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Reproductive dynamics of the common sole *Solea solea* (Linnaeus, 1758) from Bardawil lagoon, North Sinai, Egypt

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Abstract

The soles (family Soleidae) are one of the most important fish species inhabiting Bardawil lagoon, North Sinai, Egypt. The soles catch composed of two species from which the common sole, *Solea solea* is the most common one. They are exploiting by trammel nets (locally known as Dabba) and earning up to 10 million LE annually. Reproduction is an important biological aspect among fishes, where the recruitment and stock abundance depend, so the maturity, spawning season, fecundity, length and age at first sexual maturity and sex ratio of *S. solea* in Bardawil lagoon were studied. The monthly gonado-somatic indices and macroscopically investigated maturity stages indicated that *S. solea* spawns in the late autumn to the early spring from November to April with peak in December. The overall sex ratio throughout the study period was 1:2.11 males to females, which was significantly different from 1:1. The absolute fecundity ranged from 270,000 to 1,200,000 eggs in females with total weights varying from 31 to 400 g. The size at 50% sexual maturity (L_{50}) was 18.7 and 19.6 cm TL for males and females respectively. It was found that about 58% of *S. solea* were caught before reaching their first sexual maturity. The estimated L_{50s} indicate that the current minimum legal length in Bardawil lagoon is not appropriate for managing this species. The study recommends reduction of fishing pressure especially during the spawning season and reevaluated the mesh sizes of dabba nets used in the lagoon as well as prohibited the trawling in the lagoon.

Introduction

Bardawil lagoon (Fig. 1) is one of the northern lakes in Egypt and it is a part of the Mediterranean coastal lands of Sinai. It plays an essential role in the fish production in Egypt, where it produces very economically important species of fishes such as seabass, seabream, sole, grey mullet, eel, meager and white grouper. In the Bardawil lagoon total annual

commercial landings varied between 2226 and 5410 ton during the last 15 years (Annual statistical report 2012). In 2013, only 3237 ton was landed corresponded to a value of almost 100 million Egyptian pounds. The sole fishes (family Soleidae) are one of the most important fish species inhabiting the lagoon. Their catches fluctuated between 123 and 343 ton during the last 15 years (Annual statistical report 2012) forming about 5% of the total lagoon production and 11% from fish production of the lagoon. In 2013, 122 ton of soles were landed forming a net profit of about 10 million Egyptian pounds.

Common sole *Solea solea* and Egyptian sole *S. aegyptiaca* (Order: Pleuronectiformes; Family: Soleidae) are the most important sole species that occurs in the Egyptian waters. They tend to occupy shallow, sandy and sandy/muddy habitats as well as the shallow lagoons. The common sole is highly appreciated fish by the Egyptians especially in the coastal communities because of its high quality flesh and is one of the commercially important fish in Egypt providing up to 90 million LE annually. Despite its worldwide importance, little work has been dedicated on its reproductive biology. In Egypt, the information about the reproductive biology of this species was very scarce (Salman, 2014). The aim of this study is to provide the basic information about the reproductive dynamics of the common sole in Bardawil lagoon as an effective tool for its management.

Material and methods

Study area

Bardawil is a shallow hyper-saline lagoon that extends to about 90 km length with a maximum width of 22 km, and range in depth from 0.3 to 5 m. It is occupying much of the Mediterranean coast of Sinai and separated from the sea by a sandbar that varies in width between 100 m and 1 km. Originally, Bardawil was connected to the sea via two small natural inlets at its eastern extremity (Bughaz Zaranik and Abo Salah), usually becoming inundated with seawater only during winter when storms often breached the unstable sandbar. During summer, most of the lagoon was isolated from the sea and water evaporated, leaving behind large areas of sabkha. Several man-made inlets have been dredged along the sandbar since 1905 in an effort to allow the permanent inundation of the lagoon and maintenance of salinity levels suitable for the development of fisheries. Today, there are two man-made inlets (Bughaz I & II), which are continually being blocked through sedimentation. The average area of the lagoon is about 650 Km^2 and the mean annual fish production was about three thousand ton. Bardawil is the least polluted wetland in Egypt and represents one of the least polluted in the entire Mediterranean region. The lagoon is an important wintering and staging area for large numbers of water-birds and is an important source of local fishery. Fishing is

