Age and Reproduction of *Sthenoteuthis oualaniensis* in the Bay of Bengal

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Abstract

The specimens of *Sthenoteuthis oualaniensis* were caught by automatic squid jigging machines in the Bay of Bengal from 6 November to 7 December 2007. Fifteen fishing stations were conducted in three areas off Bangladesh waters, India and Sri Lanka waters, and Myanmar waters. Size distribution of *S. oualaniensis* ranged from 105 mm ML to 221 mm ML (169±30.8 mm ML in average and SD, n=32) for females and from 45 mm ML to 124 mm ML (104±28.2 mm ML in average and SD, n=7) for males, respectively. Statoliths from a total of 34 individuals (6 males, 28 females) of specimens (ML ranged from 45 to 221 mm) were used for the age estimation. Age of *S. oualaniensis* estimated from the counting of the statolith increments ranged from 63 days at 175 mm ML to 120 days at 199 mm ML for females and 40 days at 45 mm ML to 114 days at 124 mm ML for males, respectively. The mean age of females and males were 81.1 and 79.2 days old, respectively. The ML-BW relationships for *S. oualaniensis* was expressed as $BW = 16.183ML^{4.1603}$ ($r^2 = 0.855$, n = 32, 105-221 mm ML) and $BW= 2.932ML^{1.4875}$ ($r^2 = 0.622$, n = 7, 45-124 mm ML) for female and male, respectively. Based on the back calculation on the specimens collected from 6 to 30 November 2007, hatching date of the females *S. oualaniensis* was estimated to be from July to October 2007. There were different growth rates between sexes. Males those hatched in the same period with females grew with slower growth rates and captured in a smaller size than females.

Key words: *Sthenoteuthis oualaniensis*, age, reproduction, Bay of Bengal

Introduction

The purpleback flying squid *Sthenoteuthis oualaniensis* (family Ommastrephidae) is widely distributed in the tropical and subtropical areas of the Indo-Pacific and Indian Ocean (Nesis, 1977; Voss, 1973; Carpenter and Niem, 1998). The biomass of *S. oualaniensis* in the Indian Ocean was estimated to be about two million tons by the counting of the squid at the surface at night light stations (Zuev *et al*., 1985). Pinchukov (1989) and Zuev *et al*.(1985) had been reported the biomass of *S. oualaniensis* in the Indian Ocean was generally ranged from 50 to 75 kg per square km and high concentration from 4 to 42 ton per square km was mainly found in the Arabian Sea. The latest assessment of the total biomass of those squid throughout its range was about 8 to 11 million tons (Nigmatullin, 1990). Recent studies had been suggested that *S. oualaniensis* is probable under exploited resources and could sustain higher exploitation levels in the future (Dunning, 1998; Xinjun *et al*., 2007; Yatsu, 1997).

Since the statolith microstructure is useful for age determination of squids as otoliths in teleost fishes, the age and growth of *S. oualaniensis* are relying on the indirect validation studies, assuming the daily deposition of increments (Arkhipkin and Bizikov, 1991; Takagi *et al*., 2002). The squid was reported a short life span (1-1.5 years), high growth rates and complex population structure at least three main forms are distinguishable with and

without a large dorsal photophore, and different by the structure of the gladius (Zuev and Nesis, 1971; Nesis, 1977; Zuev *et al*., 1985; Nesis, 1993; Yatsu, 1997; Yatsu *et al*., 1998). As a consequence of those important component of *S. oualaniensis* in the marine ecosystem and has been interested from the view point of target of commercial fisheries of the Indian Ocean. More information on the fishery biology of *S. oualaniensis* needs more attention. The present study is objective to provide information on age and reproduction of *S. oualaniensis* collected during the BIMSTEC survey in the Bay of Bengal from 6 November to 7 December 2007.

Materials and Methods

Data Ccollection and Method of Analysis

The specimens of *Sthenoteuthis oualaniensis* were caught by automatic squid jigging machines in the Bay of Bengal from 6 November to 7 December 2007. Fifteen fishing stations were conducted in three areas off Bangladesh waters (area A; latitude 16°N-19°N, longitude 88°E-91°E), India and Sri Lanka waters (area B; latitude 09ºN-14ºN, longitude 82°E-85°E), and Myanmar waters (area C; latitude 10°N-12°N, longitude 95°E-97°E) (Fig. 1 and Table 1).

