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Age and Growth Studies of Oceanic Squid, *Sthenoteuthis oualaniensis* using Statoliths in the South China Sea, Area III, Western Philippines

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ABSTRACT

Studies on age and growth using statolith of oceanic squids, *Sthenoteuthis oualaniensis* collected from Western Philippines, South China Sea, Area III have been conducted from 7 April – 19 May, 1998 by MV SEAFDEC Cruise No. 50-4/1998. A total of 1,707 squids were sampled and measured onboard. 74 statoliths which consist of 53 statoliths from female specimens and 21 from male specimens were extracted and processed using statolith ageing techniques with the body mantle length range from 107 – 217 mm and 115 – 167 mm, respectively. The male is smalled than the female where the male does not exceed 180 mm and the the female can grow upto 260 mm.There is slighly a different dimension of growth at the statolith microstructure between the male and female specimens. In the ground statolith, growth increments were examined and grouped into four growth zones distinguished mainly by the width of the increments. It was found that the male exhibit slower growth and maturation occur at the same time with the female but at smaller size. The age of the male and female ranged from 135 – 259 days and 95 – 275 days, respectively. The life span of the species was considered within one year. It was also observed that the putative microcohort of the female could be explained from the length frequency distribution of the immature and mature female and a pool data of length frequency distribution from all stations.

Keywords: squids; statoliths; age and growth; Philippines waters; South China Sea

Introduction

There has been increasing worldwide interest in cephalopod resources, especially in squid species(Caddy,1989). Loligonid species is one of the most numerous and economically valuable squid species compared to other species as they are a neritic species occurring in coastal waters.

The application of daily growth increments to age determination has been used primarily to age larval and juvenile fish (Methot and Kramer, 1979; Steffensen, 1980; Barkman *et al.*,1981; Powell, 1982). Growth of young-of-the-year fish and timing of behavioural changes have been documented(Brothers and McFarland, 1981; Methot,1981; Victor, 1982; Lough *et al.*, 1982) and the technique has also been used to age young tuna(Wild and Foreman, 1980; Uchiyama and Struhsaker, 1981; Radtke, 1983). The ability to locate the position of the first annulus has been a major contribution to routine age determination.

Daily growth increments have been of little use in ageing older fish or in solving interpretation problems in adults. The studies on squids shows that most of the squids are short life species with a life span of 1 – 2 years and and can be age by using the method of daily growth increments(Hixon and Villoch, 1984; Dawe *et al.*, 1985; Natsukari *et al.*, 1988; Jackson, 1990; Nakamura and Sakurai, 1990; Arkhipkin, 1993; Arkhipkin and Nekludova, 1993; Arkhipin *et al.*1996) by assuming that the growth increments were deposited daily.

Oceanic squids of the genus *Sthenoteuthis* were common in the upper region of the South China Sea which inhibit deeper water. However, information on the population biology parameters of these species is still scarce, and has justified recent efforts to improve data quality and quantity. Several countries have collaborated in a research project to improve knowledge on these squid and provide a solid basis for their exploitation or conservation. So therefore, the aim of this paper is to provide basic information on their age and growth of *Sthenoteuthis oualaniensis* using microstructure of the statoliths.

Materials and Methods

Data were collected on *Sthenoteuthis oualaniensis* during a preliminary survey of oceanic squid in the South China Sea, Area III, Western Philippines(Fig.1) by MV SEAFDEC Cruise No. 50-4/1998 between 7 April – 19 May 1998. Four squid jigging machines were used in the survey with a depth operation ranged between 0 – 150 m from the surface. The number of jigs on each machines ranged from 32 – 46 jigs and two jigs size has been used during the operations.

Sampling stations

A total of 11 selected stations have been choosen at a depth more than 1,000 m. that is, station No. 1, 5, 7, 9, 12, 14, 17, 21, 27, 30A and 30B. Their basic physical data of the sampling stations is as shown in Table 1. Station 9 was selected as an extra station near a coastal shallow water while sample for station 12 include the specimens from the searching method using echo traces of the echo sounder(50 specimens). The position for station 30A and 30B were slightly different from the original sampling station 30 and 31.

Length frequency sampling

A total of 1,707 specimens of *Sthenoteuthis oualaniensis* were measured during the expeditions, including both male and female specimens(number of female = 1,383 and number of male = 324). A systematic random sampling were done at each stations where an alternate number of five specimens of squids landed were taken as a subsamples, i.e. the squids number 1-5, 11-15, 21 – 15, 21 – 25 etc. Dorsal mantle length (ML) was measured to the nearest 1 mm and total body weight (BW) to the nearest 5 g using kitchen spring balance onboard MV SEAFDEC. The sex were determined through their external morphology and their sex ratio calculated. The length-frequency curve for each sex were then constructed at each sampling stations.

A total of 279 specimens from 11 sampling stations were brought to the Laboratory, Faculty of Applied Science and Technology for further analysis. The measurement of the preserved sample, i.e., length and weight were again measured to the nearest 1 mm and 0.1 g, respectively and sex recorded. These data were used to construct the curve of length-weight relationship.

Age sampling

A total of 74 statolith reading were taken under the scheme of representative sampling to ensure that all lengths and maturity stages were equally well sampled(Dawe and Natsukari,1991) from the subsamples taken for length frequency analysis which include 53 female specimens and 21 male specimens. A total of five specimen were taken at each interval class of 1-cm and at each maturity stages. However, the dissection were made only on the mature male and female

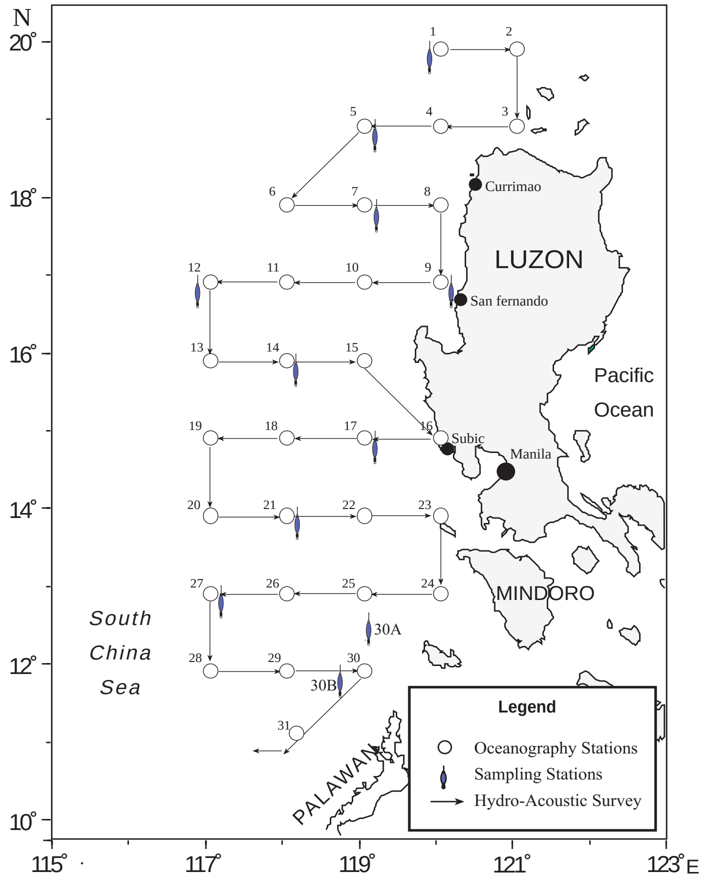

Fig. 1. The maps shows the sampling stations during the MV SEAFDEC cruise at South China Sea, Area III, Western Philippines from 7 April – 19 May 1998. The dark shows the position of the squids sampling stations.

specimens at various maturity stages. However, we could not found in our subsamples the large-size male and female specimens which have already spent. The statolith taken were first washed in distilled water, and labeled and stored in oil-paper envelopes in 96% ethanol.

