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Biometry and reproduction of three polychaete species from Egyptian coasts.

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ABSTRACT

The size variation, growth pattern, sex ratio, fertility and spawning of three nereidid polychaetes from Egyptian coasts were studied for a complete year, namely *Perinereis cultrifera* (Grube 1840), *Perinereis nuntia* (Grube 1857), and *Platynereis dumerilii* (Audouin and Milne-Edwards, 1833). The results revealed clear monthly variation in the studied parameters, and the three species showed allometric growth, while *P. cultrifera* displayed both allometric and isometric growth. *Perinereis nuntia* was characterized by the greatest size, the highest percentage of maturation, the highest fecundity and the largest oocyte diameter. *Perinereis cultrifera* and *P. dumerilii* had a close maximum length of 6.5 and 7.4 cm respectively. However, *P. cultrifera* displayed pronouncedly lower fecundity and maturation percentage than *P. dumerilii*, while the latter species recorded less biomass and smaller oocytes. In addition, the spawning of the three species occurred in different months of late spring and early summer, being in May-June for *P. cultrifera*, June-July for *P. dumerilii*, and March-April for *P. nuntia*..

INTRODUCTION

The morphometric characteristics and reproductive biology are important indication of the growth rate and the life cycle of the polychaete worms. **Giangrande (1997)** reviewed some life-cycle and life-history traits of some polychaete families, indicating a great diversity in their reproductive traits. The spawning behaviour and reproduction of *perinereis cultrifera* has received some attention (**Cassai and Prevedelli, 1998; Rouabah and Scaps, 2003b; Rouabah *et al.*, 2008; Rouhi *et al.*, 2008; Rettob, 2012 and Rettob *et al.*, 2013)**. The development and reproductive cycle of *Platynereis dumerilii* was considered in several publications (**Grant, 1989; Giangrande, *et al.*, 2002; Simonini and Prevedelli, 2003a; Lawrence and Soame, 2009 and Fischer *et al.* 2010).** Field observations were carried out on the spawning and reproduction of *Perinereis nuntia* **(Hardege, *et al.*, 1994; Hardege and Bartels-Hardege, 1995; Ong, 1996; Zheng, 2000, 2002; Poltana *et al.*, 2007 and Darya *et al.*, 2013**). Laboratory

observations were also done on the effect of salinity and different diet on *Perinereis nuntia* **(Darya *et al.*, 2016)**.

Very little attention has been given to such studies in the Egyptian Coast, except that on the nereidid *Pseudoneries anomala* from the Alexandria coast **(Dorgham *et al.*, 2014)** and *Perinereis nuntia and Halla parthenopeia* from the Suez Canal **(Osman, 2007)**.

The present study aims to follow the size variation, fecundity and oocyte diameter of three nereidid species collected from Egyptian coasts, namely *Perinereis cultrifera*, *Platynereis dumerilii*, and *Perinereis nuntia brevicirrus*.

MATERIALS AND METHODS

Some environmental parameters were measured concurrently with the collection of the polychaete species, including water temperature, pH, salinity, dissolved oxygen (DO) and biochemical oxygen demand (BOD). The water temperature and pH were measured in the field, using a digital portable instrument (HANNA 10^{pH} ; pH - ºC Meter), and salinity by a calibrated Beckman Induction Salinometer (Model RS- 7C). Dissolved oxygen (DO) and biochemical oxygen demand (BOD) were measured following the Winkler method described by **Strickland and Parsons (1972)**.

Polychaete collection

The three polychaete species were collected from the areas of their high abundance. *P. cultrifera* was obtained from exposed rocky patch covered with algae at El Mex, west of Alexandria, which is directly affected by terrestrial waste water discharges. *Platynereis dumerilii* was collected from an algal community on exposed rocky bottom at Abu Qir, east of Alexandria. *Perinereis nuntia* was gathered from a sandy bottom of the Suez Canal coast at Ismailia City **(Figure. 1)**. The monthly number of worms collected for each species is illustrated in **Table (1).** All biological parameters were measured for full not injured specimens, once after reaching the laboratory in order to minimize formalin effect.

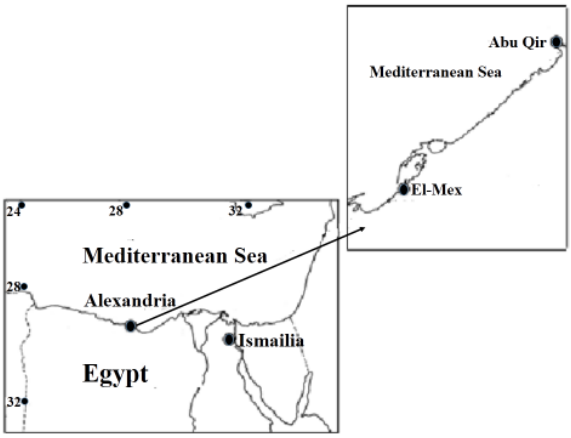

Fig. 1: A map of the sampling sites.