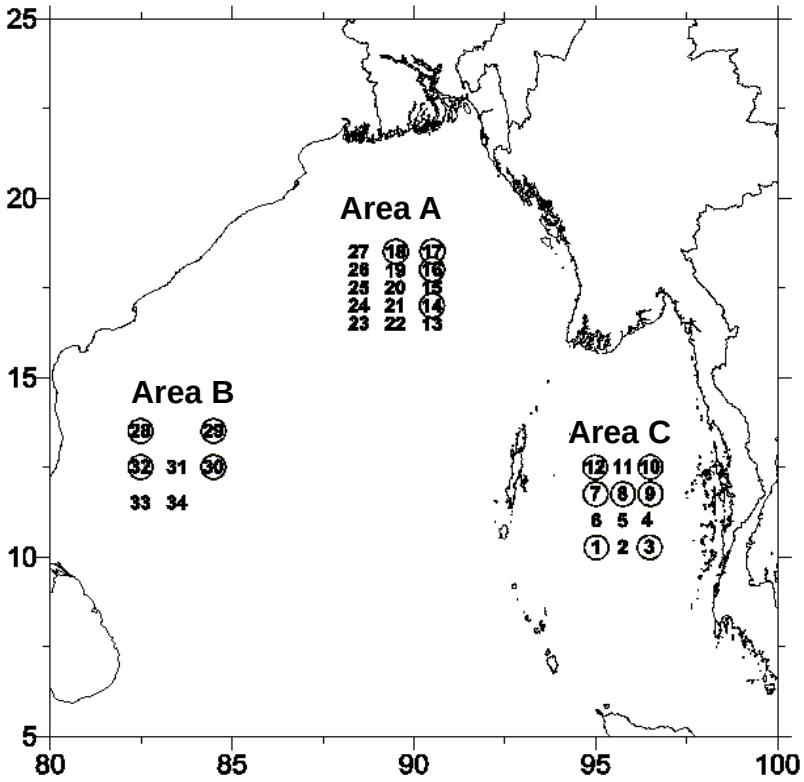

Figure 1 Map of survey stations in the Bay of Bengal. The station numbers in the circle show the fishing stations of the automatic squid jigging.

Squids were sexed using the presence or absence of the male sex organ called hectocotylus. Measurements were made on dorsal mantle length to the nearest 0.1 mm (ML in mm) and wet body weight (BW in g) to the nearest 0.1 g. A total number of individuals of *S. oualaniensis* was examined, and the mantle length ranged from 45 to 124 mm ML (n=7) and from 105 to 221 mm ML (n=32) for male and female, respectively (Table 1).

After dissection of mantle, sexual maturity stages were determined based on the

definition of stages I to VI of Lipinski and Underhill (1995), stages I and II were defined as immature stage, stage III as maturing stage, stages IV and V as mature stage, and stage VI as spent in the present study.

Statolith Handling and Ageing Technique

Paired statoliths were collected from specimens and stored in liquid paraffin until preparation following the method of Dawe and Natsukari (1991). The right statolith was used for counting increments. If the increment definition of the right statolith was poor, the left one was also examined. Anterior side of statolith was ground with 3M slim rubbing film sheet No. 4000-15000. Statolith increments were observed under an optical microscope (x400) (with digital camera attached). The image of increments were taken by digital camera and transferred to personal computer for counting on the number of growth increments. Counting of increments was made from the nucleus to the dorsal dome.

Statoliths from a total of 34 individuals (6 males, 28 females) of specimens (ML range from 45 to 221 mm) were readable and used for the age estimation.

Size at Age and Ggrowth

Since the daily deposition of statolith increments had been validated in Ommastrephid squids (*Todarodes pacificus*, *Illex argentinus*, *Ommastrephes bartramii*, *Sthenoteuthis oualaniensis*, *Dosidicus gigas*), age in the present study was estimated relying on the assumption that the increments of *S. oualaniensis* statoliths were estimated as daily increment (Rodhouse and Hatfield, 1990; Arkhipkin and Bizikov, 1991; Jackson, 1994; Yatsu, 1997; Yatsu *et al*., 1998; Takagi *et al*., 2002).

