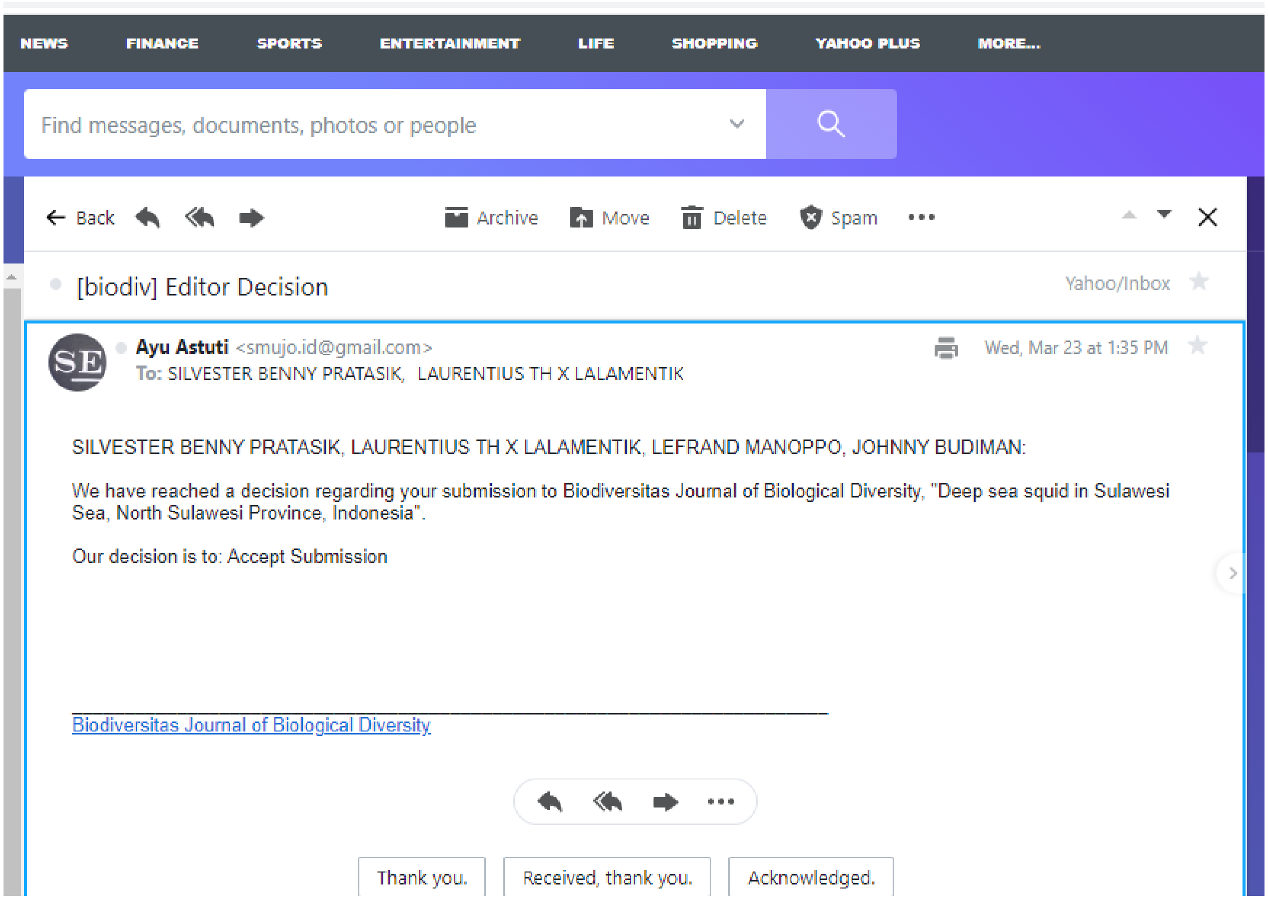

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Deep sea squid in Sulawesi Sea, North Sulawesi Province, Indonesia