Table: (1) The monthly number of examined individuals of the three polychaete species (I: Immature, F: Female, M: Male).

	Perinereis cultrifera			***Platynereis dumerilii***			***Perinereis nuntia***		
Month	**I**	**F**	**M**	**I**	**F**	**M**	**I**	**F**	**M**
Aug. 2009	3	3	1	0	5	0	0	6	1
Sep. 2009	3	0	0	0	0	0	4	23	3
Oct. 2009	13	1	2	0	2	0	24	33	7
Nov. 2009	24	6	1	4	0	0	13	18	0
Dec. 2009	8	2	1	3	0	0	17	28	0
Jan. 2010	13	9	0	1	1	0	3	27	0
Feb. 2010	4	7	0	4	0	1	14	19	0
Mar. 2010	4	4	1	6	1	0	3	19	0
Apr. 2010	7	5	0	2	2	0	22	19	0
May	0	5	0	15	5	0	26	20	0
Jun.	2	0	0	8	10	2	1	13	0
Jul.	29	1	0	5	5	1	14	9	0

The measured biometric parameters **(Figure. 2)** were the total length (TL), length to 6^{th} segment (L6S), body width at 6^{th} segment (W6S), prostomium length (PL), prostomium width (PW), and the total body weight (TW).

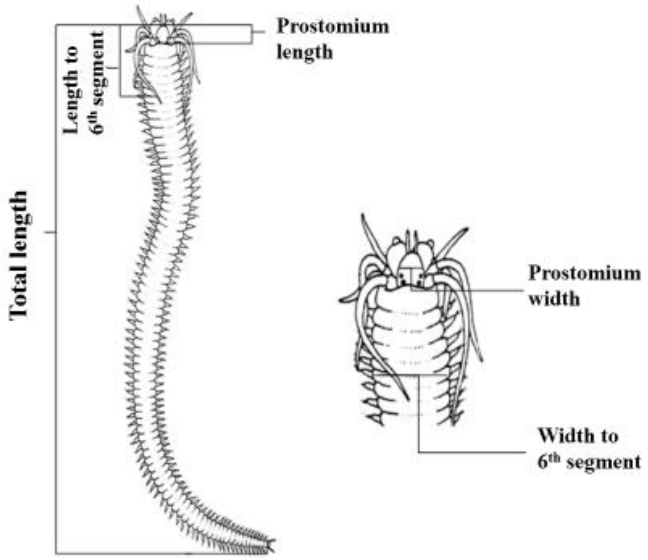

Fig. 2: **A scheme** of the biometric measurements

The length-weight relationship was calculated according to the allometric equation $W = aL^b$ **(Hile, 1936 and Beckman, 1948)**, where "W" is the total body wet weight (g), "L" the body length (cm), "a" constant and "b" is the coefficient of growth.
For reproductive observations, a monthly number of each species was examined to define the morphological changes during reproduction. Males were recognized by the sperm plates or sperm aggregates in the coelomic fluid and female by aggregation of eggs, while worms without sexual products were considered as immature. The diameter of about 40 oocytes were measured using eye-piece micrometer, and the fecundity (eggs/female) was estimated by counting all the ripen oocytes in the coelom of fully mature, complete, non-injured females during the spawning seasons.

RESULTS

1.Physico-chemical conditions:

The water temperature varied monthly between 18.8 ^{o}C in February and 32.3 ^{o}C in October at Mex, 18.2 ^{o}C in December and 32.3 ^{o}C in October at Abu Qir, and 16.8 ^{o}C to 29.3 ^{o}C at Ismailia.

The surface salinity at Mex experienced wide monthly variation over the year, from 24.4 to 32.6 ‰ relative to the variations in the volume of the discharged waste water, while it falls within a range of 37.4 - 39.8 ‰ at Abu Qir, and 33 - 37.4 ‰ at Ismailia. The pH displayed narrow range of fluctuation between 8.1 – 9 at Mex, and 7.85 – 8.6 at Abu Qir. The dissolved oxygen sustained concentrations between 6.5 – 14.6 mg/l at Mex and 7.1 – 10.0 mg/l at Abu Qir, associated with low BOD values at Mex (1.1 – 5.7 mg/l) and Abu Qir (3.3 – 7.35 mg/l).