Recently, the non-asymptotic growth models, included linear, exponential and power curves have been applied in many studies (*I. lllecebrosus*, Balch *et al*., 1988; *S. oualaniensis*, Arkhipkin and Bizikov, 1991; *O. bartramii*, Bower, 1996; *D. gigas*, Matsuda *et al*., 1998). In the present study, the linear regression was applied to the relationship between the estimated age (t in day) and mantle length (ML in mm) (Arkhipkin and Bizikov, 1991; Yatsu, 2000) as follows;

$$ML = ML_o + at$$

Where ML_o = 2.0 (since the smallest paralarvae of *S. oualaniensis* is 2.0 mm in ML was collected during the survey); ML = Mantle length (in mm); t = estimated age (in day); a = least-squares linear regression coefficient.

The relationship between the mantle length (ML in mm) and total body weight (BW in g), expressed as $BW = aML^b$, were fitted by the least-squares linear regression of log transformed variables.

Table 1 Summary of the survey areas and sample collection of *Sthenoteuthis oualaniensis* between 6 November to 7 December 2007.

Survey station no.	Fishing operation no.	Date	Fishing position		No.of jig	No.of line	Immersion time (hrs.)	Sea depth (m)	Angling depth (m)	Total catch (individual)		ML range (mm)	Weight range (g)	Total weight (g)
			Latitude	Longitude						Female	Male			
Area C														
1	1	6 /11/ 2007	10_18.2 N	095_01.0 E	100	4	4.0	2,365	75-100	5	1	124-180	90-280	1,030
3	2	7 /11/ 2007	10_14.4 N	096_32.8 E	100	4	4.0	538	75-100	-	1	116	75	75
7	3	10 /11/ 2007	11_04.9 N	095_36.3 E	100	4	3.3	513	75-100	4	-	175-210	220-410	1,220
8	4	11 /11/ 2007	11_54.5 N	095_06.7 E	110	4	3.3	2,841	75	5	1	121-202	20-420	980
9	5	12 /11/ 2007	11_45.6 N	096_32.4 E	110	4	3.5	883	75-100	6	1	122-216	90-500	2,020
10	6	13 /11/ 2007	12_04.5 N	096_23.4 E	110	4	4.0	1,128	75-100	2	1	109-175	20-200	260
12	7	15 /11/ 2007	12_29.5 N	094_54.5 E	110	4	4.0	1,418	75	3	-	105-190	50-300	450
Area A														
14	8	17 /11/ 2007	16_49.5 N	090_20.9 E	110	4	4.0	2,353	50	3	1	45-221	18-650	798
16	9	18 /11/ 2007	18_01.4 N	090_35.7 E	110	4	4.0	2,136	75	4	-	163-181	100-180	500
17	10	19 /11/ 2007	18_27.0 N	090_28.3 E	100	4	0.4	2,353	75	operation cancelled due to the damage of jigging lines				
18	11	20 /11/ 2007	18_30.8 N	089_28.9 E	100	4	3.0	2,012	75	-	-	-	-	-
Area B														
29	12	28 /11/ 2007	13_25.0 N	084_27.0 E	100	4	4.0	1,418	75	-	-	-	-	-
30	13	29 /11/ 2007	12_25.0 N	084_25.0 E	100	4	4.0	3,329	75	-	-	-	-	-
28	14	30 /11/ 2007	13_30.6 N	082_29.8 E	100	4	4.0	2,353	75	-	1	93	20	20
32	15	1 /11/ 2007	12_27.6 N	082_18.9 E	100	4	4.0	3,425	75	-	-	-	-	-

Hatching Time and Spawning Period

Date of the hatching was estimated by back-calculation from the data of the capture of the specimen using statolith increment counts.

