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Research Article

Allometric Study of *Urotheutis (Photololigo) duvauceli* (d'Orbigny 1835) from Northern Coast of Java, Indonesia

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Abstract: This study presents some basic biology of *Uroteuthis* (*Photololigo*) *duvauceli*, the most often caught species during sampling in the area of study, such as the sex ratio and length-frequency, allometric growth of various parts of the body, with particular interest in allometric relationship of eye shape against other parts of the body. Samples were collected from Cirebon in West Java, Kendal and Semarang in Central Java and Tuban waters in East Java. During 4 mo sampling from May to August 2015, four species were identified including *Uroteuthis (Photololigo) duvauceli* (d'Orbigny, 1835), *Octopus* sp, *Sepiella inermis* (Ferussac &'d'Orbigny, 1848), and *Sepioteuthis* cf. *lessoniana* (Ferussac, 1830). In all four populations, males dominated in number, the sex ratios ranged from 1:1.21 to 1:1.95 in favour of male individuals. Allometric growth of juveniles and mature individuals (60 mm to152 mm dorsal mantle length, DML) showed that *U. (P.) duvauceli* grew its length faster than any other part of the body except its fin ($P < 0.01$). Eyes grew according to its long axis than to its height. Head length and eye shape (eye length and height) grew significantly slower compared to the body length ($P < 0.01$). This means that since early juveniles *U. (P.) duvauceli* concerned more to the fin growth and development than to its eye size, even though newly hatch squid seemed to have shown big eyes compare to its overall body size. Previous studies on this species elsewhere substantiated that the length-weight relationship of *U. (P) duvauceli* do not follow ideal cube law. The fact in this study that wet body weight was always negatively allometric ($P < 0.01$) compared to any part of the body, not only its length, suggesting that *U (P.) duvauceli* is indeed a real swimmer, shaping a very light, slim and slender body with fully developed fin since early juveniles, balance feature for a predator escaping predation.

Keywords: Allometric growth, northern coast of Java, *Urotheutis* (*Photololigo*) *duvauceli* (d'Orbigny, 1835)

1. INTRODUCTION

The contribution of cephalopods to fisheries has increased worldwide, since in proportion input of traditional finfish stocks have started to decline in various regions [1, 2]. Hunsicker et al. [3], while studying 28 LMEs (Large Marine Ecosystem) commodity and supportive services provided by cephalopods, found that the group contributed as much as 55 % of fishery landings (t) and 70 % of landed values (USD). Other study reported that as overexploitation of finfish stocks continues, cephalopod populations seemed to take over niches of finfishes in the marine ecosystem and become dominant in terms of world fisheries resources [4].

Squid was known to exhibit polymorphism and possibly is species complex, which is not surprising, considering their wide distributional range in the sea. Considering their restricted niche, *i.e.*, only in saline waters with a very few species extended into estuarine habitats, also neither in the freshwater nor on land, cephalopods fisheries should be treated with more careful and assessed with direct primary data source to conserve the stock.

The family Loliginidae is comprised of the mostly neritic squids inhabit majority of the continental shelf seas with an exception of the very cold polar region [2, 5]. A certain species, *i.e.*, the big fin squid, *Sepioteuthis lessoniana* is being used

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for biomedical research [6] as also of economic value as commercial mariculture species [7]. Indeed that *P. duvauceli* as a species has yet having regulated fishery worldwide, neither have broad ecological review nor environmental relationship studied, apart from partial population identity recognised and researched [8]. As an ecologically important component of many near-shore ecosystems either as prey or as predators [2, 5], squid in general is known to have a very advance sight and nerve systems as also shown by their big sized eyes, in particular for the swimmer loliginid.

This study aims to collect basic information about *P. duvauceli* from northern coast of Java, such as the sex ratio in length-frequency relationship, various allometric measurements, with particular interest in allometric relationship of growth in eye size against other parts of the body, since this species is both predator and prey on various other species.

2. MATERIALS AND METHODS

Taking into consideration time limit of this study to the rough water during prolonged dry season in the year 2015, the availability of the fishermen, thus, sample collection was conducted four times; each were for regency Cirebon, West Java, regency Kendal and the city of Semarang, Central Java, and regency Tuban, East Java, from May to August 2015.

