Reproductive biology of Indian squid, *Uroteuthis duvauceli* (Orbigny, 1835), in the northern Gulf of Oman

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Abstract

Some aspects of the reproductive biology of the Indian squid, *Uroteuthis duvauceli,* were studied from June 2006 to May 2007. A total of 1200 specimens were collected from approximately 30-80m depths by trawling in 50 stations, of which 360 samples were studied for sex determination and fecundity. The minimum and maximum total and mantle length, and body weight were recorded in December and June, respectively. The highest range of total length (410-420mm), mantle length (150-160mm and body weight (90-100g) were encountered in September. The specimens were composed of 34% male and 66% female (M:F = 1:2). This species was found to be more abundant in summer. The minimum and maximum ovary weighs were 2.1g and 7.9g with an average of 4.9g, respectively. These values for nidamental gland weight were 0.70 and 2.61g with an average of 1.6g. The minimum and maximum absolute fecundity were 25510 (in August) and 375600 (in April), respectively. These values for relative fecundity were 5207 (in April) and 867 (in August), respectively. The highest gonadosomatic index (GSI) was in April (14.38) and the lowest was in July (8.63). This squid is, therefore, assumed to be a spring spawner. Minimum and maximum egg diameter were 0.72mm (in August) and 2.5mm (in April), respectively.

Keywords: Indian squid, *Uroteuthis duvauceli*, Fecundity, GSI, Sex ratio, Gulf of Oman

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Introduction

Worldwide fishery during the last two decades has greatly enhanced cephalopods ranking among fishery resources. Cephalopod landings reached 2.9 million metric tones in 2003 (80% of which was squid) and the potential of cephalopods as exploitable resources is believed to lie far beyond that (FAO, 2005). Indian squid, *Uroteuthis duvauceli,* is a neritic species of the commercially important family Loliginidae, which are often caught by jigging or trawling (Boyle & Rodhouse, 2005). The Gulf of Oman possesses various commercially important fauna species of which *U. duvauceli* is one that can be named. This species has significant stocks in coastal waters of Gulf of Oman and its catch has recently increased considerably to about 3000 tones (Planning & Program Office, 2006).

In recent years the increasing market demand all over the world, along with ever more efficient fishing techniques, put strong pressure on some of the most important squid stocks (Jereb & Roper, 2006). These stocks showed wide annual fluctuations due to many different reasons some of which are still poorly understood (Jackson *et al.,* 2000). This instability, together with the increasing commercial importance, underlined the need for better understanding of squid biology, ecology and reproduction in order to obtain predictive fisheries management information (Denis *et al.*, 2005). Based on the recent studies on cephalopods, the Indian squid was found to be one of the important and abundant species (Young *et al.*, 2004).

Reproductive biology of the Indian squid has been studied in various parts of the Indian Ocean, such as Gulf of Pakistan (Majid & Khaliluddin, 1994), East Indian Ocean (Jereb & Roper, 2006), Gulf of Thailand (Kaewnuratchadasorn *et al.*, 2003) and in Anadaman Sea (Sukramongkol *et al.*, 2006). The present study has been conducted to study reproductive biology and determine the fecundity, spawning season, sex ratio of the Indian squid in the Iranian waters of the Gulf of Oman.

Materials and methods

100 specimens were randomly collected per month by commercial trawlers active in the area and also some samples were collected by the R/V Ferdows-1. The randomly selected samples were transported to the laboratory for further biological measurements. Geographical location of sampling sites is shown in Fig 1.

