

Reproduction and population dynamics of *Perinereis cultrifera* (Polychaeta: Nereididae) of the Atlantic coast, El Jadida, Morocco

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Abstract: *Perinereis cultrifera* (Grube, 1840) is a common species along the Atlantic coast of El Jadida (Morocco). Field investigations of the reproduction and population dynamics were carried out from November 2003 to October 2004. Monthly samples were taken in the intertidal zone at low tide. The reproduction is of atokous type, the laying took place from April until the end of May and the females can contain up to 4947 eggs. The annual average biomass (dry weight) of the population was $B = 9.4 \text{ g.m}^{-2}$, with an annual production $P = 21.5 \text{ g.m}^{-2}$ and a ratio $P/B = 2.3 \text{ year}^{-1}$. The algorithm EM was used for the separation of the cohort.

Résumé : *Reproduction et dynamique de population de Perinereis cultrifera (Polychaeta : Nereididae) de la côte atlantique, El Jadida, Maroc.* *Perinereis cultrifera* (Grube, 1840) est une espèce commune le long de la côte Atlantique d'El Jadida (Maroc). Des investigations sur la reproduction et la dynamique de population ont été effectuées de novembre 2003 à octobre 2004. Des échantillons mensuels ont été prélevés dans la zone intertidale à marée basse. La reproduction chez la population étudiée est de type atoque. La ponte chez les femelles a lieu du début avril jusqu'à la fin du mois de mai et peut contenir jusqu'à 4947 oeufs. La biomasse (poids sec) moyenne annuelle de la population est de $9,4 \text{ g.m}^{-2}$, avec une production secondaire annuelle de $21,5 \text{ g.m}^{-2}$ et un rapport P/B de $2,3 \text{ an}^{-1}$. L'Algorithme EM a été utilisé pour la séparation des cohortes.

Keywords: *Perinereis cultrifera* • Reproduction • Population dynamics • Secondary production • Atlantic coast • Morocco

Introduction

The polychaete *Perinereis cultrifera* (Grube, 1840) is a species characterized by a wide geographical distribution. It occurs along the North-West of Europe, the Mediterranean Sea, the Atlantic Ocean, the Indian Ocean, the Pacific Ocean and the Red Sea (Fauvel, 1923; Herpin, 1925; Durchon, 1957; Cazaux, 1965; Cabioch et al., 1968; Wu et al., 1985).

Several polychaete species are utilized by recreative fisheries or for commercial goals (Olive, 1994). Besides, the growth of entertaining fishing and the development of the aquaculture increased the necessity of finding auxiliary food for the larval stages of fish and shellfish (Scaps et al., 2000). As a common and abundant species *P. cultrifera* could be a good choice for any prospective study. In spite of its large distribution and numerical dominance in some benthic communities, the population dynamics and secondary production have not yet been described.

The mode of reproduction, the age of sexual maturity and the characteristics of the populations differ among populations. According to the literature, *P. cultrifera* has a lifespan of three years (Fauvel, 1916; Herpin, 1925; Durchon, 1951) and it reproduces with epitokous type in the Atlantic Ocean and in the English Channel (Cazaux, 1965; Scaps et al., 1992), whereas, in Algerian coast, Marcel (1962) pointed out that this species did not exceed two years and reproducing without epitoke. The species is gonochoric and reproduces from epitokous or atokous forms. Based on that, Marcel (1962) thought of splitting the species into two physiological races. On the other hand, the observations of Scaps et al. (2000) indicate that it may involve a complex of species.

This study is part of a broad investigation of *Perinereis cultrifera* with a view to provide a model of the population dynamics. This is the preliminary work to a large scale research program to study repartition of polychaetous Annelids and research indicator species of pollution in the El Jadida, Atlantic coast of Morocco (Sif et al., 2003; Ferssiwi et al., 2004; Rouhi et al., 2007), with national program REMER/LAGMAR 'Réseau de la Mer/Lagunes Marocaines'. In this paper, we describe the cycle of reproduction, the secondary production and dynamics of the population of *P. cultrifera* at El Jadida coast.

