BIODIVERSITAS
Volume 25, Number 4, April 2024
Pages: 1359-1367

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d250403

Species identification and population dynamics of cuttlefish *Sepia* spp. (Mollusca: Cephalopoda) landed at Brondong Fishing Port, Lamongan, East Java, Indonesia

DADUK SETYOHADI[1,♥], MUHAMMAD ARIF RAHMAN[1,2], LEDHYANE IKA HARLYAN[1,2], MIHROBI KHALWATU RIHMI[1]

[1]Program of Fisheries Resource Utilization, Faculty of Fisheries and Marine Science, Universitas Brawijaya. Jl. Veteran, Malang 65145, East Java, Indonesia. Tel.: +62-341-553512, Fax.: +62-341-557837, ♥email: daduks@ub.ac.id

[2]Marine Resources Exploration and Management Research Group, Universitas Brawijaya. Jl. Veteran, Malang 65145, East Java, Indonesia

Manuscript received: 16 November 2023. Revision accepted: 3 April 2024.

Abstract. *Setyohadi D, Rahman MA, Harlyan LI, Rihmi MK. 2024. Species identification and population dynamics of cuttlefish* Sepia *spp. (Mollusca: Cephalopoda) landed at Brondong Fishing Port, Lamongan, East Java, Indonesia. Biodiversitas 25: 1359-1367.* Cuttlefish (*Sepia* spp.) is one of Indonesia's fisheries resources with high economic value. It is often caught in the northern Java waters, including Lamongan. As it is high value, cuttlefish resources should be managed to ensure sustainability. However, information on its biology and population dynamics is limited as the basis of fisheries management. This research aimed to identify species of cuttlefish and to estimate its biological aspects and population dynamics. Samples were randomly collected at Brondong Fishing Port from July to September 2022. The result indicated that there were two species of cuttlefish, *Sepia aculeata* (needle cuttlefish) and *Sepia pharaonis* (pharaoh cuttlefish), with a proportion of 57.1 and 42.9%, respectively. In addition, *S. pharaonis* was bigger and heavier than *S. aculeata*. The mean mantle length = 10.5 cm and weight = 166.6 g for *S. aculeata*, while *S. pharaonis* has mean mantle length = 11.4 cm and weight = 208.1 g, and both species have negative allometric growth patterns. Moreover, the asymptotic mantle length (L_∞) = 24.6 cm and 22.7 cm, growth rate (K) = 0.68 year^{-1} and 0.78 year^{-1}, total mortality rate (Z) = 1.96 year^{-1} and 4.61 year^{-1}, natural mortality rate (M) = 0.97 year^{-1} and 1.64 year^{-1}, fishing mortality (F) = 0.99 year^{-1} and 2.97 year^{-1}, and exploitation rate (E) = 0.51 year^{-1} and 0.65 year^{-1} for *S. aculeta* and *S. pharaonis* respectively. This finding might contribute to managing cuttlefish fishery in the north Java waters, especially in East Java.

Keywords: Fisheries management, FMA 712, length-weight relationship, needle cuttlefish, pharaoh cuttlefish

INTRODUCTION

Cephalopods are a class of marine mollusks including squid, octopus, and cuttlefish. Globally, the export value of cephalopods was around USD 10.2 billion, equivalent to 6.8% of the total value of exports for aquatic products in 2020, increasing over time (FAO 2022). In Indonesia, cuttlefish (*Sepia* spp.) is one of the high value fisheries resources. Statistics data export for Indonesian fishery products 2017-2021 recorded this type of cephalopod, together with squid and octopus, increased 9.6% and 13.24%t per year by volume and value, respectively. In 2021, this group of mollusks was the fourth export commodity by volume (174.7 tons), equivalent to 6.24% of global cephalopod products, and the third by value (USD 618.9 million) (KKP 2022). This high economic value might lead to an increase in catch by fishermen and threaten the sustainability of cuttlefish in the wild, in addition to the poor management strategy for this fishery. Recently global cuttlefish products are mainly served by fishing activities (FAO 2022). Breeding and cultivating this species is challenging as the process is extremely sensitive to ammonia nitrogen pollution stress (Chen et al. 2022).

Cephalopods have an ecosystem role in the marine environment as predators of small fish, shrimp, worms, and prey for several types of fish, seabirds, and marine mammals (Hastie et al. 2009). Cephalopods inhabit the continental shelf and upper slope to a maximum depth of around 600 m and bottom dwellers in a variety of environments, including rocky, sandy, and muddy bottoms to seagrass, seaweed, and coral reefs (Carpenter and Niem 1998). Living cephalopods comprise nautilus, squid, octopus, and cuttlefish (Oluboba et al. 2021). The nautilus is the only cephalopod with a fully developed external shell, while squid and cuttlefish have internal shells (King 2007).

In Indonesia, no cuttlefish fishery is reported (Pratasik et al. 2016), as cuttlefish was often traded and recorded as squid data in the fisheries statistical report. The cuttlefish data as a separate species was finally available on the Indonesian fisheries statistical database (statistik.kkp.go.id) in 2020, producing 17,596 tons (around 8% of squid and cuttlefish production in Indonesia). In addition, the management of squid (including cuttlefish) in Indonesia was limited to information on squid production estimation, total allowable catch, and exploitation rate. The National Committee on Fish Stock Assessment conducted this harvest control rule, known as Komisi Nasional Pengkajian Sumber Daya Ikan (KOMNAS KAJISKAN), officially documented in the ministerial decree by the Indonesian government. The latest decree, number 19/2022, stated that out of 11 Fisheries Management Areas (FMA) in Indonesia, the exploitation rate of squid in three FMAs was over-exploited (FMA 573, 713, 718), one FMA in moderate status (FMA 571), and the rest FMAs were fully exploited. Yet, neither size limit regulation nor a document of the fisheries management plan is available for this valuable resource.

The fisheries resources should be used and exploited sustainably to prevent its extinction. Information on a species' biology and population dynamics is important to provide basic information for management purposes (Soomro et al. 2015; Kavitha et al. 2022). For instance, data on length and weight was useful, easy to collect, and provided data for various analyses. The data could be analyzed using the biostatistical approach in fisheries biology, length-weight relationship, to estimate fish's general well-being (allometric or isometric). When combined with age data, the data can also provide information on life span, mortality, growth, reproduction, and maturity (Kumar et al. 2014; Getso et al. 2017).

Management of fishery resources requires information on targeted species' biology and population dynamics. Studies on the species identification, biology, and population dynamics of cuttlefish in Indonesian waters are limited (Pratasik et al. 2015) compared to squid. This research aimed to identify species of cuttlefish and to estimate its biological aspects and population dynamics. The outcome is expected to provide basic information on cuttlefish in the North Java Sea (FMA 712), East Java part, as one of the data for fisheries managers to manage cuttlefish fishery sustainably and measurably.

