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# REPRODUCTIVE BIOLOGY OF *SPHYRAENA* SPECIES IN THE EGYPTIAN EDITERRANEAN WATERS OFF ALEXANDRIA

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***Key words**: Sex ratio, Spawning season, Sphyraena species, Fecundity.*

## ABSTRACT

The reproductive biology of *Sphyraena* species found in the Egyptian Mediterranean water was studied during the period from March 1998 to February 1999. Sex ratio (males: females) was 0.83: 1.00 for S. chrysotaenia; 1.85: 1.00 for S. flavicauda and 0.89: 1.00 for S. sphyraena. Size at first sexual maturity for males and females was 17.3 & 19.3 cm TL for S. chrysotaenia; 25.5 & 28.0 for S. flavicauda and 26.7 & 27.6 for S. sphyraena. Spawning season extended from May to October for S. chrysotaenia; May to September for to S. flavicauda and April to August for S. sphyraena. The minimum size of transparent ripe ova for S. sphyraena was 0.95mm; for S. flavicauda was 0.47mm and S. chrysotaenia was 0.44mm. The average fecundity estimates ranged from 74,399 to 241,853 eggs for S. chrysotaenia (20.0- 27.0 cm TL); 84,197 to 260,549 eggs for S. flavicauda (28.0 -40.0 cm TL) and 46,778 to 103,453 eggs for S. sphyraena. Variations in absolute and relative fecundity in relation to fish length, weight and age were determined.

## INTRODUCTION

The barracudas fish, family Sphyraenidae, are widely distributed and economically important marine fish in the tropical and temperate waters of the world. All members of family Sphyraenidae are mostly pelagic, single or in schools (Whitehead *et al*., 1986). It is capable of adaptation to diverse ecological condition from tropical to temperate seas of nearly all over the world (Kuronuma & Abe, 1986). The largest individuals are found in the open sea, while the smaller individuals are caught near the coast; this the typical behavior of Sphyraenidae previously described by Whitehead *et al.* (1986) and Fischer *et al.* (1987).

The barracudas of the Mediterranean Sea include three species; these are *Sphyraena chrysotaenia*, *Sphyraena sphyraena* and *Sphyraena viridensis* (Hureau& Monod, 1979; Whitehead *et al.*,198; Fischer *et al.*,1987 and Fredj & Maurin, 1987). In addition, the present result recorded a new Red Sea immigrant *Sphyraena flavicauda* in the Egyptian Mediterranean waters.

The study of reproductive biology of *Sphyraena* species in the Mediterranean Sea has received little attention (George *et al*.; 1971 and Wadie *et al.*, 1988). On the other hand Turki & ktari-Chakroun (1985) determined the egg-laying season of *Sphyraena sphyraena* during their study on the ichthioplankton in the gulf of Tunis. De Sylva (1963) studied the reproductive biology of *S. barracuda* from Florida bay. Okera (1982) made some observation on the maturation condition of *S. jello, S. obtusata* (=*S.* c*hrysotaenia*) and *S. forsteri* from Australia waters.

Accordingly, the present study was undertaken to study the reproductive aspects (sex ratio, maturation, length and age at first sexual maturity, spawning season and fecundity) in order to manage and improve its fisheries.

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## MATERIALS AND METHODS

Samples of barracudas were monthly collected from the commercial catch of different gears (trawlers, purse-seines, gill nets, trammel nets and longlines) landed at Alexandria during the period from March 1998 to February 1999. A total of 1244 fish of *S. chrysotaenia* (13-27 cm TL), 424 *S. flavicauda* (17-41 cm TL) and 629 *S. Sphyraena* (16-44 cm TL) were taken for reproduction study. In the laboratory, total length (cm) and gutted body weight (g) and sex were recorded. Otoliths were taken and kept for age determination. Gonads were weighed (mg). Maturity stages of the gonads were classified according to De Sylva (1963) with some modification (immature, maturing, nearly ripe, ripe, spawning and spent stage). Samples of ripe ovaries were preserved in 4% formalin solution for fecundity and ova diameter. Gonadosomatic index (GSI) was estimated as the percentage of gonads to gutted body weight. Ova diameters were measured using an eye piece micrometer at 50 X and all measurements were then converted to millimeters. Absolute fecundity was estimated as the number of mature ova that were likely to be spawned using the method of Batts (1972). Also, the relative fecundity; i.e. the number of ova per unit length or weight were determined.

## RESULTS

**Sex ratio**

The overall sex ratio (males: females) was 0.83:1.00 for *Sphyraena chrysotaenia*, 1.85:1.00 for *S. flavicauda* and 0.89:1.00 for *S. Sphyraena*. Chi-square test showed a significant difference for both *S. chrysotaenia* and *S. flavicauda* while the difference was insignificant for *S. Sphyraena* (Table 1.).

For all *Sphyraena* species studied males dominated the catch at lengths less than 22cm TL for *S. chrysotaenia*, 37 cm TL for *S. flavicauda* and 32 cm TL for *S. Sphyraena*. Males disappeared from the catch of *S. flavicauda* and *S. Sphyraena* at lengths more than 39 cm TL (Table 1).

The sex ratio of *S.chrysotaenia* was in favor of females in all seasons but the difference was significant only in summer. Contrarily males of *S. flavicauda* were significantly predominated the catch in all seasons except in summer where the difference was insignificant. For *S. Sphyraena*, the sex ratio was nearly parity all the year except in autumn where females ou-tnumbered males with significant difference (Table 2).

Females predominated the catch during and out the spawning *of S. chrysotaenia* (M: F = 0.81:1.00 & 0.86:1.00 respectively). However the sex ratio was only highly significant during the spawning season which extends from May to October ($X^2$ =7.202; df = 1; p<0.01). Contrarily, males of *S.flavicauda* out-numbered females insignificantly during the spawning which extends from May to September (M: F = 1.33: 1.00) and significantly out the spawning season (M: F = 2.07: 1.00; $X^2$ = 38.624; df = 1; p<0.0001). On the other hand, sex ratio was nearly parity (M: F = 1.03:1.00) during the spawning season *of S. Sphyraena* (April to August) while females were insignificant predominated males out of spawning (M: F = 0.75:1.00).