Materials and Methods

The sampling site (SM) is located in the immediate vicinity of an urban rejection coming from the district «Mouilha», located approximately to 4 km from of the central town of El Jadida, on Moroccan Atlantic coast (Fig. 1). Specimens of *Perinereis cultrifera* of atokous type were collected monthly

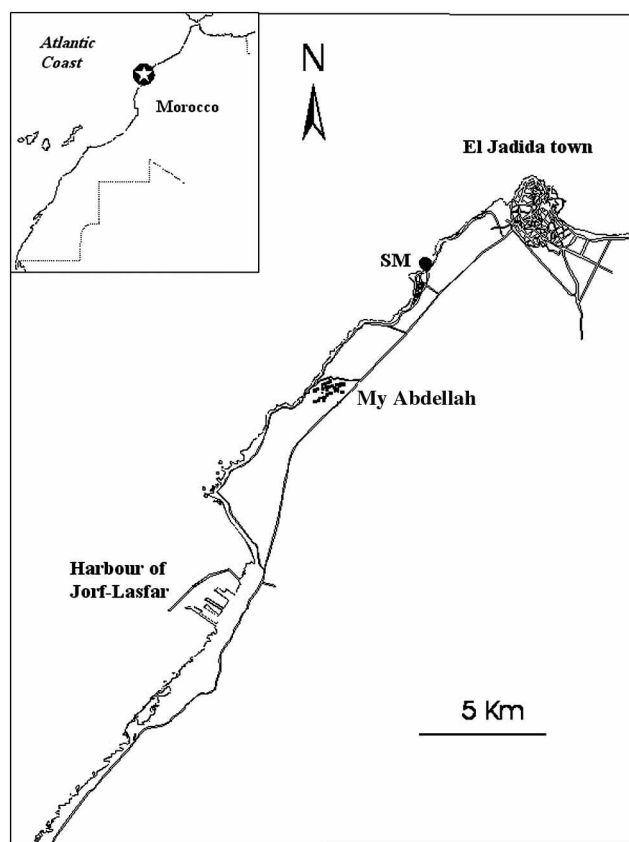


Figure 1. *Perinereis cultrifera*. Location of the sampling site (SM) in the Atlantic Coast of El Jadida, Morocco.

Figure 1. *Perinereis cultrifera*. Localisation du site de prélèvement (SM) dans la côte Atlantique, El Jadida, Maroc.

from November 2003 to October 2004, at low tide. Four samples of sediment (625 cm² for 25 cm of depth) were taken with a spade in the intertidal zone. Specimens were sorted using sieves with a mesh size of 1 millimeter. Samples were fixed with 8% neutral formalin. Individuals were relaxed by a magnesium chloride solution to prevent any contraction or tears during fixation. At each sampling date, pH, temperature (T°C) and salinity (S) of sea water were measured at the study site with pH-meter/thermometer handle (WTW, model 521) and salinometer (WTW, model inolab) respectively.

For each worm, the fresh weight (formolized fresh weight) was measured and the number of the chaetigerous was counted. The relationship between the total fresh weight and the weight of the first 45 chaetigerous was established on selected individuals of all classes of size. The regression obtained between the total Fresh Weight (FW) and the Partial Weight (PW) (the first 45 chaetigerous) is given by the following equation:

$$FW = 1.6973 \times PW - 0.0267 \quad (1)$$

$$(r = 0.98, n = 43, p < 0.001)$$

The investigation of the reproductive cycle of *P. cultrifera* was derived from the recommendations of Batten (1994). Ten females were removed from each sample and preserved in 70% ethanol solution. Three segments were removed from anterior portion of the worm using scalpel, opened and the contents released. The counting of the oocytes was carried out on about thirty adult and mature individuals. A volume of 2 ml of the oocyte solution (solution mother of $V = 20$ ml) is adjusted to 80 ml by the isotone one, then counting is made on three sub samples by «Counter-Coulter» (Multisizer II, type Beckman company). The diameters of thirty oocytes from each worm were measured using an optical microscope provided eye piece graticulate. The maximum and minimum lengths of each oocyte were measured and the resulting average was used to estimate the size of the oocyte.