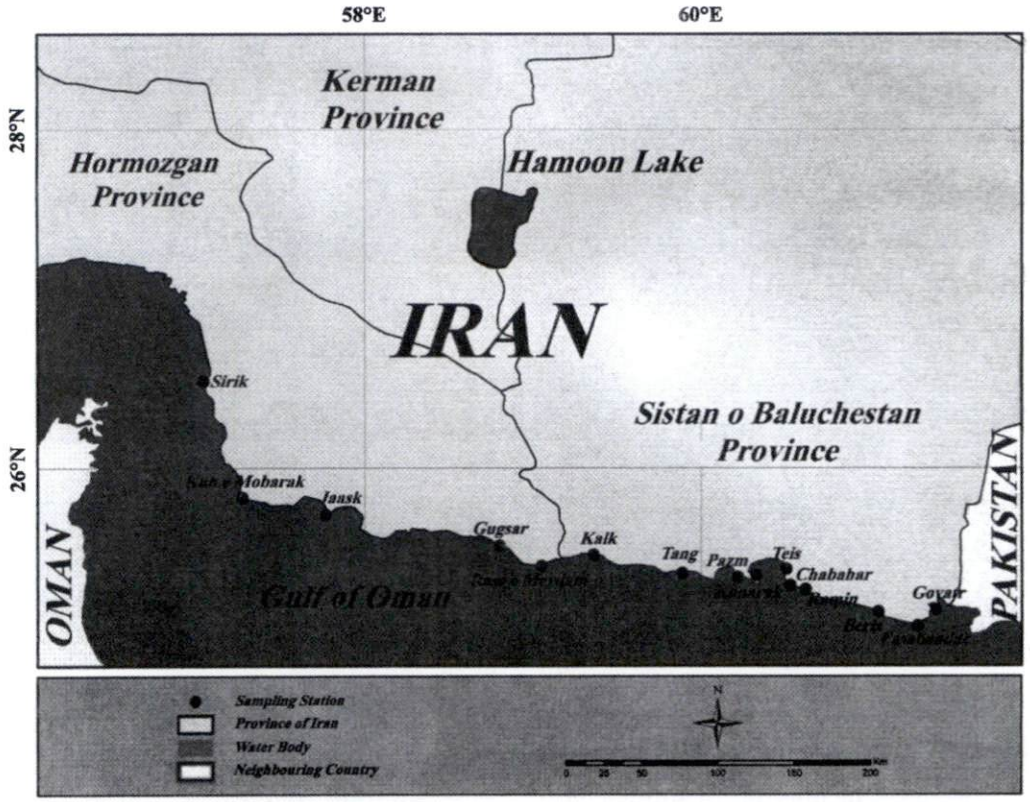

Figure 1: Study area and geographical location of sampling sites for *U. duvauceli* in the Gulf of Oman

A total of 1200 samples were brought to the laboratory, of which 360 adult specimens were selected to study the reproductive biology. Squids were weighed (0.01g) and their body length (total & mantle) measured (0.01mm). Mantle length and body weight relationship was derived from the following equation (Sparre & Venema, 1992):

$BW = a L^b$, where:

BW = Body Weight (g)

L = Length (cm),

a, b = constant factors,

Sex determination was done based on gonad observation after post–mortem (Fig. 2). The nidamental gland, as a main part of the female sexual organ (Fig. 2), was removed and weighed (0.01g). Hectocotylisation of the ventral arm and presence of spermatophores in Needham's sac were used as indicators of sexual maturity in males. In females, development of the nidamental gland and presence of mature oocytes in the ovaries were used as indicators of sexual maturity. Fecundity was calculated according to Biswas (1993). Gonadosomatic index was calculated from the following formula:

$$GSI = \frac{GW}{BW} \times 100$$

Where:

GSI = Gonadosomatic index,

GW = Gonad weight (g),

BW = Body weight (g).

Analysis of variance (ANOVA) followed by Newman-Keul's test were used to evaluate the significance of the result. A value of $P \leq 0.05$ was considered significant.