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Abstract. *Pratasik SB, Lalamentik LTHX, Manoppo L, Budiman J. 2022. Deep sea squid in Sulawesi Sea, North Sulawesi Province, Indonesia. Biodiversitas 23: 1774-1779.* This study aimed to identify one of the deep sea squids caught in artisanal fisheries by traditional fishermen in Sulawesi Sea, North Sulawesi Province, Indonesia. Samples were collected using the vertical hand line of traditional fishermen. The specimen was identified using Cytochrome c oxidase subunit 1 (CO1). For morphometric characteristics, all body parts were measured, and each part was compared with mantle size. Results showed that the specimen was identified as purpleback flying squid *Sthenoteuthis oualaniensis* and had 99.35% similarity to *S. oualaniensis* (CO1) from China (NCBI - MN101944) with sufficient genetic diversity. Based on the body size, species recorded in the present study belong to the dwarf form, the smallest form of *S. oualaniensis* groups. The species has the following morphometric characteristics: Head length is 0.28 of mantle length, tentacle length is 1.158 of mantle length, and fin area is 0.5 of mantle length. The fourth arm is the shortest and the second arm is the longest. *S. oualaniensis* recorded in the present study belonged to dwarf form living in equatorial waters. This finding may contribute to the list of marine resources of fisheries in Indonesian waters.

Keywords: CO1 gene, hand line, morphometric, species identification, traditional fishermen

INTRODUCTION

Squids are cephalopods that live in the marine environment. This group is an ecological opportunist adapted to exploit favorable environmental conditions (Rodhouse 2013). It is a favorite food type due to its high nutritional content with high-quality protein for human consumption and nearly all body parts are edible (Triharyuni and Puspasari 2012). Cephalopod production from fishing has continued to grow (Doubleday et al. 2016), with total commercial annual catches varying between 3.5 and 4.9 million tonnes in 2008-2017 (FAO 2019) and averagely supports about 15 and 20% of marine fishery landings and landed values, respectively (FAO 2019). Demand for this commodity has increased in both fresh and processed forms (Baskoro and Mustaruddin 2019). High market demand for squids as an export commodity of Indonesia has made squids become one of the major catches besides fish and lobster (Wulandari 2018). This trend will urge fishermen to conduct intensive fishing while the squid production is still dependent upon the stock in the wild (Tresnati et al. 2012). Squids also grow fast with high feeding rates and conversion efficiencies (Arkhipkin et al. 2015). These biological features make them be ecological opportunists in which they can quickly exploit favorable environmental conditions, but their abundance responds rapidly to poor conditions so that recruitment and abundance may be highly variable on annual time scales (Rodhouse et al. 2014). Therefore, high dependence on wild stock can lead to stock overfishing.

In Indonesia, squid production is far below the world market demand despite its increasing squid production (Triharyuni and Puspasari 2012; Hulalata et al. 2013). This condition is caused by an uneven distribution of squid fisheries across the country. Only several regions do the squid fisheries, and the others do on a very low scale for local consumption.

Information on this group is, so far, mostly related to commercial promotion for fisheries production. This group has been introduced together with other cephalopod groups as an export commodity. It is evident that there is a major artisanal and small-scale inshore element to the world squid fishing fleet and that large volumes of loliginid squids caught in tropical and subtropical regions have high species diversity. Thus, a taxonomic study on this group in Indonesian waters is needed. The taxonomy of the squid fauna generally is poorly understood. Correct species identification is the basis of ecological studies (Veijalainen 2011).

There are 290 species of squids, and about 30-40 species have substantial commercial importance (Arkhipkin et al. 2015) belonging to the family Ommastrephidae, Loliginidae, Onychoteuthidae, and Gonatidae. Triharyuni and Puspasari (2012) have grouped family Lolinginidae from Indonesian waters into several genera, *Afrololigo, Alloteuthis, Doryteuthis, Heterololigo, Loliolus, Lollinguncula, Pickfordiateuthis, Sepioteuthis*, and *Uroteuthis*, but there are much more species to be described. In Rembang waters, Central Java, four species were found, *Loligo chinensis, L. singhalensis, L. edulis*, and *L. duvauceli*, in which *L. duvauceli* is the most often caught species (Triharyuni and Puspasari 2012).