The size-frequency histograms were treated by algorithm Stimulated Annealing Estimation Maximization (SAEM), witch is an improvement of the well-known algorithm EM (Dempster et al., 1977; Redner & Walker, 1984; Mc Lachlan & Krishnan, 1997) used for identification of parameters of a mixture of distributions and replaces the methods based on the analysis of modes of histograms. The secondary production (P) was estimated by the method of Crisp (1971) with equation:

$$P = (n_1 + n_2)/2(w_2 - w_1) \quad (2)$$

n_1 and n_2 representing number of individuals in cohort at time 1 and 2, w_1 and w_2 the mean dry weight of a cohort at time 1 and time 2. The secondary production and biomass (B) ratio P/B were calculated from November 2003 to October 2004.

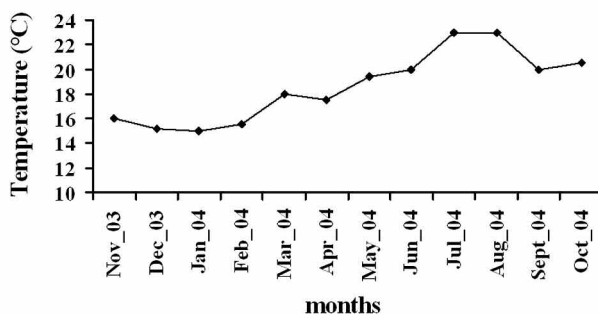


Figure 2. *Perinereis cultrifera*. Annual variation of the temperature of the water at the site of the Atlantic coast, El Jadida, Morocco.

Figure 2. *Perinereis cultrifera*. Variation annuelle de la température de l'eau de la station d'étude de la côte Atlantique, El Jadida, Maroc.

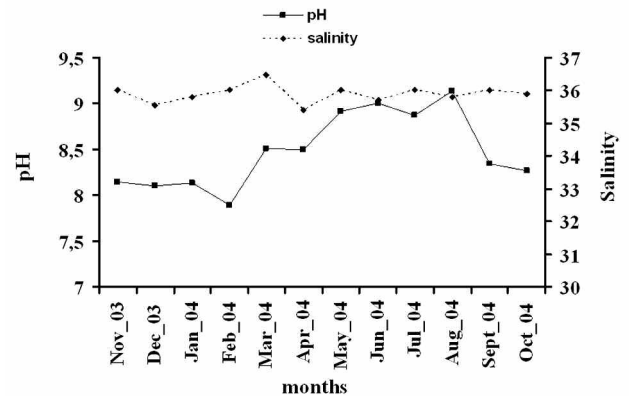


Figure 3. *Perinereis cultrifera*. Temporal variations of the pH and salinity of the sea water from the Atlantic coast, El Jadida, Morocco.

Figure 3. *Perinereis cultrifera*. Variation annuelle du pH et de la salinité de l'eau de la station d'étude de la côte Atlantique, El Jadida, Maroc.

Results

Abiotic parameters

During the period of study from November 2003 to October 2004, the temperature of sea water varied between a minimum in January 2004, 15°C, and a maximum in August, 23°C with an average annual value of $18.6 \pm 2.8^\circ\text{C}$ (Fig. 2). The annual values of the pH varied from 7.9 to 9.1 respectively in February and August (Fig. 3). The salinity showed a moderate temporal variation from 35.4 in April to 36 in March, the annual mean was 35.9 ± 0.3 (Fig. 3).

Reproduction

The examined specimens did not show any morphological change characteristic of the epitoky throughout the year characterizing an atokous population. During the period of reproduction, the oocytes became increasingly large and simultaneously gave the females a sexual differentiation, whereas the milky color whitish was characteristic of the males. The account of the oocytes in 23 mature females showed that the number of oocytes varied from 1935 to 8920 oocytes, the mean was 4912 ± 1948 oocytes.

