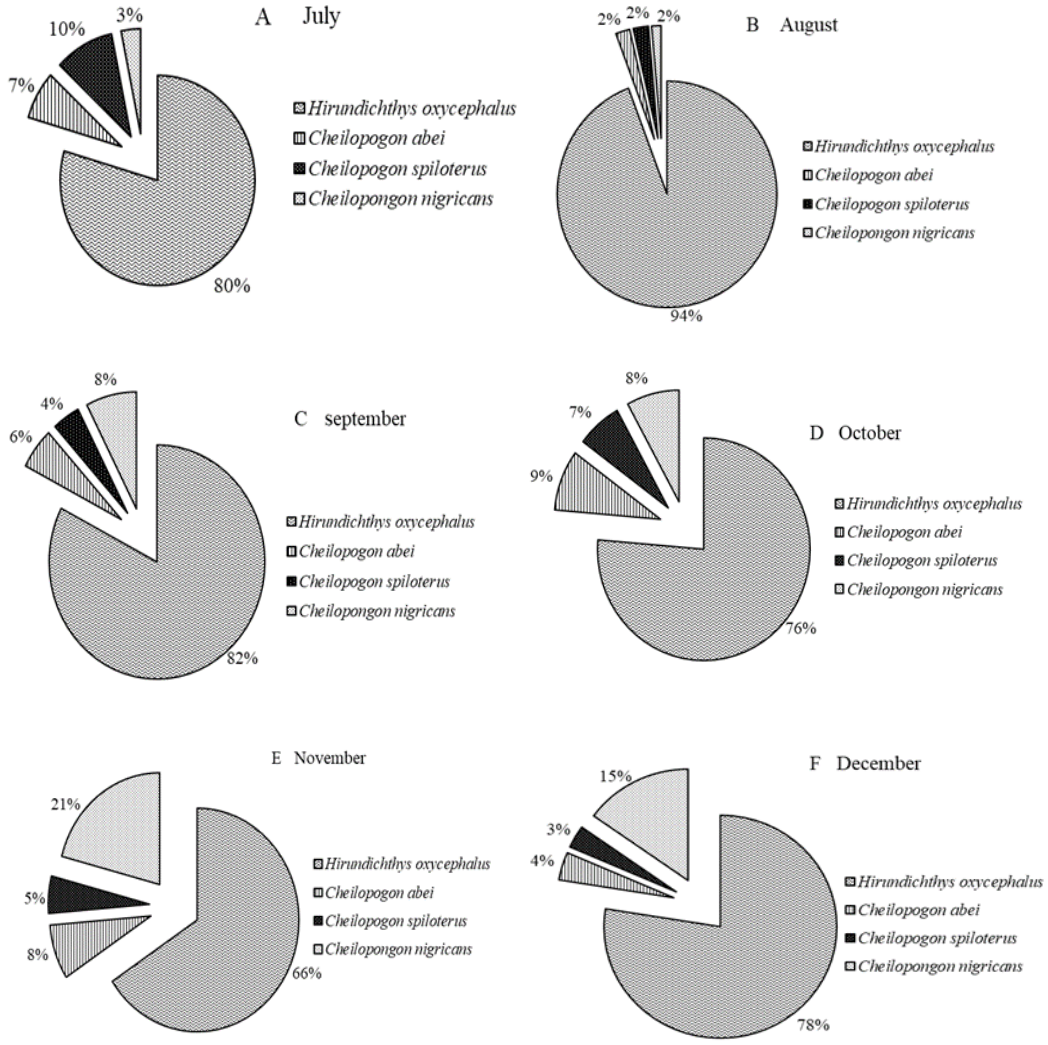

Fig. 4. Composition of the catch of fish landed at the PPI of Rangas Village, West Sulawesi Waters, based on the month of sampling

The variation results are influenced by factors such as the fishing season, abundance and availability of food, as well as seasonal weather changes such as currents and sea waves. These conditions cause changes and shifts in fishing times [28]. Each water region experiences different fishing times, resulting in varying fleet sizes engaging in operations. According to *H. Glon et al.* [36], the diversity of species within a specific water body is influenced by the capacity to thrive in the environmental conditions unique to the habitat. The duration of fishing operations produces different catch results since flying fish abundance can vary during certain seasons. Oceanographic conditions are a primary factor causing differences in flying fish production during specific seasons. The differences in the composition of flying fish are also attributed to water conditions and fishing seasons [28].