prohibited between January and April, in order to allow fish stocks to recuperate. A number of fishing methods were used in the lagoon including dabba (trammel nets), veranda (bouss), sinnar (lines), kalsa (trawl), dahbana and el-tair nets. The surface water temperature fluctuated between a minimum of 14.8^{0}C during January to a maximum of 29.4^{0}C in August, with annual mean of 22.7±5.17^{0}C. While, the salinity of Bardawil lagoon is much higher than in the open sea as a result of low rainfall and high evaporation rate. The salinity in the lagoon varied between a minimum of 46‰ in February and a maximum of 50.9‰ during August with a mean of 48.86±1.57‰.

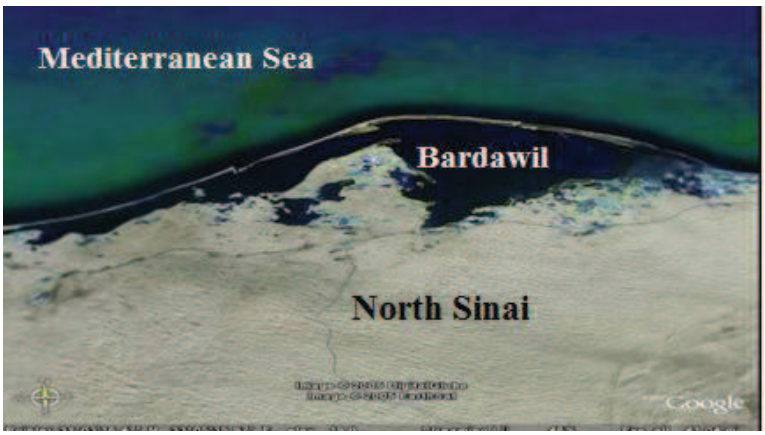

Fig. 1: Bardawil lagoon taken by Google earth

Sampling

Fish samples, the surface water temperature of the lagoon and salinity were collected monthly from April 2011 to December 2013.

Laboratory examination

In the laboratory, each individual was measured to the nearest cm for the total length (TL) and weighed to the nearest 0.01 g for the body total mass (Wt) with a Sartorius balance of range 3000 g. They were dissected and the sex was determined by the macroscopic investigation. The gonads were weighed to the nearest 0.001 g. The sex-ratios, determined by month and by size classes, the overall sex ratio (males: females) was also recorded.

Average length at first maturity (L_{50}) was defined as the 1cm length class at which 50% of the individuals of both sexes reached maturity. The percentage of sexual maturity was described by a logistic function (Ghorbel et al., 1996) as $P = 1/ 1+ e^{-(a+bTL)}$ where P = proportion of mature individuals; TL = total length (cm), and a and b are constants, the value of L_{50} was estimated from the negative ratio $L_{50} = -(a/b)$

The spawning period was determined from the gonado-somatic index (GSI) and by computing the proportions of fish at each maturity stage. The gonado-somatic index (GSI)

was estimated as GSI = gonad weight/ body weight x 100. While the gonadal maturity stages were recognized as (I = immature; II = developing; III = ripe; IV = ripe running; V = spent).

For determination of the absolute fecundity (AF), only the ripe ovaries were preserved in 4% neutral formalin. Three sub-samples were taken from each lobe and weighed to the nearest 0.001 g. Then, each sub-sample was crumbled in Petri-dish containing water. The number of eggs in each sub-sample was counted using Nikon Zoom Stereomicroscope focusing block fitted with transmitted light. The absolute fecundity F was estimated as F = W'/W * X, Where W' is the weight of ovary's sub-sample, W is the weight of whole ovary and X is the number of eggs in the sub-sample. The relationship between absolute fecundity - total length was described by the equation AF = Y + ß TL where AF = absolute fecundity; TL = total length; ß = slope and Y = regression intercept.

Statistical analysis

The analysis of variance (ANOVA) was used to determine the effect of the months and sex on the gonado-somatic index. The sex ratio was statistically tested for significant deviations from the expected 1:1 ratio with a χ^2 test. All Statistical analyses were carried out with the software Statistica 7.1 version.

