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Maturity and Spawning of Shortfin Scad (*Decapterus macrosoma*) (Carangidae) of the Java Sea

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Abstract

Maturity and spawning of shortfin scad *(Decapterus macrosoma)* in the Java Sea were investigated using macroscopic characteristics of the gonad for determining the stages of maturity and gonadosomatic index (GSI) for the growth of the gonads. The fish reached maturity in July; spawning would likely occur in July/August. Overall sex ratio was 1 : 0.28 (male : female). Length at first maturity of males was 14.8 cm and for females, 15.5 cm.

Introduction

Among the pelagic fish resources of the Java Sea, two species of scads, the Indian scad *(Decapterus russelli),* often misidentified as *D. maruadsi* which is restricted to the coasts of Japan and China (Gushiken 1983), and shortfin scad (*D. macrosoma* Bleecker 1851) play a significant role both in terms of yield and economic values.

Jong (1940) carried out a preliminary study on the spawning habits of *D. russelli* along with several other fish from the Java Sea. Based on the frequency distribution of the diameter of the eggs in the ovary, he concluded that the spawning of the species is periodic; there is only one batch of eggs and after spawning the ovary resembles an empty sack.

However, his observation covered only 4 months. This periodicity was confirmed by the results of the investigation by Atmadja (1983).

Very little is known about the reproductive biology of *D. macrosoma* from the Java Sea. The shortfin scad was an obvious choice for study, since it was known to be abundant in the Java Sea, especially in its eastern portion.

Methods and Materials

The fish came from commercial landings of purse seiners, chiefly at the port of Pekalongan on the northern coast of Central Java, Indonesia. Samples from all the major fishing grounds in the Java Sea, were collected in 1986. A multiple stratified random sampling scheme was designed to determine landing places, vessels and fish to be sampled. Full details are given in Widodo (1988).

A total of 194 samples of 19,367 specimens of *D. macrosoma* were collected. Each fish was assessed for several characters, of which the following are relevant to the present work: total length, total weight, sex, maturity and gonad weight.

Length was measured in fork length to the nearest lowest 0.5 cm. Fish were weighed to the nearest 0.01 g.

After the sexual organs of each fish were examined macroscopically, the sex and maturity stage were recorded. The general appearance and extension of the gonad in the body cavity were used to determine the stages of maturity. The Holden and Raitt (1974) scale of maturity was followed with some minor modification.

The average size at maturity was estimated by two methods, first, by plotting the percentage cumulative frequency of mature fish versus size, then employing the standard logistic model:

$$\varnothing (x_i) = (1 + ae^{-b}x_i)^{-1} \qquad \text{... 1)}$$

where a is a constant, b is slope, and x_i is length. Data were fitted to the model by using SPSS NONLINEAR (SPSS-Statistical Package for the Social Sciences, Vogelback Computing Center, Northwestern University, USA). The length at first maturity (l_m) was then taken as the length corresponding to 50% maturity.

The second method employed the Spearman-Karber method used in estimating mean lethal dose (LD_{50}), as suggested by Udupa (1986). Several statistical methods for estimating LD_{50} using the Spearman-Karber equation have been developed by Finney (1971). By employing the Spearman-Karber equation, the logarithm of l_m could be estimated as:

$$\log l_m = x_k + \frac{d}{2} - d \sum \rho_i \qquad \text{... 2)}$$

where $d = x_{i+1} - x_i$ for $i = 1,2, ..., k - 1$; x_i = the logarithm of mid-length of a length group (equally spaced), $i = 1,2,.., k$; x_k = the logarithm of mid-length at which 100% of fish were mature (or where $\rho_i = 1$); n_i = number of fish in ith length group; r_i = number of mature fish in ith length group; $\rho_i = r_i/n_i$; $q_i = 1 - \rho_i$.

Thus by taking the antilog of equation (2), l_m could be estimated. The 95% confidence limits were:

$$\text{antilog}\left[l_m \pm 1.96 \sqrt{d^2 \sum_{i}^{k-1} \frac{\rho_i q_i}{n_i - 1}} \right] \quad \text{... 3)}$$

Since maturity staging by visual examination was subjective, the more precise gonadosomatic index (GSI) was also used, determined as:

$$GSI = \frac{\text{gonad weight (g)}}{\text{somatic weight (g)}} \cdot 100 \quad \text{... 4)}$$

where somatic weight = body weight - gonad weight.

Results

Based on the collection of larvae of this species in this area (Delsman 1926) along with the occurrence of ripe and spawning individuals in the commercial catch, it appears that *D. macrosoma* spawns over the continental shelf in the Java Sea.