Size Structure of Flying Fish

The flying fish successfully collected amounted to 820,232 individuals. Observations showed that the fish obtained possessed varying size structures or fluctuations each month, as reported in figure 5.

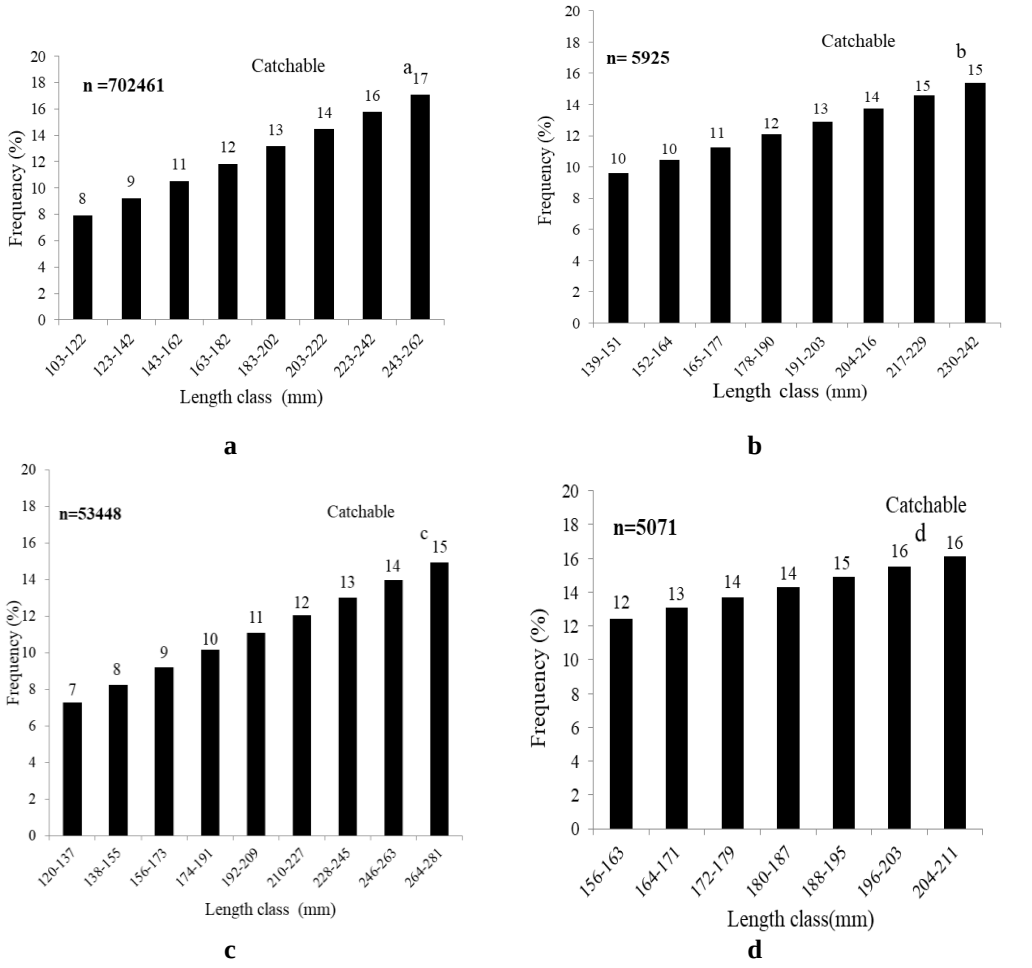

Fig. 5. Size distribution of flying fish landed at the Rangas Village Fish Landing Harbor, West Sulawesi Waters. Information a: *Hirundicthys oxycephalus*, b: *Cheilopogon abei*, c: *Cheilopogon spilopterus*, d: *Cheilopogon nigricans*

Based on the measurements of length frequency distribution, *Cheilopogon abei* has the largest size among all the species. *Cheilopogon abei* was observed in the size range of 139-242mm, with an average captured size of 194mm. The largest and smallest size was in the length class range of 230-242 and 139-151mm, accounting for 15.39% and 9.61%, respectively. Furthermore, *Hirundichthys oxycephalus* had captured lengths ranging from 103-262mm, with an average of 183mm. The largest and smallest size was in the length class range of 243-262 and 103-122mm, representing 17.06% and 7.94%, respectively. For *Cheilopogon spiloterus*, the captured lengths ranged from 120-281mm, with an average of 190mm. The largest and smallest size was in the length class range of 264-281 and 120-137mm, accounting for 14.94% and 7.28%, respectively. Finally, *Cheilopogon nigricans* had captured lengths ranging from 156-211

mm, with an average of 181mm. The largest and smallest size was in the length class range of 204-211 and 156-163mm, representing 16.12% and 12.45%, respectively.