Results and discussion

Knowledge of reproductive biology of a fish species is essential for effective fishery management (Marshall et al., 2003). Determination of sex, gonad maturity and quantifying the reproductive potential of the fish at capture are important in population dynamics and management models (Macias et al., 2005a&b). In this study the reproductive dynamic as a management tool of the common sole in Bardawil lagoon are estimated including sex ratio, reproductive season, size at maturity and fecundity.

Sex ratio

The sex ratio for common sole fish collected in this study was 785 males to1657 females, or 1 : 2.11. A χ^2 test of the sex ratio indicated statistically significant deviations (df = 1; $P<0.001$) from a 1:1 sex ratio. It was noticed that females were outnumbered males for all length groups and during all months (Figs. 2 and 3).

The differentiation of sex ratio from the unity, can be the result of several factors such as mortality rate (Mazzoni & Caramaschi, 1997), selective capture influence (Hood & Johnson, 2000), partial segregation by sex (Mejuto et al., 1998), season (Hoey, 1991; Mejuto et al., 1995), migration patterns (Sadovy & Shapiro, 1987) and change in population structure between inshore and offshore locations (Hyndes &Potter, 1997; Sun et al., 2009).

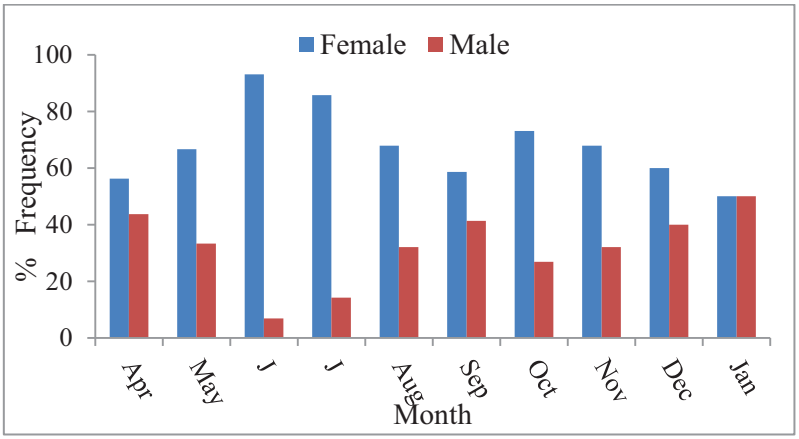

Fig. 2: Sex ratio by month of *Solea solea*.

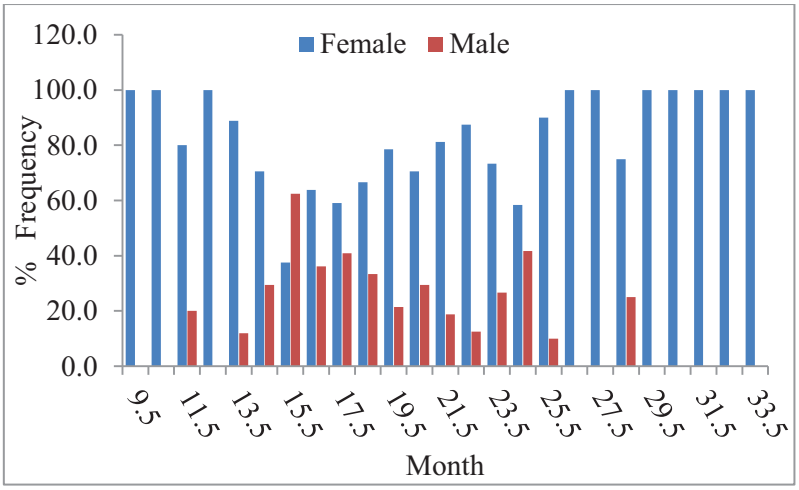

Fig. 3: Sex ratio by length groups of *Solea solea*.

Reproductive cycle

Gonado-somatic index (GSI) reflects the physiological activity of the gonads, where the increase of it is an indication of the beginning of the breeding season of the fish. The GSI values in female and male were significantly different among the months ($P < 0.001$). The monthly changes in males and females GSI were represented in Fig. 4. Generally, males GSI of *S. solea* in Bardawil lagoon was lower than females. The lowest value of males GSI (0.39) was recorded in August, slightly increased in September through November, reaching its highest value (2.81) in December. The mean GSI decreased again from January till August. The mean GSI of females showed a similar pattern as males. It attained the lowest value (0.93) in July and increases slightly during August, September, October and November reaching its maximum value in December. Female GSI decreased in period from February to June. GSI of both sex were showed a definite breeding season which extends from November to early April. As the samples were missing during February to the end of March, the

maturity stages confirm that December is the month of the greatest spawning activity for males and females and after December, the mean GSI started to decrease.