However, the temporal evolution oocyte diameter at *P. cultrifera* (Fig. 4) was highly variable during the period of study (from November 2003 to October 2004). It varied between a minimum in August 2004, $113 \pm 30.9 \mu\text{m}$ to a maximum in March 2004, $341.5 \pm 16.3 \mu\text{m}$. The oocyte diameter increased quite regularly from November 2003 to March 2003 and then decreased from April 2004 ($316.5 \pm 67.4 \mu\text{m}$) to August 2004. This situation is recorded with a

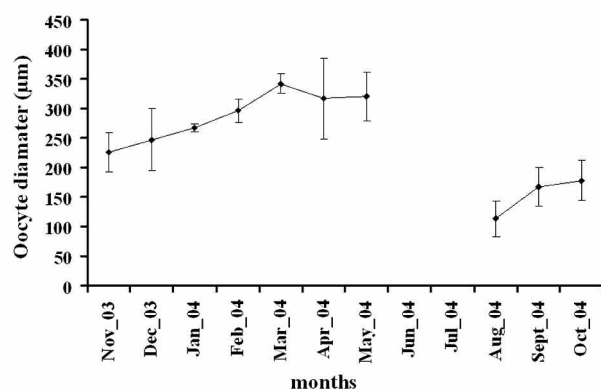


Figure 4. *Perinereis cultrifera*. Temporal evolutions of the oocyte diameter (mean \pm standard deviation).

Figure 4. *Perinereis cultrifera*. Evolution temporelle du diamètre ovocytaire (moyenne \pm écart-type).

variation of mean of worm weights, from 0.41 ± 0.117 g to 0.37 ± 0.152 g (Fig. 5).

Table 1. *Perinereis cultrifera*. Secondary production of the cohorts of the population (W: mean weight variation of the cohort between t_1 and t_2 ; W_t : mean weight of the cohort at time t ; N_1 , N_2 and N_t : number of individuals of a cohort at time 1, 2 and t).

Tableau 1. *Perinereis cultrifera*. Production secondaire des cohortes de la population (W : variation du poids moyen de la cohorte entre t_1 et t_2 ; W_t : poids moyen de la cohorte au temps t ; N_1 , N_2 et N_t : Nombre d'individus de la cohorte aux temps 1, 2 et t).

	W_t (g)	W (g)	N_t	$(N_1 + N_2)/2$	Production (g.m ⁻²)
Cohort A					
N-03	12.67	12.67	22.00	11.00	1.39
D-03	22.05	9.38	20.00	21.00	1.97
J-04	23.47	1.02	50.00	35.00	0.36
F-04	34.90	11.43	47.00	48.50	5.54
M-04	40.51	5.61	50.00	48.50	2.72
A-04	42.28	1.77	19.00	34.50	0.61
Total C_A					12.59
Cohort B					
A-04	18.16	18.16	6.00	3.00	0.54
M-04	29.91	11.75	40.00	23.00	2.70
Total C_B					3.24
Cohort C					
A-04	13.51	13.51	40.00	20.00	2.70
S-04	14.87	1.36	39.00	38.50	0.52
O-04	22.24	7.37	28.00	33.50	2.47
Total C_C					5.69
TOTAL					21.52

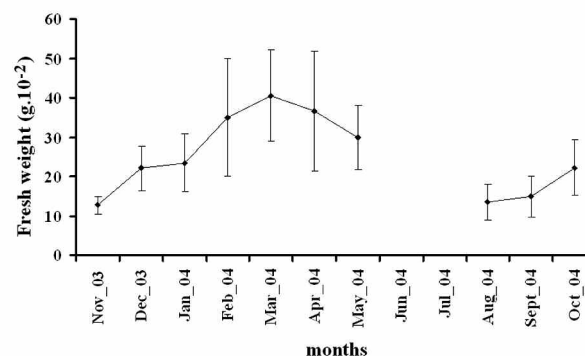


Figure 5. *Perinereis cultrifera*. Temporal evolution of the individual fresh weight (mean \pm standard deviation).

Figure 5. *Perinereis cultrifera*. Evolution temporelle du poids frais moyen individuel (moyenne \pm écart type).