MATERIALS AND METHODS

Study area

This study was conducted at Brondong Fishing Port (6°52'05.2"S, 112°17'19.5"E), Lamongan, East Java, Indonesia (Figure 1). Fishermen in Brondong Fishing Port mainly operated their fishing gear at FMA 712. According to ministerial decree of marine affairs and fisheries 187/2023, Brondong port is the largest port, type B, in East Java which has a role in supporting the implementation of Indonesian measurable fisheries policy in zone 6 (WPP 712). This port has roles as a center for data collection, training, control and monitoring, where data collection is important for tracking the number of fish caught, and ensuring its compliance with predetermined quotas (Nurlaela 2023). Currently, the catch data were collected by officers using a fishing logbook, as regulated in PERMEN KP 48/2014 (Yuwandana et al. 2022). The cuttlefish in Brondong Fishing Port was landed as a bycatch of "cantrang" fishing gear, a type of seine net operated by fishermen in this port (Figure 2). Based on the fishing trip, there were two types of cantrang operated in Brondong Fishing Port: daily operated cantrang (one-day fishing operation) and weekly operated cantrang (10-20 days of fishing operation).

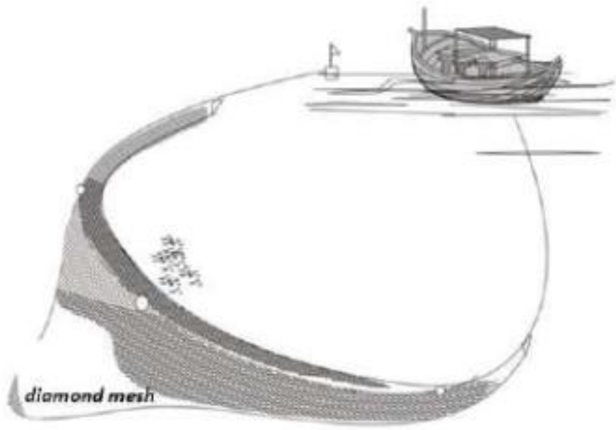


Figure 2. Cantrang (KKP 2021)

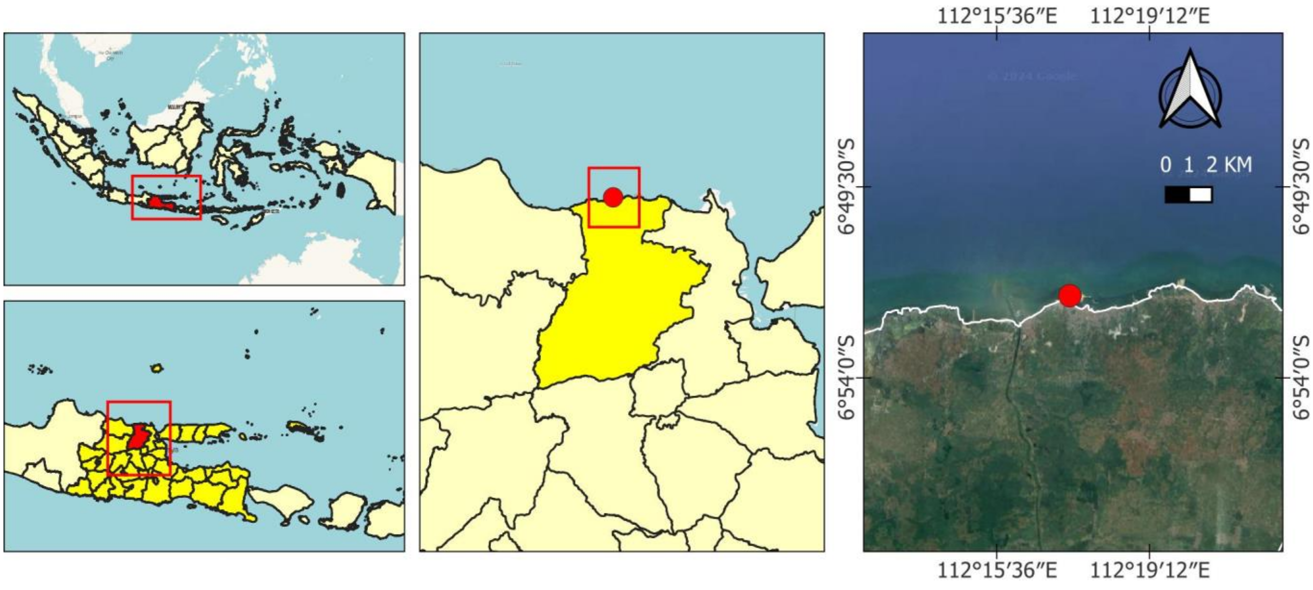


Figure 1. Location of Brondong Fishing Port in Lamongan, East Java, Indonesia

Data collection

The data collection was conducted from August to October 2022. Therefore, 1,412 cuttlefish were collected to identify their species and measure their weight (g) and mantle length (cm). Cuttlefish were initially distinguished by their distinct visual appearance. Five samples of each visually different cuttlefish were identified by examining some morphological characteristics, such as mantle shape, mantle color, mantle pattern, mantle size, tentacular cubs, number of suckers, spines, hectocotylus arm, and anterior striae (Carpenter and Niem 1998). The characteristics were also scored to identify the kinship of cuttlefish species. In addition, all samples were individually measured in their body Weight (W) and Dorsal Mantle Length (DML) to the nearest 0.1 g and 0.1 cm, respectively. See Figure 3 for the measurements and cuttlefish features.

Data analysis

Kinship of cuttlefish species

Kinship analysis was conducted to examine the similarity of species based on their morphological characteristics. The scored characteristics were analyzed using hierarchical cluster analysis in SPSS software, and a dendrogram was produced. The data consisted of estimated cuttlefish found at Brondong Fishing Port and other species found in Indonesian waters.

Length-weight Relationship (LWR)

The length-weight relationship was calculated using the power function:

$$W = aDML^b \quad \text{.....................................} (1)$$

The constants a and b were used to estimate the formula was transformed into a regression model:

$$\ln W = \ln a + b \ln DML \quad \text{..............................} (2)$$

Where: W is cuttlefish weight (g) and DML is cuttlefish's Dorsal Mantel Length (cm). The constants a and b are the intercept and slope of the linear regression model, respectively. The b value indicated the growth pattern of cuttlefish. The value of b was verified using the student's *t-test* to determine the growth pattern of cuttlefish, whether isometric (b = 3) or allometric (b ≠ 3; negative allometric b <3, and positive allometric b >3) growth.