About 50 to 60 specimens for population structure analyses from each trawling station along the coast of Cirebon, Kendal, Semarang and Tuban were randomly collected from the catch on the deck. Assorted trawled specimens for ordinary collections were preserved in ethanol 70 % until further identification analyses. Fresh squid were sexed externally to assess the presence of the hectocotylus. No small immature animals that could not be sexed externally. Further, morphological characteristics of the specimens, such as mantle, fin, tentacle club, beaks, hectocotylus shape, arm sucker and arrangement, as well as number and shape of sucker teeth were examined. Whereas mantle width and length, head, gladius, tentacle and fin length, eye height and width were measured to the nearest 0.1 mm; total number and wet weight (to the nearest 0.1 g) of each specimen measured.

Allometric growth represents the growth rate of one parameter relative to that of another part of the body or to the whole organism, since body shape does not always change uniformly with an absolute increase in the size of the whole organism. Analysis of relative (allometric) growth of various shell parameters of the body normally used for bivalve mollusk was applied to this soft-bodied organism, urging the specimen evenly treated all way through the process. The relationship of any two parts of the body can be expressed by a non-linear exponential equation:

$$Y = ax^b \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Which can be linearized as the following:

$$\log_{10} Y = \log_{10} a + b \log_{10} x \quad \ldots\ldots (2)$$

For which, x and Y are the measurements of parts of the body to be compared. The exponent b is the growth coefficient, which illustrates the relative growth rate of the two variables under consideration; while the constant a is the value of Y when x is unity [9–11]. For example, if Y is a weight or volume (g or cm^3) and x is a fin coverage area (cm^2), then b equal to 3/2 would correspond to isometry. If b is greater than 3/2 is positively allometry, whilst if less than 3/2 is negatively allometry. This simple statistic test was used to verify the deviation of b from isometry β [9, 10]:

$$t\,\text{obs}\,(n-1)\text{df} = \frac{(b-\beta)}{S\,\text{error}\,b} \quad \ldots\ldots\ldots\ldots\ldots\ldots .(3)$$

3. RESULTS AND DISCUSSION

Four species were identified during the course of this study, including *Uroteuthis (Photololigo) duvauceli* (d'Orbigny, 1835), *Octopus* sp and *Sepiella inermis* (Ferussac & d'Orbigny, 1848), whereas the fourth, big-fin squid, *Sepioteuthis lessoniana* (Ferussac, 1830) was rarely found during the trawling survey, *i.e.*, with only one individual recorded in Kendal during particular months of field work. This finding may be related to the gear selectivity and the ecology of the species. The low numbers of *S. lessoniana* obtained in the trawl survey may therefore be a result of not sampling in its main habitat.

Species composition of coastal trawling and light luring surveys conducted in Thailand [12, 13] showed similar findings to the present study. There, the catches were dominated by *U. (P.) duvauceli* comprising over 60 % of total cephalopod catches, followed by *U. (P.) chinensis*

Table 1. Descriptive statistics of dorsal mantle length (DML, mm) of *P. duvauceli* from four localities on the northern coast of Java, May to August 2015.

Locality	South	East	n	Min.	Max.	Median	Mean	SD
Cirebon	06° 38’ 12.04”	108° 37’ 47.95”	65	60.12	105.10	77.68	80.03	11.06
	06° 38’ 32.97”	108° 39’ 15.09”						
	06° 40’ 41.04”	108° 40’ 42.29”						
Kendal	06° 49’ 56.55”	110° 17’ 19.19”	62	72.90	152.08	90.67	92.43	13.71
	06° 49’ 32.24”	110° 16’ 53.93”						
Semarang	06° 55’ 42.80”	110° 24’ 30.92”	53	64.32	144.02	94.86	92.29	15.27
Tuban	06° 46’ 08.77”	111° 43’ 44.18”	31	62.12	129.02	81.62	85.42	14.54
	06° 45’ 14.54”	111° 44’ 05.04”						