Production estimates

The mean annual biomass (dry weight) for the period of study was $B = 9.4$ g.m⁻² (Table 1). The biomass showed temporal variation with a maximum of 24.3 g.m⁻² in April 2004. Lower values were obtained in November 2003 with $B = 2.4$ g.m⁻². It varied together with a significant decrease in density and biomass in winter in relation to the mortality of adults and an increase in spring in relation to the recruitment of juveniles. The secondary production of the population was $P = 21.5$ g.m⁻² and the ratio $P/B = 2.3$ year⁻¹.

Recruitment pattern

The size-frequency histograms (Fig. 6) at *P. cultrifera* were separated into size classes. Three cohorts C_A , C_B and C_C were observed in April 2004. The first cohort (C_A) corresponded to the old individuals, the second (C_B) to those which were less old and the third cohort (C_C) represented the youngest specimens. It should be noted that the cohort C_A was recorded during six months (from November 2003 to April 2004), followed by the cohort C_B during two months (from April 2004 and May 2004) and C_C during three months (from August 2004 to October 2004). With the exception of April, all the distributions of the size-frequency histograms were unimodal (Fig. 6).

Growth curves (Fig. 7) have been constructed using the mean of fresh weight for each cohort shown in Figure 6. In April, a new troop C_B (cohort B) appeared with a mean weight of 0.18 ± 0.341 g. It was a new generation of specimens which has been just dwelt there installed. This last cohort was well represented by female individuals with oocytes diameters ranging between 220 and 300 μ m in April (Fig. 8).