Growth parameters

Asymptotic length (L_∞) and growth rate coefficient (K) of cuttlefish were obtained using FISAT II (FAO-ICLARM Stock Assessment Tools) software - ELEFAN I (Electric Length Frequency Analysis). The parameters were estimated based on the Von Bertalanffy growth model:

$$L_t = L_\infty(1-e^{-K(t-t_0)}) \quad \text{.......................................} (3)$$

Where: L_t is the mantle length of cuttlefish at age t, and t_0 is the theoretical age at zero length. The total mortality (Z) was estimated using the length-converted catch curve. The natural mortality (M) was calculated using Pauly's (1980) formula:

$$\text{Log } M = -0.0066 - 0.279 \text{ Log } L_\infty + 0.6543 \text{ Log } K + 0.4634 \text{ Log } T \quad \text{.......................................} (4)$$

Where: T is the temperature of seawater (°C); in addition, the exploitation rate (E) was determined from the calculation of fishing mortality (F) divided by Z. Furthermore, the estimation of relative Yield/Recruit (Y'/R) used Beverton and Holt (1966) model. Several values of E and Lc/L_∞ were used to generate a yield isopleth diagram.

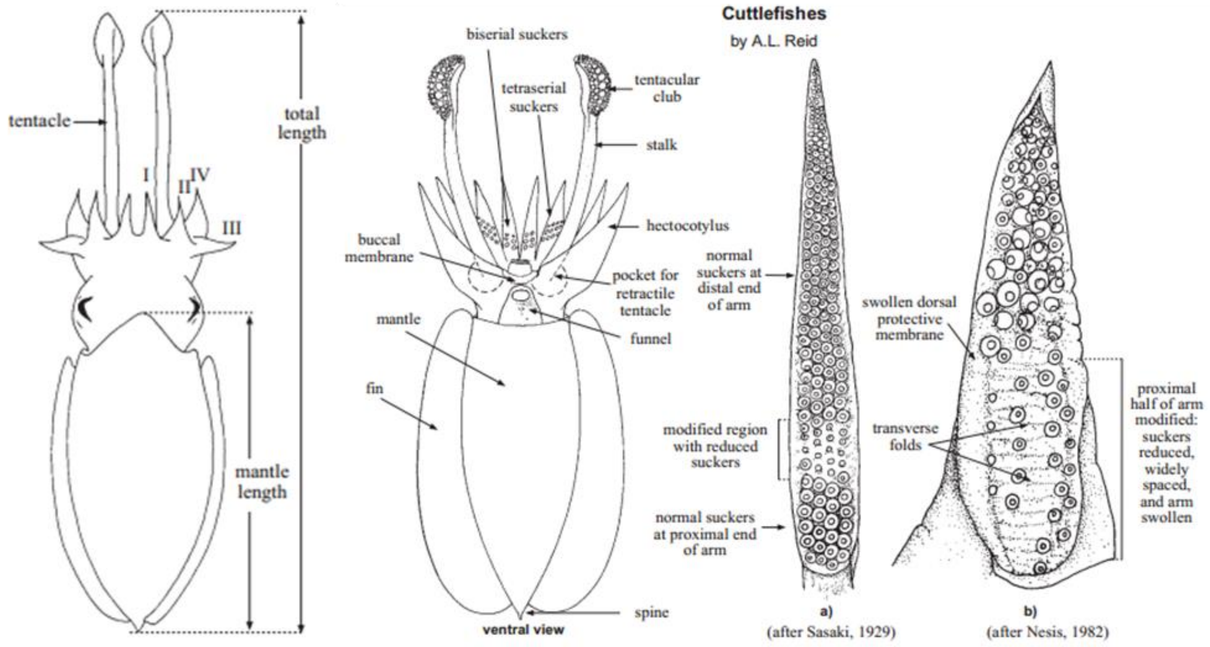


Figure 3. Measurements and features of cuttlefish (Carpenter and Niem 1998)

RESULTS AND DISCUSSION

Identification of cuttlefish

Based on the morphological characteristics, there were two species of cuttlefish found at the Brondong Fishing Port: *Sepia aculeata* (needle cuttlefish) and *Sepia pharaonis* (pharaoh cuttlefish), locally known as bekutak jawa and bekutak tiger, respectively. *Sepia aculeata* (Figure 4.A) has a broad oval mantle shape (long and oval) with a pale brownish color and a white spot pattern on its mantle. It has a long tentacular club with 10-12 suckers on it (Figure 4.B). This species also has a spine at the cuttlebone's posterior end (lower end) and the cuttlebone's anterior striae inverted U-shape (Figure 4.C). Another cuttlefish species identified was *Sepia pharaonis* (Figure 5.A). It has an oval mantle shape with a pale brownish color and has a transverse stripe pattern along the mantle, and has a long tentacular club with eight suckers (figure 5.B). The spine is also present at the cuttlebone's lower end, and the cuttlebone's ventral view indicates the inverted U-shape of the anterior striae (Figure 5.C).

Fisheries statistical data from Brondong Fishing Port in 2021 stated that 35 species were landed from cantrang operation with a total catch of 54,823 tons. The largest catch was bigeye fish (*Priacanthus* spp.) (22.7%), while squid (including cuttlefish) was the sixth largest cantang's catch (7.1%). Cuttlefish production at Brondong Fishing Port has always been recorded as squid data, despite the Indonesian fisheries statistical database splitting cuttlefish into separate species data since 2020. In addition, from 1,412 samples (around 250 kg), the catch composition of cuttlefish species indicated that *S. aculeata* was harvested more than *S. pharaonis*, with percentages of 57.1 and 42.9%, respectively.

Moreover, there was one species that local fishermen named sotong, an Indonesian cuttlefish. However, based on the morphological characteristics, the species was suggested as *Sepioteuthis lessoniana*. This species is recognized as one squid species rather than a cuttlefish. Despite having some superficial resemblance to cuttlefish, the loliginid genus (*Sepioteuthis*) may be identified and separated from cuttlefish due to the existence of a gladius in the dorsal mantle rather than a cuttlebone (Carpenter and Niem 1998; Riad 2020).