2. Biometric and reproductive parameters

2.1 Perinereis cultrifera

The length of immature forms of this species varied between 1.4 -4.7 cm, against 3.4 – 7.4 cm for females, and 3.8 – 4.9 for males. The abundance ratio among the three stages (Im:F:M 15.7:6.1:1) indicated the dominance of immature forms by 68.8% of the total population, while females constituted 26.9%, and males (4.4%)**.** As shown in **Figure 3**, the majority of the immature individuals of *P. cultrifera* had length between 2-3 cm (37.3%) and 3-4 cm (36.4%), while the weight falls within 0.02-0.04 g (25.5%) and 0.04 0.06 g (20.6%) **(Figure 3)**. The longest and heaviest immature individuals occurred in February and March while the shortest and lightest were observed in August. The female length was distributed among 5-6 cm (44.2%), 4-5 cm (20.9%) and 6-7cm (16.3%) **(Figure 3)**, with weight fall mainly within the range of 0.1-0.2 g (34.9%) and 0.2-0.3 g (32.6%) **(Figure 3)**. The male of *P. cultrifera* was represented by 7 individuals, sustaining length between 3.8 -4.9 cm and weights between 0.078 - 0.158 g. The maximum length of female (7-7.4 cm) occurred in different months (November, January, February, and April), against the shortest ones in August. Similarly, the highest female weight appeared in November, January and April and the lowest weight occurred in August.

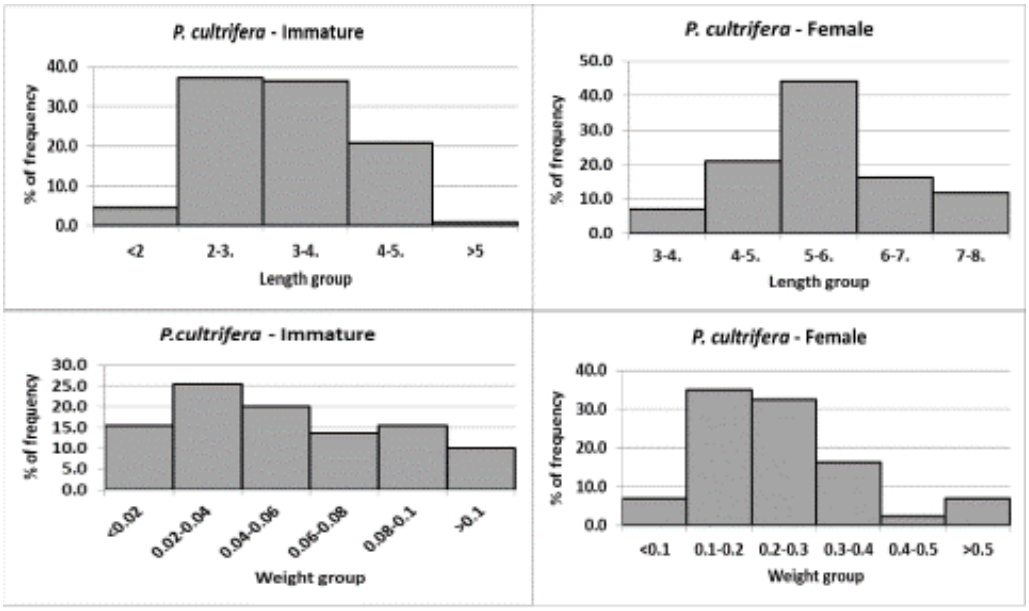

Fig. 3 – Length and weight frequency in the immature stages and female of *Pernereis cultrifera*

The length-weight relationship of *P. cultrifera* **(Table 2)** demonstrated allometric growth, but the regression equation between the length to 6th segment and weight **(Table 3)** suggested isometric growth as b value (3.06) slightly exceeds 3. The relationship between the width of 6th segment and body weight was exponential, and a power relationship was calculated between body weight and both prostomium length and width **(Table 3)**. The relationship between body length and both prostomium length and width was linear, against power relationship between body length and the other biometric parameters **(Table 3)**.

Table: (2) The length-weight relationship in the three polychaete species.

	Regression equation	r	N
Platynereis dumerilii	$W=0.002L^{2.611}$	0.96	83
Perinereis cultrifera	$W=0.002L^{2.681}$	0.955	160
Perinereis n. brevicirrus	$W=0.001L^{2.465}$	0.955	386

Table: (3) Correlations between length and weight with different parameters of some polychaete species from Egyptian Coast (Prostomium length: PL, Total length: TL, Prostomium width: PW, Length to 6^{th} segment: $L6^{th}$, Width of 6^{th} segment: $W6^{th}$, weight: Wt, r at p<005).