The correlation of the two maturity indices (visual inspection and GSI) for this species is depicted in Fig. 1. It can be seen that the maturity stages chosen fit the pattern of weight change in the gonad, providing an additional degree of confidence in the maturity assessments. Note that the ovary attains a greater final weight than the testes at the peak of stage VI. Females have much more energy invested in gonadal tissue than males.

The highest percentage of ripe female of *D. macrosoma* (fish of stage VI), was found in July (Table 1). The peak time of spawning would likely occur in July/August, approximately two weeks after the occurrence of the highest percentage of ripe fish in the Java Sea.

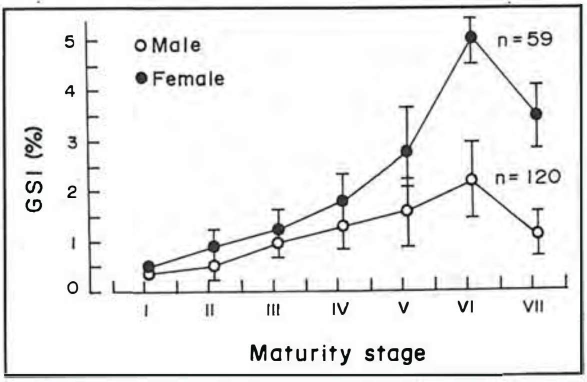

Fig. 1. Relationships between gonadosomatic index (GSI) and maturity stage of *Decapterus macrosoma* from the Java Sea in 1986. For each stage the mean ± 2 x S.E. is shown.

Table 1. Monthly distribution of maturity stages (%) for female *Decapterus macrosoma* from the Java Sea in 1986.

Mo.	Maturity stages I	II	III	IV	V	VI	VII	n
Jan	-	23.1	-	40.2	6.9	19.6	10.3	81
Feb	33	-	-	24.6	16.2	18.5	12.9	56
Mar	10.5	18.6	19.3	13.5	-	10.4	6.1	108
Apr	15.8	10.5	15.8	-	5.3	28.6	24.0	99
May	6.3	17.5	-	10.8	16.1	12.9	36.3	84
Jun	5.1	15.3	19.5	7.5	9.3	29.7	13.7	135
Jul	4.4	8.9	2.2	-	13.3	57.8	13.3	90
Aug	16.7	22.2	36.1	5.6	2.8	13.9	2.8	108
Sep	27.0	18.9	32.4	9.4	5.4	2.7	8.1	74
Oct	5.3	10.5	26.3	5.3	10.5	-	42.1	95
Nov	36.4	27.3	18.2	9.1	4.6	-	4.6	66
Dec	8.3	8.3	-	8.3	-	16.7	58.3	72

The results of observations on maturity stages by length for 769 specimens of *D. macrosoma* are shown in Table 2. In order to apply both logistic and Spearman-Karber methods, maturity stages I to III were grouped into immature individuals, and the rest were classified as mature.

Estimates of the mean length at first maturity, l_m for *D. macrosoma* (males, females and sexes combined) were derived by plotting the percentage cumulative frequency of mature fish against its corresponding length (Fig. 2) and fitting the standard logistic equation.

Table 2. Maturity classification by length category for *Decapterus macrosoma*.

Length group (cm)	Male					Female				
	Maturity stages					Maturity stages				
		Immature			Mature		Immature			Mature
	No.	I	II	III		No.	I	II	III	
10.0-11.9	6	4	1	1		2	1	1		
12.0-13.9	74	29	22	16	7	21	7	9	2	3
14.0-15.9	200	11	25	68	96	50	9	13	19	9
16.0-17.9	280	14	15	34	217	67	11	7	12	37
18.0-19.9	59		1	2	56	35		3	2	30
20.0-21.9	2				2	1				1
Total	621	58	64	121	378	176	28	33	35	80