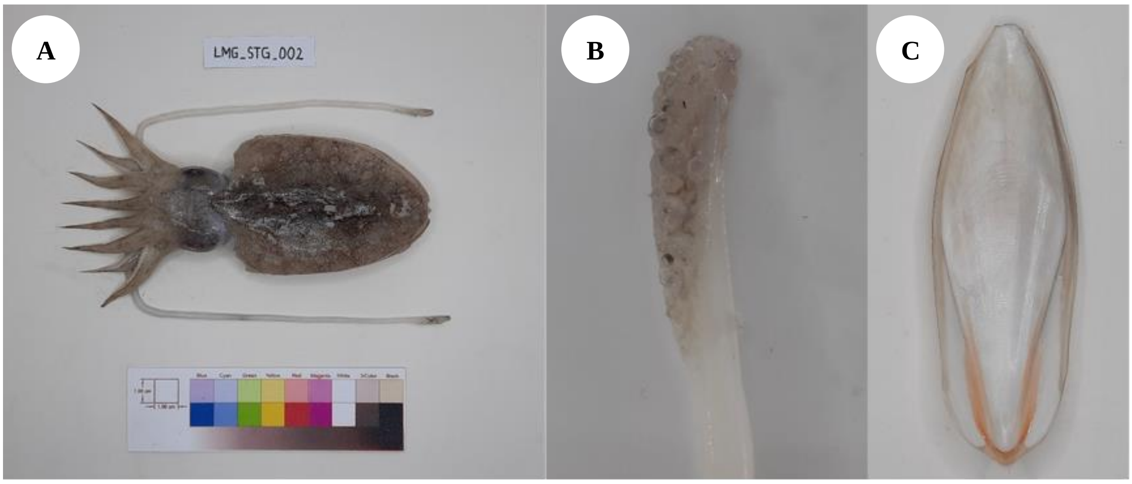


Figure 4. *Sepia aculeata.* A. whole animal dorsal view; B. tentacular club; C. cuttle bone ventral view

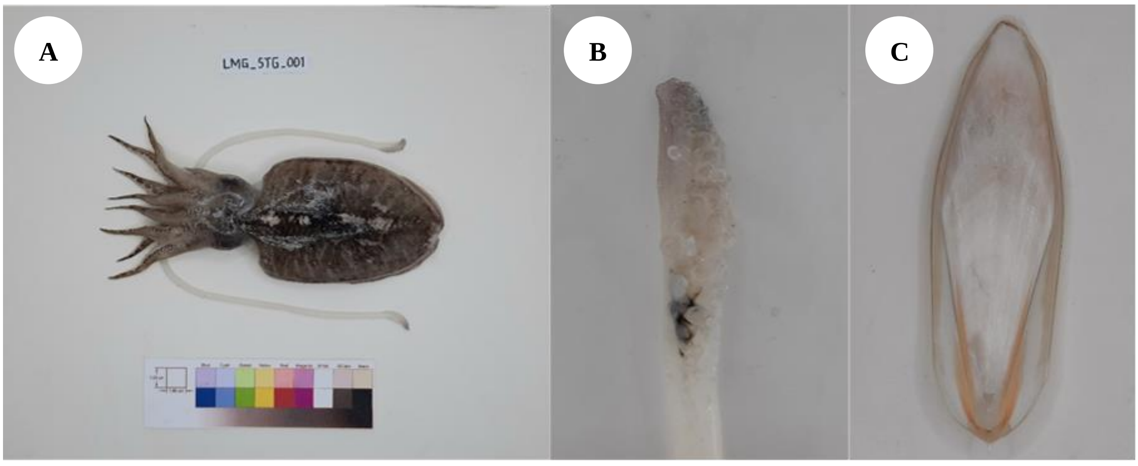


Figure 5. *Sepia pharaonis.* A. whole animal dorsal view; B. tentacular club; C. cuttle bone ventral view

The kinship analysis indicated that *S. aculeata* and *S. pharaonis* have different morphological characteristics, as the distance of these species was quite far (Figure 6). The percentage of differences in morphological characters was 56% and the percentage of similarities was 44%. *Sepia aculeata* exposed has a close kinship with *S. inermis*; both species have close appearances in some characteristics such as mantle pattern, number of suckers, and the presence of hectocotylus arm. The closest cuttlefish species to *S. pharaonis* was *S. recurvirostra*. Meanwhile, *Sepioteuthis lessoniana* has no morphological characteristics or similarity with other cuttlefish species. It confirmed that this species is not a cuttlefish species, as described in the previous paragraph.

Population dynamics

The biological aspects and population dynamics analysis of *S. aculeata* and *S. pharaonis* were conducted for 858 and 554 samples, respectively. In general, samples consist of various sizes and a wide range of dorsal mantle length and weight, with *S. pharaonis* being bigger and heavier than *S. aculeata* (Table 1). Both species were observed have highest average of DML and weight in October.

Length-Weight relationship

The length-weight equation for *S. aculeata* was estimated as $W = 0.29*DML^{2.62}$, while for *S. pharaonis* was $W = 0.25*DML^{2.67}$. The value of the *b* coefficient in each as well as pooled month for both species were significantly different from the isometric value (3) ($p < 0.05$) (Table 2). The slope *b* value denoted a negative allometric growth ($b < 3$), indicating a slower weight increase rate than in dorsal mantle length.

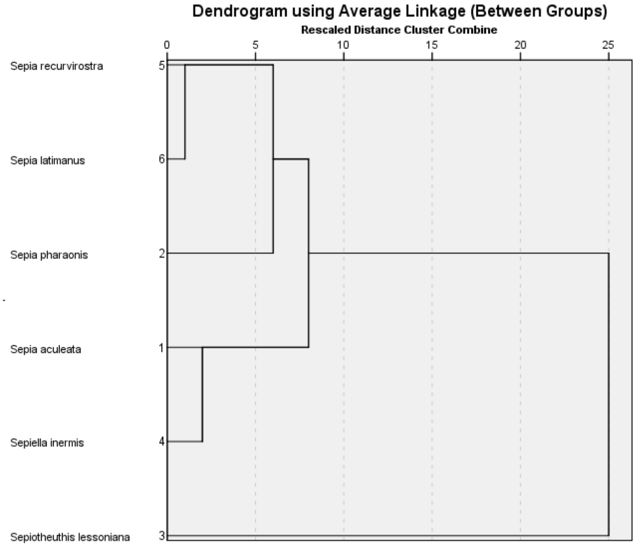


Figure 6. Dendrogram of kinship among species

Table 2. Dorsal Mantle Length-Weight relationship ($W = a*DML^b$) of *S. aculeata* and *S. pharaonis*

Species	Variable	Month			
		August	September	October	All
S. aculeata	a	0.8	0.32	0.34	0.29
	b	2.1*	2.58*	2.56*	2.62*
	R^2	0.7	0.96	0.95	0.96
S.pharaonis	a	1.1	0.29	0.26	0.25
	b	2.0*	2.60*	2.67*	2.67*
	R^2	0.69	0.92	0.97	0.94

Note: * significant ($p<0.05$) means $b \neq 3$ (allometric)

Table 1. Descriptive data for *Sepia aculeata* and *Sepia pharaonis* during the study