Statolith ageing analysis

The statolith terminology used in this paper followed Clarke(1978) and Lipinski *et al.*(1991). Preparation of statoliths for age analysis has been made by the method described in Dawe and Natsukari(1991). The statolith weight, length of the rostrum, length of the wing, length of statolith body and statolith length were recorded before grinding process(Fig. 5). The statoliths were ground (on 800 grit) and polished (on 1,200 grit) wet waterproof sandpaper. Because the direction of the maximum growth within statoliths changed during ontogenesis, it was necessary to grind the convex side of the same statolith in two planes; one plane running through the lateral and dorsal domes and spur, and the other plane running through the spur and along the central axis of the rostrum. This method of grinding exposes the growth increments lying immediately below the wing. The ground statolith was not flat and thin as in Natsukari *et al.*(1993) but thickened in the region of the lower part of the lateral dome and the proximal part of the rostrum. This feature allowed all increments from the nucleus to the most distal part of the rostrum to be ambiguously resolved.

Ground statoliths were embedded in glycerin and covered with glass for immediate reading. Statoliths were read under a light microscope with 200 – 500X magnification. Growth increments were counted from the nucleus to the distal part of the rostrum and from farther within the rostrum as described by Natsukari *et al.* (1993) by using the eyepiece. To avoid possible counting errors, each statolith was counted at least twice by two observers, and if the difference between readings was less than 5%, squid age was taken as the mean of these counts. Readings were made only after achievement of the maximum resolution of growth increments with fine-adjustment focusing.

Results and Discussions

Length frequency distribution

The length-frequency distribution of oceanic squids, *Sthenoteuthis oualaniensis* at each sampling station is as shown in Fig. 2 and Fig. 3. While complex, the length frequency histograms are quite similar in all the stations sampled. And are consistent with the assumption of an underlying annual cycle and a lifespan of approximately one year especially the male which have only one size mode. However, putative microcohorts are more readily identified in data for female at each station, but when the data are pooled together from all stations it tends to show one normal distribution skewed towards the right side of the curve. Sexual dimorphism in size clearly occur in this species and similarly to other species such as *Loligo forbesi* (Pierce *et al.*,1994; Guerra and Rocha,1994), *Berryteuthis magister*(Arkhipkin *et al.*,1996), *Illex coindefii* and *Todaropsis* (Gonzalez et al, 1994) and therefore, by implication, effect the growth rates. The males are significantly smaller than the female at all post-recruitment sizes and, consequently, in all population studies the male and female components must be treated separately. It was found that the male does not exceed 18 cm while the female can grow up to 26 cm .

The fishery by automatic squid jigging operated during night time may cause an error in samplings. This might be caused by either the selectivity of the gear and technique used which in turn are related to ecological factors such as feeding behaviour and vertical distribution (Porteiro and Martins, 1994). Since net are not employed, small squid were not collected at all stations and as a results the population sample might not represent the true population.

Length-weight relationship

Since, the length frequency distribution shows that there is a significant different between the male and female specimens, therefore, we will separate all our analysis according to their sex. The length-weight relationships of male and female *S. oualaniensis* is as shown in Fig. 4. Only data from the preserved samples were used since the data for weight during the onboard MV SEAFDEC would not be appropriate for the analysis. The relationship for;

a) Female

$\ln(BW) = 2.9209 \ln(ML) - 9.6818$; $r^2 = 0.8094$ $n = 223$

b) Male

$\ln(BW) = 3.2331 \ln(ML) - 11.28$; $r^2 = 0.7981$ $n = 56$

where the length for female and male specimens range from 107 – 234 mm and 114 – 181 mm, respectively. This gave a sex ratio between female and male of 4:1 and this ratio is also equivalent to the whole sampling (1,707 where the female is 1,383 and male is 324).

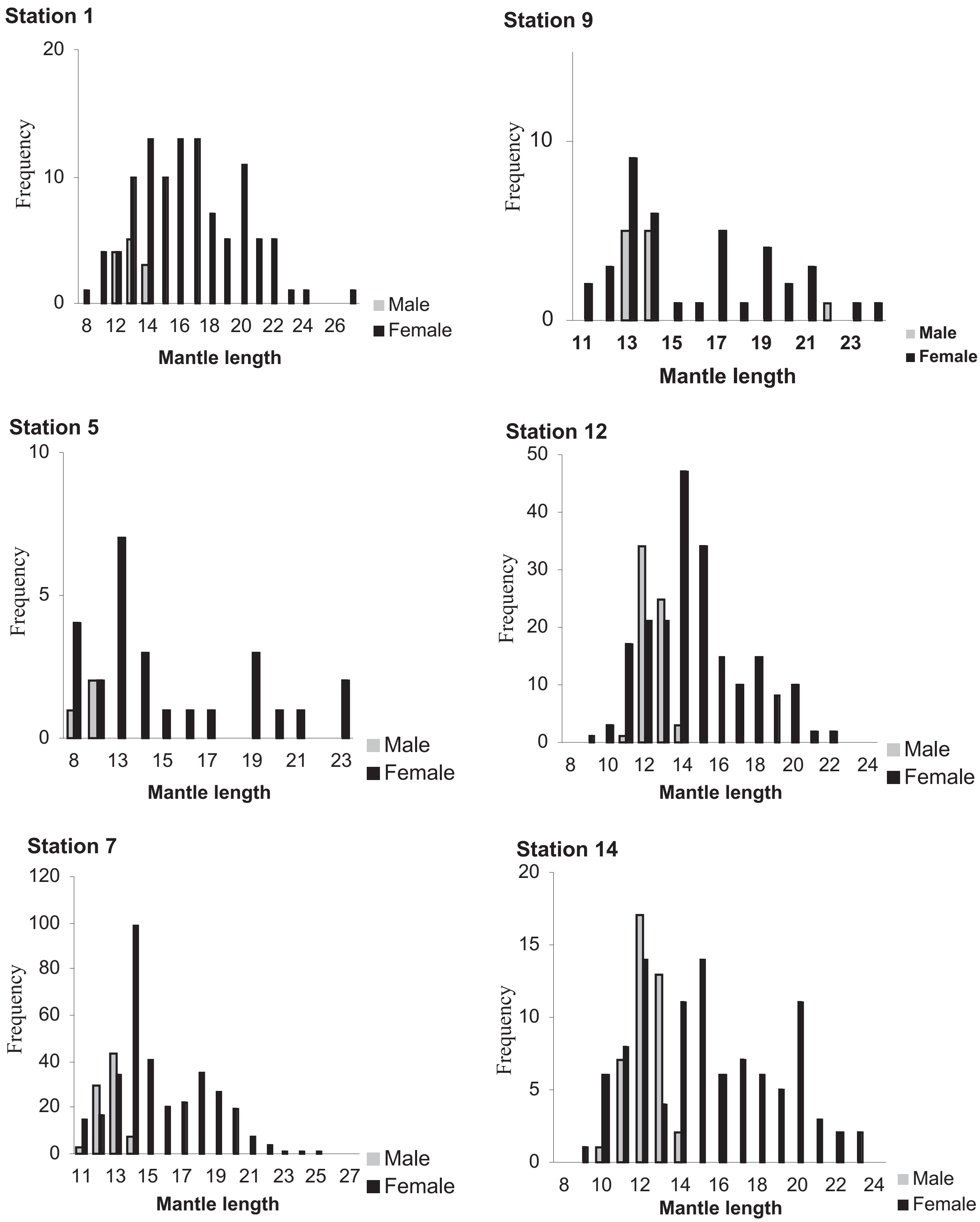

Fig.2. The length frequency distribution of male and female oceanic squid, *Stenoteuthis oualaniensis* at station 1,5,7,9,12 and 14.