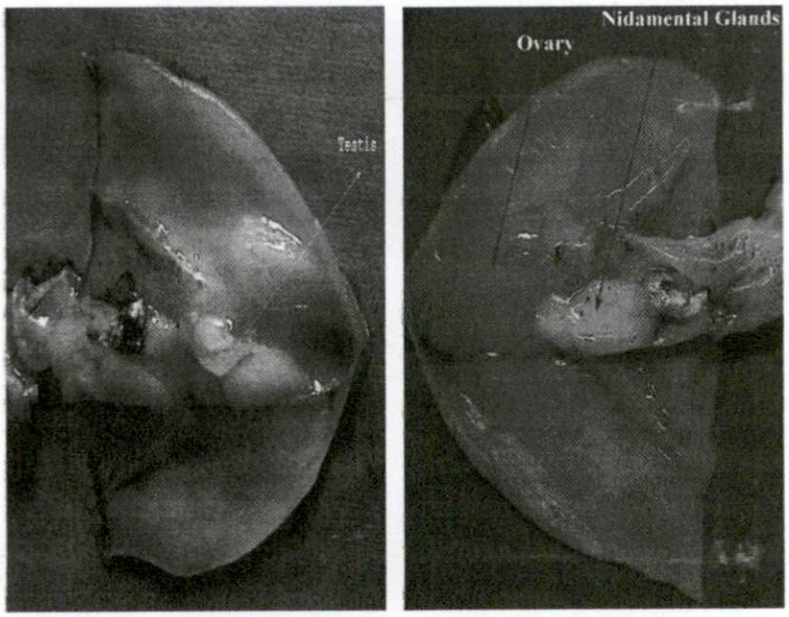

Figure 2 : Location of testis, ovary and nidamental glands of *U. duvauceli*

Results

The minimum and maximum total length of 240mm and 290mm, respectively, were found in December and June of which the highest range of total length was found between 410-420mm in September. The result of the total length-frequency analysis in different months is shown in Table1.

The minimum and maximum mantle length was measured as 110mm and 210mm in December and June, of which the highest range of mantle length was found between 150-160mm in September. The result of the mantle length analysis in different months is shown in Table 2.

The minimum and maximum body weight were measured during December and June (with values of 30g and 210g), also the maximum range of body weight was between 90-100g in September. The result of the body weight analysis in different months has been tabulated in Table 3.

Results from biometry of 360 specimens showed direct relationship between the mantle length and body weight (Fig. 3).

The specimens were composed of 34 percent male and 66 percent female. Overall sex ratio of M:F = 0.52:1.00 was observed, which was significantly different from the expected ratio of 1:1 ($P \leq 0.05$). According to the results, the sex ratio of the samples varied greatly throughout the year. The highest sex ratio of *U. duvauceli* with value of M:F=0.52:1.00 was found in September (Fig. 4).

Table 1: The distribution of total length frequency of *U. duvauceli* in the Gulf of Oman (2006-2007)

Total Length (mm)	Month												Total
	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	
240-250	-----	-----	-----	-----	-----	-----	1	-----	-----	-----	-----	-----	1
250-260	-----	-----	-----	-----	-----	-----	1	-----	-----	-----	-----	-----	1
260-270	-----	-----	-----	-----	-----	2	4	-----	-----	-----	-----	-----	6
270-280	-----	-----	-----	-----	-----	1	-----	-----	-----	1	-----	-----	2
280-290	-----	-----	-----	-----	1	3	2	1	-----	-----	-----	-----	7
290-300	-----	-----	-----	-----	3	3	1	-----	-----	1	-----	-----	8
300-310	-----	-----	-----	1	3	1	2	2	-----	-----	-----	1	10
310-320	1	-----	-----	-----	-----	-----	2	3	1	5	-----	-----	12
320-330	4	-----	1	1	-----	-----	1	3	2	1	2	-----	15
330-340	-----	-----	-----	1	-----	-----	1	8	9	4	-----	1	24
340-350	-----	-----	-----	2	2	3	-----	2	6	1	1	-----	17
350-360	-----	-----	5	-----	5	1	1	2	4	1	-----	1	20
360-370	-----	1	4	2	6	2	2	1	4	-----	3	2	27
370-380	-----	3	2	2	3	4	2	2	-----	1	1	-----	20
380-390	1	2	4	4	2	3	4	1	1	2	2	3	29
390-400	1	5	5	3	1	2	2	3	2	2	4	2	32
400-410	-----	5	3	13	4	1	1	1	-----	1	7	2	38
410-420	2	-----	1	1	-----	1	-----	-----	-----	4	5	5	19
420-430	2	5	1	-----	-----	2	1	1	-----	1	3	4	20
430-440	2	4	1	-----	-----	1	-----	-----	-----	1	1	6	16
440-450	4	3	-----	-----	-----	-----	1	-----	-----	2	1	3	14
450-460	4	-----	-----	-----	-----	-----	-----	-----	1	1	-----	-----	6
460-470	5	1	2	-----	-----	-----	-----	-----	-----	1	-----	-----	9
470-480	2	1	1	-----	-----	-----	1	-----	-----	-----	-----	-----	5
480-490	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	2
Total	30	30	30	30	30	30	30	30	30	30	30	30	360