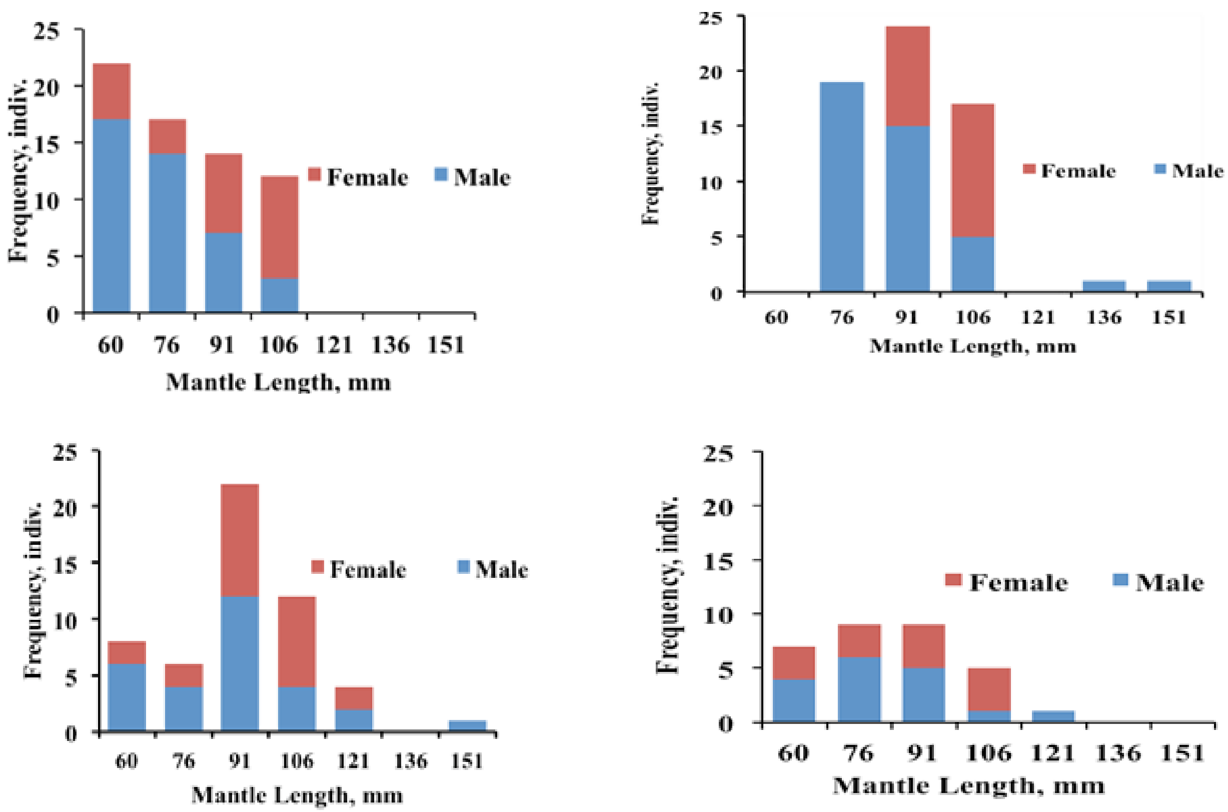

Fig. 1. Size frequency distribution based on DML of male and female *P. duvauceli*: top left A. Gebang, Cirebon (May 2015), B. Bandengan, Kendal (June 2015), bottom left C. Tambak Lorok, Semarang (July 2015), and D. Bulu, Tuban (August 2015).

at 18 % and *Loliolus* sp. (*L. sumatrensis*) which represented about 12 % of total catches. The catch of *S. lessoniana* was relatively minor, only at about 7 %. The high percentage of *U. (P.) chinensis* catches in Thailand may be due to the depth of trawling, which was between 10 m to 60 m in comparison to the present study *i.e*., 12 m to 18 m depth. Furthermore, *U. (P.) chinensis* were caught in more off shore regions (from 30 m to > 50 m depth [13]. *U. (P.) duvauceli* occurs at depths between 30 m and 170 m, and it forms large aggregations during the spawning season [14].

Maximum dorsal mantle length (DML) of *U. (P.) duvauceli* is indeed varies with geographical location, being the largest found in India ranged from 228 mm [16] up to 355 mm DML [15], or 238 mm for males and 162 mm for the females in the northwestern Red Sea [17], whereas in Thailand it attained a maximum size of 300 mm DML [13] whereas in Hong Kong, the maximum size of 155 mm DML for this species was recorded. In the present study, however, the maximum size attained was the smallest amongst the other four places of previous studies, *i.e*., 152.08 mm from Kendal waters. Seasonal variations of water temperature and productivity, which in turn affected food availability for the growth of aquatic organisms, might be the cause of these variations in maximum body size of the cephalopods [16]. Within the localities studied, specimen from Kendal waters was in average the largest (92.43 mm ± 3.71 mm; Table 1), whereas those from Cirebon were the smallest (80.03 mm ± 1.06 mm). Besides food availability, this difference in maximum attainable length could be attributable to seasonal reproduction, sampling size [16, 17] and perhaps lack of effort to apply an open and close season for the caught of squid in Indonesia, unlike in South Africa [18, 19].