The analysis of the curve of evolution of the individual

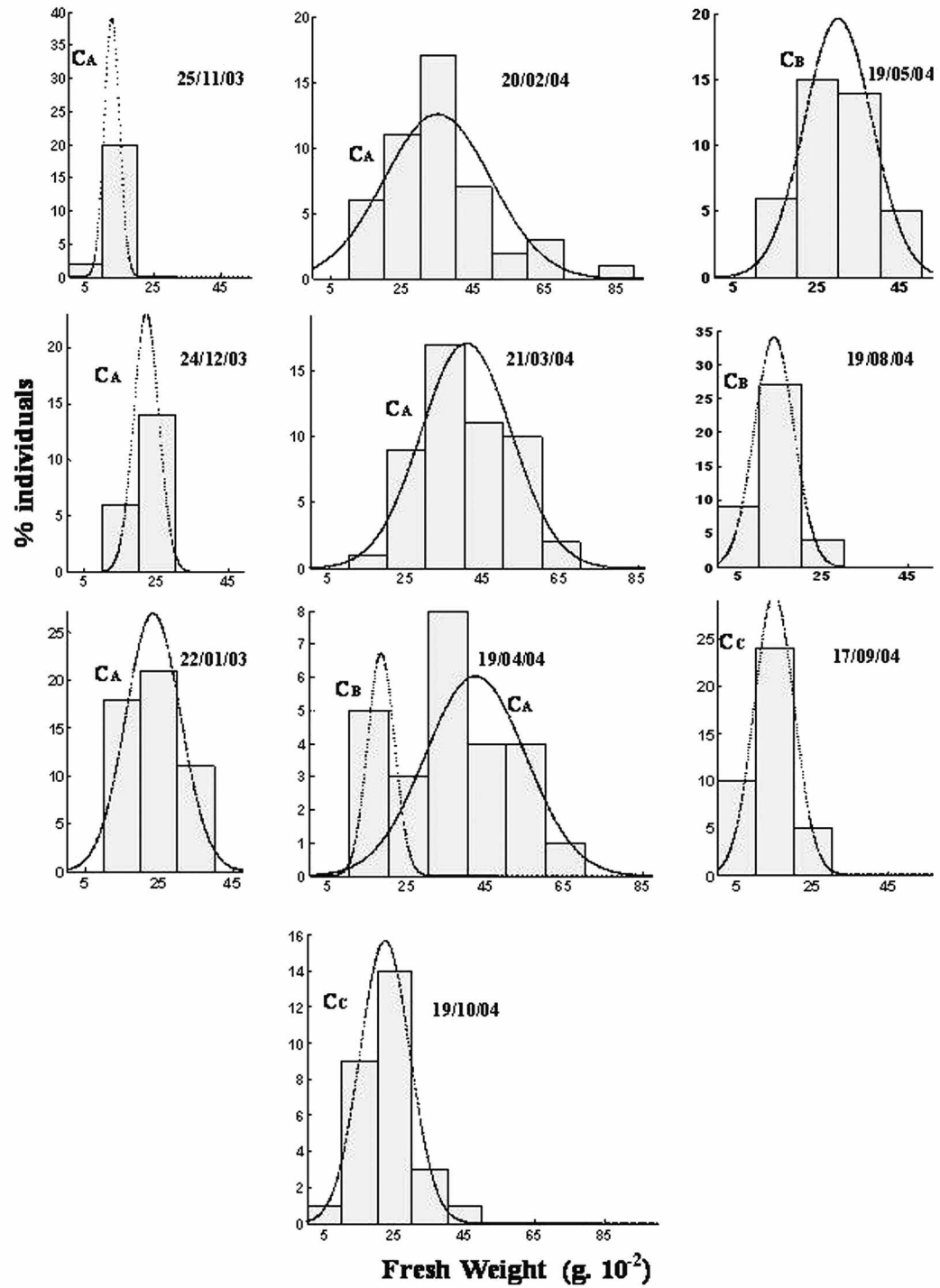


Figure 6. *Perinereis cultrifera*. Histograms of frequency of weight.

Figure 6. *Perinereis cultrifera*. Histogrammes de fréquence de poids.

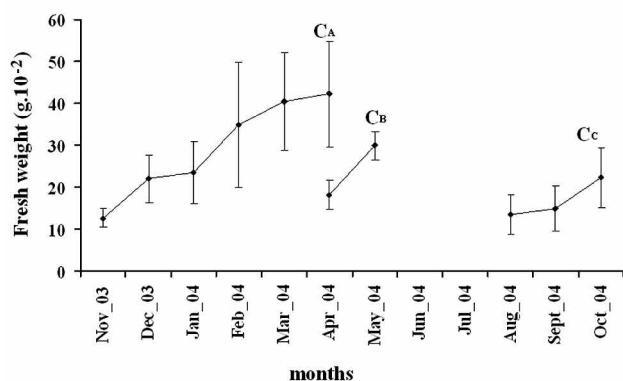


Figure 7. *Perinereis cultrifera*. Growth curves of the cohorts (mean and \pm standard deviation).

Figure 7. *Perinereis cultrifera*. Courbe de croissance des cohortes (moyenne \pm écart type).

mean weight (Fig. 8) showed a progressive increase from November 2003 to March 2004. From the end of March and the beginning of April, the mean of weight starts to decrease. This is related to the disappearance of the largest individuals of the cohort C_A after reproduction and appearance of other still young individuals of cohort C_B (Fig. 7). The latter disappeared in its turn after the end of May. Throughout July and June, a total disappearance of the population in the site of sampling was recorded. From August onward, a new cohort C_C appeared.

Discussion

The densities of the population of *Perinereis cultrifera*

observed in the coast of El Jadida and the mean annual biomass ($B = 9.4 \text{ g.m}^{-2}$) are generally lower than those observed for other polychaetes. Compared with *Hediste diversicolor* (Müller, 1776) (Gillet & Torresani, 2003), the results are similar to the data of biomass $B = 9.1 \text{ g.m}^{-2}$ in Loire estuary (France), but lower than those observed in Bou Regreg estuary (Morocco) for the same species (Gillet, 1993). The values of the biomass $B = 9.4 \text{ g.m}^{-2}$ and the secondary production $P = 21.5 \text{ g.m}^{-2}$ (Table 1) are situated within the average of the observed values for polychaetes (Table 2). The ratio $P/B = 2.3 \text{ year}^{-1}$ also represents an average value, ratio P/B vary from 1.2 to 6.8 year^{-1} , the detritivorous species having generally higher values than the carnivorous species.