Table 2: Frequency distribution of mantle length of *U. duvauceli* in the Gulf of Oman (2006-2007)

Mantle Length (mm)	Month												Total
	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	
110-120	-----	-----	-----	-----	1	2	4	-----	-----	-----	-----	-----	7
120-130	2	-----	-----	-----	3	6	10	2	1	4	1	-----	29
130-140	3	-----	-----	2	4	4	3	10	7	4	2	2	41
140-150	1	2	8	9	5	6	-----	10	12	5	3	-----	61
150-160	1	10	6	13	9	5	2	3	6	5	5	2	67
160-170	5	6	5	5	4	1	2	2	2	2	11	10	55
170-180	2	5	7	1	4	2	5	2	1	3	5	8	45
180-190	5	4	3	-----	-----	2	3	1	-----	6	3	7	34
190-200	6	3	1	-----	-----	2	1	-----	1	1	-----	1	16
200-210	5	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	5
Total	30	30	30	30	30	30	30	30	30	30	30	30	360

Table3: Frequency distribution of body weight of *U. duvauceli* in the Gulf of Oman (2006-2007)

Body Weight (g)	Month												Total
	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	
30-40	-----	-----	-----	-----	-----	-----	1	-----	-----	-----	-----	-----	1
40-50	-----	-----	-----	-----	-----	3	7	-----	1	-----	-----	-----	11
50-60	-----	-----	-----	-----	6	6	3	2	-----	2	-----	1	20
60-70	4	-----	-----	2	1	1	2	8	3	4	1	-----	26
70-80	2	-----	-----	-----	1	-----	3	8	9	6	1	-----	30
80-90	1	-----	6	2	5	4	1	3	6	4	1	2	35
90-100	-----	3	6	10	2	5	1	4	1	2	2	1	37
100-110	-----	7	7	4	3	5	3	2	1	-----	1	3	36
110-120	1	7	3	2	-----	-----	1	3	1	3	1	4	26
120-130	-----	8	1	4	3	1	-----	1	2	2	6	3	31
130-140	3	4	3	2	1	1	2	-----	-----	2	8	3	29
140-150	3	1	-----	1	3	-----	2	1	-----	1	2	3	17
150-160	2	-----	1	1	1	-----	2	-----	-----	1	2	7	17
160-170	3	-----	1	1	2	1	2	-----	-----	2	3	2	17
170-180	1	-----	1	1	-----	2	-----	-----	-----	1	1	1	8
180-190	6	-----	-----	-----	-----	1	1	-----	1	1	1	-----	11
190-200	3	-----	1	-----	2	-----	-----	-----	-----	1	-----	-----	7
200-210	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1
Total	30	30	30	30	30	30	30	30	30	30	30	30	360

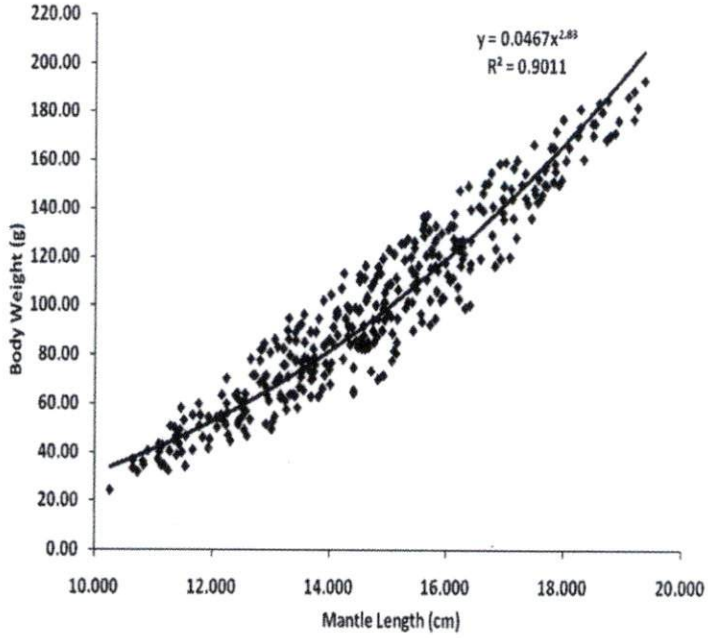

Figure 3: Mantle length-body weight relationship of *U. duvauceli* in the Gulf of Oman (2006-2007)