**Size and age at first sexual maturity**

The lengths at first maturity, i.e. the length at which 50 % of fish were matured; for males and females were respectively 17.3 and 19.3 cm TL for *S. chrysotaenia*; 25.5 and 28.0 cm TL for *S.flavicauda* and 26.7 and 27.6 cm TL for *S. Sphyraena* (Fig.1) with the corresponding ages of 1.16 & 1.77, 1.99 & 2.57 and 2.66 & 2.35 years respectively. All individuals were matured when they attained 22 cm for *S. chrysotaenia*, 30 cm for *S .flavicauda* and 29 cm for *S. Sphyraena*. Generally, males reach sexual maturation at smaller sizes than those of females for all *Sphyraena* species.

**Monthly distribution of maturity stages**

Immature and maturing individuals of *Sphyraena* species were found in most months of the year while nearly ripe ones were well represented during spring and early summer (Fig. 2). For *S. chrysotaenia*, ripe individuals of both sexes appeared in the catch from May reaching its maximum value in July (100 % for males & 92.86 % for females). Spawning individuals began to appear in August reaching a higher percent in October (69.77 % for males & 72.73 % for females). By December the majority of males (86.96 %) and females (93.88 %) were completely spent (Fig. 2).

For *S. flavicauda*, ripe individuals were well represented in the catch in June and July with the appearance of spawning individuals. Spent individuals of both sexes disappeared from the catch after November (Fig. 2).

For *S. sphyraena*, the majority of fishes were ripe in May and June representing 83.78 & 58.54% for males and 97.06 & 81.08 % for females respectively. Spawning individuals appeared in June reaching a highest value in July (56.25 % for males and 94.74 % for females). Spent fish were found from June to November for males and to December for females (Fig. 2).

**Gonadosomatic index (GSI)**

The gonadosomatic index for the three species studied began to increase in May reaching its maximum value in July for *S. chrysotaenia* (5.87 for males &13.65 for females); June – July for *S. flavicauda* (2.17 , 2.11 for males and 4.92 , 7.91 for females) and May – June for *S. sphyraena* (3.22 , 2.87 for males & 10.02, 9.95 for females). The GSI was minimum in autumn and winter seasons for all *sphyraena* species (Fig. 2). The GSI of females was higher than that of males and follow nearly the same pattern for all *Sphyraena* species. The spawning season takes place from May to October for *S. chrysotaenia*; May to September for *S. flavicauda* and April to August for *S. sphyraena*.

**Ova diameters**

The egg size ranged from 0.05 to 0.85 mm for *S. chrysotaenia*, 0.05 to 1.20mm for *S. flavicauda* and 0.05 to 1.50 mm for *S. sphyraena*. Three modes of ova could be detected from size distribution of ova (Fig. 4); these were 0.20, 0.40 &0.65mm for *S. chrysotaenia*, 0.20, 0.50 & 0.80 mm for *S. flavicauda* and 0.30-0.4, 0.65- 0.80 & 1.10-1.25mm for *S. sphyraena*. These were representing immature (small, non-yolked & whitish translucent), maturing (partially opaque & heavily yolked) and ripe ova (completely transparent) respectively. The minimum size of transparent ripe ova was 0.44, 0.47 and 0.95 for *S. chrysotaenia*, *S. flavicauda* and *S. sphyraena*. Thus, it appears that *Sphyraena* species are fractional spawners releasing their ripe eggs in a number of batches during the spawning.

**Fecundity**

The absolute fecundity ranged from 74,399 to 241,853 eggs for *S. chrysotaenia* (20.0- 27.0cm TL), 84,197 to 260,549 eggs for *S. flavicauda* (28.0- 40.0cm TL) and 46,778 to 103,453 eggs for *S. sphyraena* (30.0- 38.0cm TL). Relative fecundity ranged from 3,720 to 8,958 (mean = 6566 ± 1421) eggs length$^{-1}$ for *S. chrysotaenia*, 3,007 to 6,514 (mean = 3794 ± 1309) eggs length$^{-1}$ for *S. flavicauda* and 1,521 to 2,722 (mean = 2095 ± 336) eggs length$^{-1}$ for *S. sphyraena*.

**Fecundity – length relationship**

Absolute fecundity ($F_{abs}$) and relative fecundity ($F_r$) of *Sphyraena* species showed increasing values as they increased in length (Fig. 5). These relationships were curvilinear and the regression equations were as follows:

$$\text{Log Fabs} = -0.236 + 3.952 \text{ Log L}$$

(r = 0.989) for S. chrysotaenia

$$\text{Log Fabs} = -0.772 + 3.852 \text{ Log L}$$

(r = 0.969) for S. flavicauda

$$\text{Log Fabs} = -0.987 + 3.822 \text{ Log L}$$

(r = 0.979) for S. sphyraena

Log Fr = - 0.236 + 2.952 Log L

(r =0.9 79) for S. chrysotaenia

Log Fr = - 0.773 + 2.853 Log L

(r = 0.946) for S. flavicauda

Log Fr = - 0.986 + 2.821 Log L

(r = 0.961) for S. sphyraena

**Fecundity – weight relationship**

The relation between absolute fecundity ($F_{abs}$) and gutted body weight (W) of *Sphyraena* species revealed a linear relationship (Fig.6). The equations representing these relationships were as follows:

Fabs = - 45332.202 + 3159.722 W

(r = 0.992) for S. chrysotaenia

Fabs = - 63024.623 + 1176.358 W

(r = 0.930) for S. flavicauda

Fabs= -3706.193 + 617.609 W

(r = 0.923) for S. sphyraena

No relationship exists between relative fecundity and gutted body weight for *S. flavicauda* and *S. sphyraena* and this relationship was determined only for *S. chrysotaenia* as:

$F_r$ = 1651.747 +11.859 W

(r = 0.831).

**Fecundity - age relationship**

Absolute fecundity ($F_{abs}$) was found to be increase as fish grows older (Fig. 7) and the relationships were linear as follows:

$F_{abs}$ =53538.020 +374202.156 Age

(r=0.999) for *S. chrysotaenia*

$F_{abs}$ =-28443.227+44819.818 Age

(r=0.912) for *S. sphyraena*

$F_{abs}$ =26197.237 +14581.535 Age

(r=0.966) for *S. sphyraena*

On the other hand, no relationship exists between relative fecundity and age for all *Sphyraena* species.