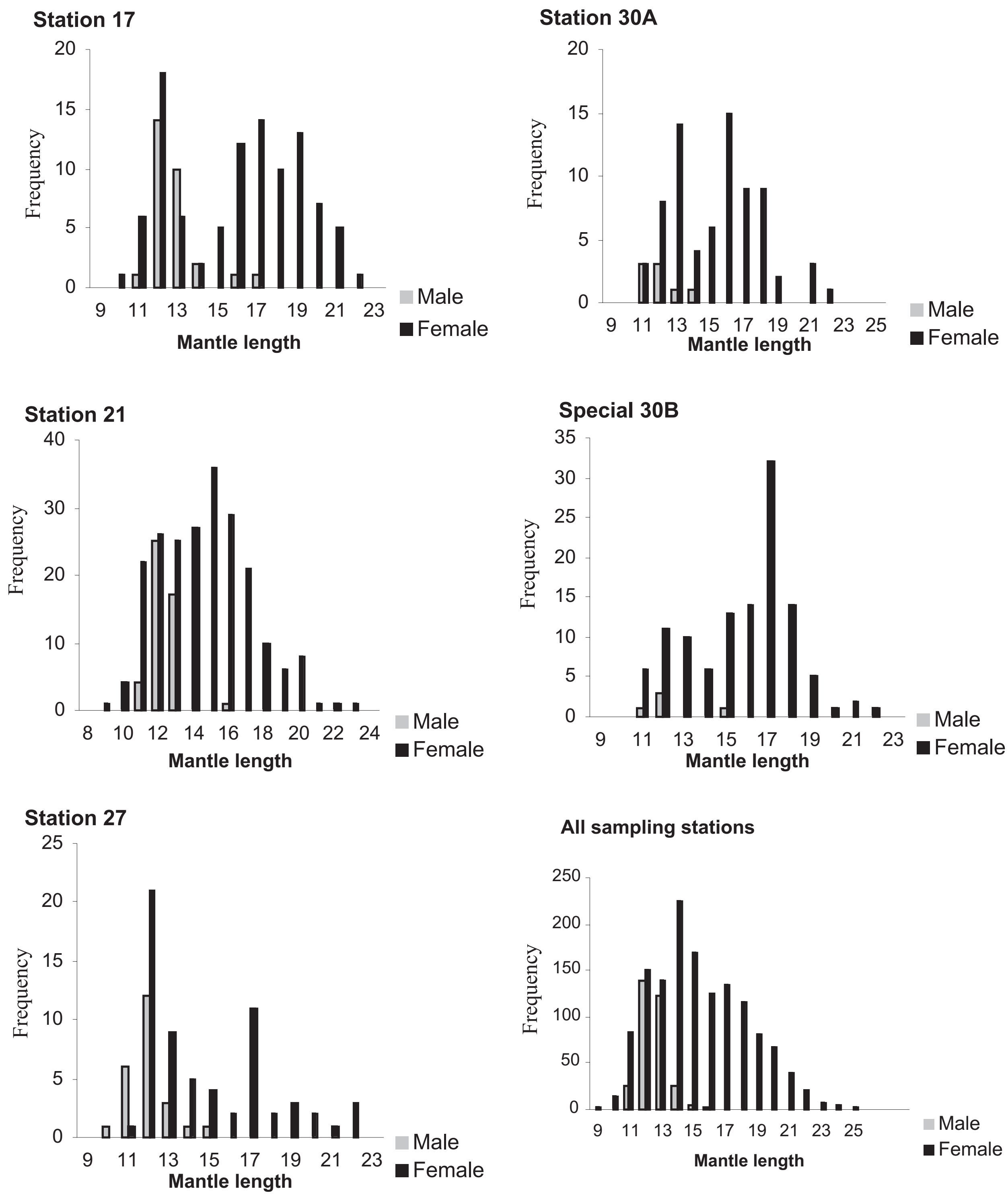

Fig.3. The length frequency distribution of male and female oceanic squid, *Stenoteuthis oualaniensis* at station 17,21,27,30A, 30B and pool data from all sampling station

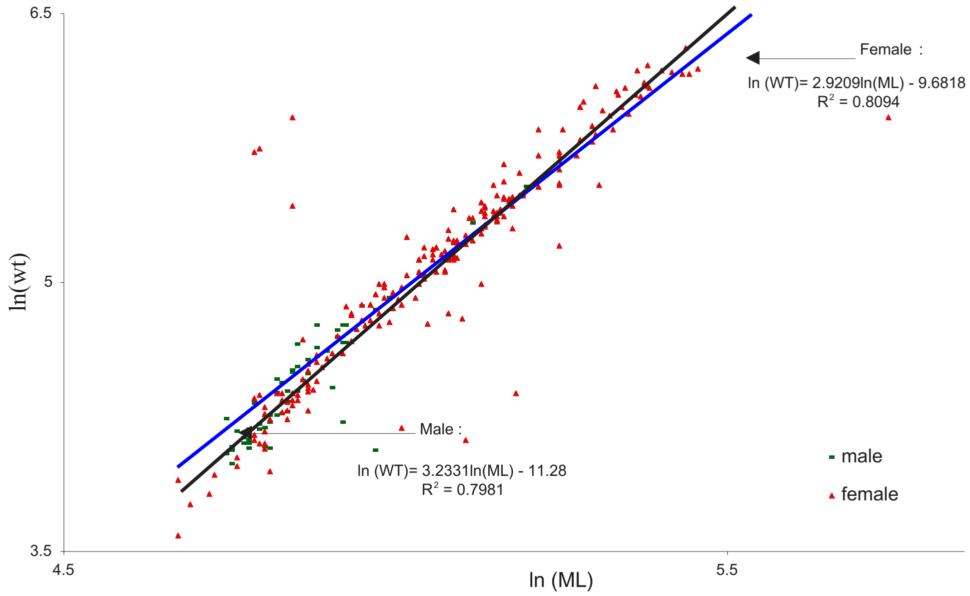

Fig.4. The length-weight relationship of male and female oceanic squid, *S. oualaniensis*.

Statolith morphology and microstructure

Statolith growth increments were faint but clearly visible in all statolith preparations. They are smooth and tiangular(Fig.5) with the dorsal dome relatively small and rounded. A lateral dome is present and is smooth. The rostral angle is obtuse and the rostrum long.

In the ground statolith of *Sthenoteuthis oualaniensis* four growth zones were observed (Fig. 6). The nucleus is oval in shape and is situated under the spur and is surrounded by the first faint growth increment. The post-nuclear zone is dark-coloured, located between the nucleus and the opaque zone. The number of narrow growth increments (0.9 – 1.2 μm) in the post-nuclear zone ranged from 12 to 29. According to Morris(1991), the post-nuclear zone is developed during embryogenesis. The well-pronounced check(‘natal ring’) lies on the boundary between the post-nuclear and opaque zones. It was observed that the growth ring of the male specimens are much clear and easier to processed as compared to the female specimens.