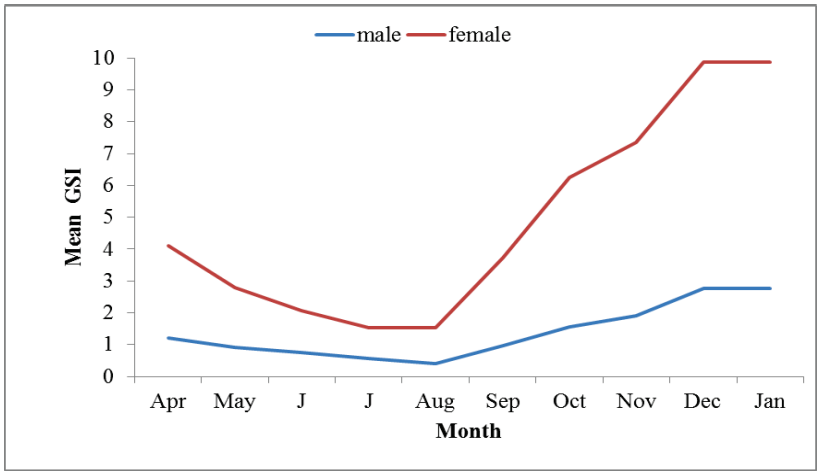

Fig. 4: Monthly gonado-somatic indices (GSI) of females and males of *Solea solea*.

The gonads of 650 males and 1100 females *S. solea* were used to evaluate the monthly variations in their maturity stages in Bardawil lagoon (Fig. 5). It was obvious that for both sexes, the immature and maturing stages (I & II) were found throughout the study period. The highest percentages were recorded in June for stage I and July for stage II. The mature stage III for both sexes was observed with a high percentage in August, September and October. The ripe stage IV was firstly appeared in late August for males and females and comprised 2.15% for males and 1.77% for females. The percentages of the ripe stage was increased progressively and reached its highest values in November, December and January, for both sexes with a peak in December. The spent males and females were first appeared in November, increased progressively but we can't detect which month of the highest percentages because we don't have data for February and March.

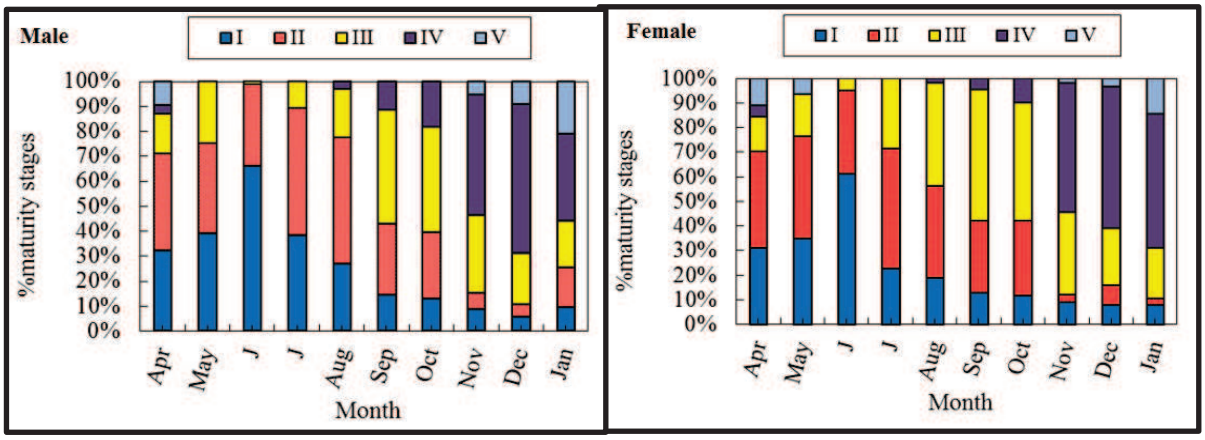

Fig. 5: Monthly Maturity stage percentages of *Solea solea*.