The population of *Perinereis cultrifera* of Moroccan Atlantic Coast of El Jadida showed that reproduction is the atokous type. The laying in the females took place at the beginning of April until the end of May. The polychaete *P. cultrifera* is a species characterized by a great ecological plasticity. It is a gonochoric species which, according to the geographical location, reproduces itself with or without morphological modifications. Indeed, in the English Channel and in the Atlantic Ocean (Herpin, 1925; Fage & Legendre, 1927; Durchon, 1951; Cazaux, 1965; Scaps et al., 1992), in the Atlantic French coast (Cazaux, 1965), on the coasts of the North Sea (Scaps et al., 1992), in the lagoon of Venice (Ansaloni et al., 1986) and on the coast of Tunisia (Zghal & Ben Amor, 1986 & 1989) *P. cultrifera* reproduces with epitoky. On the other hand, in Mediterranean French coast (Pérès & Rancurel, 1948) and in Algeria (Durchon, 1957; Marcel, 1962) the reproduction is the atokous type.

The period of reproduction (Fauvel, 1916; Herpin, 1925;

Table 2. *Perinereis cultrifera*. Comparison of the ratio P/B between the secondary production (P) and the biomass (B) in some species of polychaetous annelids.

Tableau 2. *Perinereis cultrifera*. Comparaison du rapport P/B entre la production secondaire (P) et la biomasse (B) chez quelques espèces d'Annélides polychètes.

Family	Species	P/B ratio (year ⁻¹)	Site	Author
Arenicolidae	<i>Arenicola marina</i> (Linnaeus, 1758)	1.14	Grevelingen estuary, North Sea	Wolff & de Wolff (1977)
Nephtyidae	<i>Nephtys hombergii</i> Savigny 1818	1.9	Lynher estuary, English Channel	Warwirck & Price (1975)
Nereididae	<i>Nereis (Hediste) diversicolor</i>	3.6	Loire France	Gillet & Torresani (2003)
	<i>Nereis diversicolor</i>	4.9	Spain	Arias & Drake (1995)
	<i>Nereis diversicolor</i>	2.0	Bay of Biscay, Spain	Garcia-Arberas & Rallo (2002)
	<i>Nereis diversicolor</i>	1.9-4.0	Portugal	Fidalgo e Costa et al.(1998)
	<i>Nereis diversicolor</i>	4.4-7.9	Ria de Aveiro Portugal	Abrantes et al. (1999)
	<i>Nereis diversicolor</i>	3.9-4.6	Bou Regreg Morocco	Gillet (1993)
	<i>Nereis diversicolor</i>	1.7-1.9	Souss Morocco	Aït Alla et al. (2006)
Nereididae	<i>Perinereis cultrifera</i>	2.3	El Jadida Morocco	Present work
Oweniidae	<i>Owenia fusiformis</i> Delle Chiaje, 1841	0.89	English Channel	Ménard et al. (1989)
Spionidae	<i>Scolecopsis squamata</i> (Müller, 1868)	2.0	Morocco	Bayed et al. (2006)