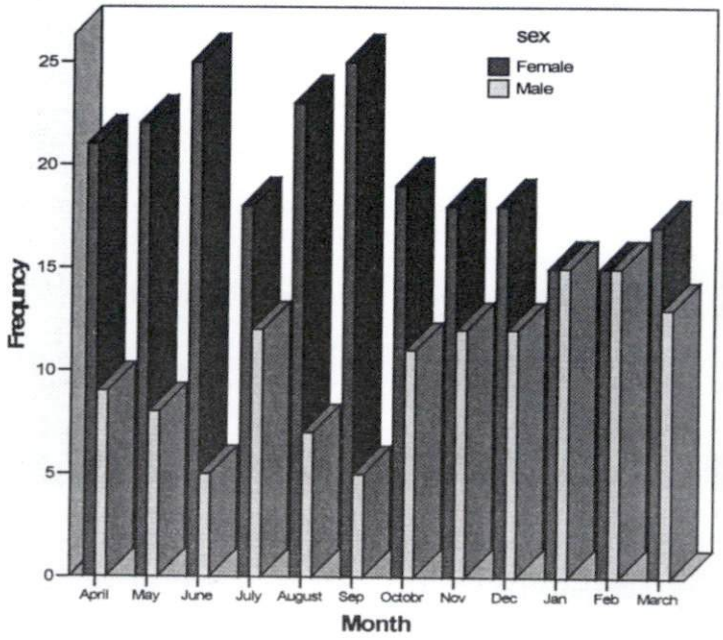

Figure 4: Sex ratio distribution of *U. duvauceli* in the Gulf of Oman (2006-2007)

Minimum, maximum and mean ovary weight of *U. duvauceli* was 2.1, 7.9 and 4.9g, respectively, and minimum, maximum and mean nidamental gland weight was 0.69, 2.61 and 1.6g, respectively (Table 4).

Table 4: Descriptive statistics of ovary and nidamental gland weight of *U. duvauceli* in the Gulf of Oman (2006-2007)

Parameter	N	Minimum	Maximum	Range	Mean±S.E
Ovary weight (g)	360	2.1000	7.9000	5.8000	4.8653±0.00007
Nidamental gland weight (g)	360	0.6900	2.6100	1.9200	1.6155±0.00002

The minimum and maximum absolute fecundities of 25510 and 375600 were found in August and April, respectively. These values were estimated for relative fecundity as minimum and maximum values of 867 and 5207 in August and April, respectively (Fig. 5).

The highest gonadosomatic index of 14.38 was found in April and gradually decreased in later months, reaching its lowest level (8.63) in July (Fig. 6); this squid is therefore assumed to be a spring spawner. The mean of gonado-somatic index of *Uroteuthis duvauceli* was 10.90.

Measurement of the ova diameter in 360 specimens revealed the minimum and maximum egg diameter of 0.72 (in August) and 2.5mm (in April), respectively (Fig. 7).