Table (1): Variations of sex ratio (Males: Females) of *Sphyraena* species with length groups.

| Length groups (cm) | *S. chrysotaenia* | | | *S. flavicauda* | | | *S. sphyraena* | | |
|---|---|---|---|---|---|---|---|---|---|
| | Number | | Sex ratio | Number | | Sex ratio | Number | | Sex ratio |
| | Males | Females | | Males | Females | | Males | Females | |
| 13 | 3 | 4 | 0.75:1.00 | | | | | | |
| 14 | 8 | 6 | 1.33:1.00 | | | | | | |
| 15 | 20 | 10 | 2.00:1.00 | | | | | | |
| 16 | 32 | 35 | 0.91:1.00 | | | | - | 1 | 0.00:1.00 |
| 17 | 63 | 49 | 1.29:1.00 | 4 | 2 | 2.00:1.00 | 2 | - | 1.00:0.00 |
| 18 | 78 | 40 | 1.95:1.00 | 7 | 2 | 3.50:1.00 | 8 | 2 | 4.00:1.00 |
| 19 | 75 | 48 | 1.56:1.00 | 12 | 4 | 3.00:1.00 | 8 | 6 | 1.33:1.00 |
| 20 | 92 | 74 | 1.24:1.00 | 16 | 4 | 4.00:1.00 | 8 | 8 | 1.00:1.00 |
| 21 | 82 | 70 | 1.17:1.00 | 16 | 7 | 2.29:1.00 | 8 | 3 | 2.67:1.00 |
| 22 | 41 | 114 | 0.36:1.00 | 14 | 3 | 4.67:1.00 | 10 | 7 | 1.43:1.00 |
| 23 | 43 | 87 | 0.49:1.00 | 16 | 9 | 1.78:1.00 | 13 | 14 | 0.93:1.00 |
| 24 | 22 | 55 | 0.40:1.00 | 16 | 5 | 3.20:1.00 | 8 | 11 | 0.73:1.00 |
| 25 | 4 | 66 | 0.06:1.00 | 21 | 8 | 2.63:1.00 | 6 | 9 | 0.67:1.00 |
| 26 | 2 | 17 | 0.12:1.00 | 27 | 12 | 2.25:1.00 | 10 | 7 | 1.43:1.00 |
| 27 | - | 4 | 0.00:1.00 | 32 | 16 | 2.00:1.00 | 12 | 5 | 2.40:1.00 |
| 28 | | | | 37 | 15 | 2.47:1.00 | 13 | 10 | 1.30:1.00 |
| 29 | | | | 16 | 11 | 1.45:1.00 | 31 | 7 | 4.43:1.00 |
| 30 | | | | 10 | 4 | 2.50:1.00 | 52 | 14 | 3.71:1.00 |
| 31 | | | | 2 | 12 | 0.17:1.00 | 53 | 34 | 1.56:1.00 |
| 32 | | | | 2 | 5 | 0.40:1.00 | 30 | 60 | 0.50:1.00 |
| 33 | | | | 4 | 5 | 0.80:1.00 | 13 | 48 | 0.27:1.00 |
| 34 | | | | 4 | 4 | 1.00:1.00 | 5 | 32 | 0.16:1.00 |
| 35 | | | | 5 | 2 | 2.50:1.00 | 1 | 21 | 0.05:1.00 |
| 36 | | | | 7 | 3 | 2.33:1.00 | 2 | 5 | 0.40:1.00 |
| 37 | | | | 2 | 3 | 0.67:1.00 | 2 | 8 | 0.25:1.00 |
| 38 | | | | 2 | 7 | 0.29:1.00 | - | 6 | 0.00:1.00 |
| 39 | | | | 3 | 3 | 1.00:1.00 | 1 | 4 | 0.25:1.00 |
| 40 | | | | - | 2 | 0.00:1.00 | - | 4 | 0.00:1.00 |
| 41 | | | | - | 1 | 0.00:1.00 | - | 3 | 0.00:1.00 |
| 42 | | | | | | | - | 1 | 0.00:1.00 |
| 43 | | | | | | | - | 2 | 0.00:1.00 |
| 44 | | | | | | | - | 1 | 0.00:1.00 |
| Total | 565 | 679 | | 275 | 149 | | 296 | 333 | |
| Sex ratio | 0.83:1.00 | | | 1.85:1.00 | | | 0.89:1.00 | | |
| Chi-square | 10.447** | | | 37.443** | | | 2.176 | | |
| ** Significant at 0.01 | | | | | | | | | |

**Table 2**: Seasonal variations in sex ratio (Males: Femals) of *Sphyraena s*pecies in the Egyptian Mediterranean waters, off Alexandria during the period from March 1998 to February 1999.

| Season | *S. chrysotaenia* | | | | *S. Flavicauda* | | | | *S. sphyraeena* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number | | Sex ratio | Chi-square | Number | | Sex ratio | Chi-square | Number | | Sex ratio | Chi-square |
| | Males | Females | | | Males | Females | | | Males | Females | | |
| Spring | 118 | 127 | 0.93: 1.00 | 0.331 | 121 | 59 | 2.05: 1.00 | 21.356** | 42 | 38 | 1.11: 1.00 | 0.200 |
| Summer | 145 | 213 | 0.68: 1.00 | 12.916** | 25 | 19 | 1.32: 1.00 | 0.818 | 130 | 129 | 1.01: 1.00 | 0.004 |
| Autumn | 163 | 178 | 0.92: 1.00 | 0.660 | 63 | 41 | 1.54: 1.00 | 4.654* | 65 | 105 | 0.62: 1.00 | 9.412** |
| Winter | 139 | 161 | 0.86: 1.00 | 1.613 | 66 | 30 | 2.20: 1.00 | 13.500** | 59 | 61 | 0.97: 1.00 | 0.033 |