Based on the monthly variation of both gonado-somatic index and maturity stages it was obvious that the common sole in Bardawil lagoon is winter spawner and *S. solea* spawns for about 5 months from late October to early April, with a peak activity during December.

This agreed with the previous studies about the reproduction of soleid species in Egypt. El-Husseiny (2001) reported that the GSI of female of *S. aegyptiaca,* in Lake Quarun, increased progressively to reach its maximum value in January, while the minimum value was recorded in July, while Ahmed et al. (2010) found that the monthly changes in GSI of males and females *S. aegyptiaca* showed a definite breeding season which extends from January to June. Both sexes reached the highest values of GSI in January, while the minimum was in June and August for females and males respectively. Salman (2014) confirmed that the common sole in Bardawil lagoon is a winter spawner and spawned once a year.

Length (L_{50}) at first sexual maturity

Length at first sexual maturity (L_{50}) has a great importance in the determination of optimum mesh size. L_{50} is an essential factor for sustainable fishery and is an important parameter for fish stock assessment (Wang et al., 2003). The length at first sexual maturity of *S. solea* in Bardawil lagoon was 18.7 cm for males and 19.6 cm for females (about an age of 1.57 and 1.41 year respectively). Although, males matured at a slightly smaller size than females, there was no significant difference between the sizes of maturity for males and females ($P < 0.05$). These results are coincides with the findings of Mehanna and Salem (2012), where they gave L_{50} equal to 19.9 cm TL for combined sexes in Bardawil lagoon. Salman (2014) gave L_{50} at 18.6 cm for males and 19.1 cm for females *S. solea* from Bardawil lagoon.

It is evident that a considerable proportion (58%) of *S. solea* catch didn't reach their sexual maturity and the bulk of sampled fish were smaller than 20 cm total length (Fig. 6). On the other hand, in term of weight or biomass, fishes smaller than size at first sexual maturity represented about 40% of the total catch.

Also, the smallest length recorded in the catch was 11 cm for males and 9 cm for females, which is smaller than the L_{50}. This means that the exploited *S. solea* must be protected in order to spawn at least once before being fished. Therefore, the mesh sizes used in Bardawil lagoon should be increased to catch fish of lengths greater than 20 cm.

Fecundity

A total of 55 ripe females representing lengths from 16 to 33.5 cm TL were used for fecundity estimation of *S. solea* in Bardawil lagoon. The fecundity ranged from 270,000 to 1,200,000 eggs in females with weight varying from 31 to 400 g, while the ovaries weights

varied from 8 to 25 g. There was a general increase in fecundity with the increase of the total length (TL) and total weight of the fish (Fig. 7). The regression analyses showed significant linear relationship between fecundity and total weight and total length. The coefficient of determination indicated fecundity in relation to the total length was highly correlated (r^2 = 0.87) than the weight of the fish (r^2= 0.82).