Fig. 1B revealed that specimen from Kendal consists of the largest-in-average-size specimen (92.43 mm; Table 1) and was mostly male. Choi [14] reported that in the Gulf of Thailand size at 50 % maturity ranges between 90 mm and 130 mm mantle length for females and 70 mm to 150 mm for males. Therefore, in general, all samples in this study were consists of juvenile to adult size (Table 1). Subsequently, sex ratio for population in Cirebon and Kendal was 1:1.7 and 1:1.95 in favor of males, whereas population from Semarang and Tuban shared the same sex ratio, *i.e.,* 1:1.21 for male individuals. Further, observations on growth after sexual maturity support a suggestion that an extended reproductive phase existed within the life cycle of *U. (P.) duvauceli*, *i.e.,* not a strictly semelparous reproduction, as is the case in other squid [14]. This finding was supported by recent study of the same species from northwestern part of the Red Sea [17], which reported that this species been experiencing longevity ranged from 3.08 yr to 3.54 yr.

In natural food web, squid is a main prey for large carnivorous fish [20], for which the consumer includes at least 19 species of fish, 13 species sea bird and six sea mammals [21] yet, squid also a robust predator themselves. Thus, despite its advance vision, innervation and pigmentation, it is thought that morphologically their eyes grow quickly to escape predation and to prey – since, hatchlings, about 1 mm to 1.8 mm mantle length, have big eyes and are planktonic.

Table 2 shows 54 allometric growth coefficients (*b*) measured from various parts of *U. (P.) duvauceli* body. In general, Kendal and Cirebon populations showed more similarity to each other compared to the other two populations, *i.e*. Tuban and Semarang. It can be seen in those four populations that growth rate of mantle length was always relatively faster than the width, resulting a slender body shape of the organism. Length and width of the fin grow comparably at the same rate or even faster (isometrically or positively allometric) than the length and width of the body. It is also shown that head length and eye shape (length and height of the eye) grow significantly slower compared to the body length means that *P. duvauceli* concerned more to the fin growth and development than to its eye size, even though newly hatch squid seemed to have shown big eyes compare to its overall body size. It does not mean though that the sight is less developed [22]. Eyes grow according to the long axis than to its height. Likewise gladius width that grow isometrically to its length, fin length and width grow more or less isometrically to each other to get its perfect shape. Fins developed significantly faster ($P < 0.01$) than the mantle, the head, the eyes, tentacles, gladius and even to the overall weight of the animal. These measurements then suggest that *P. duvauceli* is indeed puts balance into priority as a true swimmer.

Table 2. Allometric coefficient noted as slope or *b* value in logarithmic regression equation ($Y = ax^b$; a is the intrecept) of *P. duvauceli* from Semarang, Tuban, Kendal and Cirebon. All isometry, positive (+) and negative (-) allometric growth were significant at P < 0.01.