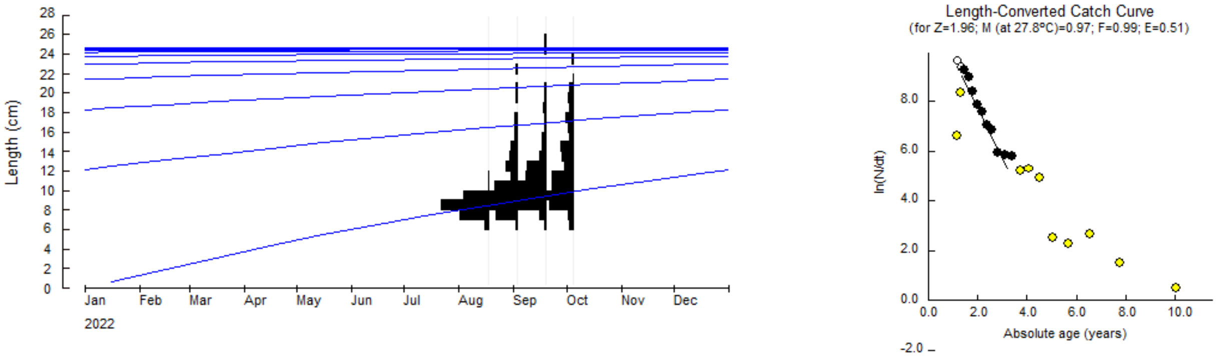
Species	Size	Parameter	Month			
			August (n = 145)	September (n = 463)	October (n = 250)	All (n = 858)
S. aculeata	Dorsal Mantle Length (cm)	Minimum	6.1	6.4	6.6	6.1
		Maximum	11	25.3	23.8	25.3
		Std.Dev.	0.84	2.75	3.65	3.07
		Average±S.E	8.4±0.07	10.4±0.13	11.9±0.23	10.5±0.11
	Weight (g)	Minimum	35.9	36.4	37.7	35.9
		Maximum	115.4	1516.2	1088.5	1516.2
		Std.Dev.	17	151.2	213.1	169.8
		Average±S.E	70.4±1.41	156.3±7.03	241.6±13.5	166.6±5.8
			Month			
			August (n = 148)	**September (n = 228)**	**October (n = 178)**	**All (n = 554)**
S. pharaonis	Dorsal Mantle Length (cm)	Minimum	5.6	6.7	7.8	5.6
		Maximum	11.5	28.6	24.5	28.6
		Std.Dev.	0.95	3.2	4.2	3.4
		Average±S.E	9.3±0.08	11.3±0.22	13.3±0.32	11.4±0.15
	Weight (g)	Minimum	32.8	45.6	37.7	32.8
		Maximum	160.4	1813.3	1088.5	1813.3
		Std.Dev.	22.45	232.1	213.1	226.4
		Average±S.E	90.9±1.85	203.4±15.37	241.6±15.97	208.1±9.62

Growth, mortality, and recruitment rate

The asymptotic length (L_∞) and annual growth coefficient (K) of *S. aculeata* were estimated at 24.6 cm and 0.68 year^{-1}, respectively, with the Rn value at the ELEFAN program being 0.554 (Figure 7.A). The theoretical age at zero length (t_0) was estimated at -0.17 year^{-1}. Hence, the von Bertalanffy growth formula was L_t = 24.6 (1-e$^{-0.68(t-(-0.17))}$). In addition, the total mortality rate (Z), natural mortality (M), fishing mortality (F), and Exploitation rate (E) were 1.96, 0.97, 0.99, and 0.51, respectively (Figure 7.B).

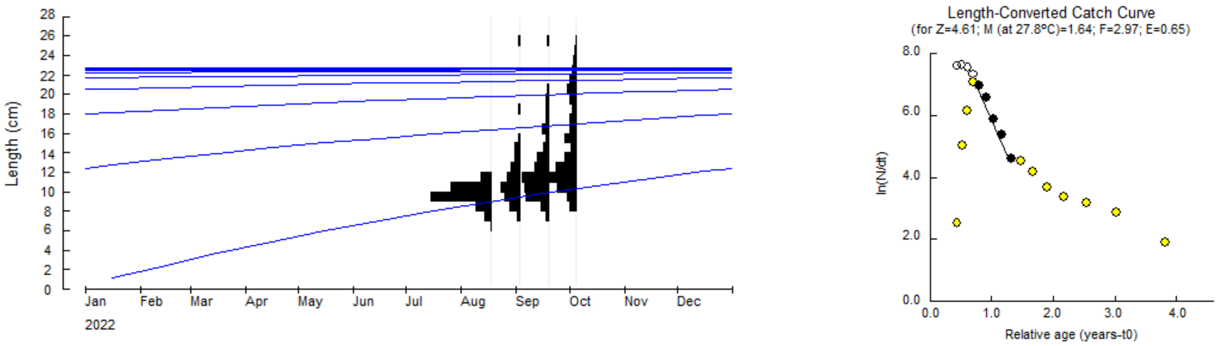
Meanwhile, for *S. pharaonis*, the asymptotic length (L_∞) and annual growth coefficient (K) were estimated at 22.7 cm and 0.78 year^{-1}, respectively, with Rn value at the ELEFAN program being 0.47 (Figure 8.A). The theoretical age at zero length (t_0) was estimated at -0.17 year^{-1}. Hence, the von Bertalanffy growth formula was L_t = 22.7 (1-e$^{-0.78(t-(-0.17))}$). The total mortality rate (Z), natural mortality (M), fishing mortality (F), and Exploitation rate (E) were 4.61, 1.64, 2.97, and 0.65, respectively (Figure 8.B).

The optimum exploitation rate (E_{opt}) and maximum exploitation rate (E_{max}) based on the selection ogive method were 0.51 and 0.62, respectively, for *S. aculeata* (Figure 9.A). Meanwhile, for *S. pharaonis*, E_{opt} was estimated to be 0.65, and the E_{max} was 0.76 (Figure 9.B). For both species of cuttlefish, at E_{max}, the percentage of biomass at the time of recruitment was reduced to approximately less than 38% of the initial biomass. The yield isopleth diagram revealed potential yield at E of 0.51 and Lc/L_∞ of 0.39 for *S. aculeata* (Figure 10.A), while for *S. pharaonis* at E of 0.65 and Lc/L_∞ of 0.46 (Figure 10.B).