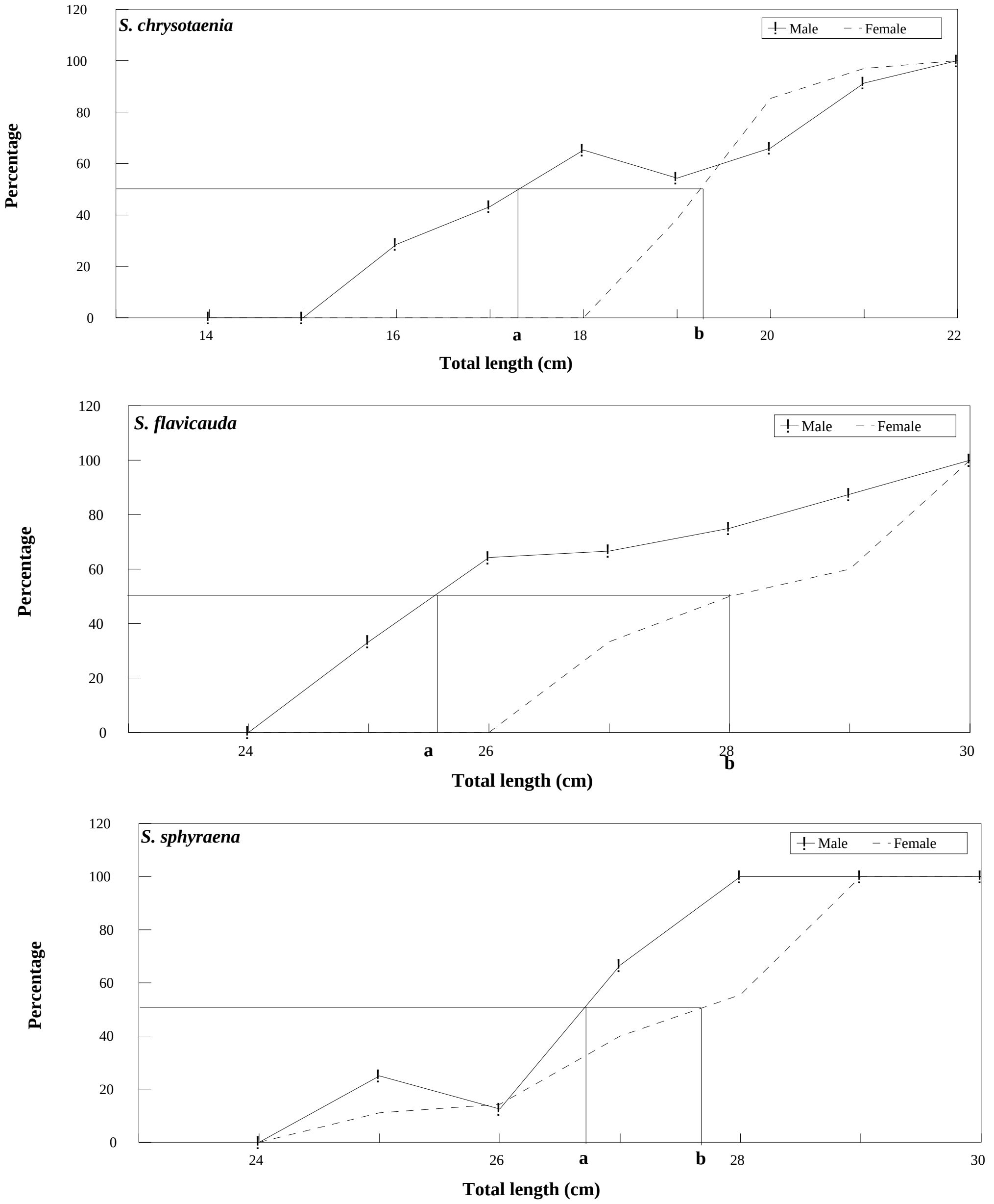



**Fig. 1:** Percentage distribution of mature fishes of males and females per length groups of *Sphyraena* species (a & b are the length at 50% maturity of males and females)