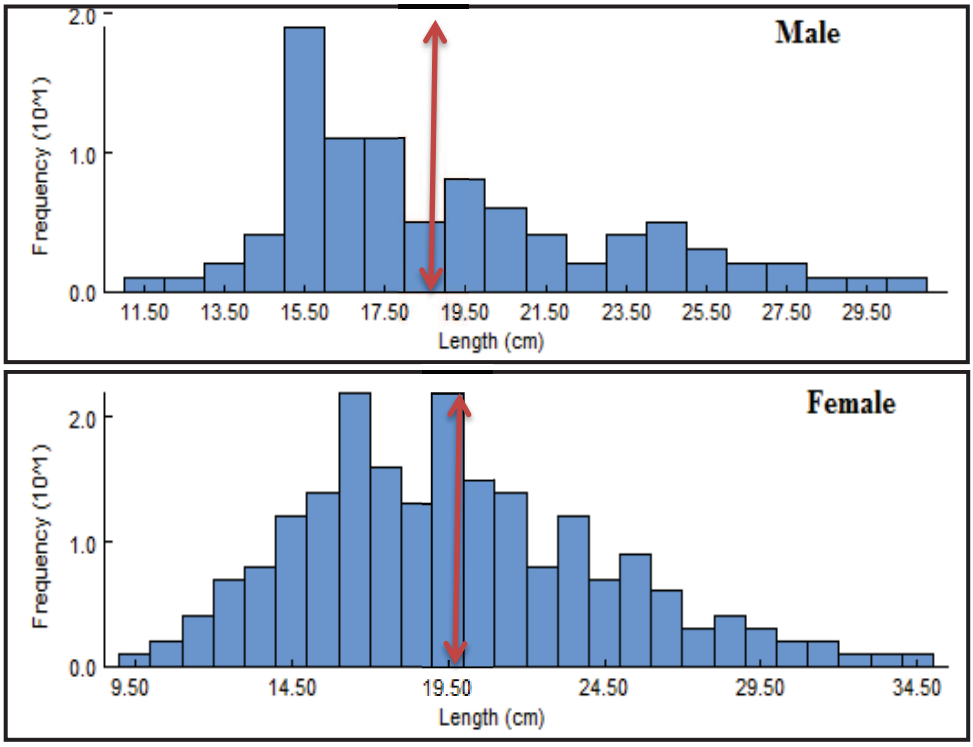

Fig. 6: Length at first maturity of males *Solea solea*.

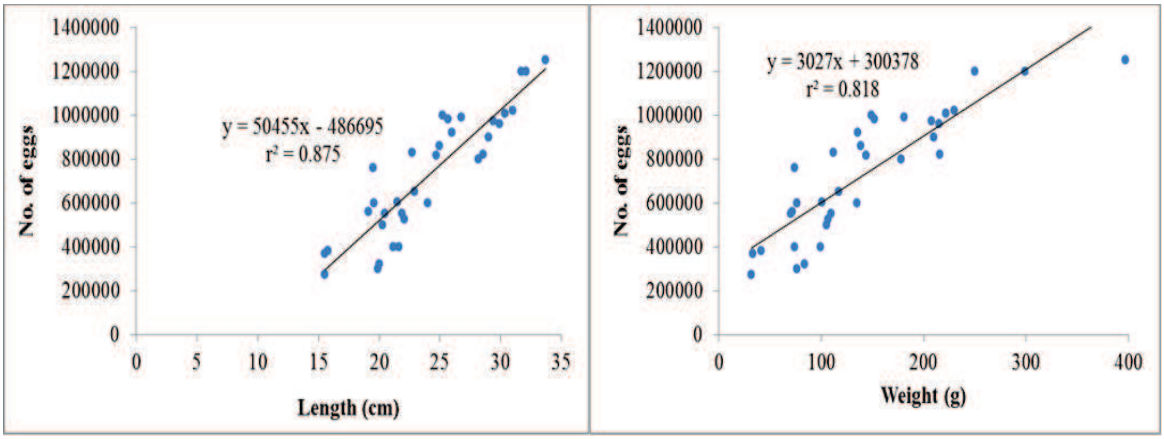

Fig. 7: Relationship between both total length and weight of *Solea solea* in Bardawil lagoon

Conclusion and recommendations

The study of reproductive dynamics of *S. solea* in Bardawil lagoon revealed two important facts which should be taken into consideration during the managing its fishery. Firstly, *S. solea* in Bardawil lagoon is a winter spawner and spawn once a year and its

spawning period occurs between October and April with a peak activity during December (the active fishing season). Secondly, a considerable proportion (58%) of *S. solea* number didn't reach the first sexual maturity and don't contribute in spawning. In term of weight or biomass, fishes smaller than size at first sexual maturity represented about 40% of the total catch. For the management purpose, it could be recommend that:

- Reduce the fishing pressure on this species during the spawning season or reconsider the timing of fishing and closed seasons to protect it during its spawning season
- Study in detailed the gear selectivity of trammel nets used
- Prohibiting all kinds of illegal fishing techniques working in the lagoon and affect the productivity of the lagoon like kalsa (trawl nets) and dahbana nets.
- Protect the nursery grounds through implementing MPA.

References

Ahmed A. I., M. M. Sharaf and H. A. Laban, 2010. Reproduction of the Egyptian sole, *Solea aegyptiaca* (Actinopterygii: Pleuronectiformes: Soleidae), from Port Said, Egypt, Mediterranean Sea. Acta Ichthyol. Piscat., 40 (2): 161–166.

Anderson R. O. and S. J. Gutreuter, 1983. Length, weight and associated structural indices. In: L.A. Nielson & D.L. Johnson (Eds). Fisheries Techniques, Am. Fish. Soc. Bethesda: 283-300.