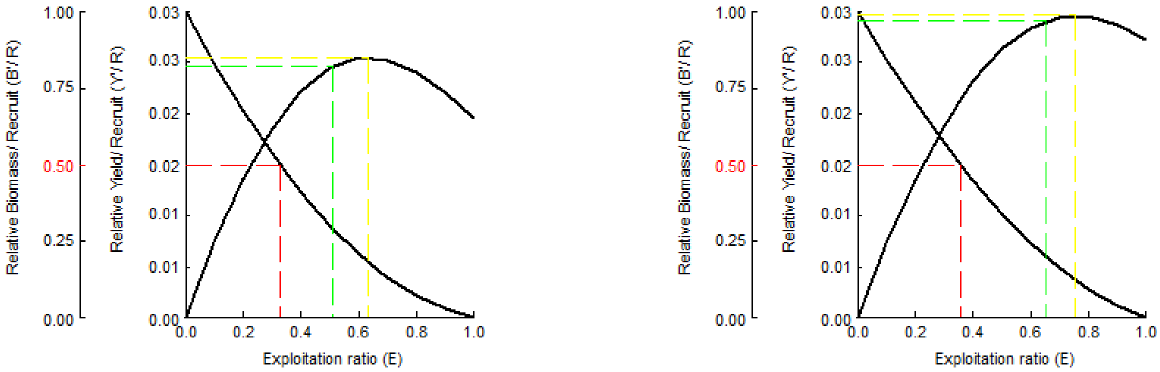
A B

Figure 7. Growth curve (A) and Z estimation (B) for *S. aculeata*



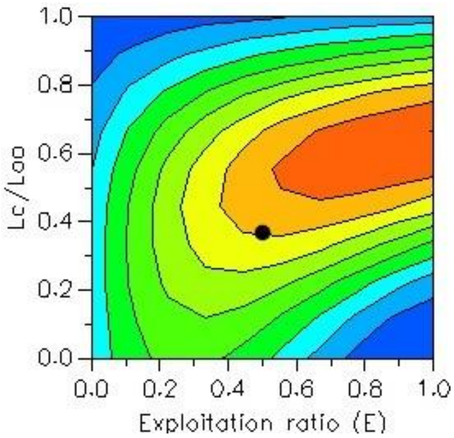
A B

Figure 8. Growth curve (A) and Z estimation (B) for *S. pharaonis*



A B

Figure 9. Relative yield per recruit and relative biomass per recruit for *S. pharaonis* (A) and *S. pharaonis* (B)



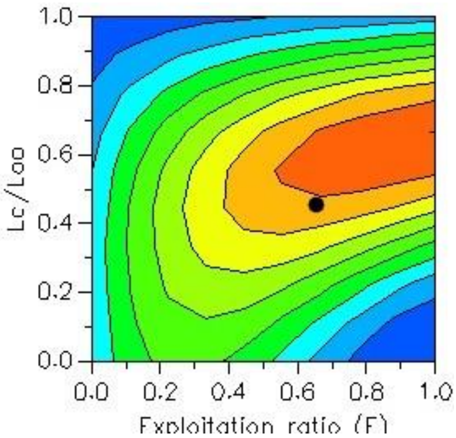


Figure 10. Yield isopleth diagram of *S. pharaonis* (A) and *S. pharaonis* (B)

Table 3. Population parameters of *Sepia aculeata* and *Sepia pharaonis* from different locations

Location	Sex	L_∞ (cm)	K	Z	M	F	Authors
Kakinada, India*	Pooled	22.5	0.92	4.56	2.22	2.34	Abussamad et al. (2004)
Mumbai, India*	Pooled	30	0.67	10.56	1.33	9.23	Chakraborty et al. (2013)
Arabian Sea of Oman**	Pooled	46.2	0.52	2.57	1	1.57	Mehanna et al. (2014)
Lamongan, Indonesia*	Pooled	24.6	0.68	1.96	0.97	0.99	*This study*
Lamongan, Indonesia**	Pooled	22.7	0.78	4.61	1.64	2.97	*This study*

Note: *: *S. aculeata*; **: *S. pharaonis*

Discussion

Species identification in this study was based on the visual examination of morphological characteristics. This method was simple and promptly provided an initial understanding of a species' identity, which would benefit fisheries managers to make swift decisions when required. However, this method has some limitations, such as depending on the expert personnel, some specific techniques (Jereb and Roper 2010), the completeness of morphological characteristics, and the different descriptions of identification keys based on the specific guidance book used (Currò et al. 2023). Lupše et al. (2023) suggested combining morphological and molecular features. This combination would obtain better and more precise results to identify genus.

The presence of *S. aculeata* and *S. pharaonis* in Brondong, Lamongan, was suggested because the fishermen applied demersal fishing gear (cantrang or seine nets), and the fishing ground was in the Java Sea, FMA 712. According to Carpenter and Niem (1998), *S. aculeata* inhabits seabed up to 60 m depth, and in Indonesia, it was distributed across the Andaman Sea, Karimata strait, and Java Sea. Meanwhile, the distribution of *S. pharaonis* was wider up to around Makassar Strait, Bali Strait, and Arafuru Sea. Other studies in Indonesia also reported *S. pharaonis* landed as the dominant cuttlefish catch in Muncar, Banyuwangi (Setyohadi et al. 2016) and Arafuru Sea (Tirtadanu and Suprapto 2016). In addition, *S. aculeata* and *S. pharaonis* were also grouped in a similar clade of genus *Acanthosepion,* distributed across northern Japan to northern Australia waters, including Indonesia (Lupše et al. 2023).

The estimation of the length-weight relationship in this study was conducted from unsexed samples, with negative allometric growth for both species. Some studies on *S. aculeata* and *S. pharaonis* mostly used sexed samples also revealed a negative allometric or hypoallometric growth pattern (Sasikumar et al. 2013; Setyohadi et al. 2016; Siddique et al. 2016), which means the growth of dorsal mantle length was faster than weight. In addition, other species of cuttlefish such as *S. inermis* (Siddique et al. 2016), *S. prabahari* (Kavitha et al. 2022), *S. officinalis* (Razek et al. 2014; Saddikioui et al. 2017; Torres et al. 2017; Vasconcelos et al. 2018), and *S. bertheloti* (Guerra-Marrero et al. 2023) were also showed negative allometric patterns. It appears that the general growth pattern for cuttlefish was always negative allometric. Despite the common *b* value for almost all species of cuttlefish described, the growth pattern might vary in another group of species due to biotic and abiotic factors, such as food supply, diet, temperature, salinity, and sexual dimorphism (Vasconcelos et al. 2018).

Compared to other studies, the estimation of L_∞, K, Z, M, and F for *S. aculeata* and *S. pharaonis* varied among locations, including this study (Table 3). The growth parameters (L_∞ and K) estimated for *S. aculeata* in the present study are within the range of growth parameters reported by earlier researchers i.e., L_∞ from 22.5-30 cm and

K from 0.47 to 0.92 yr^{-1}. However, the parameters estimated for *S. pharaonis* indicated differences from value reported earlier from Oman. The variations were suggested due to different factors in each place, such as water temperature and pollution (Sabrah et al. 2015). Variations in water temperature can affect the growth and development of cuttlefish populations (Chung et al. 2020). Meanwhile, pollution can increase mortality rates, impacting population dynamics by reducing survival rates (Torre et al. 2019). In addition, mate choice, a crucial factor in determining fitness and population dynamics, is also affected by environmental pollution (Candolin and Wong 2019). Furthermore, the length at first maturity for *S. aculeata* and *S. pharaonis* was 9.5 and 12.2 cm, respectively (Palomares and Pauly 2023). Based on dorsal mantle length frequency distribution, around 51% of *S. aculeata* and 72% of *S. pharaonis* were harvested below their length at maturity. It was indicated that cuttlefish fishery faced the growth overfishing state, in which many small individuals were harvested before they reached a size that maximizes stock biomass (King 2007).