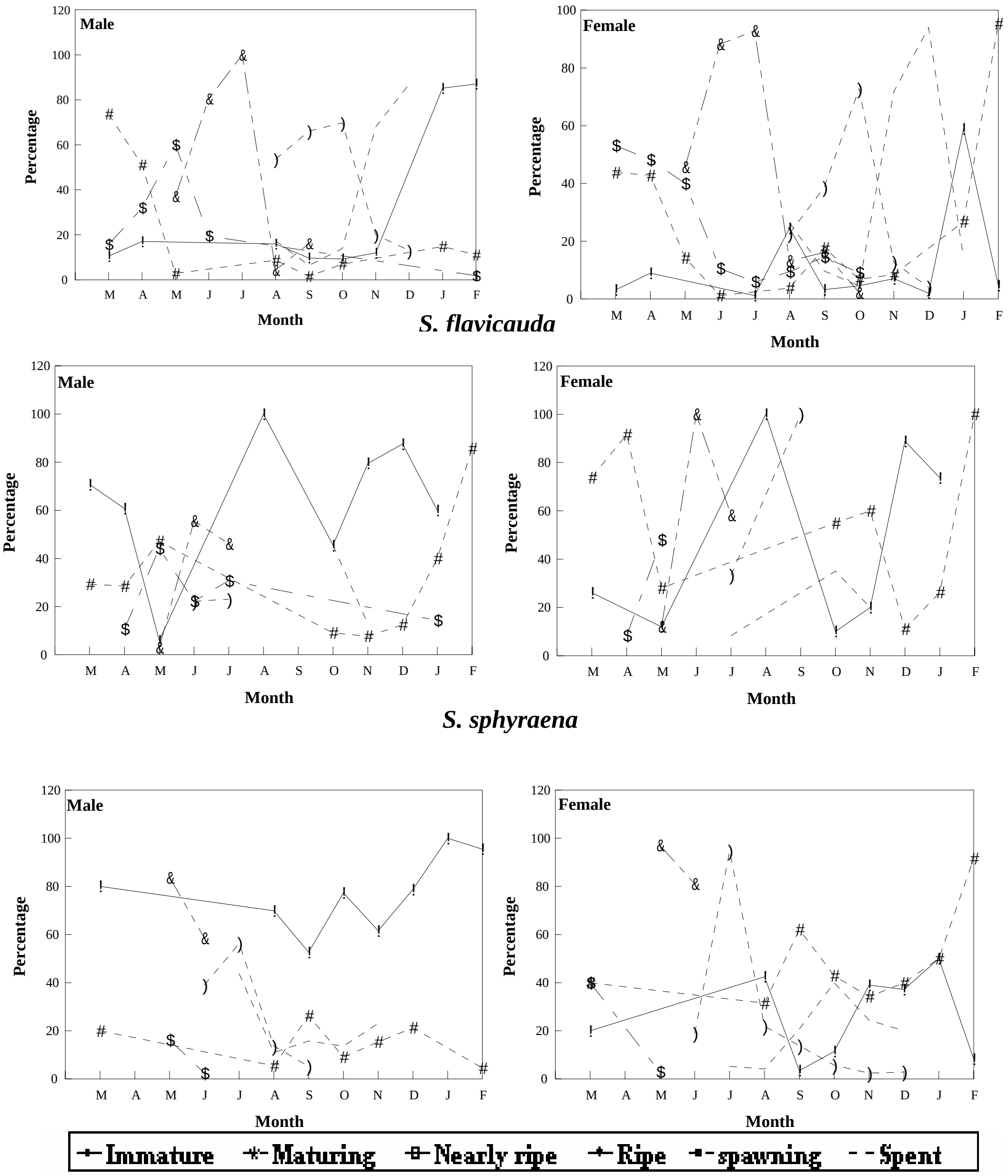



**Fig.2:** Monthly distribution of maturity stages for males and females of *Sphyraena* species.

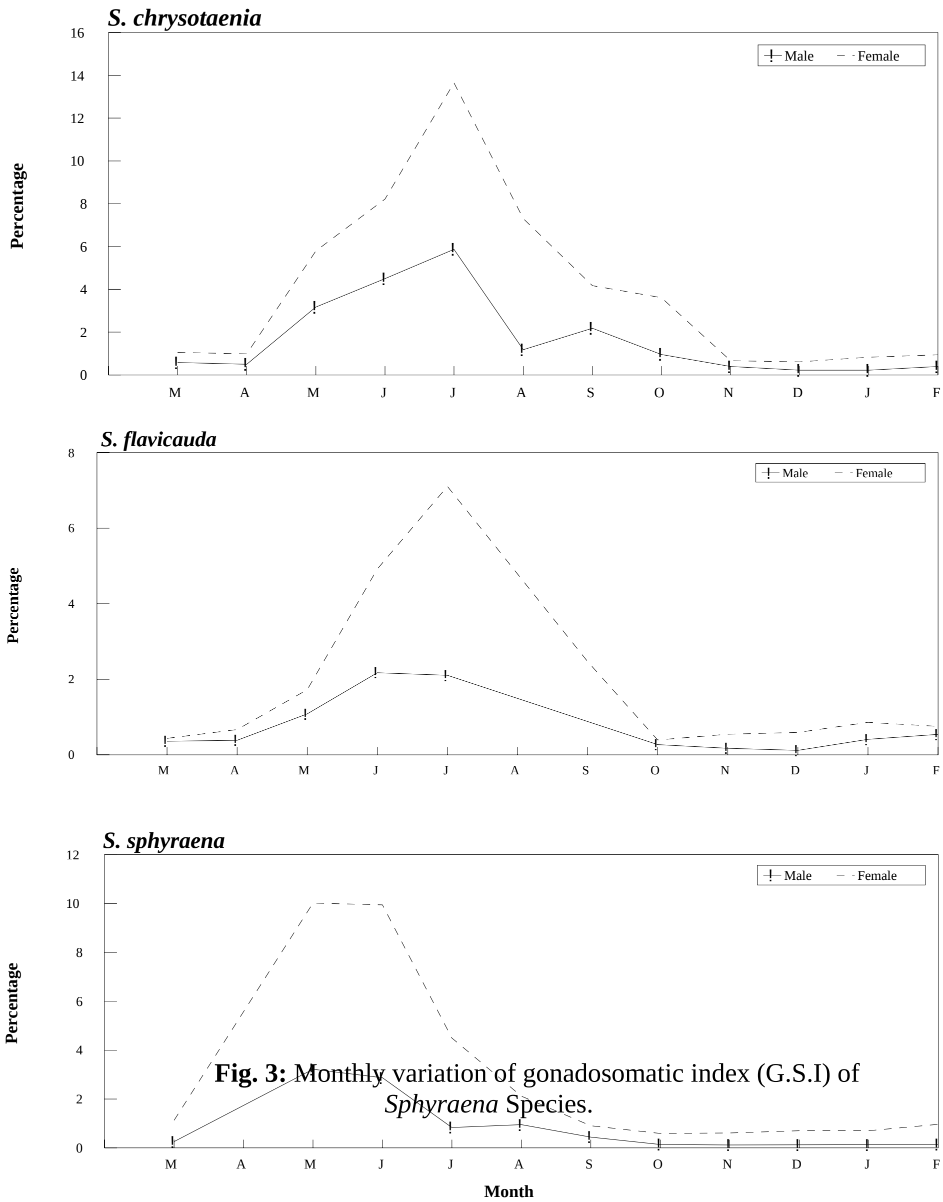