In North Sulawesi, Indonesia, there are no squid fisheries and the squid catches are bycatch of other fisheries, but squid production of different species is available every month. Squid catches are obtained at a certain moon period, especially during an early new moon, when the large squid schools come near the surface. The local fishermen catch them using small mesh-sized seine, lift net or using scoop net. A small group of fishermen along Manado Bay, North Sulawesi, Indonesia, have benefitted deep sea squid as an income source and food by relying on hand line fishing or jig fishing as practiced by international squid fisheries (Sundaram and Sawant 2014). Nevertheless, very few fishermen do squid fishing, the amount of catches is very low. This group has become a very important resource so that its sustainability needs to be maintained, and thus, basic information on this resource needs to be provided. This study is intended to identify the deep-sea squid caught by local fishermen of Manado Bay in Sulawesi waters. The findings may enrich the inventory of economically valuable squid species and develop squid fisheries in this area for future regional economic growth.

MATERIALS AND METHODS

Squid samples were obtained from fishermen's catch in the Sulawesi Sea, North Sulawesi, Indonesia, about 5 miles from the shore of Manado Bay. The fishing operations were carried out at the geographic position covered by the area formed in the east border (1º30'45"N and 124º42'49"E to 1º32'47"N and 124º42'59"E) and the west one (1º29'30"N and 124º40'48"E to 1º33'45"N and 124º40'50"E) (Figure 1).

Ten fishing trips were done in May to June 2020 using a traditional outboard-motored outrigger boat and fishing activities relied on hand-line facilitated with flashlight artificial bait that was lowered down to 20-25 m depth to get the squid to bite.

A total of 600 squid samples were collected and measured in order to describe the species physical characteristics through comparison of mantle size and other morphometric characteristics, such as head length, tentacle length, arm length, fin length, and fin width. For DNA identification, a piece of the squid arm was taken and preserved in 95% ethanol solution before extraction to wash the sample from saltwater and draw water from the cell. All samples were preserved in 95% ethanol and stored at room temperature before DNA extraction.

Extraction, PCR, and sequencing

Genome DNA extraction of all samples used Innu PREP DNA Micro Kit (Analytic Jena). The CO1 gene was amplified applying universal primer pairs LCO1490: 5'-ggtcaacaaatcataaagatattgg-3' and HCO2198: 5'taaacttcagggtgaccaaaaaatca-3' (Folmer et al. 1994). Polymerase chain reaction (PCR)was carried out in 35 cycles at 95ºC (30 sec), 50ºC (30 sec), 72ºC (50 sec). The PCR product was visualized in 1% (b/v) agarose gel electrophoresis. Bi-directional sequencing was done by First Base CO (Malaysia) using Big Dye© terminator chemistry (PerkinElmer).

Data analysis

The specimen chromatogram was edited using Mega X v10.1 software (Kumar et al. 2018). The sequences were then compared with Gen Bank data using BLAST (BasicLocal Alignment Search Tools) method (Altschul et al. 1997) and BOLD Systems (Ratnasingham and Hebert 2007). In this study, the sample sequence was compared with that of 7 specimens from South China Sea, one from Mid-Pacific, and one from Eastern Pacific. Besides, another specimen of the same genus *S. pteropus* from Spain, was also used as an outgroup in order to strengthen the comparison. The phylogenetic tree was built using Neighbor-Joining Method of MEGA X and the heterogeneity index was also estimated (Kumar et al. 2018).