The total mortality of *S. aculeata* consisted of almost equal natural and fishing mortality rates. Chakraborty et al. (2013) stated the equal rate of natural and fishing mortality denoted the healthy state of the stock. However, looking into more detail on the value, fishing mortality is higher than natural mortality. It could be an early warning for fishery managers in managing cuttlefish resources. Action plans should be formulated and implemented appropriately to prevent the cuttlefish resources from declining. In addition, the exploitation rate of *S. aculeata* (0.51) was slightly above an optimum state (0.5), which means that the fishery status was entering an initial phase of over-exploitation. Meanwhile, the exploitation rate for *S. pharaonis* was 0.65, also above the optimum state. The high values for exploitation rate and fishing mortality indicated the high level of exploitation for this fishery, which is suggested due to the increased fishing effort in harvesting cuttlefish in Lamongan.

Furthermore, cuttlefish in Lamongan landed as a bycatch of seine net, and it was known that recommending management strategies for a nontargeted fishery is challenging. However, some control methods should be introduced to sustain this important and valuable fishery. Based on the Brondong Fishing Port's statistical data in 2021, the number of trips for cantrang increased from 2017 to 2020. Shifting fishing ground, changing the depth of fishing gear operated, and regulating the time (day/night) of cantrang operation outside the behavior and habitat of cuttlefish are some options that could be tried to minimize the negative impact of cantrang on the fishery. In addition, recording cuttlefish as separate data and excluding it from squid was important to give a picture of the actual production data of this species. Some actions could be prepared when the data indicated that the cuttlefish fishery was deplorable. If the high exploitation pattern continues, the cuttlefish population might decline and be threatened. Hence, the present study would assist the fisheries regulator in formulating an effective management strategy for cuttlefish fishery.

ACKNOWLEDGEMENTS

The authors would like to thank Alfina Dwi Damayanti and Diah Ayu Rengganis, who collected the data, and all staff and fishermen of Brondong Fishing Port, Indonesia, for supporting fisheries statistical data and assisting data collection in the field. This study is part of the Doktor Lektor Kepala research grant of the Faculty of Fisheries and Marine Science, Universitas Brawijaya, Indonesia 2023, number: 2321/UN10.F06/KS/2023.

REFERENCES

Abdussamad EM, Meiyappan MM, Somayajulu KR. 2004. Fishery, population characteristics and stock assessment of cuttlefishes, *Sepia aculeata* and *Sepia pharaonis* at Kakinada along the east coast of India. Bangladesh J Fish Res 8 (2): 143-150.

Candolin U, Wong BBM. 2019. Mate choice in a polluted world: Consequences for individuals, populations and communities. Philos Trans R Soc B: Biol Sci 374 (1781): 20180055. DOI: 10.1098/rstb.2018.0055.

Carpenter KE, Niem VH. 1998. FAO Species Identification Guide for Fishery Purposes: The Living of Marine Resources of the Western Central Pacific Vol. 2. Food and Agriculture Organization of the United Nations, Rome.

Chakraborty SK, Biradar RS, Jaiswar AK, Palaniswamy R, Kuma P. 2013. Growth, mortality and population parameters of three cephalopod species, *loligo duvauceli* (Orbigny), *Sepia aculeata* (Orbigny) and *Sepiella inermis* (Orbigny) from north-west coast of India. Indian J Fish 60 (3): 1-7.

Chen H, Zhang Z, Wu Z, Peng R, Jiang X, Han Q, Jiang M. 2022. Effect of ammonia nitrogen on the detoxification metabolic pathway of cuttlefish (*Sepia pharaonis*). Aquaculture 553: 738133. DOI: 10.1016/j.aquaculture.2022.738133.

Chung M-T, Huang K-F, You C-F, Chiao C-C, Wang C-H 2020. Elemental ratios in cuttlebone indicate growth rates in the cuttlefish sepia pharaonis. Front Mar Sci 6: 796. DOI: 10.3389/fmars.2019.00796.

Currò S, Balzan S, Novelli E, Fasolato L. 2023. Cuttlefish species authentication: Advancing label control through near-infrared spectroscopy as rapid, eco-friendly, and robust approach. Foods 12 (15): 2973. DOI: 10.3390/foods12152973.

FAO. 2022. The state of world fisheries and aquaculture 2022. Towards Blue Transformation. FAO, Rome. DOI: 10.4060/cc0461en.

Getso BU, Abdullahi JM, Yola IA. 2017. Length-weight relationship and condition factor of *Clarias gariepinus* and *Oreochromis niloticus* of Wudil River, Kano, Nigeria. Agro-Science 16 (1): 1-4. DOI: 10.4314/as.v16i1.1.

Guerra-Marrero A, Bartolomé A, Couce-Montero L, Espino-Ruano A, Jiménez-Alvarado D, Castro JJ, Perales-Raya C. 2023. Age, growth, and population structure of the African cuttlefish *Sepia bertheloti* based on beak microstructure. Mar Biol 170: 118. DOI: 10.1007/s00227-023-04272-7.

Hastie LC, Pierce GJ, Wang J, Bruno I, Moreno A, Piatkowski U, Robin JP. 2009. Cephalopods in the North-eastern Atlantic: Species, biogeography, ecology, exploitation and conservation. Oceanogr Mar Biol: Annu Rev 47: 111-190. DOI: 10.1201/9781420094220.ch3.

Jereb P, Roper CF. 2010. Cephalopods of the World—An Annotated and Illustrated Catalogue of Cephalopod Species Know to Date, 2nd ed. FAO, Rome, Italy.

Kavitha M, Sasikumar G, Iyadurai J, Lakshmanan R, Felix J. 2022. Insight on the reproductive biology of small striped cuttlefish, *Sepia prabahari* in Gulf of Mannar, Indian Ocean and recommendation for a minimum legal size. Fish Res 248: 106227. DOI: 10.1016/j.fishres.2022.106227.

King M. 2007. Fisheries biology assessment, and management. Oxford: Blackwell Publishing Ltd. DOI: 10.1002/9781118688038.