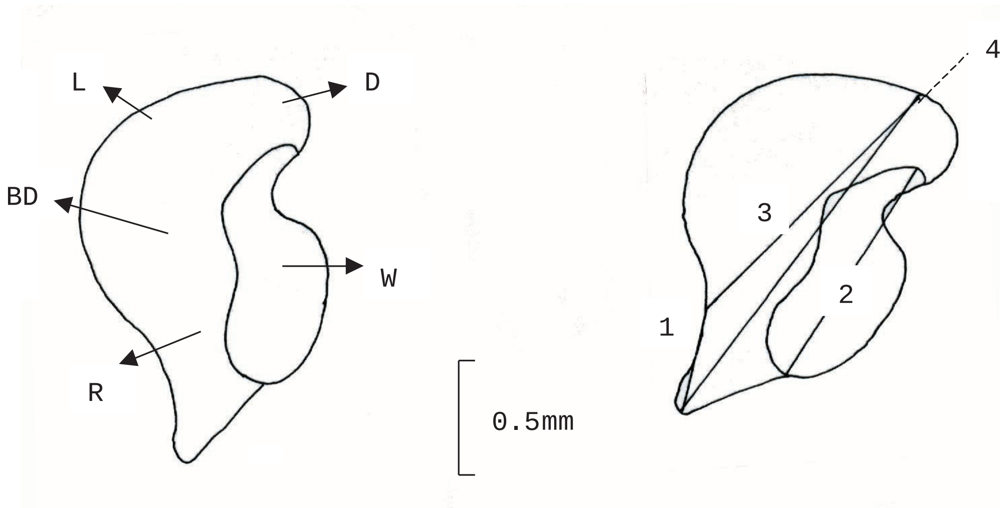

Fig. 5. Statolith of *Stenoteuthis oualaniensis*(mature female, ML 165 mm, (A) the anterior view of the statolith; D, dorsal dome; L, lateral dome; R, rostrum; W wing: BD statolith body, and (B) their measurements; 1, length of the rostrum; 2, wing; 3, statolith body; and 4, statolith length.

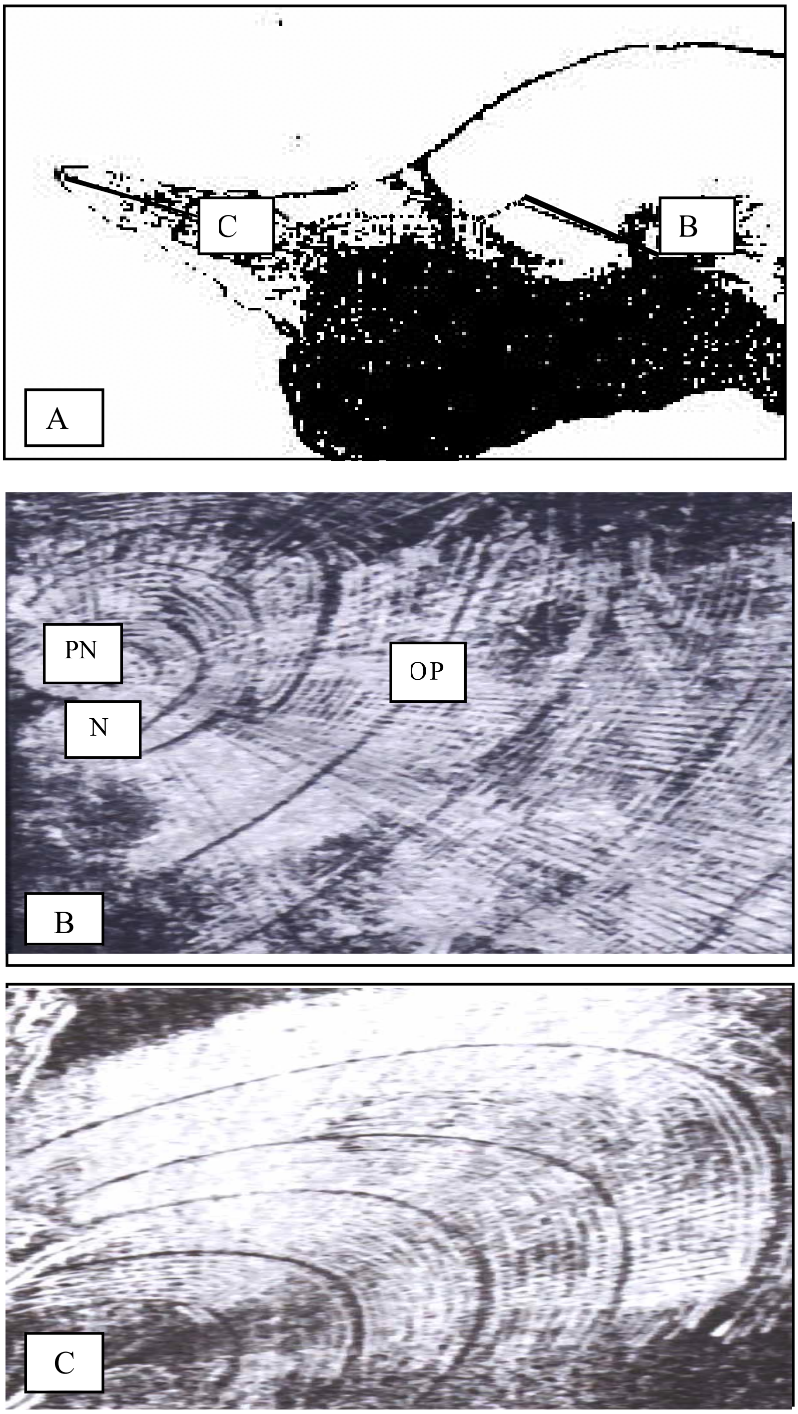

Fig. 6. Light micrograph of statolith *Stenoteuthis oualaniensis* from South China Sea, Western Philippines, Area III. (A) General view, (B) Growth zones; N, nucleus, PN, post-nucleur, OP, opaque, (C) Peripheral zone (PF) in the rostrum.

The opaque zone is light and almost translucent in transmitted light, but slightly opaque in reflected light. Growth increment are wide. A transition between the opaque and the peripheral zones is not clearly recognized and can be distinguished by a decreased in the width of the growth increments ranging from 2.2 to 3.7 µm in the peripheral zone of the rostrum. The peripheral zone is translucent. The number of growth increments in both opaque and peripheral zones ranges from 95 to 275.

Statolith growth

The correlation between the body size [dorsal mantle length(ML) and body weight(BW)] *vs* the statolith weight (sw) were depicted in Fig. 7 and Fig. 8. It was found that the male developed heavier weight of statolith compared to female. This might be due to the wider increments of the width of the male statoliths compared to the female at the same size (see Fig. 9).

At the same size of the dorsal mantle length the total statolith length of the females grow longer than the males population as shown in Fig. 10. It was also observed that there are three growth stages of female, i.e., first, the transitions periods from the immature to mature where the growth rates are slow, secondly, the growth rate increases dastically during various maturity stages and finally the growth reach their asymptode. The same phenomena also observed for male populations but at lower size class.

Allometric growth of the different parts of the statolith was studied. An index was calculated by dividing the statolith body, rostrum and wing lengths by the statolith length and multiplying the result by 100 for a percentage. Allometric growth was negative with the index of the body length and rostrum length(Fig. 11A and 11B) and positive for wing length/total statolith length.