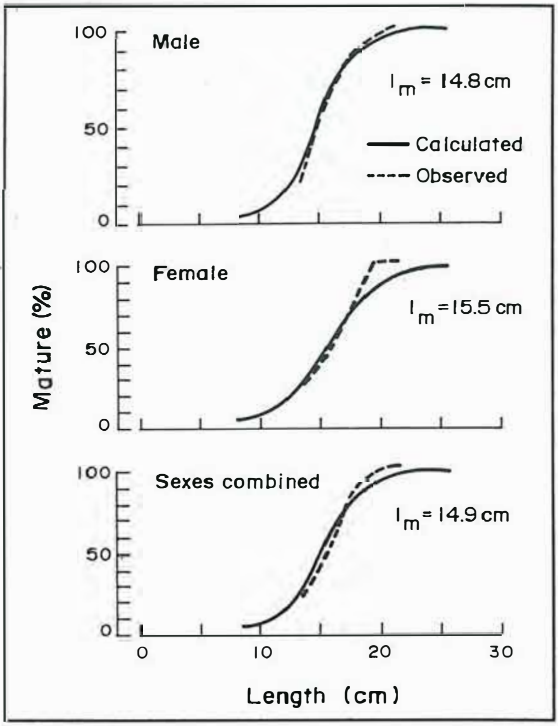

Fig. 2. Maturity ogive for *Decapterus macrosoma*.

In this case, length at first maturity was defined as the length at which 50% of the fish had begun to show the first signs of maturation. Calculated lengths at first maturity l_m were 14.8 cm for males, 15.5 cm for females and 14.9 cm for sexes combined (Table 3). Additional estimates of l_m using the Spearman-Karber method are shown in Table 3.

In general, males of *D. macrosoma* mature at a smaller size than females. The length at maturity was approximately two-thirds of maximum length. Tiews et al. (1970) suggested that this species in the Philippines matures at the length of 18-20 cm at the beginning of the third year of life. They also suggested that *D. macrosoma* spawns only once in its lifetime. So far, no information is available as to whether or not this species spawns several times within one spawning season as characterized by a number of subtropical and tropical fish (Nikolsky 1963).

Table 3. Length at first maturity, l_m (cm), of *Decapterus macrosoma* derived using two different methods.

Sex	Logistic model	Spearman-Karber method	95% confidence limits
male	14.8	14.6	14.6-14.6
female	15.5	15.7	15.2-16.3
combined	14.9	14.9	14.6-15.1

A relatively high percentage of ripe *D. macrosoma* (stage VI) occurred from January to August with a peak in July (Table 1). The spawning was likely protracted over several months with a peak in July/August, two weeks after the occurrence of the highest percentage of ripe fish in the area concerned. The prolonged spawning period of *D. macrosoma* agrees with that found by Delsman (1926) in his investigation of fish eggs and larvae in the Java Sea; with studies on the biology of scads in Palawan waters in the Philippines (Tiews et al. 1970; Pauly and Navaluna 1983); and a preliminary study on the fishery biology of *Decapterus* spp. in the Gulf of Thailand (Chullasorn and Yusukswad 1977).

The sex-ratio of mature and immature *D. macrosoma* was 1:0.21 and 1:0.34 (male:female), respectively, i.e., males dominated the catch. The overall sex ratio was 1:0.28 (n = 797).

Discussion

The peak of spawning for *D. macrosoma* in July/August coincided with shifts in the monsoon regime in the Java Sea (Wyrtki 1961), when winds are weaker and of variable direction. These spawning times confirm that coastal marine fish in the tropics often concentrate their spawning at times of the year when prevailing winds are at their weakest, reducing the transport of larvae away from their point of origin (Johannes 1978).

An extended spawning time for *D. macrosoma* is also found in the Gulf of Thailand during December-May (Chullasorn and Yusukswad 1977) and in Manila Bay and Palawan waters during November-March (Tiews et al. 1970; Ronquillo 1974).

Differences between distribution and behavior of the two sexes are often observed in finfish, crustaceans and marine mammals, especially at spawning time, which causes fishing to affect the population of males and females differently. Data on sex-ratios of commercial catches of this species show significant variations. For example, the sex-ratio of *D. macrosoma* in the Gulf of Thailand is 1:0.9 females:males (Chullasorn and Yusukswad 1977); in Palawan waters it is 1:0.99 females:males (Tiews et al. 1970).

A deviation from 1:1 in the sex-ratio of the catches cannot inevitably be associated with a corresponding difference in fishing pressure on the two sexes, i.e., in terms of fishing mortality rates (F), if only because their natural mortality rates (M) may also be different. Since sex-specific estimates of M for *D. macrosoma* in the Java Sea were not available, the occurrence of sex-selective F remains an open question.

The effect of sex-selective fishing on the reproductive capacity of a population and thus on its longer-term dynamics is more speculative. Mathisen (1962), based upon his research on size-selectivity of gillnets which cause male red salmon to be caught in favor of females, concluded that in wild populations there is normally a surplus of males that can be harvested without detriment to the reproductive capacity of the salmon population.

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