	Perinereis cultrifera		*Platynereis dumerilii*		*Perinereis nuntia brevicirrus*	
Parameters	Regression equation	r	Regression equation	r	Regression equation	r
PL ≠ TL	$Y=0.0186x+0.0217$	0.86	$Y=0.0236x^{0.7472}$	0.83	$Y= 0.0096+0.0244$	0.794
PW ≠ TL	$Y= 0.0264x+0.0212$	0.87	$Y=0.0279x^{0.8573}$	0.83	$Y= 0.0163+0.0332$	0.843
$L6^{th}$ ≠ TL	$Y= 0.1595x^{0.7375}$	0.86	$Y=0.1534x^{0.6589}$	0.91	$Y= 0.0447x+0.1328$	0.825
$W6^{th}$ ≠ TL	$Y= 0.0388x^{1.178}$	0.81	$Y=0.0336x^{1.1832}$	0.83	$Y= 0.2396x+0.6602$	0.768
PL ≠ Wt	$Y= 39.608x^{2.6191}$	0.89	$113.85x^{2.6856}$	0.883	$Y= 0.0331e^{19.598x}$	0.855
PW ≠ Wt	$Y= 20.962x^{2.6518}$	0.91	$Y=21.481x^{2.345}$	0.89	$Y= 16.251x^{2.2829}$	0.878
$L6^{th}$ ≠ Wt	$Y= 1.0325x^{3.0396}$	0.92	$Y=2.4548x^{3.5176}$	0.93	$Y= 1.5137x^{2.4852}$	0.895
W 6^{th} ≠ Wt	$Y= 0.0105e^{9.5674}$	0.86	$Y=0.0065e^{13.615}$	0.86	$Y= 0.0369e^{0.7345}$	0.83

Despite the dominance of immature worms in *P. cultrifera*, the females were the total component of May population, the major in February and displayed active contribution in other months **(Figure 4)**. In contrast, males were completely absent during several months and showed their highest contribution intermittently during August, October, December and March.

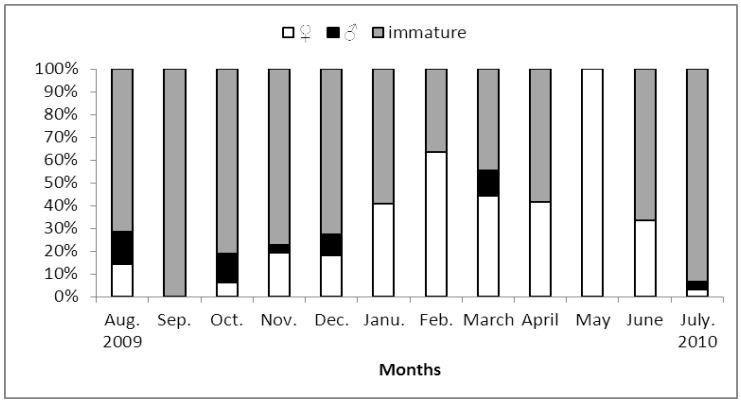

Fig. 4: Monthly maturation percentage of *Pernereis cultrifera* population.

The oocyte diameter in *P. cultrifera* was the smallest in September (40 µm) and increased gradually reaching the maximum (400 µm) in May **(Figure 5)**. This indicates that spawning of this species occurred during May and June, when the oocyte attained diameter between 320 µm and 400 µm with fecundity amounted to 5,389 ± 109 egg/female.

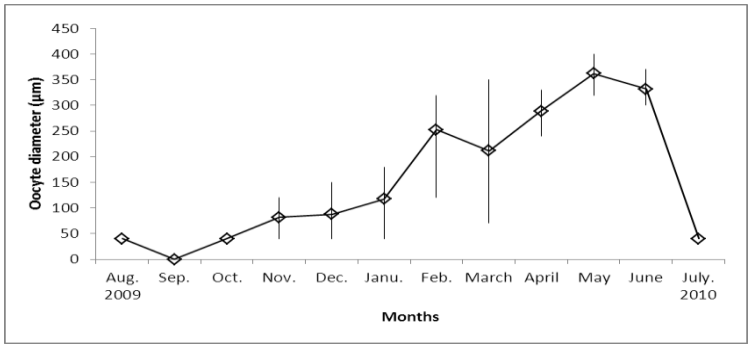

Fig. 5: Monthly mean of oocyte diameter of *Pernereis cultrifera*.

2.2.Platynereis dumerilii

The length range of this worm varied between 1.05 – 5.0 cm for the immature stages, 2.1 -6.5 cm for female, and 3.1 – 3.5 cm for male. The weight falls between 0.003 g - 0.138g for the immature forms, 0.028 – 0.268 g for the female and 0.038 -0.201 g for the male. The abundance ratio of the three stages was Im:F:M 12.0 : 7.8 : 1, reflecting the dominance of the immature forms by 57.8%, followed by females (37.3%) and pronouncedly small role of males (4.8%)**.**

Figure 6 illustrates that 39.6% of the immature worms of *P. dumerillii* had length of 2-<3 cm, 27.1% with length of 3-<4 cm, while the great majority of these forms (91.7%) displayed weight <0.1 g **(Figure 6)**. The longest immature individuals were observed in December, while the shortest occurred in November. In female population, the length of 4-<5 cm and 5-<6 cm displayed similar contribution (29%), and 3-<4 cm constituted 22.6% **(Figure 6)**. About half of the females (48.4%) had weight of 0.1 - <0.2 g, 22.6% weighed 0.2 - <0.3 g and 29% weighed <0.1 g **(Figure 6)**. The longest (> 6 cm) and heaviest (> 0.2 g) females were observed during October, June, and July, while the shortest (< 3 cm) occurred in August, and the lightest (<0.1 g) in May and June.