Based on figure 4, show that the greater the length class, the more fish caught. *Hirundichthys oxycephalus, Cheilopogon spilopterus, Cheilopogon abei* and *Cheilopogon nigricans* were caught in the 243-246, 230-242, 264-281 and 204-211mm length class. Compared to the size of the first maturity of several species, the category of fish catch was classified as mature. Male and female *Hirundichthys oxycephalus* in Majene waters mature at size of 19.94-20.60 and 20.15-20.85mm or an average of 20.27 and 20.50mm, respectively [37]. *Cheilopogon abei* found in the waters of the Geser Seram Timur Strait in Maluku, attains sexual maturity for male and female individuals at lengths of 210.5 mm and 214.1 mm, respectively [11].

The size of flying fish caught using gill nets in Rangas Majene waters varies greatly in size. The dimensions of fish caught by fishermen in the waters of Rangas Majene show annual variations in size and length. Based on structure of *Hirundichthys oxycephalus* found in Rangas Majene waters, the size is relatively smaller than those in Seram Sea. According to *Indrayani et al.* [18], the maximum length of *Cheilopogon spilopterus, Cheilopogon abei* and *Hirundichthys oxycephalus* is 250, 220 and 180mm, respectively. *F. Tuapetel et al.* [26] mentioned that the flying fish of *Hirundicthys oxycephalus* and *Cheilopogon abei* species in Seram Sea and waters of the Geser Seram Timur Strait have a total length range of 187.1 - 281.1 and 182.6 - 243.3mm, respectively. The differences in the size structure can be caused by the influence of differences in location and environmental conditions of the waters. Influential environmental factors include the availability of food sources, water temperature and competitors. Furthermore, the relatively small size of flying fish can also show that a body of water is experiencing overfishing. According to *C.L.A. Gough et al.* [38], catches showing a tendency towards smaller sizes and a diminution in average fish size are indicative of overfishing. Even though the largest size class is in the adult category, there are many sizes below the first-time mature gonads of fish caught. This is due to the use of the fishing gear used various mesh sizes by fishermen to catch flying fish. The sizes of juvenile and adult flying fish can be seen in figure 6.

Based on Figure 5 and 6 spesies *Hirundichthys oxycephalus*, the catchable size of flying fish starts from 203-262 with the total number 726 and the percentage 47%, the uncatchable size starts from 103-202 with the total number 810 and the percentage 53%. The catchable size of species *Cheilopogon spilopterus* starts from 204-242 with the total number 687 and percentage 44%, berjumlah 687 ekor sebesar 44%, uncatchable size starts from 139-203 with the total number 885 and the percentage 56%. Then there are 789 species *Cheilopogon spilopterus* that catchable size from the length class 228-281, amounting to 42, the flying fish that are uncatchable size from the length class 120-227 with the total number 1092, amounting to 58% and the last is from spesies *Cheilopogon nigricans*, the catchable size from the length class 196-211 amounted 414 fish with percentage 32%, the the fish uncatchable size from the length class 156-195 with the total of fish 895 amounting to 68%.

In general, the average that catch in every species was the uncatchable size or not yet in length at first maturity (LM), it indicates that the flying fish was still in juvenile phase. The length at first maturity (LM) in other study can be seen in Table 2.

The catching of flying fish in immature gonads could feared that can cause interrupted regeneration because the reproduction was unoccur. According to some researchers, reproduction and stock recruitment of fish in their habitat that can occur if there is a shoal of fish spawning in the waters, otherwise if there is overfishing activities can caused the decreasing of fish stock and extincting of fish resources [28]. Moreover, the act of capturing juvenile fish has the potential to impede the maturation of the species, exerting a broader impact

on the disrupted aquatic ecosystem [41]. The utilization of a potential fish resource must be based on the principle of sustainable management which pays attention to its sustainability and also can be used in the future [37, 42, 43, 44].