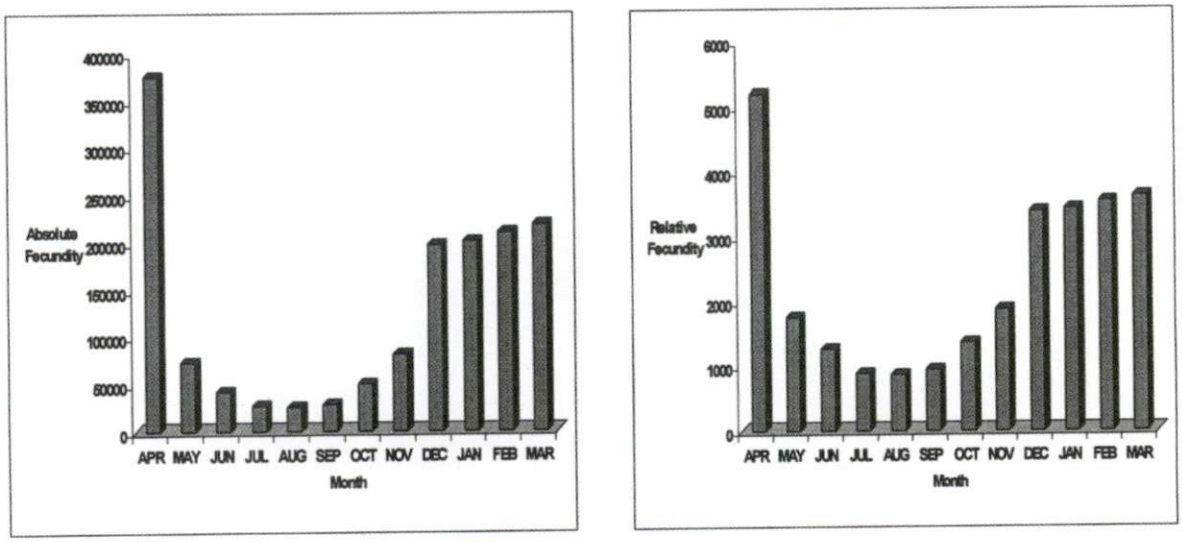

Figure 5: Absolute and relative fecundities of *U. duvauceli* in the Gulf of Oman (2006-2007).

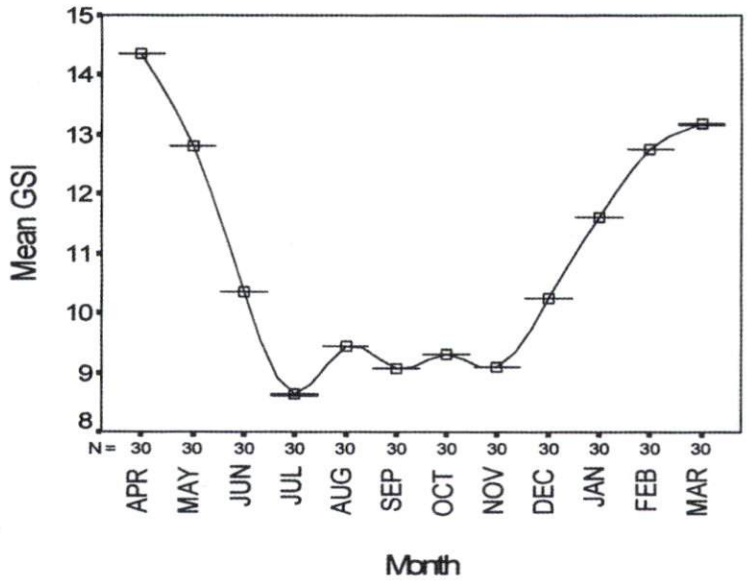

Figure 6: Gonadosomatic index variation of *U. duvauceli* in the Gulf of Oman (2006-2007)

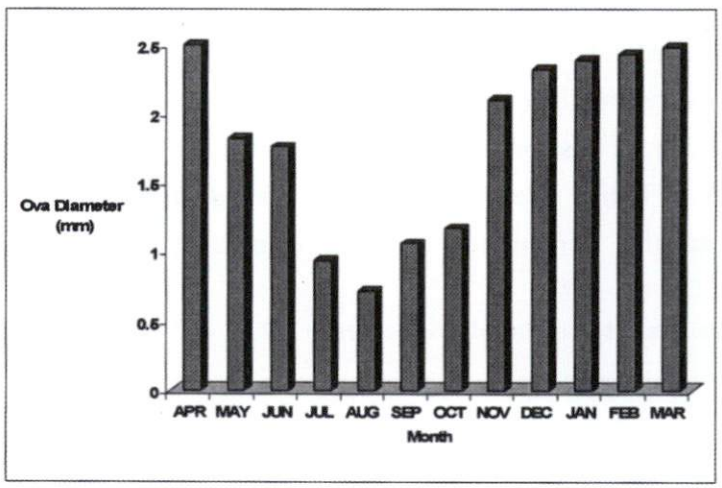

Figure 7: Frequency distribution of ova diameter of *U. duvauceli* in the Gulf of Oman (2006-2007).