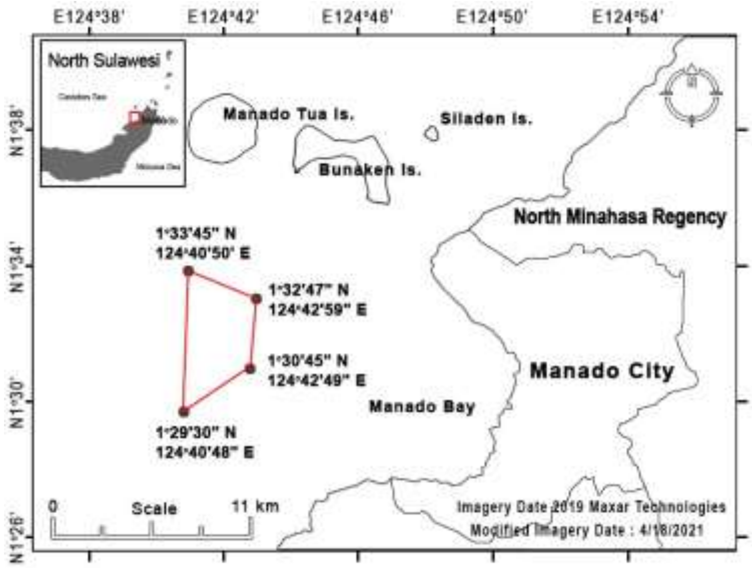

Figure 1. Sampling location. Red lines point out the sampling area

RESULTS AND DISCUSSION

DNA characteristics

Based on molecular identification using the Internal Transcribed Spacer (ITS) region, the DNA bands obtained were around 500-750bp, the success of PCR was detected by the presence of a single DNA band around 680 bp, the PCR results can be seen in Figure 2.

The sample was identified as purpleback flying squid *Sthenoteuthis oualaniensis*, as shown in the BLAST results in the Gen Bank of NCBI. This species, according to the WoRMs database, has synonymized names as *Loligo brevitentaculata* Quoy & Gaimard, 1832 (synonym), *L. oualaniensis* Lesson, 1830 (original combination), *L. vanikoriensis* Quoy & Gaimard, 1832 (synonym), and *Symplectoteuthis oualaniensis* (Lesson, 1830). This species belongs to class Cephalopod, subclass Coleoides, suborder Decapodiformes, order Oegopsida, superfamily Ommastrephidae, family Ommastrephidae, subfamily Ommastrephinae, and genus *Sthenoteuthis* (Jerep and Roper 2010). This finding is the first report on this species from the Sulawesi Sea. To confirm the species status, the sample sequence was then compared to 9 *Sthenoteuthis oualaniensis* specimens from the South China Sea, Eastern Pacific, and Central Pacific. The present study shows that *S. oualaniensis* specimen from the Sulawesi Sea has a similarity rate of 99.3% to NCBI record (acc. no. MN101944.1) from South China and 96.4-96.8% to 8 other NCBI records from the South China Sea, Eastern Pacific, and Mid Pacific (Table 1). Specimen of the same genus *Sthenoteuthis pteropus* from Spain used as outgroup also clearly indicates great difference from the specimen and supports the kinship status of the specimen on the study.

The difference is also demonstrated in specimen grouping (Figure 3) as well in which there are 3 different groups formed to indicate the kinship. Group 1 comprises 5 specimens from the South China Sea, one from Mid Pacific, and one from Eastern Pacific. Group 2 comprises specimen from the Sulawesi Sea and 1 NCBI China specimen indicating the species on the study has the closest similarity to one of the South China Sea specimens, while group 3 is an outgroup that is taken from different species of Spain specimen, *Sthenoteuthis pteropus*. These grouping reflects the kinship of compared *S. oualaniensis* specimens from different areas.

This evidence is supported by the closest kinship to the deep sea squid *S. oualaniensis* specimens from South China waters of NCBI record and they could originate from the same ancestor. Besides, this comparison also indicates that there is intraspecific genetic diversity in *S. oualaniensis* (Table 1 and Figure 3). Genetic diversity could result from population size, in which the larger the population size within species is, the higher genetic diversity will be. This condition is also supported by Hague and Routmant (2016). It could also be caused by different environmental conditions with localities that restrict the organism distribution due to its tolerance limit to the environment.

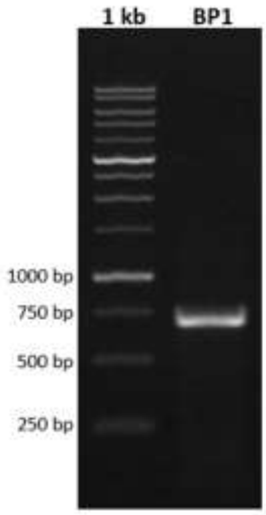

Figure 1. PCR product of the sample specimen

Table 1. Similarity rate of *Sthenoteuthis oualaniensis* from Sulawesi Sea and those from the Gen Bank DNA sequence database