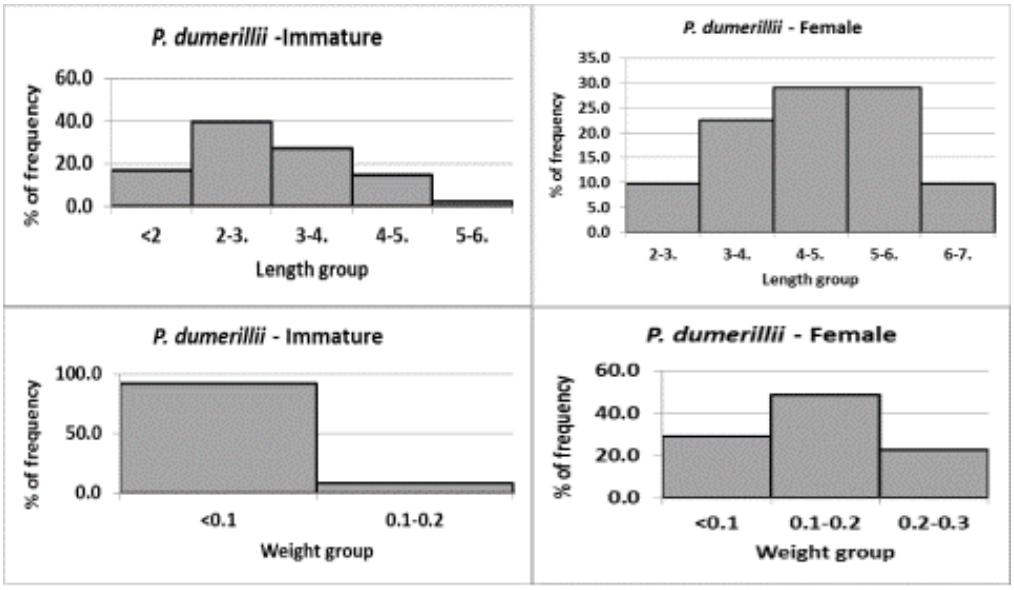

Fig. 6 - Length and weight frequency in the immature stages and female of *Platynereis dumerilii*

According to the length-weight relationship **(Table 2)** negative allometric growth was observed in *P. dumerilii*, while the regression equation between the length to 6th segment and weight illustrated positive allometric growth. An exponential relationship was observed between the width of 6th segment and body weight, while a power relationship occurred between body weight and both prostomium length and width and between body length and all the measured biometric parameters **(Table 3)**.

As shown in **Figure 7**, the sex distribution in *P. dumerilii* population revealed the complete dominance of females during August and October, and displayed crucial contribution beside the immature forms during most of the year. Males recorded their highest relative abundance in July (45.5%) and comparatively low contribution in February and June (10 - 20%).

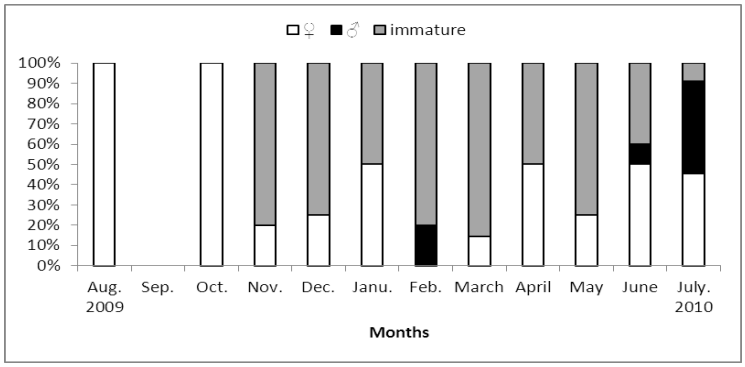

Fig. 7: Monthly maturation percentage of *Platynereis dumerilii*.

The oocyte diameter attained the lowest value (45 µm) in December but it was mostly >100 µm, reaching the maximum (200 - 220 µm) in June and July **(Figure 8)**. It seems that the spawning of *P. dumerilii* occurred in June and July when the oocyte become ripen at its maximum diameter. The fecundity amounted to 22,614 ± 1,919 egg/female.