Results

Variation in Size and Age Distribution

Size distribution of *S. oualaniensis* ranged from 105 mm ML to 221 mm ML (169±30.8 mm ML in average and SD) for females and from 45 mm ML to 124 mm ML (104±28.2 mm ML in average and SD) for males, respectively.

Age of *S. oualaniensis* estimated from the counting of the statolith increments ranged from 63 days at 175 mm ML to 120 days at 199 mm ML for females and 40 days at 45 mm ML to 114 days at 124 mm ML for males, respectively. The mean age of females and males were 81.1 and 79.2 days old, respectively.

ML-BW Relationships

The ML-BW relationships for *S. oualaniensis* was expressed as $BW = 16.183ML^{4.1603}$ ($r^2 = 0.855$, n = 32, 105-221 mm in ML) and $BW= 2.932ML^{1.4875}$ ($r^2 = 0.622$, n = 7, 45-124 mm in ML) for female and male, respectively (Fig. 2).

Size and Age at Sexual Maturation

Length distribution of each maturity stage of female squid ranged in size from 105 mm ML to 134 mm ML for immature stages (stage I and II combined), ranged size of 118-181 mm ML for maturing stage (stage III), and a range size of 168-221 mm ML for mature stage (stage IV). There were differences in male maturities as immature and maturing individuals were smaller than female and ranged in size of 45-109 mm ML and 116-124 mm ML, respectively. A single specimen of mature male at mantle length of 121 mm was found in this study.

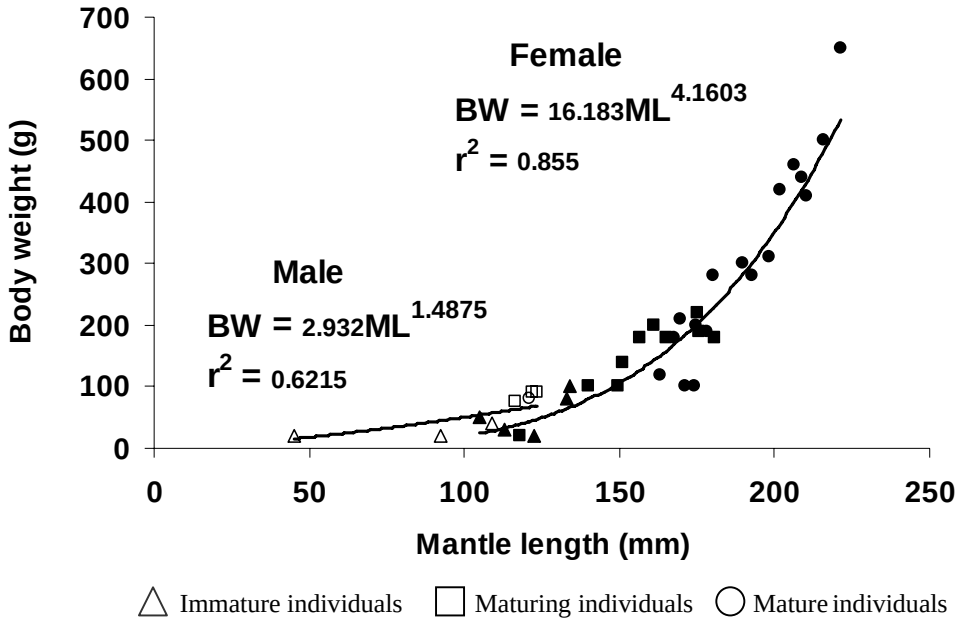

Figure 2 The relationship between mantle length (mm) and body weight (g) for male (open symbol) and female (closed symbol) *S. oualaniensis*.