Discussion

Indian Squid, *U. duvauceli,* is regarded as one of the most important species in the Persian Gulf and Gulf of Oman and is a main target for commercial fisheries purposes (Crawford, 2002). In spite of its economic value, no clear information on its reproductive biology in the waters of the Gulf of Oman was available. This research was, therefore, carried out to get more information on the reproductive biology of this species which can be useful in sustainable exploitation of this species. The results indicated that *U. duvauceli* was the dominant squid species in the Gulf of Oman. The maximum and minimum TL, ML

and body weight were found in June and December (Tables 1, 2 and 3). Result from biometry showed direct relationship (R^2=0.90) between the mantle length and body weight (Fig. 3). The sex ratio was found to fluctuate in different sampling months (Fig. 4), with an overall ratio of M: F = 0.52: 1.00 that differed significantly from the expected ratio of 1:1.

Comparison of the reproductive characteristics of *U. duvauceli* in the Gulf of Oman (present study) with similar data from of 499.5mm, 206mm and 202.6g, respectively, in East Indian Ocean (Jereb & Roper, 2006) and the lowest quantities of 339.8mm, 89mm and 19.8g for TL, ML and other regions shows the highest TL, ML, BW respectively, in the Gulf of Pakistan, (Majid & Khaliluddin, 1994).

The maximum ovary weight (8.2g) and nidamental gland (2.75g) for this species have been reported from East Indian Ocean (Jereb & Roper, 2006) and the minimum ovary (2.0g) and nidamental gland (0.64g) weights have been reported from Andaman Sea of Thailand (Sukramongkol *et al.*, 2006). Maximum absolute (379800) and relative fecundities (6405) for this species were reported in West Indian Ocean (Jereb & Roper, 2006), while minimum fecundities of 25510 and 866.6 were obtained in the present study.

The highest gonadosomatic index (14.69) for *U. duvauceli* was recorded from East Indian Ocean (Jereb & Roper, 2006) and the lowest index (8.24) was observed in Andaman Sea in Thailand (Sukramongkol *et al.*, 2006). The maximum egg diameter (2.72mm) of the Indian squid was reported from East Indian Ocean (Jereb & Roper, 2006) and the minimum (0.72mm) was obtained in the present study. Based on the results achieved in this research, it seems that most of the reproductive characteristics

Table 5: Comparison of some reproductive characteristics of *U. duvauceli* in different regions

Region	TL (mm) min-max	ML (mm) min-max	BW (g) min-max	OW (g) min-max	NM (g) min-max	A-Fe min-max	R-Fe min-max	GSI min-max	Ova-d (mm) min-max	Reference
Gulf of Oman, Iran	340.1-492.0	90-195	20.1-194.5	2.1-7.9	0.69-2.61	25510-375600	866.6-5205.5	8.63-14.38	0.72-2.51	Present study
Andaman Sea, Thailand	351.2-468.2	92-198	24.5-197.5	2.0-7.6	0.64-2.71	26500-376500	868.6-5403.0	8.24-14.25	0.73-2.61	Sukramongkol *et al.*, 2006
Gulf of Thailand, Thailand	371.2-465.5	91-199	32.2-199.6	2.5-7.8	0.67-2.65	27100-376800	870.6-5260.6	8.65-14.34	0.73-2.64	Kaewnuratchadasorn *et al.*, 2003
East Indian Ocean, India	368.9-499.5	91-206	29.8-202.6	2.6-8.2	0.71-2.75	27800-379800	893.2-6405.3	9.98-14.69	0.87-2.72	Jereb & Roper, 2000
Gulf of Pakistan, Pakistan	339.8-490.6	89-198	19.8-198.5	2.2-7.8	0.70-2.63	25600-37600	868.3-5206.3	8.65-14.35	0.82-2.65	Majid & Khaliluddin, 1994

TL: Total length; ML: Mantle length; BW: Body weight; OW: Ovary weight; NM: Nidamental glands; A-Fe: Absolute fecundity; R-Fe: Relative fecundity; GSI: Gonadosomatic index and Ova-d: Ova diameter.

of *U. duvauceli* in the Gulf of Oman (including TL, ML, OW, NM, A-Fe, R-Fe, GSI, Ova-d) are to some extent similar to the results obtained by Majid and Khaliluddin (1994) from the Gulf of Pakistan, which may be due to the similarities in environmental conditions of these two adjacent water bodies.

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