Sequence	1	2	3	4	5	6	7	8	9	10
MN101944.1_ *S. oualaniensis* (South_China Sea)										
MW542205.1_ *S. oualaniensis* (South China Sea)	0.029									
EU660577.1_ *S. oualaniensis* (Eastern_Pacific)	0.029	0.000								
MF411106.1_ *S. oualaniensis* (South_China_Sea)	0.031	0.005	0.005							
MF411105.1_*S. oualaniensis* (South China Sea)	0.031	0.005	0.005	0.003						
MF411100.1_*S. oualaniensis* (South China Sea)	0.031	0.005	0.005	0.003	0.003					
MF411094.1_*S. oualaniensis* (South China Sea)	0.031	0.007	0.007	0.005	0.005	0.005				
MF411108.1_*S. oualaniensis* (South China Sea)	0.032	0.007	0.007	0.005	0.005	0.005	0.007			
DQ885836.1_*S. oualaniensis* (Mid Pacific)	0.029	0.003	0.003	0.002	0.002	0.002	0.003	0.003		
BP_*S. oualaniensis* (Indonesia- North_Sulawesi)	0.007	0.032	0.032	0.034	0.034	0.034	0.034	0.036	0.032	
MF980608.1_*Sthenoteuthis pteropus* (Spain)	0.119	0.114	0.114	0.116	0.116	0.112	0.116	0.114	0.114	0.116