Variable														
Ind.	**Dep.**	**β**	***b*-Smrg**	**Allo.**	**R**	***b*-Tuban**	**Allo.**	**R**	***b*-Kendal**	**Allo.**	**R**	***b*-Crbn**	**Allo.**	**R**
ML	MW	1	0.42	-	0.762	0.72	-	0.883	0.50	-	0.678	0.74	-	0,757
	FL	1	1.19	+	0.962	1.28	+	0.981	1.11	iso	0.942	1.40	+	0.864
	FW	1	1.27	+	0.878	1.43	+	0.939	1.04	iso	0.838	1.12	iso	0.728
	HL	1	0.38	-	0.445	0.46	-	0.79	0.44	-	0.437	0.50	-	0.402
	EL	1	0.26	-	0.359	0.49	-	0.821	0.29	-	0.385	0.38	-	0.371
	EH	1	0.35	-	0.496	0.30	-	0.533	0.31	-	0.383	0.22	-	0.147
	TL	1	0.65	-	0.651	0.97	iso	0.805	0.79	-	0.763	0.81	iso	0.552
	GL	1	0.95	iso	0.949	0.99	iso	0.998	0.94	iso	0.966	0.78	-	0.78
	GW	1	0.86	iso	0.735	0.98	iso	0.896	0.83	iso	0.744	0.79	iso	0.355
	WWT	3	2.05	-	0.938	2.37	-	0.969	2.13	-	0.928	2.30	-	0.813
MW	FL	1	1.60	+	0.714	1.38	+	0.869	0.99	iso	0.613	1.18	iso	0.707
	FW	1	1.86	+	0.708	1.58	+	0.849	0.99	iso	0.575	0.86	iso	0.541
	HL	1	0.93	iso	0.603	0.53	-	0.75	0.47	-	0.345	0.48	-	0.379
	EL	1	0.44	-	0.343	0.53	-	0.737	0.32	-	0.306	0.25	-	0.238
	EH	1	0.67	iso	0.526	0.33	-	0.468	0.40	-	0.365	-0.10	-	0.061
	TL	1	1.13	iso	0.628	1.05	iso	0.719	0.68	iso	0.485	0.87	iso	0.579
	GL	1	1.37	iso	0.758	1.07	iso	0.882	0.87	iso	0.657	0.61	-	0.591
	GW	1	1.49	+	0.7	1.19	iso	0.889	0.73	iso	0.483	0.50	iso	0.22
	WWT	3	3.32	iso	0.84	2.72	iso	0.91	1.96	-	0.628	1.87	-	0.641
FL	FW	1	0.94	iso	0.798	1.10	iso	0.936	0.89	iso	0.848	0.59	-	0.625
	HL	1	0.27	-	0.387	0.36	-	0.792	0.32	-	0.372	0.21	-	0.272
	EL	1	0.24	-	0.409	0.38	-	0.827	0.21	-	0.328	0.19	-	0.306
	EH	1	0.30	-	0.534	0.22	-	0.489	0.27	-	0.402	0.17	-	0.183
	TL	1	0.57	-	0.707	0.71	-	0.769	0.63	-	0.720	0.42	-	0.469
	GL	1	0.73	-	0.905	0.75	-	0.983	0.77	-	0.932	0.42	-	0.67
	GW	1	0.66	-	0.695	0.75	-	0.885	0.71	-	0.755	0.41	-	0.298
	WWT	3	1.60	-	0.902	1.81	-	0.959	1.73	-	0.891	1.28	-	0.735
FW	HL	1	0.29	-	0.484	0.31	-	0.819	0.20	-	0.250	0.38	-	0.477
	EL	1	0.21	-	0.419	0.30	-	0.786	0.24	-	0.392	0.24	-	0.36
	EH	1	0.24	-	0.504	0.16	-	0.424	0.30	-	0.461	0.23	-	0.235
	TL	1	0.33	-	0.474	0.64	-	0.814	0.58	-	0.697	0.39	-	0.407
	GL	1	0.60	-	0.875	0.61	-	0.94	0.65	-	0.829	0.46	-	0.711
	GW	1	0.56	-	0.691	0.61	-	0.851	0.63	-	0.698	0.48	-	0.331
	WWT	3	1.33	-	0.885	1.48	-	0.924	1.51	-	0.810	1.13	-	0.614
HL	EL	1	0.36	-	0.429	0.83	iso	0.813	0.30	-	0.392	0.19	-	0.227
	EH	1	0.39	-	0.473	0.55	-	0.566	0.21	-	0.261	-0.22	-	0.176
	TL	1	0.40	-	0.343	1.41	iso	0.685	0.35	-	0.342	0.41	-	0.348
	GL	1	0.57	-	0.488	1.33	iso	0.784	0.43	-	0.448	0.27	-	0.334
	GW	1	0.54	-	0.392	1.39	iso	0.738	0.13	-	0.121	0.24	-	0.133
	WWT	3	1.38	-	0.542	3.42	iso	0.815	1.19	-	0.521	0.83	-	0.362
EL	EH	1	0.66	-	0.673	0.53	-	0.544	0.48	-	0.453	0.44	-	0.295
	TL	1	0.27	-	0.19	1.55	iso	0.763	0.52	-	0.382	0.52	-	0.359
	GL	1	0.60	iso	0.424	1.38	iso	0.824	0.58	-	0.456	0.40	-	0.408
	GW	1	0.70	iso	0.42	1.44	iso	0.777	0.50	-	0.344	0.89	iso	0.406
	WWT	3	1.29	-	0.42	3.55	iso	0.857	1.29	-	0.428	0.95	-	0.341
EH	TL	1	0.61	iso	0.424	0.87	iso	0.415	0.47	-	0.359	-0.02	-	0.022
	GL	1	0.72	iso	0.504	0.91	iso	0.526	0.48	-	0.394	0.25	-	0.384
	GW	1	0.72	iso	0.426	1.01	iso	0.525	0.62	-	0.448	0.20	-	0.136
	WWT	3	1.83	-	0.583	2.31	iso	0.538	1.17	-	0.408	0.39	-	0.21
TL	GL	1	0.61	-	0.607	0.66	-	0.794	0.72	-	0.767	0.38	-	0.55
	GW	1	0.61	-	0.513	0.70	-	0.767	0.71	-	0.658	0.20	-	0.132
	WWT	3	1.54	-	0.703	1.64	-	0.806	1.78	-	0.802	0.88	-	0.452
GL	GW	1	0.91	iso	0.77	0.99	iso	0.893	0.86	iso	0.750	0.98	iso	0.442
	WWT	3	2.02	-	0.923	2.39	-	0.966	2.21	-	0.936	1.82	-	0.646
GW	WWT	3	1.42	-	0.765	2.08	-	0.931	1.60	-	0.775	0.32	-	0.251