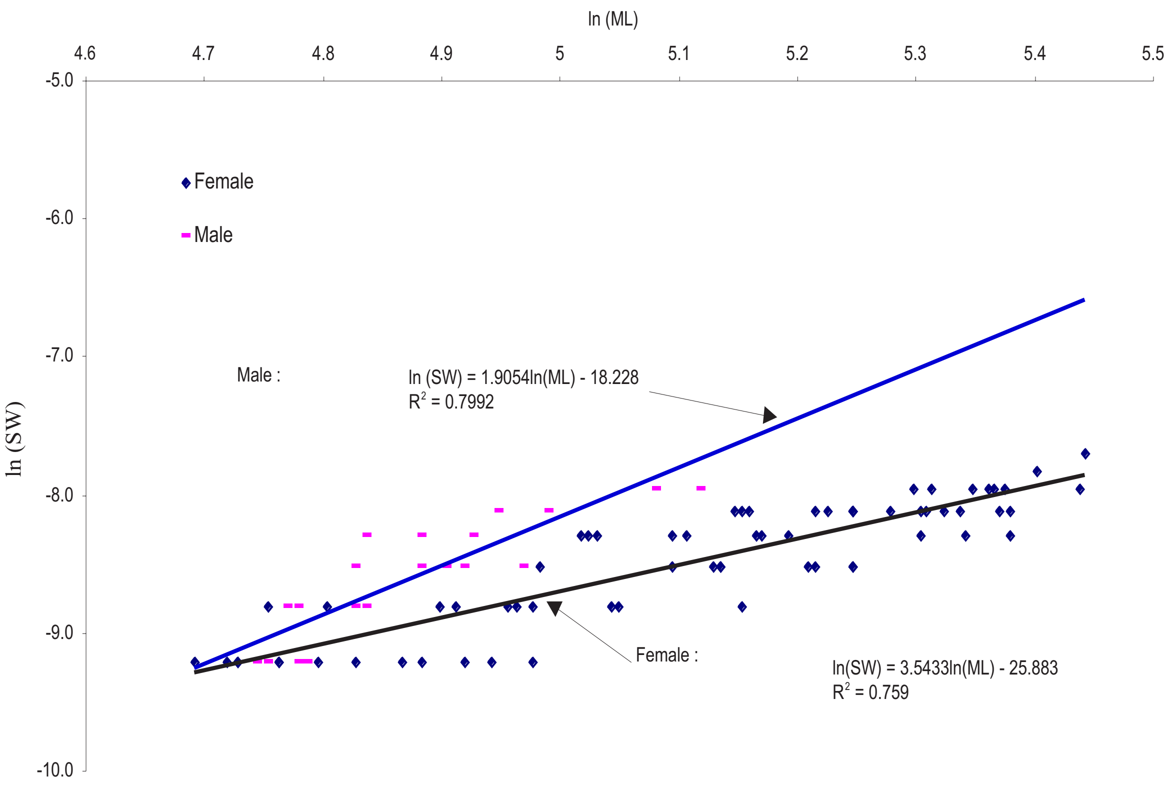

Fig. 7. Relationship between mantle length vs statolith weight of male and female oceanic squid, *Stenoteuthis oualaniensis.*

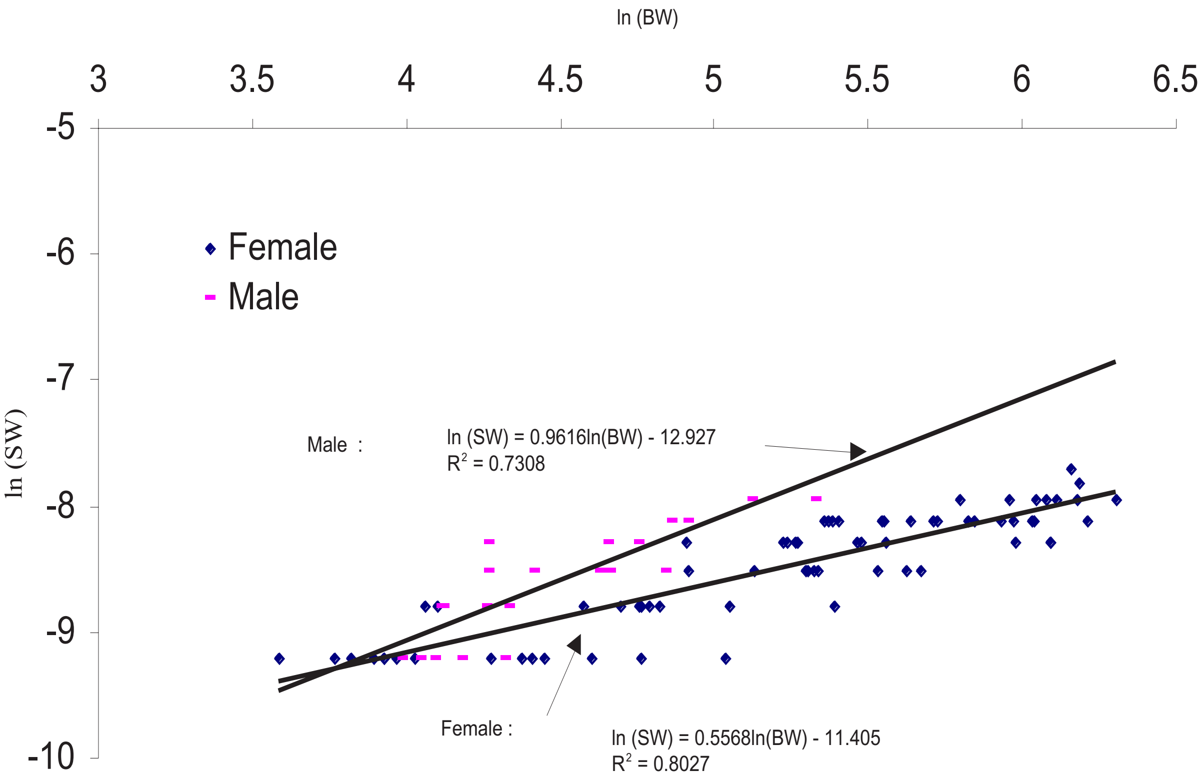

Fig.8. Relationship between body weight vs statolith weight of male and female oceanic squid, *Stenoteuthis oualaniensis.*