**Fig. 3:** Monthly variation of gonadosomatic index (G.S.I) of *Sphyraena* Species.

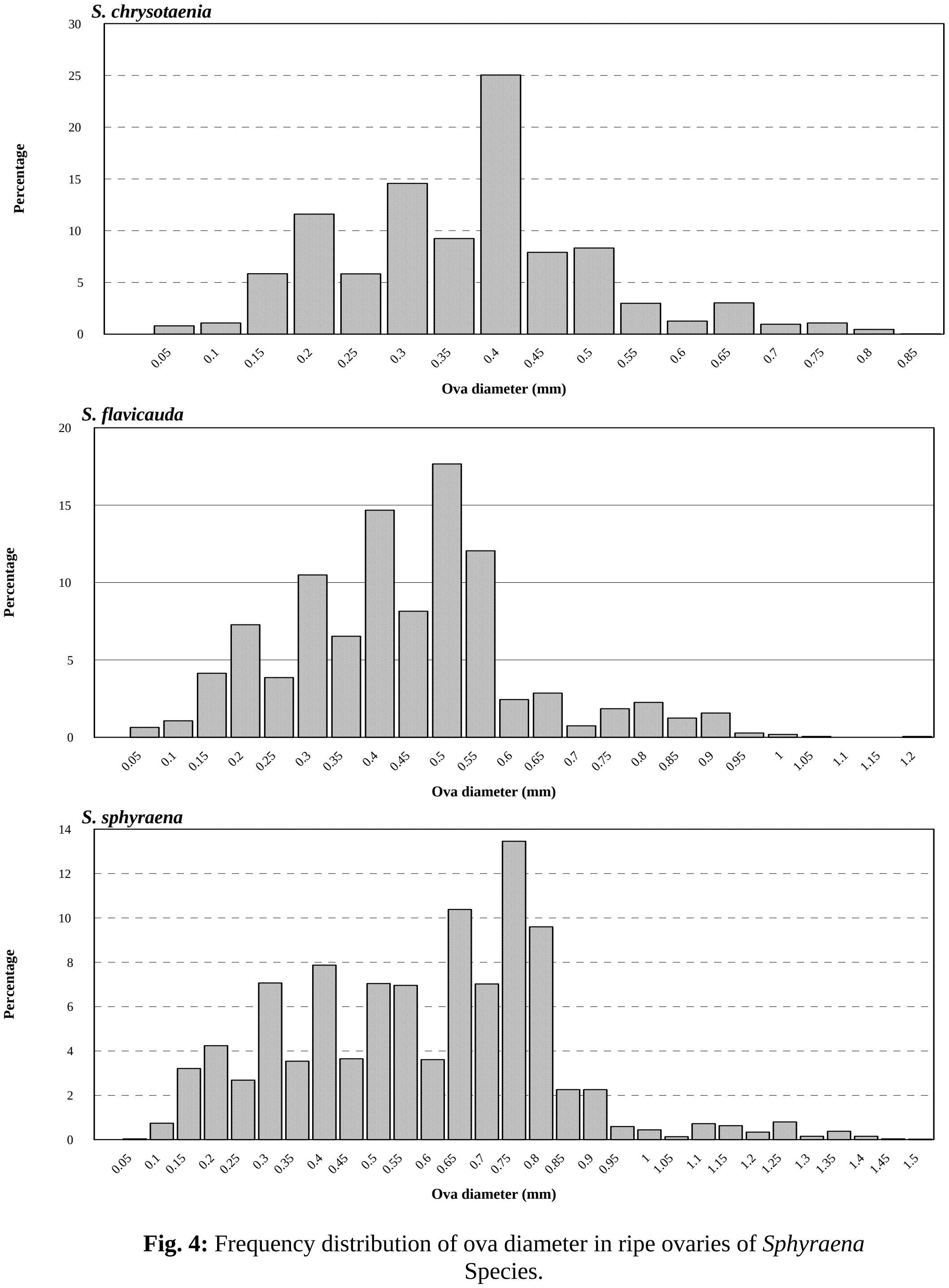
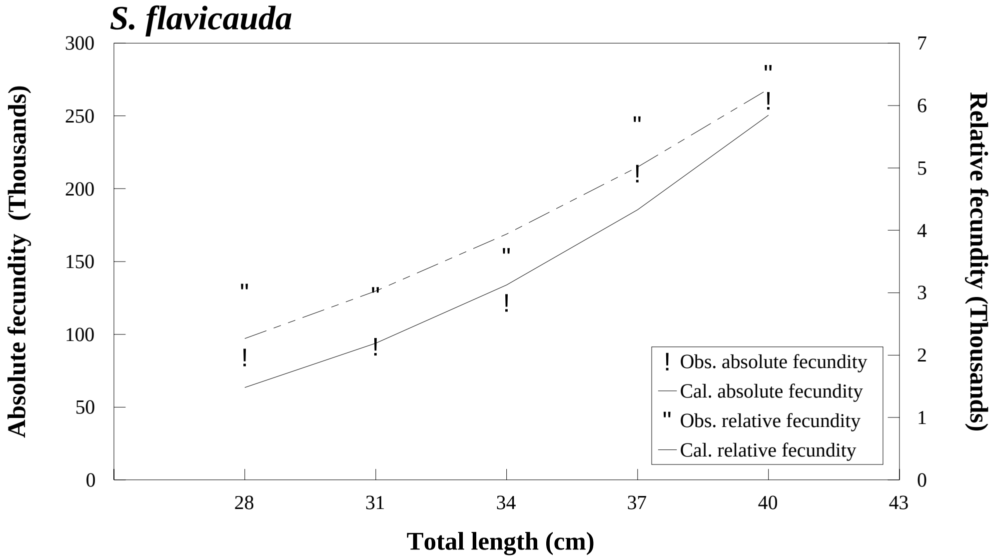