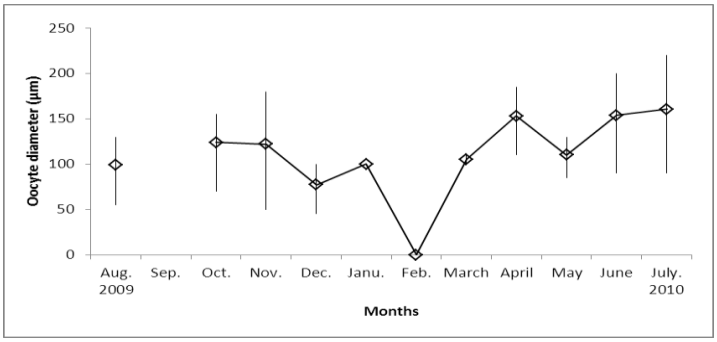

Fig. 8: Monthly mean of oocyte diameter of *Platynereis dumerilii* at AQ.

2.3.Perinereis nuntia

The population of this species was characterized by long individuals, displaying wide variability in the length range for the three developmental stages. The immature worms had length from 3.4- 16.2 cm, the female: 5.2 – 19.9 cm, and the male: 5.4 - 9.5 cm. The weight falls between 0.031 - 1.582g for the immature forms, 0.11 – 2.141 g for the female and 0.13 - 0.448 g for the male. The ratio between the immature, female, and male was 12.8: 21.3:1. As shown in **Figure 9**, 34.8% of the immature worms had length between 5 - 7 cm and 30.5% had 7 - 9 cm, while 24.3% were longer. The majority of the immature worms (76.6%) weighed <0.3 g **(Figure 9)**. The longest (>13 -16.2 cm) and heaviest (>0.9 g) immature worms of *P. nuntia* existed mainly in February. For female, the length was distributed between 8-10 cm (26.1%), 10-12cm (26.9%), 12-14 cm (23.1%), and longer females constituted 17.1% of the total females **(Figure 9)**. In the meantime, 74.8% of the females had weight < 0.8 g, against 25.2% of higher weight **(Figure 9)**. The longest females (15.5 - 19.9 cm) as well as the highest weight of females (1.3 - 2.14 g) were observed intermittently from January to July, while the shortest female occurred from August to January, but the lowest weight (< 0.4 g) was recorded during most of the year. Eleven males only were recorded during the present study, during August, September and October, with a maximum length (9.5 cm) in October and the highest biomass (0.448 g) in August.

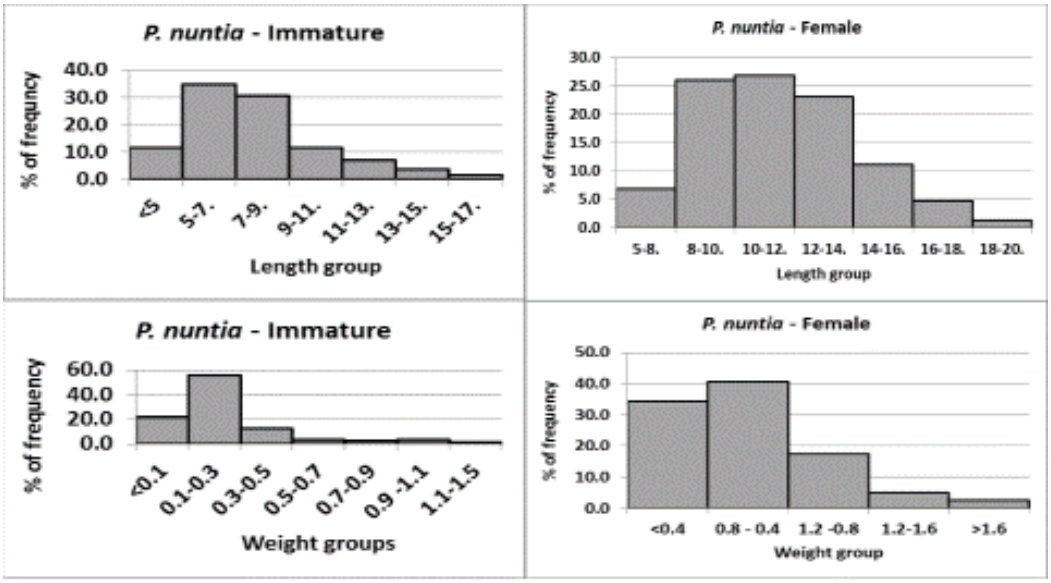

Fig. 9 - Length and weight frequency in the immature stages and female of *Perinereis nuntia*.

Tables 2 and 3 illustrates that the b value in the length-weight relationship and the regression equation between the length to 6th segment and weight was <3, confirming allometric growth in *P. nuntia*. The relationship between the body weight and prostomium length and width of the 6th segment was exponential, while a power relationship was observed between the body weight and both prostomium width and length to the 6th segment **(Table 3)**. Also, a linear relationship was found between body length and the measured biometric parameters **(Table 3)**.