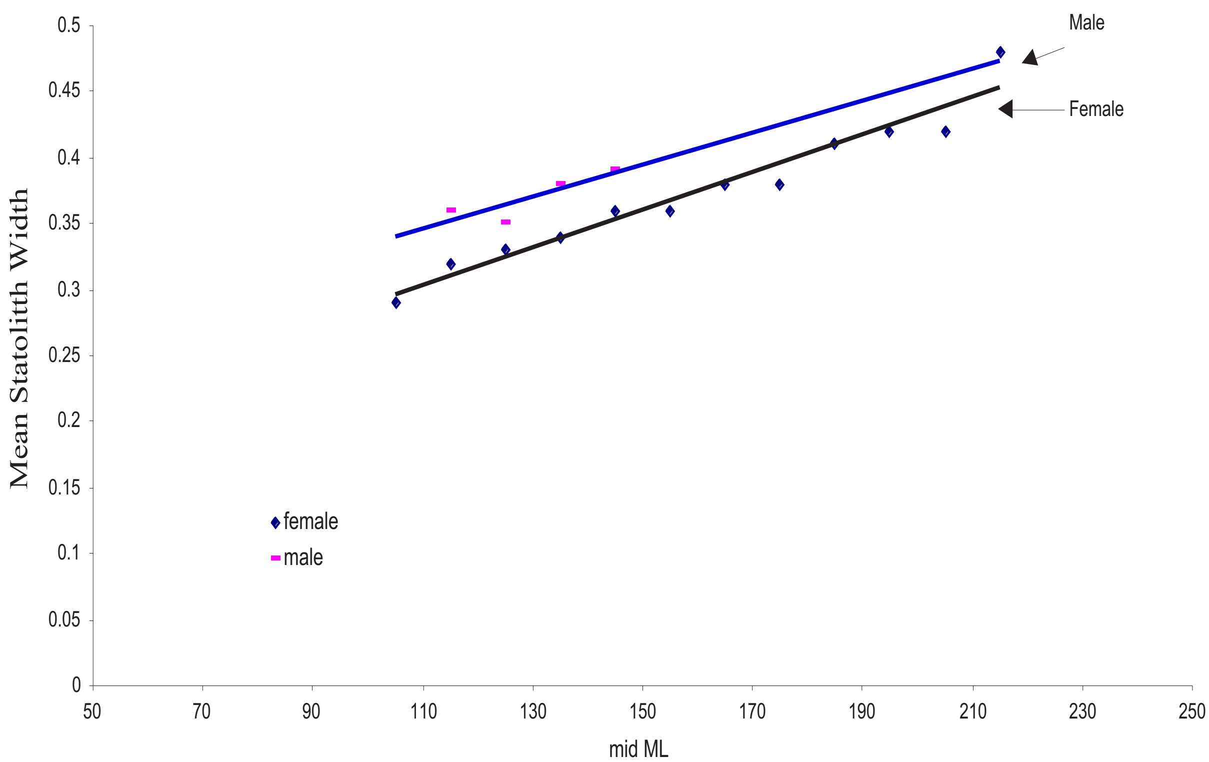

Fig.9. Comparison of the width length of the statolith for male and female oceanic squid, *Stenoteuthis oualaniensis.*

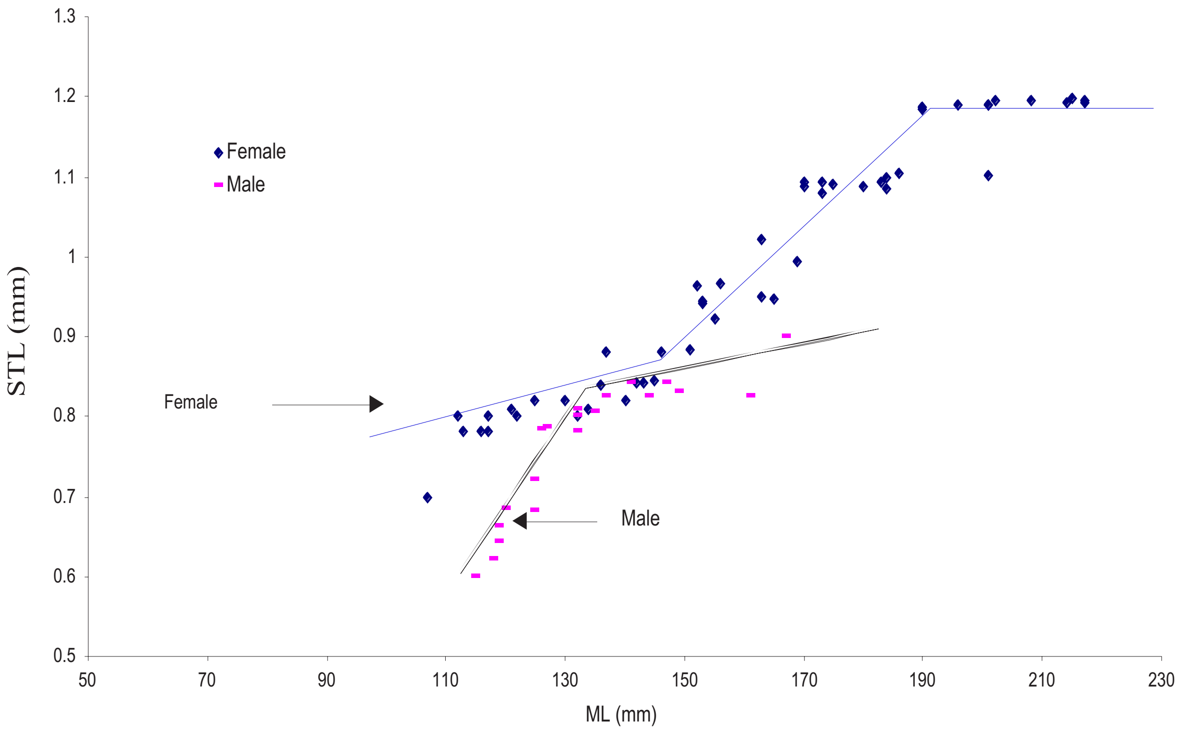

Fig. 10. Allometric growth of the total statolith length (TSL) vs mantle length (ML) for male and female oceanic squids, *Stenoteuthis oualaniensis.*

Age and growth of squids

In our samples, the smallest oceanic squids, *S. oualaniensis* of 107 mm ML was 102 d old. In female, *S. oualaniensis* the maximum age obtained was 275 d (217 mm ML) and for male 259 d (161 mm ML). These data shows that the females live longer than males. The females grew faster than males after they reach 100 mm (see Fig. 12).

It was observed that there is a weak correlation between the total body weight and the number of growth increments for male specimens. It would suggest that it is better that the correlation between the number of growth increments and the body mantle length be used rather than body weight especially for male (see Fig. 13) for these species.

Conclusions

Statolith of *S. oualaniensis* have a similar shape with loligonid statoliths, which are characterized by a well developed lateral and dorsal dome and a long finger-shape rostrum (eg. *Loligo forbesi*, Clarke,1978; *Photololigo edulis*, Natsukari *et al.*, 1988). However, there are slightly different in the dimension of growth between the males and females where males towards a wider statolith width length and female towards longer statolith length.

Since the length frequency distribution shows that there are two different cohorts of female sample population, i.e., the immature and mature population it might suggest that there might exist a prolong spawning seasons (see Fig. 14). The difficulty is that our population samples does not include the small squids size. This might be due to the selectivity of the fishing gears used during the sampling procedures.

We have dissected a sample of *S. oualaniensis* onboard of MV SEAFDEC which were chosen at