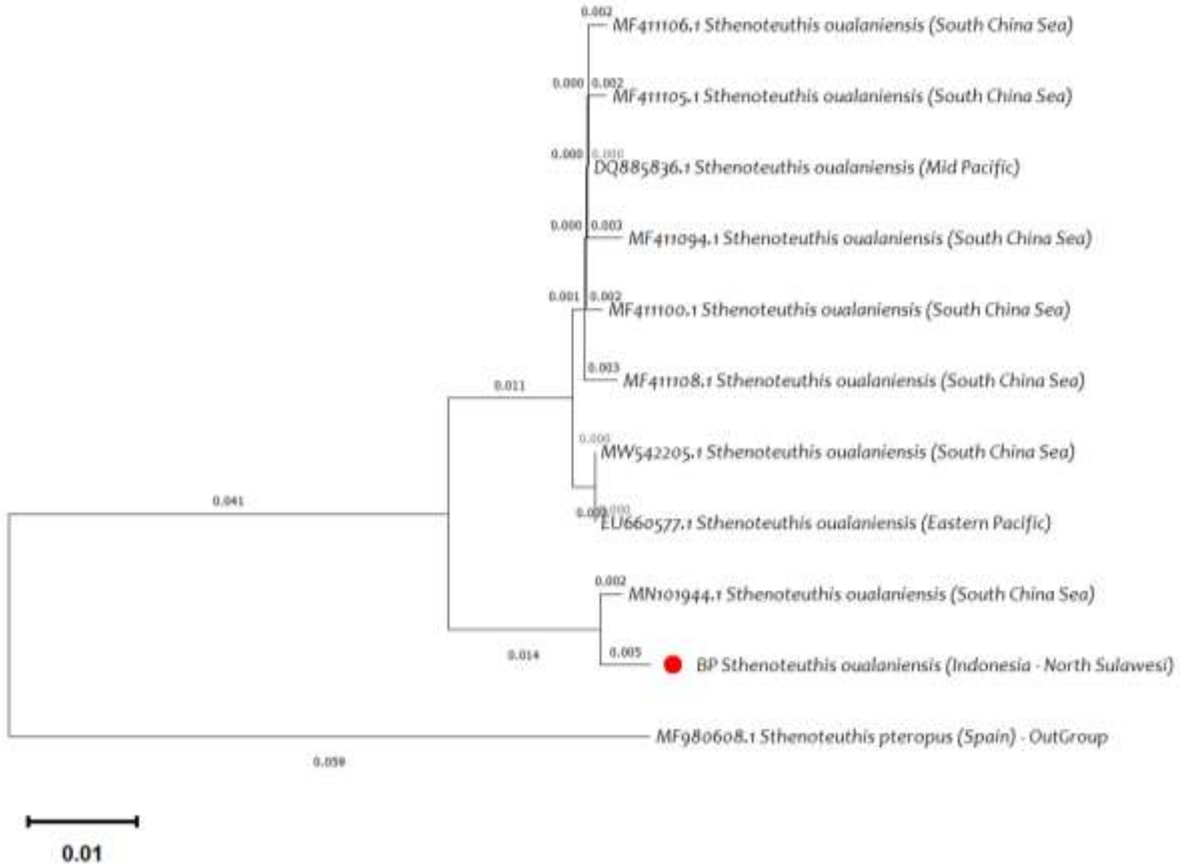

Figure 3. Phylogenetic tree of *Sthenoteuthis oualaniensis*

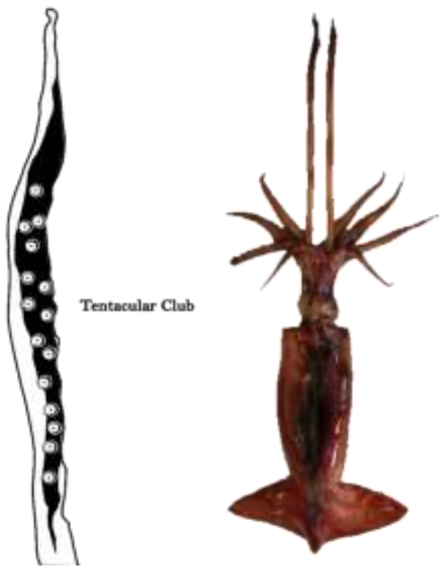

Figure 4. Tentacular club (*left*) and Squid *Sthenoteuthis oualaniensis*

Morphological description

Sthenoteuthis oualaniensis specimen from Sulawesi Sea has the following morphometric characteristics: Head length is 0.28 of mantle length (ML), tentacle length is 1.158 ML, fin width is 0.3 ML, and fin length is 0.4 ML. The fourth arm is the shortest and the second arm is the longest among the squid arms (Figure 4). These morphometric characteristics could become typical characteristics in *S. oualaniensis* from the Sulawesi Sea. Hence, the present study is in agreement with Staaf et al. (2010) and Xua et al. (2020), who found the existence of a morphologically distinct form that is highly genetically divergent in *S. oualaniensis* that separates the dwarf and medium-sized species and exhibits a distinct biogeographic break at equatorial waters of Eastern Pacific Oceans.

Sthenoteuthis oualaniensis is known as purpleback flying squid, a tropical Indo-Pacific species that occurs in the Pacific from southern Japan to southern Queensland and from just south of Baja California to northern Chile. *S. oualaniensis* belongs to family Ommastrephidae widely distributed in the tropical and subtropical areas of the Pacific Ocean and the Indian Ocean, and this species is important for resource exploitation in the South China Sea as one of the major target species of large-scale light falling-net fishing (Yu et al. 2019; Zhao et al. 2021). This species is known to do diurnal vertical migration between the surface at night to the deeper layer during the day, and thus, the species is caught by local fishermen of Manado Bay using the artificial flashlight bait near the surface water column. Fishing operations used a traditional outboard-motored outrigger boat and fishing activities relied on hand-line facilitated with flashlight artificial bait that was lowered down to 20-25 m depth to get the squid to bite.

Cephalopods are sensitive to water temperature (Li et al. 2020) that becomes one of the major environmental factors affecting squid activities, including aggregation, breeding, and emigration (Klemas 2013). Deep sea squids *S. oualaniensis* are distributed from 0-4500 M depth with a peak at 0-500 M depth, water temperature of 25-32ºC, and salinity of 34-35 PSU (Jerep and Roper 2010). These seawater temperature ranges cover that of Sulawesi Sea, which enables to support of the occurrence of this squid species based on 10 years of Sulawesi Sea water temperature data (Seawater temperature Sulawesi today Indonesia (seatemperature.info). Besides sea surface temperature (SST), sea surface height anomaly (SSHA) at -0.05-0.05 m and chlorophyll-a concentration higher than 0.18 µg/L are required to gain higher catch (Zhao et al. 2021).