The maturity percentage in *P. nuntia* showed monthly fluctuation, whereas the August population comprised only females and males, with the absolute dominance of females, which were also predominant in March, June. The immature displayed less contribution than females, except their absolute dominance and less so in April and July **(Figure 10)**. Males were observed from August to October only, with small percentages.

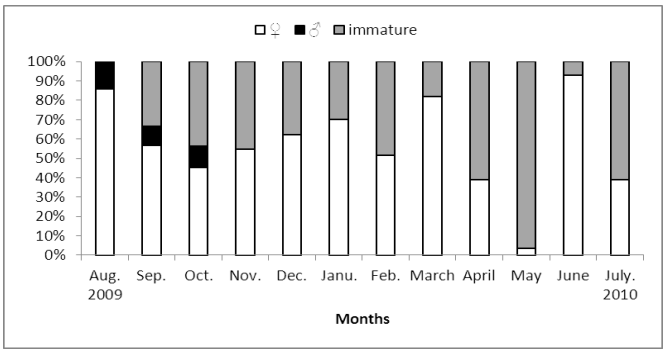

Fig.10. Monthly maturation percentage of *Perinereis nuntia* population

High number of eggs (51,404 ± 1,444 egg/female) was recorded for *P. nuntia*, particularly during March and April. The oocyte had maximum diameter between 60 – 140 µm from August to January, increasing 205 - 260 µm from February to July **(Figure 11)**. The spawning period of this species occurred during spring (March-April).

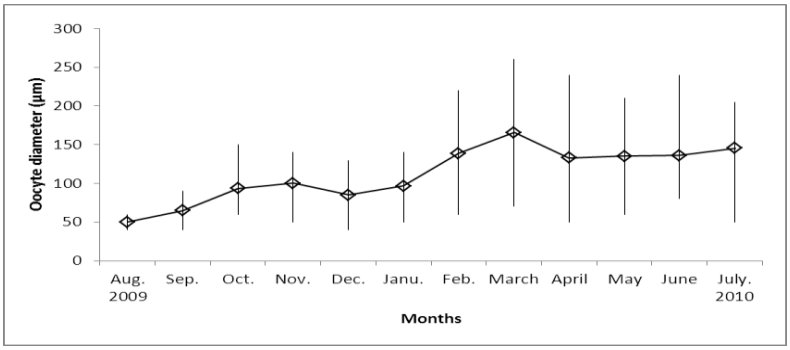

Fig. 11. Monthly mean oocyte diameter of *Perinereis nuntia*.

DISCUSSION

The present study revealed that the three concerned polychaete species displayed length and weight pronouncedly different from those recorded in other coastal areas. During the present study, the maximum length (7.4 cm) and weight (0.58 g) of *P. cultrifera* were different from those (3.6 -9 cm and 0.306 - 0.856 g) recorded in other geographical areas (**Ben-Eliahu, 1975; Rouabah and Scaps, 2003a; Rouabah *et al*., 2008; Rouhi *et al*., 2008; Younsi, *et al*., 2010; Rettob, 2012 and Guemouda *et al*., 2014)**. For *P. dumerillii* the worms on Alexandria coast (6.5 cm) were pronouncedly longer than those (1.5 -3.8 cm) in other records **(Fishelson and Rullier, 1969 and Giangrande *et al*., 2002)**. Meanwhile, *P. nuntia* from the Suez Canal coast attained higher values for length (19.9 cm) and weight (2.14 g) than (10 – 14 cm and 1.4- 1.626 g) in other areas **(Fishelson and Rullier, 1969; Ong, 1996; Osman, 2007 and Darya *et al*., 2016)**.

The body size may reflect the relationship between a species' evolution and its surrounding ecological conditions **(Magurran *et al*., 2013)**, whereas it is affected by temperature **(Rowe, 1997)**, food availability **(Polloni *et al*., 1979)**, depth **(Thiel, 1979)**, latitude **(Linse *et al*., 2006)**, oxygen levels **(Chapelle and Peck, 1999)**, and pH and salinity variation **(Dorgham *et al*., 2014)**. Size also is correlated to growth and age at first reproduction **(Giangrande, 1997)**, and to life-history traits **(Olive, 1985)**.

Perinereis cultrifera is known to reproduce by atoky **(Rouhi *et al*., 2008; Rouabah *et al*., 2008)** and epitoky. Such differences was attributed to sibling species (Maltagliati et al. 2001) or the species complexity **(Rouabah and Scaps, 2003b)**. During the present study, *P. cultrifera* showed a tendency towards atokous reproduction, particularly at the stressed area (El Mex). This is in consistent with **(Prevedelli and Simonini, 2003)**, who stated that nereidid species living in extreme habitats (e.g., brackish) tend to atokous reproduction. Epitoky is known also for *P. dumerilii* **(Giangrande, *et al*., 2002 and Fischer *et al*., 2010)** and *P. nuntia* **(Hardege and Bartels-Hardege, 1995 and Ong, 1996)**, but it was not observed during the present study for both species. This may be due to the migration of the swarming adults to the open water for spawning, as admitted earlier **(Hardege and Bartels-Hardege, 1995 and Ong 1996)**.