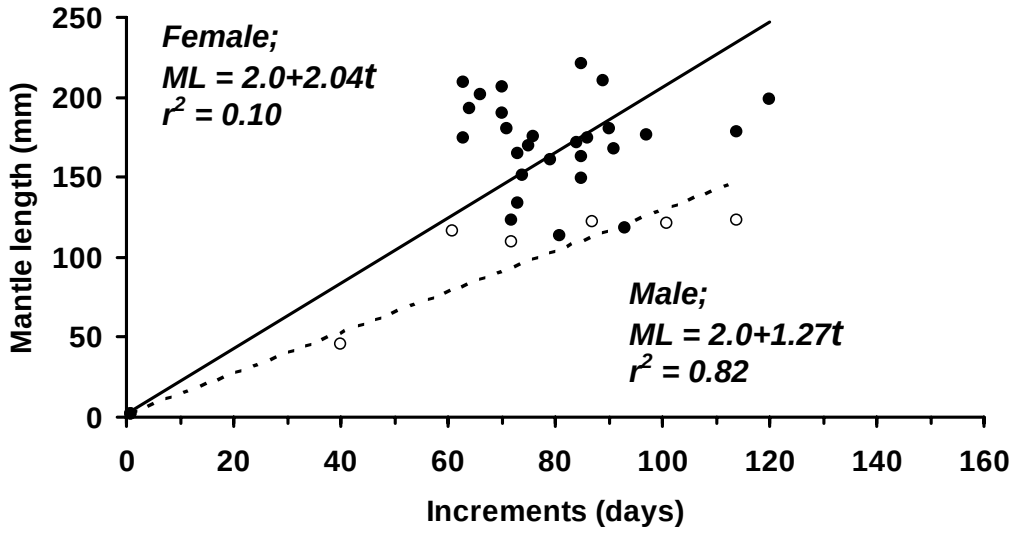

Figure 3 The relationship between statolith increments (days) and mantle length (mm) for male (open circle) and female (closed circle) *S. oualaniensis*.

The age of immature females varied between 72 and 81 days, and that of the males varied between 40 and 70 days old. The age of maturing females were younger than males with a range of 73-97 days old, and that of the males ranged between 61 and 114 days old. Wide range of age at matured females was found between 63 and 120 days old. The biggest squid analyzed was a mature female of 221 mm ML (85 days) whereas the mature male of 121 mm ML was age 101 days old.

Size at Age and Hatching Date

The relationship between the number of increments (days) and ML was plotted in fig. 3. The linear regression lines show that females had progressively faster growth than males (Fig. 3).

Based on the back calculation on the specimens collected from 6 to 30 November 2007, hatching date of the females *S. oualaniensis* was estimated to be from July to October 2007. Fig. 4 indicated the relationships between estimated hatching date and ML at the date of capture. An individual growth lines for each male and female squid hatched in July and early of August had the shallower individual growth slopes indicating a slower rate of growth (Fig. 4). There were differences growth rate between sexes. Likewise those males hatching in the same period of females had lower growth rates and be captured in a smaller size than females.

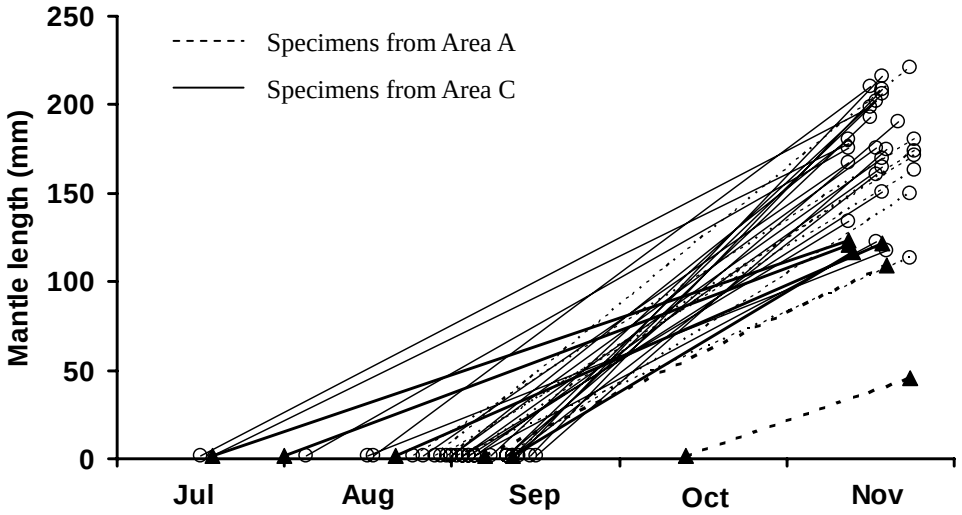

Figure 4 The relationships between estimated hatching date and ML at the date of captured for male (closed triangle) and female (open circle) *S. oualaniensis*.