**Fig. 4:** Frequency distribution of ova diameter in ripe ovaries of *Sphyraena* Species.



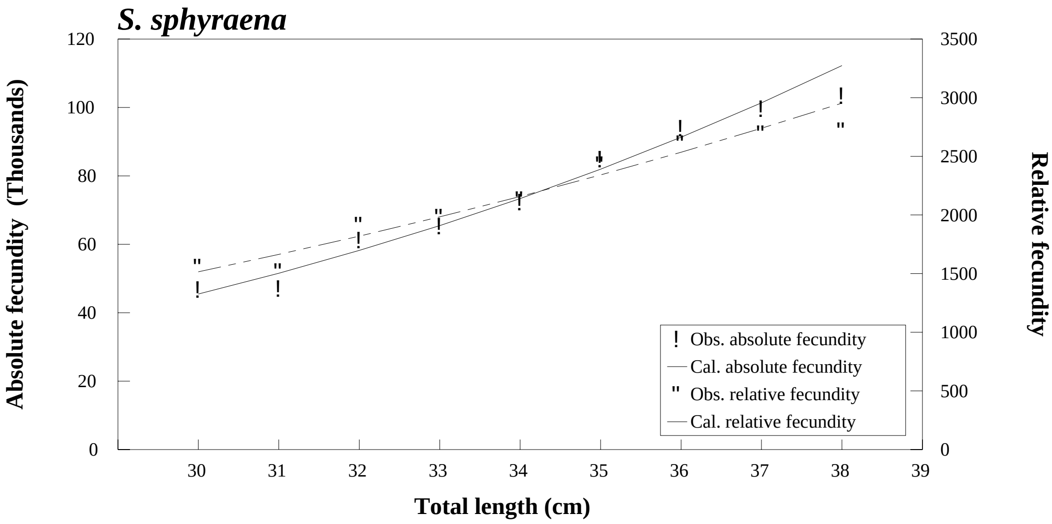




**Fig. 5:** Relationship between fecundity (absolute & relative) and total length for *Sphyraena species.*

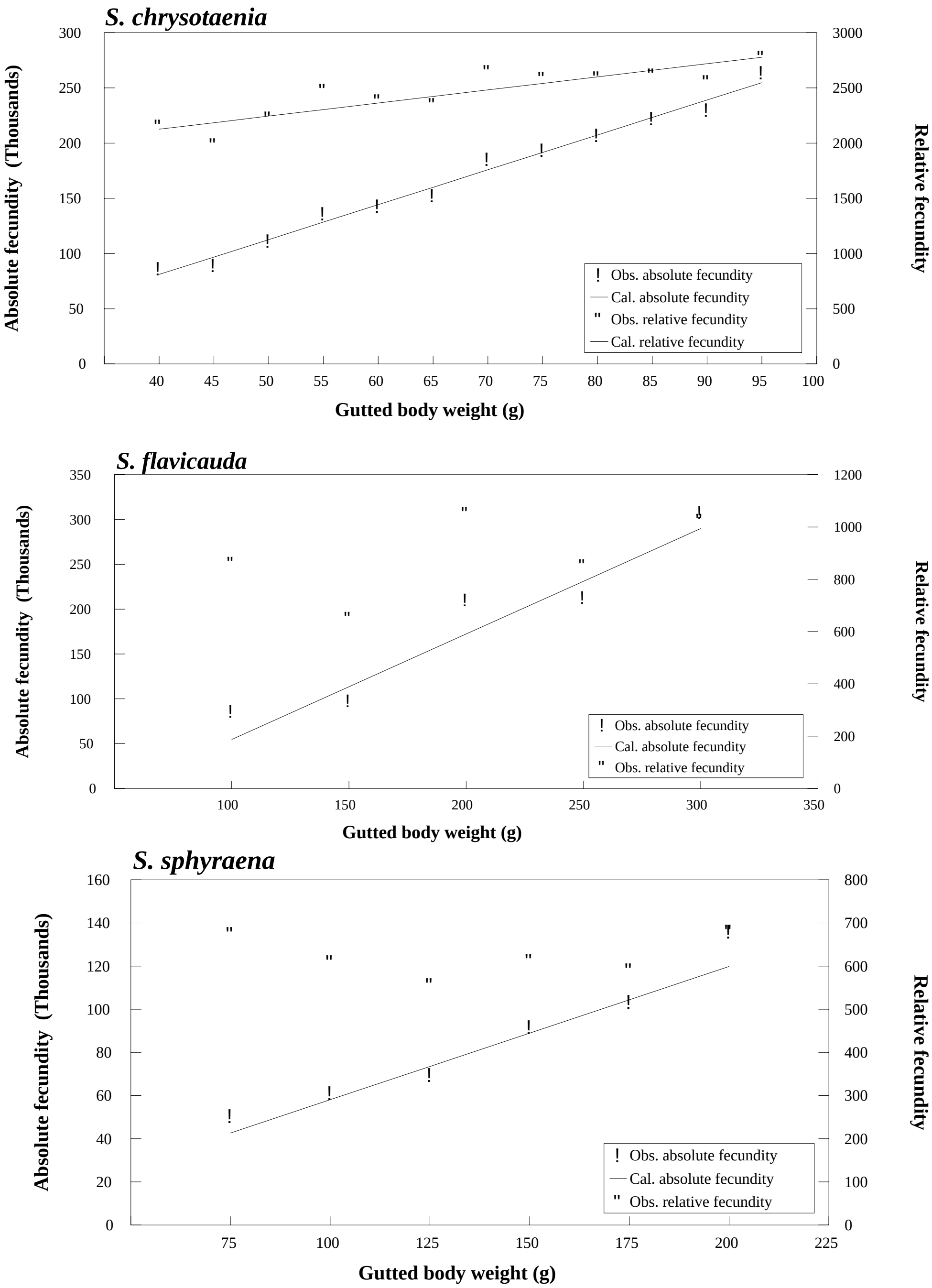



**Fig.6:** Relationship between fecundity (absolute & relative) and gutted weight for *Sphyraena* species.

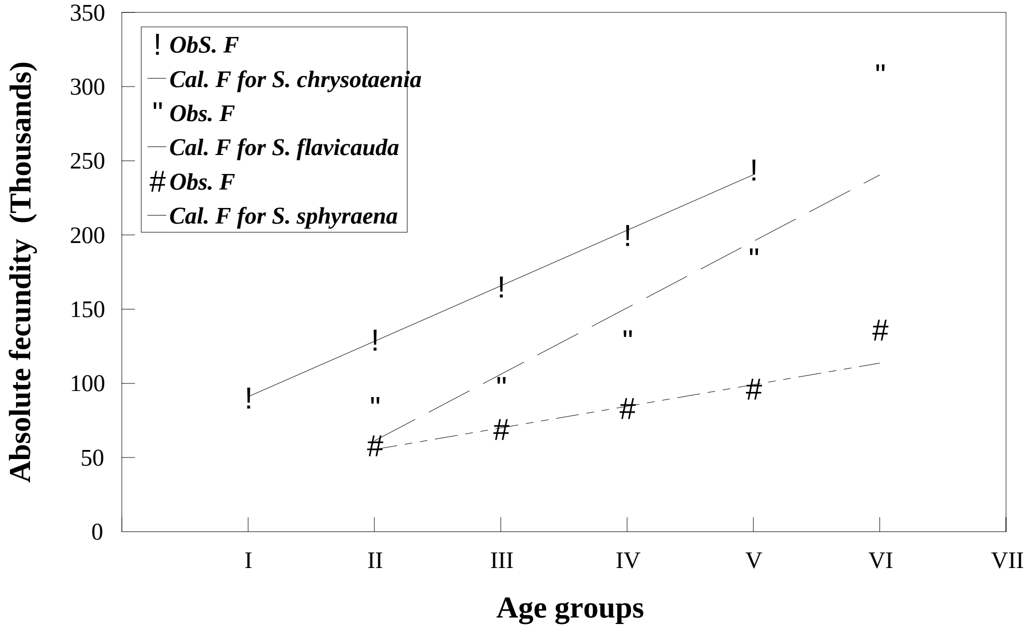



**Fig. 7:** Relationship between absolute fecundity and age for *Sphyraena* Species

## DISCUSSION

Successful exploitation of any fish solicits a thorough knowledge of its reproductive biology, such as gonad cycle, spawning time and fecundity in order to maintain and manage its vital resource.