Legend:
WWt = Total Wet Weight, FL = Fin Length, EL = Eye Length, GL = Gladius Length
ML= (Dorsal) Mantle Length, FW = Fin Width, EH = Eye Height, GW = Gladius Width
MW = Mantle Width, HL = Head Length, TL = Tentacle Length, Ind.= Independent variable
Dep. = Dependent variable, Smrg = Semarang, Crbn = Cirebon, Iso & Allo. = Isometry & Allometry

Changes in the relative (allometric) growth of the brachial crown (tentacles) in squid are thought as an adaptation of pelagic biomass spectra [20]. In most squid as predators, arm size increases relatively rapidly in relation to overall body size especially in early life. It has probably evolved in response to the need to shift predation from one peak in the biomass spectrum to the next, accommodating the transition between diets differing in body size by at least one order of magnitude [23]. Discontinuities often occur in allometric growth of the brachial crown of juvenile squid [24, 25]. In this study, however, growth in tentacle length of *P. duvauceli* increased slower than fin and head length ($P < 0.01$), isometrically to the mantle width and positively allometric toward gladius length and width as well as body weight in those four juvenile's populations (Table 2; $P < 0.01$).

Recent studies in India waters (b= 2.368) [16], Red Sea (b=2.02) [17], Sabah, Malaysia for the congeneric *U. chinensis* (b= 2.579) [26], South China Sea and Beibu Gulf, China (b = 2.217 and 2.229, respectively) [27], Goa in the west coast of India (b= 1.613 to 1.672) [28], shown that all recorded 'b' values of length-weight relationship significantly differed from the ideal cube law of '3' or isometry (mostly $R \geq 0.900$) [29]. In line with those studies, wet weight proved negatively allometric to length (b= 2.05, 2.37, 2.13 and 2.30 for Semarang, Tuban, Kendal and Cirebon, R ranged from 0.813 to 0.969 respectively; Table 2) as well as to almost all any other part of the body (Table 2), suggesting that as a true swimmer *P. duvauceli* urges light body weight. Meanwhile, females at the same length were heavier than males; yet, males ultimately attained a larger size. These findings of weight and female body length conformed to that of Choi [14].

4. CONCLUSIONS

As a true swimmer *U. (P.) duvauceli* put forward the need of fin and lightweight body (perhaps to escape predation) more than for brachial crown and eye size, which supposed to be the main feature of squid as predator. Regardless the variability of squid caught in four localities along northern coast of Java island, for which the maximum attainable size in particular of *U. (P.) duvauceli* is the smallest among other countries, for example compared to various places in India, Malaysia, Thailand, Hong Kong, Red Sea and China, it is an urgency for the Government of the Republic of Indonesia to set up a regulation on squid fisheries, including open and close season scheduled throughout the country. This is due to the lack of current and accurate data on basic fisheries analyses for mollusks in general, including cephalopods, in the Fisheries Bureau.

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