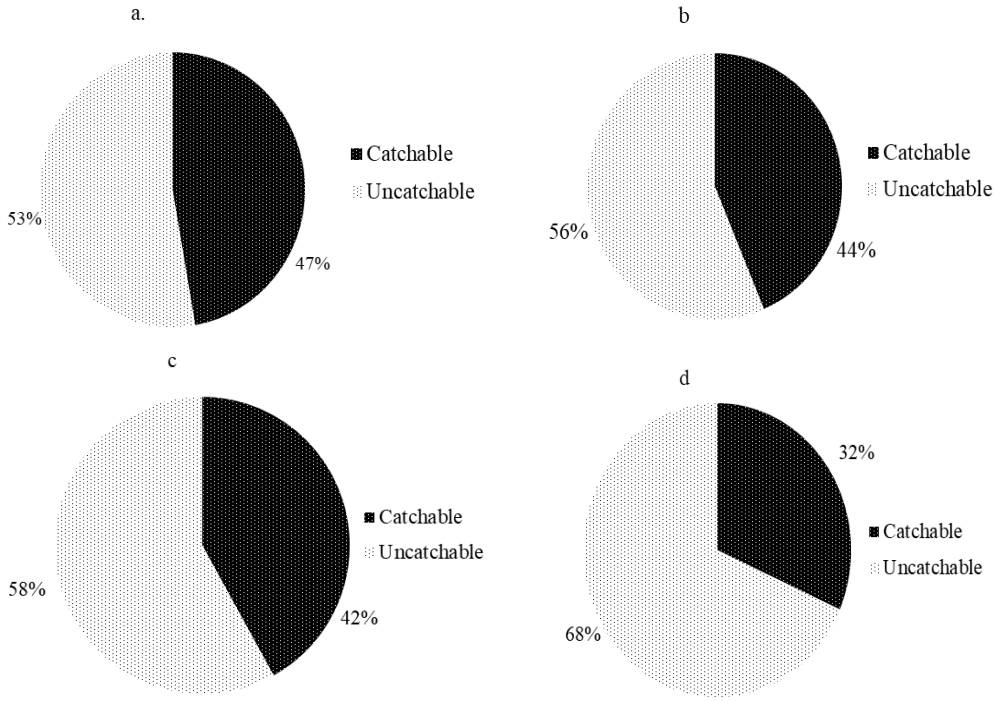

Fig. 6. Size of flying fish suitable for catching and not suitable for catching caught in Majene Waters, Description: a (*Hirundichthys oxycephalus*), b (*Cheilopogon abei*), c (*Cheilopogon spilopterus*), d (*Cheilopogon nigricans*)

Table 2. The length at first maturiry of some flying fish species

Species	Lm (cm)	Location	Literature
Hirundichthys oxycephalus	20,15-20,85	Makassar Strait	M. Nur *et al*. (2023)
Cheilopogon abei	21,41	Geser Seram Timur Strait	F. Tuapetel, (2021)
Cheilopogon spilopterus	28,48	Tual Waters	B.M. Rehatta *et al.* (2021)
Cheilopogon nigricans	24,3	Makassar Strait	M. Palo *et al.* (2017)

As a conservation effort, it is necessary to make regulation about fishing gear especially the mesh size of fishing gear that suitable with the mature size of flying fish. Based on the Ministry of Maritime Affairs and Fisheries regulation No. 18 (2021) about the placement of fishing gear and navigation aids in the State Fisheries Management Area of Republic Indonesia (WPPNRI), the mesh size of a drtift gill net is ≥1,5. According to the size were obtained that there is still found uncatchable size. Recommendations for management and conservation effors of flying fish are needed especially to pay attention in catchable size.

Conclusions

There were four types of flying fish found in the waters of West Sulawesi belonging to one family and two genera. The species caught were *Hirundichthys oxycephalus*, *Cheilopogon abei*, *Cheilopogon spilopterus* and *Cheilopogon nigricans*. Furthermore, the composition showed that *Hirundichthys oxycephalus* was the most common species obtained. The length

structure of flying fish caught was highest in *Hirundichthys oxycephalus, Cheilopogon abei*, *Cheilopogon spiloterus* and *Cheilopogon nigricans* in the length class interval of 243-262, 230-242, 264-281 and 204-211, According to the size were obtained that there is still found uncatchable size. Recommendations for management and conservation effors of flying fish is need especially to pay attention in catchable size.

Acknowledgments

The authors are grateful to the Ministry of Education, Culture, Research and Technology (Kemendikbud Ristek) and the Indonesia Education Fund Management Agency (LPDP) for funding the research through the Indonesian Education Scholarship (BPI) 2022 program. The authors are also grateful to the fishermen of Rangas Village and the research assistants who helped with the implementation of the research.

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Received: July 30, 2024
Accepted: February 08, 2025