For this, *S. oualaniensis* can move at high speeds through the water, easily manoeuver and quickly respond to their environmental changes. Under distress of external factors, such as predation, this species can reach a high speed and glide above the surface over ten meters**.** They also found that the cruising speed of an adult squid is between 3 to 10 km per hour, their burst speed achieves greater speeds of up 35 km per hour, and it can be important for sudden changes in movement and escape behavior. They can occur into shoals from 2 individuals to 800 individuals, and when geographical distributions overlap, they can exist with other members of similar-sized family Ommastrephidae schools, *Dosidicus gigas* and *Ommastrephes bartramii* that are distributed from the Indo-Pacific to Indian Ocean as well (Liu et al. 2016). Ommastrephidae squids are known as voracious and adaptable predators of a broad range of prey, including small crustaceans and fishes at early life stages and shift to micronekton, larger fishes, and cephalopods (including cannibalism) (Gong et al. 2020). These species are highly migratory undertake diel vertical migrations of several hundred meters and seasonal migrations between the shelf and open ocean (Stewart et al. 2013). Thus, they can work as important linkages between both neritic and oceanic food webs (Arkhipkin 2013; Alegre et al. 2014).

In North Sulawesi, this squid species fishing is done by artisanal fishermen using jigging with artificial flashing bait, and the fishing operation has been done in the Sulawesi Sea. In the present study, the squids *S. oualaniensis* caught in the Sulawesi Sea had a size range of 68 mm to 119 mm ML, with a mean mantle length of 89.833$\pm$0.9000 mm, reflecting that the squid catches are dominated by large individuals. According to the classification of Nesis (1993), this size range belongs to dwarf form with body size of 90-100 mm ML for mature males and 90-120 mm ML in mature females, and occurs in the equatorial waters and lacks of dorsal mantle photophore patch. The occurrence of *S. oualaniensis* in Sulawesi waters could result from the influence of environmental factors. Similar finding is also reported that changes in marine environments affect cephalopod fishery resources at different spatial and temporal scales (Zhang et al. 2012). Furthermore, the distribution of purpleback flying squid *S. oualaniensis* in this area could not be separated from the impact of the Kuroshio from the Pacific Northern Equatorial current toward the east coast of Luzon, Philippines that forms the southward-flowing Mindanao Current (Qiu and Lukas 1996) and transfers the upper ocean waters from the Pacific to the Indian Ocean through the Indonesian Seas (Taufiqurrahman et al. 2020). As the water mass enters the Indonesian Seas, the warm and relatively salty characteristics of the Pacific water tend to disappear due to strong vertical tidal mixing. The mixing is believed to affect the carbon, oxygen, and nutrient (nitrate, phosphates) concentrations in the eastern Indonesian Seas and subsequently in the Indian Ocean (Ayers et al. 2014). This event makes Indonesian marine waters be fertile to support the high occurrence of marine animals in the area. The Indonesian Throughflow is the only ocean connector pathway in the equator (Sprintall et al. 2014), and it has an important purpose in the transport of mass and heat from the Pacific into the Indian Ocean (Feng et al. 2018). The throughflow brings the eggs and larvae, along with the rich detritus of the sea that is swept up from the deep offshore basins. It is in agreement with Dell et al. (2011) that the biophysical environment plays an essential role in controlling the distribution and abundance of pelagic predators in the ocean. Cheng et al. (2018), who studied the sword tip squid *Uroteuthis edulis* found that complex oceanographic conditions might affect their population in the Southern East China Sea due to seasonal changes in the Kuroshio Current and Mainland China Coastal Current during the northeasterly monsoon and southwesterly monsoon seasons. This finding has reconfirmed the distribution of *S. oualaniensis* reported in previous studies as tropical deep sea squid.

The present study has provided information on the occurrence of one of the important economic squid resources in Indonesian waters, especially the Sulawesi Sea, that can be used for national economic development. As a center of biodiversity, we strongly believe that there are more squid species living in these waters that need to be described so that there are more taxonomic works that need to be done on species richness of squids in Sulawesi Sea waters as well for future development. Besides, other biological studies of the species need to be done as well in order to have a better understanding of this species that future management and conservation efforts could be well prepared.

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