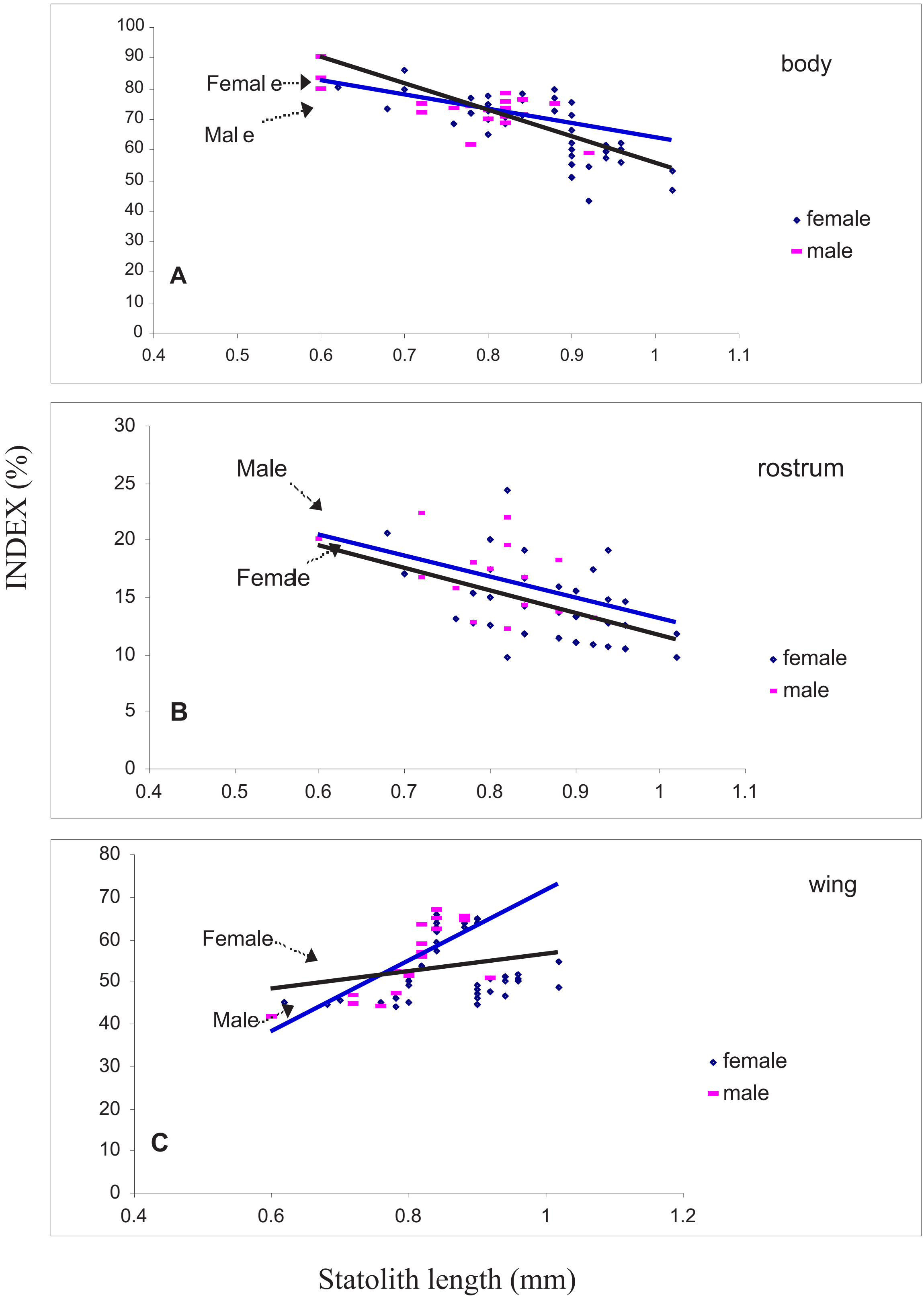

Fig. 11. Allometric growth of the length of (A) statolith body, (B) the rostrum and (C) the wing vs statolith length of oceanic squids, *Stenoteuthis oualaniensis.*

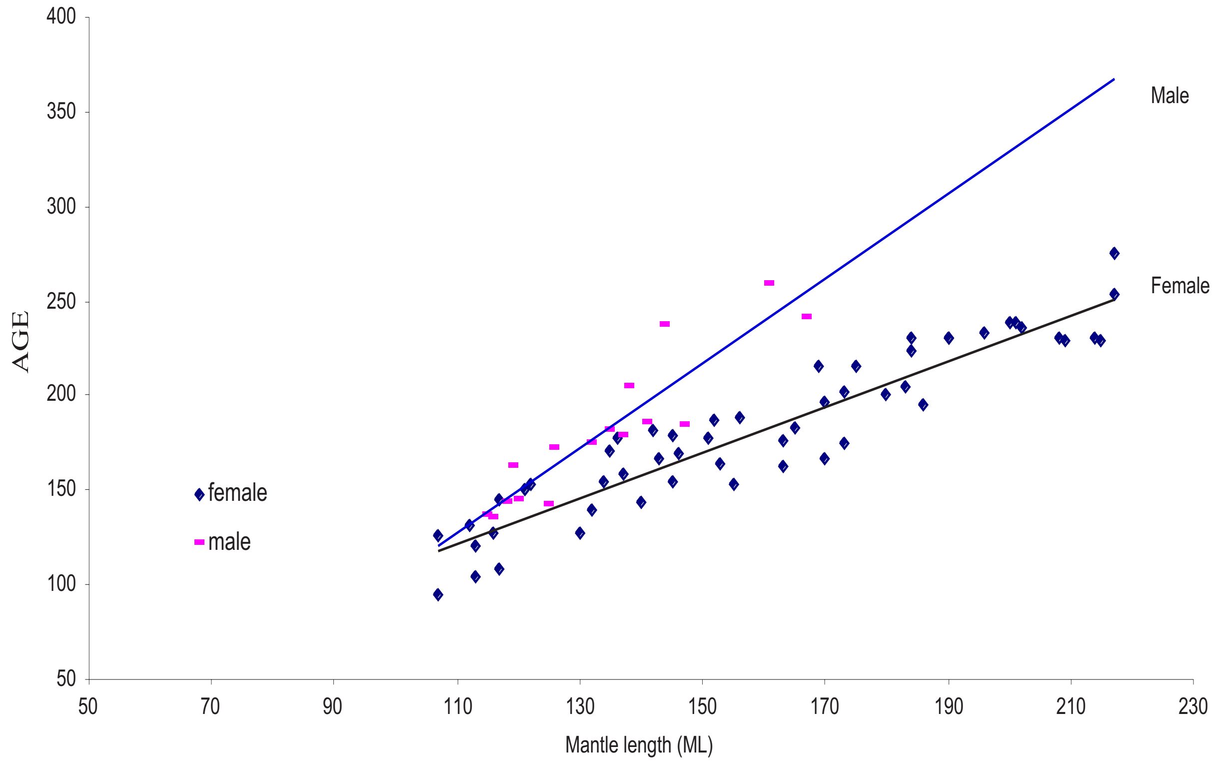

Fig. 12. Relationship between age (number of daily growth increments) and mantle length of male and female oceanic squids, *Stenoteuthis oualaniensis.*