The oocyte diameter of *P. cultrifera* on Alexandria coast attained a maximum of 400 µm at 18.8 – 27.8 ºC, while in other coastal areas it was smaller (200 - 341.5 µm) and found at 17 - 23º C **(Rouabah and Scaps, 2003b; Rettob, 2007; Rouhi *et al*., 2008; Rouabah *et al*., 2008: Daas, *et al*., 2010 and Rettob *et al*., 2013)**. For *P. dumerilii* on Alexandria coast, the maximum oocyte diameter (220 µm) was recorded at 25.2 º-28.5 ºC, against less values in other areas **(Grant, 1989: Lawrence and Soame, 2009 and Fischer *et al*., 2010)**. In contrast, the oocyte diameter of *P. nuntia* attained close diameters (250 – 260) at different geographical areas **(Present study; Hardege and Bartels-Hardege, 1995; Ong, 1996 and Osman, 2007)**. Differences in the environmental conditions and food availability may explain the variation in oocyte diameter of a polychaete species **(Olive and Garwood, 1981 and Rettob *et al*., 2013)**, and to the temperature **(Simonini and Prevedelli, 2003b)**. However, the maturation of polychaete oocyte at different geographical areas may indicate that temperature is not fundamental as compared to other environmental factors.

The spawning season of *P. cultrifera* on the Alexandria coast occurred during spring and early summer, while in other areas the spawning of this species was observed in spring **(Rouabah and Scaps, 2003b; Rouhi *et al*., 2008; Rouabah *et al*., 2008)**. *Platynereis dumerillii* showed spawning on Alexandria coast in early summer, similar to other observations **(Giangrande, 1989 and Grant, 1989)**. However, the timing and spawning stimulation of *P. dumerilii* depend on endogenous lunar rhythmicity rather than seawater temperature **(Fischer, 1999),** and because its oogenesis lasts for at least seven months **(Grant, 1989)**. During the present study, the spawning of *P. nuntia* was recorded

during March-April, at 20 º - 21 ºC, while in other areas it was observed from March to May at 18.4 º - 21.9 ºC **(Osman, 2007)**, from June to September, at 12.4 º -23 ºC **(Hardege and Bartels-Hardege, 1995)**, and from October to April/May **(Ong, 1996)**.

In our area, *P. cultrifera* displayed less fecundity (5,389±77 egg/female) than those (up to 136.500 egg/female) observed elsewhere **(Cassai and Prevedelli, 1998: Rettob, 2007; Rettob, 2012; Rettob *et al*., 2013 and Rouhi *et al*., 2008)**. The great variability in the fecundity of this species could be attributed to the effect of the biotic and abiotic characteristics of the different regions **(Cassai and Prevedelli, 1998)**, water fertility **(Rettob, 2012)** and body size of the worm **(Giangrande, 1997)**. The fecundity of *P. dumerilii* during the present study amounted to 22,614 ± 1,919 egg/female. Unfortunately, no data were available on the fecundity of this species. *Perinereis n. brevicirrus* attained a maximum of 52,426 egg/female during the present study, which was pronouncedly higher than that (30000 egg/female) observed by **Zheng (2002)**, but it was about one seventh of that (393245 eggs/female) recorded by **Darya *et al*. (2016).**

The sex ratios in the three polychaete species (6.1:1 for *P. cultrifera*, 7.8:1 for *P. dumerilli* and 21.3:1 for *P. nuntia*) from our area were different from those found in other coastal regions **(e.g. Hardege and Bartels-Hardege, 1995; Zheng, 2002; Prevedelli and Simonini, 2003; Osman, 2007 and Darya *et al*. 2016)**. This may be related to sex-specific differences in survivorship and/or differential production of female vs male larvae **(Zajac, 1991).**

CONCLUSION

The present study revealed clear differences in the biometry and reproduction strategy of three polychaetes species collected from different localities of the Egyptian coast. These species were *Perinereis cultrifera, Platynereis dumerilii and Perinereis nuntia*. Allometry was the common growth pattern for the three species, but *P. cultrifera* displayed also isometric ic growth. Although *P. cultrifera* and *P. dumerilii* had close size the former species sustained pronouncedly lower fecundity and maturation percentage, while *P. dumerilii* recorded less biomass and smaller oocytes. The three species spawned during late spring and early summer, but in different months.

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