El-Husseiny M. M., 2001. Reproductive Biology of *Solea* sp. in Lake Quarun. MSc Thesis, Faculty of Science, Ain Shams University, Egypt.

Ghorbel M., O. Jarboui, M. N. Bradai and A. Bouain, 1996. Détermination de la taille de première maturité sexuelle par une fusion logistique chez *Limanda Limanda, Pagellus erythrinus* et *Scorpaena porcus*, Bull. INSTM, n. spec., 3: 24-27.

Hood, P. and A. K. Johnson, 2000. Age, growth, mortality, and reproduction of red porgy, *Pagrus pagrus*, from the eastern Gulf of Mexico. Fish. Bull., 98: 723-735.

Hoey J. J., 1991. Sex-ratio data for the western North Atlantic swordfish. ICCAT. Col. Vol. Sci. Pap. Vol. XXXV (2): 429-436.

Hyndes G. A. and I. C. Potter, 1997. Age, growth and reproduction of *Sillago schomburgkii* in south western Australian near shore waters and comparisons of life history styles of a suite of *Sillago* species. Environ. Biol. Fishes, 49: 425-447.

Macias D., A. Fenech-Farrugia, J. M. De la Serna, M. J. Gómez-Vives and L. Lema, 2005a. First result about swordfish (*Xiphias gladius*) fecundity in the Central and Western Mediterranean, an updated approach. Col. Vol. Sci. Pap. ICCAT 58(4): 1543-1553.

Macias D., A. Hattour, J. M. De la Serna, M. J. Gómez-Vives and D. Godoy, 2005b. Reproductive characteristic of swordfish (*Xiphias gladius*) caught in the Southwestern Mediterranean during 2003. Col. Vol. Sci. Pap. ICCAT 58(2): 454-459.

Marshall, C.T., L. O'Brien, J. Tomkiewicz, F.W. Köster, G. Kraus, G. Martteinsdottir, M. J. Morgan, F. Saborido-Rey, J.L. Blanchard, D. H. Secor, P.J. Wright, N.V. Mukhina and H. Bjornsson, 2003. Developing alternative indices of reproductive potential for use in fisheries management, cases studies for stocks spawning, an information gradient. J. Northw. Atl. Fish. Sci., 33: 161-190.

Mazzoni, R. and E. P. Caramaschi, 1997. Spawning season, ovarian development and fecundity of *Hypostomus affinis* (Osteichthyes, Loricariidae). Rev. Brasil. Biol. 57:455-462.

Mehanna, S. F. and M. Salem, 2012. Fisheries regulations for the common sole *Solea solea* (Soleidae) at Bardawil lagoon, Mediterranean coast of Sinai, Egypt. (In press)

Mejuto J., J. M. de la Serna and B. Garcia, 1995. An overview of the sex ratio at size of the swordfish (*Xiphias gladius* L.) around the world: similarity between different strata. ICCAT. Col. Vol. Sci. Pap. Vol. XLIV (3): 197-205.

Mejuto J., J. M. De la Serna and B. Garcia, 1998. Some considerations on the spatial and temporal variability in the sex-ratio at size of the swordfish (*Xiphias gladius* L.). Col. Vol. Sci. Pap. ICCAT, 48(1): 205-215.

Sadovy, Y. and D.Y. Shapiro, 1987. Criteria for the diagnosis of hermaphroditism in fishes. Copeia 1987: 136–156.

Salman, S., 2014. Fisheries characteristics and population dynamics of commercial species of family Soleidae in Bardawil lagoon, North Sinai, Egypt. MSc. Thesis, Suez Canal University.

Sun ,C., Y. Chang, C., Tszeng, S. Yeh and N. Su, 2009. Reproductive biology of blue marlin (*Makaira nigricans*) in the western Pacific Ocean.Fish.Bull.107: 420-432.

Vazzoler, A.E.A.M. 1996. Biologia da reproducão de Peixes Teleósteos. Teoria e prática. Maringá, 169p.

Wang S. P., C. L. Sun and S. Z. Yeh, 200). Sex ratios and sexual maturity of swordfish (*Xiphias gladius* L.) in the waters of Taiwan. Zooll. Stud. 42(4): 529-539.