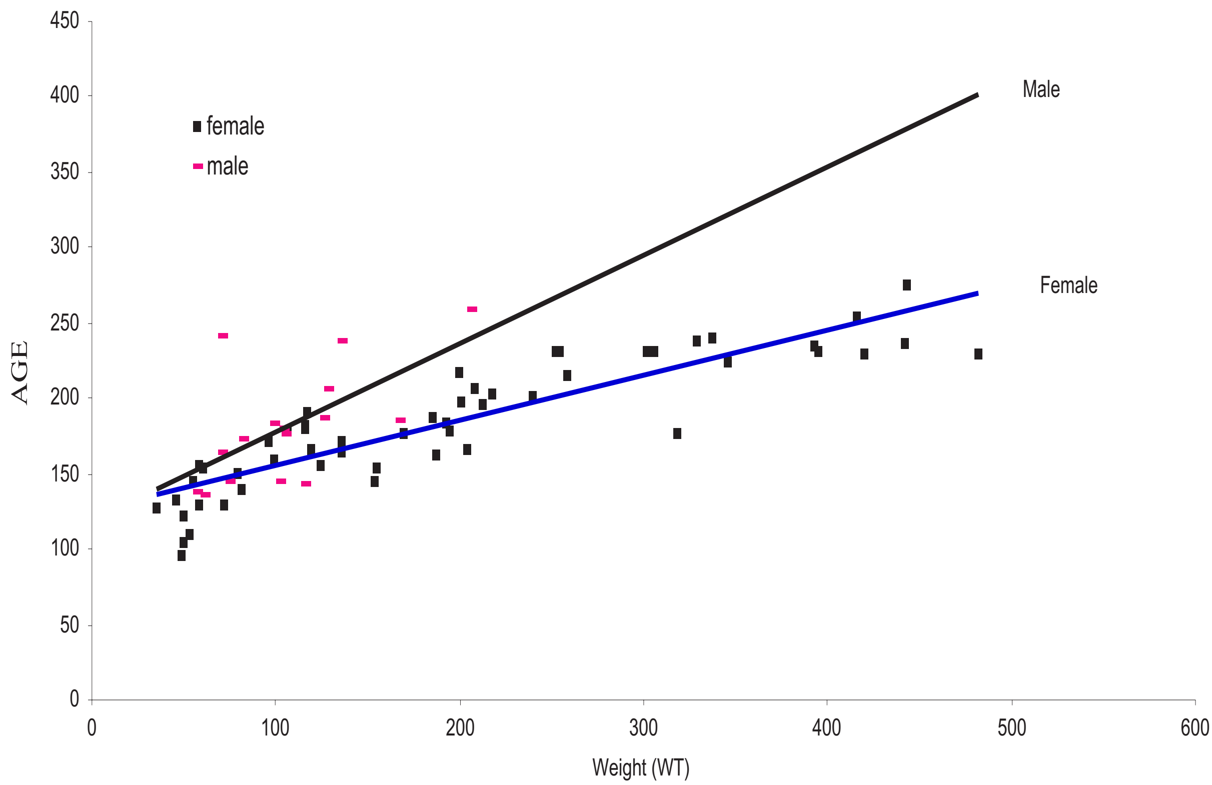

Fig. 13. Relationship between age(number of growth increments) and total body weight of male and female oceanic squids, *Stenoteuthis oualaniensis*

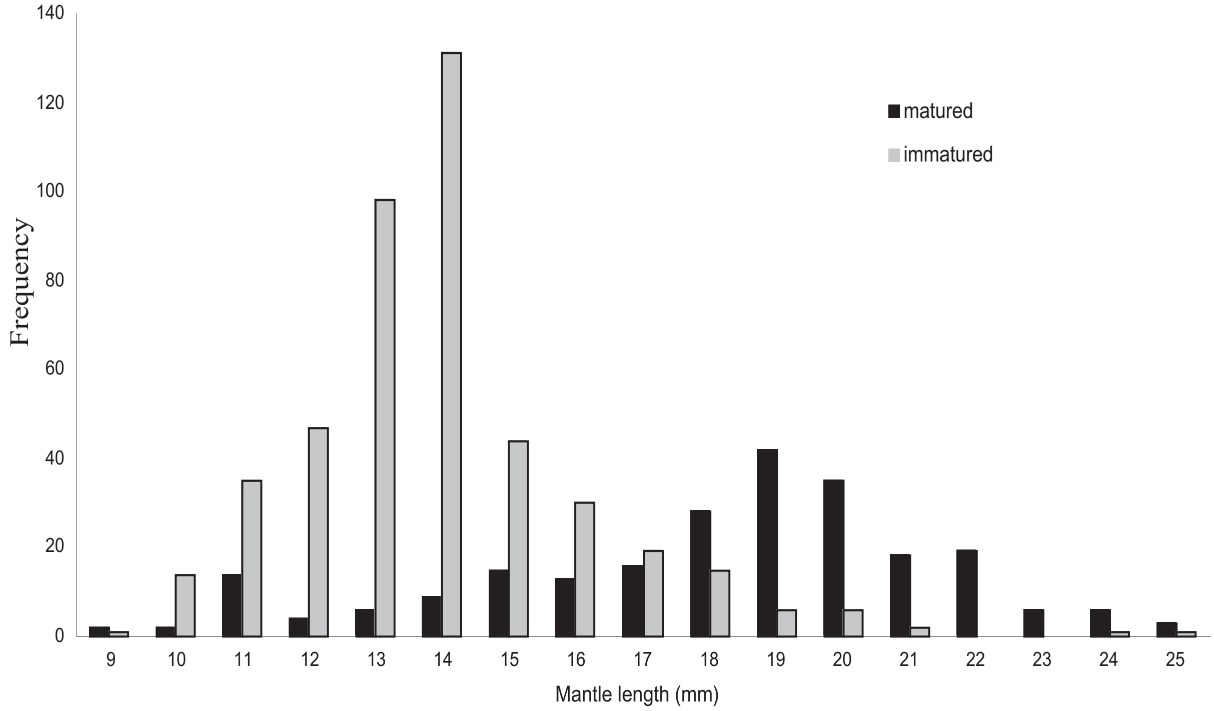

Fig. 14.Length frequency distribution of matured and immatured female of oceanic squid, *Stenoteuthis oualaniensis.*

a random sampel to quantified their maturity stages according to length. The result shows that there is roughly a correlation between the length of the female samples and the maturity stages (see Fig. 15). It can be assumed that the growth rate are very fast and these confirmed with the age reading through daily growth increment according to size. Therefore, the life span of the *Sthenoteuthis oualaniensis* are considered within 1 years. The presence of one peak for male and female would confirm these hypothesis. While the two or more peak for female representing the immature and mature female and the growth rate are very fast during these size.

Fig.15. The figure shows the maturity stages of oceanic squid, *Stenoteuthis oualaniensis* according to their length

Table 1. The table show the date and position of the sampling stations and their basic physical parameters and jigging operations

Stations	Date	Position	Position Start	Position End	Luring (time)	Jigging Start (time)	Jigging End (time)	No of jigs (number) M1	M2	M3	M4	Water depth (m)	Angling depth (m)	Trans-parency (m)	SST °C
1	17.04.1998	Lat. Long.	20° 2.600' N 119°56.800'E	20° 2.70' N 119°55.90'E	1825	1850	0000	60	60	60	60	3644	0 -120	23	25.9
5	19.04.1998	Lat. Long.	18°59.182'N 118°59.675'E	18°59.70'N 118°55.51'E	2000	2150	0100	32	32	32	32	2782	0 - 100		26.2
7	21.04.1998	Lat. Long.	18° 0.400'N 119° 0.280'E	17°59.40'N 119° 1.00'E	2105	2225	0300	32	46	44	32	1075	0- 120		25.9
9	22.04.1998	Lat. Long.	16°59.900'N 120° 1.700'E	17° 1.00'N 120° 4.30'E	1830	1835	2235	32	46	44	32		0 – 120		
12*	25.04.1998	Lat. Long.	16°59.700'N 117° 7.700'E		1910	1930	1938	44	44	46	44		0 – 120		
		Lat. Long.	16°59.640'N 117° 4.770'E	17° 0.48'N 117° 2.01'E		1938	0130	44	44	46	44	4042	0 - 120		
14	27.04.1998	Lat. Long.	15°59.500'N 118° 6.000'E	15°56.60'N 118° 3.64'E	1830	1830	2300	44	44	44	44		0 – 120		
17	29.04.1998	Lat. Long.	15° 0.640'N 118° 59.520'E	15° 5.10'N 118° 57.30'E	2320	2345	0445	44	44	44	44		0 – 120		30.16
21	30.04.1998	Lat. Long.	14° 0.500'N 117°59.900'E	14° 5.30'N 117° 57.10'E	1900	1910	0110	44	44	44	44		0 – 120		30.4
27	05.05.1998	Lat. Long.	13° 0.400'N 117° 6.410'E	13° 3.60'N 117° 5.40'E	1826	1830	0300	44	44	44	44	1260	0 – 120		30.26
30A	08.05.1998	Lat. Long.	11°59.800'N 118°45.300'E		1905	1950	0230	40	40	43	30	1622	0 – 120		30.69
30B	09.05.1998	Lat. Long.	12°47.600'N 119° 9.000'E	12°49.70'N 119° 7.20'E	1830	1845	0300	40	40	43	-	2109	0 -120		31.35

*jigging operation at first location by searching using echo sounder.

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