Discussion

The size distribution of the *S. oualaniensis* specimens in the present study was recognized two forms according to Nesis (1993). First form is the dwarf immature and early maturing males of 45-124 mm ML and females of 105-176 mm ML, without dorsal photophore. Second form is the middle-sized maturing and early mature female of 163-221 mm ML with dorsal photophore. All the squids caught in the eastern Bay of Bengal (area A and C) tended to be smaller than those caught in the Red Sea, Arabian Sea and around the area of the northwestern

Indian Ocean (Nesis, 1977b, 1985, 1993; Yatsu, 1997; Xinjun *et al*., 2007). The *S. oualaniensis* specimens contain form 1 (Nesis, 1993) was also reported in the Andaman Sea of Thailand by Nateewathana (1997). These specimens were lack of dorsal photophores, but the females were much longer than 120 mm ML (the biggest specimen, PMBC no.11795, 323 mm ML; Nateewathana, 1997). The size distribution of *S. oualaniensis* in the present study is consistent with the previous results from the former USSR research in summer of the West Indian Ocean. The ML was mainly in the range of 90-180 mm ML, and 80-270 mm ML, and in the winter mainly ranged from 90 mm to 180 mm ML (Trotsenko and Pinchukov, 1994). The size ranged from 74 mm to 321 mm ML with the dominant group in the range of 110-250 mm ML was also reported as by-catch in the Chinese trawling boats (Yang, 2002).

The complex population of *S. oualaniensis* had been described three major and two minor forms by Nesis (1993). Those characters were important and attempt was made many times to describe as a separated species (Clarke, 1965 and Wormuth, 1976). The dwarf form was also suggested to be a separate species that could only be identified as an adult (Xinjun *et al*., 2007). Snyder (1998) suggested that the giant form resulted from a plastic phenotype in the species. A new study based on RADP DNA (Random Amplified Polymorphic DNA) analysis is being done in Marine Science and Technology of Shanghai Fisheries University, and preliminary findings suggest a large variation in biology among the groups (Xinjun *et al*., 2007).

The development of dorsal photophore and the structure of the hectocotylus were suggested to be affected by the combination of growth and maturation (Nesis, 1977b). The photophore is being to develop when squid reaches a ML of approximately 10 cm, but if maturation does not begin, the photophore development will be blocked. However, this hypothesis was cited but not verified (Nesis, 1993).

Many studies indicate that *S. oualaniensis* had its life span less than 1 year (Nesis, 1993; Dong, 1991; Trotsenko and Pinchukov, 1994). However, the result from age determination based on daily increments of statoliths which samplings were different both in locations and time. Yatsu (2000) determined growth curves for both sexes and reported a female of 120 mm ML at 51 days old which contrast to the data of Zaidi bin Zakaria (2000), which places a 115 mm ML female at an age of 95 days. This may suggests that environmental conditions such as temperature and food availability are the main factors influencing to growth rates, lifespan and fluctuations of relative gonad investment. Lastly the process to count the daily increment might suggest a bit different output since there has no verification from several counters in the same specimens.

S. oualaniensis has been subjected to commercial exploitation in the northwestern Indian Ocean by the Chinese squid jigging boats (Xinjun *et al*., 2007). The species also commercially fished off Okinawa, Taiwan and Hawaii as a tuna bait and human consumption (Okutani and Tung, 1978). Although this species is abundant in the South China Sea region but the fishery has never succeeded. It is low value for human consumption relatively to other squids and due to its toughness. A wide ecological amplitude character, complex intraspecific structure, high fecundity, short life cycle, high growth rate and significant production (Zuev and Nesis, 1971; Nesis, 1977; Zuev *et al*., 1985; Xinjun *et al*., 2007) make this species an interesting for further study on life history. However, the prior needs to the development of a commercial fishery for this species in the survey area especially in the eastern Bay of Bengal, are more data collection and information on distribution and fishery biology. At present this species has not been yet exploited in the Andaman Sea of Thailand.

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