Sex ratio is useful to estimate the reproduction potential in animals (Hamano & Matsuura, 1987). In the present study, the sex ratio of *S. chrysotaenia* and *S. sphyraena* was in favor of females. This agrees with Rizkalla (1985) for only *S. chrysotaenia* in the Egyptian Mediterranean waters and De Sylva (1963) for *S. barracuda* in Florida Bay. Okera (1982) found that the sex ratio of *S. obtusata* (=*S. chrysotaenia*) and *S. jello* from the northern Australian waters was in favor of males. Generally for all *Sphyraena* species studied, males dominated in smaller length groups while females were more abundant in the larger sizes. The same results were given by Rizkalla (1985) for *S. chrysotaenia* and *S. sphyraena* from the Egyptian Mediterranean waters. The tendency of males to decrease with the increasing fish length can be due to the shorter life span of males which is associated with the earlier attainment of sexual maturity (Hashem, 1981) and/or differential mortality rates in sex resulting in disappearance of males from the population at an earlier time than females (Solomon *et al.*, 1984). Conover & Kynard (1981) showed the possibility of temperature effect on sex ratio of developing fish embryo.

Concerning the seasonal variation of sex ratio in the present study, it is found that females were predominated over males in all seasons for *S. chrysotaenia* but the reverse was true for *S. flavicauda*. For *S. sphyraena* females were more numerous than males in autumn & winter the reverse is true in spring and summer (i.e., spawning season). This finding is in agreement with Rizkalla (1985) for the same species and locality. Such seasonal variation of sex ratio may be attributed to the pre-spawning migration of males (De Sylva, 1963).

For many fish species males attain sexual maturity at a smaller size than females and this may be associated with a shorter life span (Faltas, 1993; Allam, 1996). The size of first maturity of *S. chrysotaenia* and *S. sphyraena* was markedly larger than those given by Wadie *et al.* (1988) who suggested 19.0 and20.5 cm TL for males and females of *S. chrysotaenia* and 23.0 and 26.0 cm TL for males and females of *S. sphyraena* in the Egyptian Mediterranean waters. George *et al.* (1971) showed that *S. sphyraena* mature at 27.0 cm TL at Lebanese Mediterranean waters which in agreement with the same studied species.

In the present study, the spawning season was nearly in agreement with Wadie *et al*. (1988) for *S. chrysotaenia* (May – October) & *S. sphyraena* (April - September) in the Egyptian Mediterranean waters. On the other hand, The spawning season of *S. sphyraena* extends from June to November in the Lebanese Mediterranean waters (George *et al.*, 1971), from June to September in Alger Bay (Marinaro, 1971), from end of spring to the beginning of summer for *S. sphyraena* in Mediterranean and eastern Atlantic (John & Lythgoe, 1975), from June to July in the Gulf of Tunis (Turki & Ktari-Chakroun, 1985). The spawning season of *S. obtusata* (=*S. chrysotaenia*) extends during summer months in Moretou Bay (Blaber and Blaber, 1980). Okera (1982) stated that the spawning season of *S. obtusata* (= *S. chrysotaenia*) was during November and December in northern Australian waters. De Sylva (1963) showed that the spawning season of *S. barracuda* extended from April to November in the southern Florida waters.

The size of transparent ripe oocytes of *S. sphyraena* (0.95 to 1.5 mm) studied was in the range given by Marinaro (1971); and Turki & Ktari-Chakroun (1985) and was smaller than that given by Wadie *et al*. (1988) in the Egyptian Mediterranean waters. Moreover, the transparent oocytes of *S. sphyraena* ranged from 1.00 – 1.10 mm in diameter in Alger Bay (Marinaro, 1971) and also in the Gulf of Tunis (Turki & Ktari-Chakroun, 1985). The oocytes diameter of *S. chrysotaenia* and *S. flavicauda* studied were smaller than those given by Wadie *et al*. (1988).

In the ripe ovary, a continuous graduation in oocytes size and presence of three modes of oocytes in its frequency distribution for all *Sphyraena* species studied has been used to hypothesize multiple spawning (Yoshida, 1966; Faltas, 1993; Allam, 1996; Abdallah & Faltas, 1998). Qasim (1956) deduced the general rule that species breed during spring and summer show maturing oocytes in at least two size groups, and provide a series of batches of ripe eggs during the spawning period.

The minute oocytes were not considered in fecundity estimation in *Sphyraena* species but they have a great significance in supplying the eggs to be spawned in the following seasons. Hickling & Rutenberg (1936) called these oocytes reserve fund eggs while Macer (1974) called them recruitment stock eggs.

Fecundity is regarded as an adaptive character since its change seems to be a part of density population regulating mechanism (Bagenal 1960 & 1963). In the present study, absolute fecundity increases with fish length, weight and age. This is similar to the observation of Wadie *et al*. (1988), De Sylva (1963) and Hart (1973) for other *Sphyraena* species. The absolute fecundity of *S. chrysotaenia* is higher than that of *S. flavicauda* and *S sphyraena*. The high fecundity of *S. chrysotaenia* has probably been on the expense of the relatively small size of eggs and may explain at least probably the numerical superiority (Faltas, 1995) of *S. chrysotaenia* over *S. flavicauda* and *S. sphyraena* in the fishing grounds. Also this may be due to differences of genetics and ecological factors such as food supply, population density and changes in temperatures (Scott, 1962; Nikolsky, 1963; Bardakci & Tanyoloc, 1990; Unlo & Balci, 1993). Furthermore, fish fecundity is affected by the total amount of energy given to the ovary during gonad maturation (Rogers, 1989 and Wootton, 1990). The values of the relative fecundity with respect to length in the present study are significantly larger than those values given by Wadie *et al*. (1988) for *S chrysotaenia* and *S. sphyraena*. The increasing fecundity in the present study than those given by Wadie *et al.* (1988) may be as a result of lowering egg size (Sargent *et al.,* 1987 and Beacham &Murray, 1993).

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