KKP. 2021. Peraturan Menteri Kelautan dan Perikanan Republik Indonesia Nomor 18 Tahun 2021 tentang Penempatan Alat Penangkapan Ikan Dan Alat Bantu Penangkapan Ikan Di Wilayah Pengelolaan Perikanan Negara Republik Indonesia Dan Laut Lepas Serta Penataan Andon Penangkapan Ikan. [Indonesian]

KKP. 2022. Statistik ekspor hasiil perikanan tahun 2017-2021. Sekretariat Direktorat Jenderal Penguatan Daya Saing Produk Kelautan dan Perikanan. Direktorat Jenderal Penguatan Daya Saing Produk Kelautan dan Perikanan (Ditjen PDSPKP). [Indonesian]

Kumar DB, Singh NR, Bink D, Devashish K. 2014. Length-weight relationship of Labeo rohita and Labeo gonius (Hamilton-Buchanan) from Sone beel, the biggest wetland of Assam. J Environ Res Dev 8 (3A): 587-593.

Lupše N, Reid A, Taite M, Kubodera T, Allcock AL. 2023. Cuttlefishes (Cephalopoda, Sepiidae): The bare bones—an hypothesis of relationships. Mar Biol 170: 93. DOI: 10.1007/s00227-023-04195-3.

Mehanna SF, Al-Kharusi L, Al-Habsi S. 2014. Population dynamics of the pharaoh cuttlefish *Sepia pharaonis* (Mollusca: Cephalopoda) in the Arabian Sea coast of Oman. Indian J Fish 61 (1): 7-11.

Nurlaela E. 2023. Penangkapan Ikan Terukur: tantangan dan penerapan. In: Amri K, Latuconsina H, Triyant R (eds). Pengelolaan sumber daya perikanan laut berkelanjutan. Penerbit BRIN 267-314. DOI: 10.55981/brin.908.c759. [Indonesian]

Oluboba TF, Lawal-Are AO, Ogunkanmi AL, Moruf RO. 2021. Estimation of biometric characters, relative growth and sex ratio of cuttlefish, *Sepia officinalis* Linneus, 1758 (Cephalopoda: Sepioidea) off the coast of Lagos, Southwest, Nigeria. Agric Nat Resour 55 (3): 440-447. DOI: 10.34044/j.anres.2021.55.3.14.

Palomares MLD, Pauly, D. 2023. SeaLifeBase. World Wide Web electronic publication. www.sealifebase.org. version (08/2023).

Pratasik SB, Arfiati D, Setyohadi D. 2016. Mitochondrial CO1 genetic marker-based species diversity of cuttlefish (Cephalopod; Mollusk) in Manado Bay and Lembeh Strait, North Sulawesi, Indonesia. Aquac Aquarium Conserv Legislation 9 (6): 1345-1354.

Pratasik SB, Marsoedi AD, Setyohadi D. 2015. Size at first maturity of cuttlefish, *Sepia latimanus*, from North Sulawesi waters, Indonesia. Mar Sci 5 (1): 6-10.

Razek EA, Ramadan SA, Rashad MS, Mohammed EM. 2014. Molecular phylogeny of cuttlefish (sepiidae) and morphometeric characterization of *Sepia officinalis* in Ain El-ghazala-Eastern Libya. World J Zool 9: 178-183.

Riad R. 2020. Monograph of the Egyptian squids order: Teuthoidea (Cephalopoda: Mollusca) Part II. Egypt J Aquat Biol Fish 24 (4): 197-231. DOI: 10.21608/ejabf.2020.96805.

Sabrah MM, El-Sayed AY, El-Ganiny AA. 2015. Fishery and population characteristics of the Indian squids Loligo duvauceli Orbigny, 1848 from trawl survey along the north-west Red Sea. Egypt J Aquat Res 41: 279-285. DOI: 10.1016/j.ejar.2015.07.003.

Saddikioui L, Mazouz M, Abi-Ayad SMEA. 2017. First data on reproduction and growth parameters of the cuttlefish (*Sepia officinalis* L.) in Oran Bay (western Algeria coasts). Intl J Biosci 10: 75-84. DOI: 10.12692/ijb/10.5.75-84.

Sasikumar G, Mohamed KS, Bhat US. 2013. Inter-cohort growth patterns of pharaoh cuttlefish *Sepia pharaonis* (Sepioidea: Sepiidae) in Eastern Arabian Sea. Rev Biol Trop 61 (1): 1-14. DOI: 10.15517/rbt.v61i1.10871.

Setyohadi D, Sunardi, Mukhlis N, Cahya CN. 2016. Cuttlefish (*Sepia* Spp) identification and biological analysis of a dominant cuttlefish species landed in Muncar, Banyuwangi Regency, East Java. Res J Life Sci 3 (2): 109-118. DOI: 10.21776/ub.rjls.2016.003.02.5.

Siddique MAM, Khan MSK, Habib A, Bhuiyan MKA, Aftabuddin S. 2016. Size frequency and length-weight relationships of three semi-tropical cephalopods, Indian squid *Photololigo duvaucelii*, needle cuttlefish *Sepia aculeata*, and spineless cuttlefish *Sepiella inermis* from the coastal waters of Bangladesh, Bay of Bengal. Zool Ecol 26 (3): 176-180. DOI: 10.1080/21658005.2016.1190523.

Soomro SH, Liu Q, Kalhoro MA, Memon AM, Shah SB, Kalhoro MT, Han Y. 2015. Maximum Sustainable Yield Estimates of Indian Squid *Uroteuthis (photololigo) duvaucelii* (D'Orbigny, 1835) From Pakistani Waters Using ASPIC and CEDA Software. Lasbela Univ J Sci Technol 4: 1-9.

Tirtadanu T, Suprapto S. 2016. Sebaran cumi-cumi (*loliginidae*) dan sotong (*sepiidae*) yang tertangkap trawl di laut arafura. Proceeding of National Seminary on Management of Pelagic Fisheries. Marine Resources Exploration and Management, Universitas Brawijaya, Malang, 16 November 2016. [Indonesian]

Torre DL, Liuzzi D, Marsiglio S. 2019. The optimal population size under pollution and migration externalities: A spatial control approach. Math Model Nat Phenom 14 (1): 104. DOI: 10.1051/mmnp/2019004.

Torres MA, Vila Y, Silva L, Acosta JJ, Ramos F, Palomares MLD, Sobrino I. 2017. Length-weight relationships for 22 crustaceans and cephalopods from the Gulf of Cadiz (SW Spain). Aquat Living Resour 30: 12. DOI: 10.1051/alr/2017010.

Vasconcelos P, Pereira F, Carvalho AN, Gaspar MB. 2018. Weight-length relationships and relative growth of the cuttlefish (*Sepia officinalis*): causes and effects of hypoallometry. Thalassas: Intl J Mar Sci 34: 323-331. DOI: 10.1007/s41208-018-0067-0.

Yuwandana DP, Arifianto E, Wisudo SH, Astarini JE, Komarudin D. 2022. Desain konseptual sistem basis data untuk pendataan hasil tangkapan nelayan skala kecil berbasis android. ALBACORE Jurnal Penelitian Perikanan Laut 6 (1): 101-113. DOI: 10.29244/core.6.1.101-113. [Indonesia]