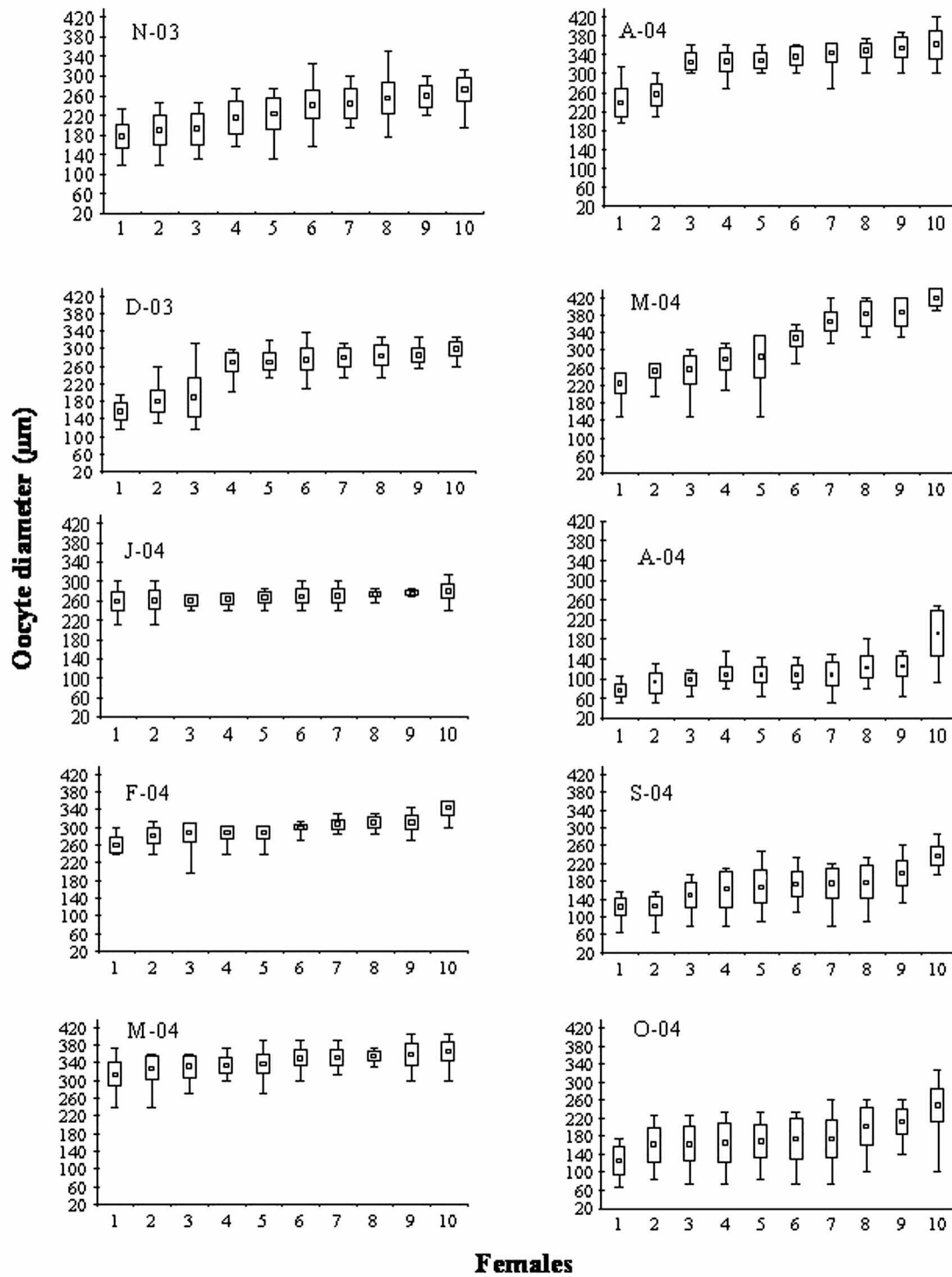


Figure 8. *Perinereis cultrifera*. Monthly distributions of oocyte diameter of each female.

Figure 8. *Perinereis cultrifera*. Distribution mensuelle du diamètre ovocytaire de chaque femelle.

Durchon, 1951) takes place between May and June and can extend up to July. Nevertheless, Marcel (1962) showed that the reproduction takes place all along the year with a higher activity between July and November. On the other hand, in the Atlantic French coast (Cazaux, 1965), it occurs at the end of April and beginning of May. Recent work by Scaps et al. (1992) and Rouabah & Scaps (2003) showed successively that, in the coast of the North Sea, the laying is done between the end of March and the beginning of April, whereas, on the coast of Algeria, it is held between the end of April and beginning of May.

Comparing with data from the literature, the biometric parameters varied according to the geographical populations. However, in the Atlantic French coast (Cazaux, 1965) the adult individuals have a weight of 3 g with a number of parapodia ranging from 115 to 120. In the same way, in the North Sea (Scaps et al., 1992), it varies from 3 to 6.6 g, whereas, in Tunisia (Zghal & Ben Amor, 1989), the specimens have an average weight of 0.24 g and a mean of chaetigers of 97. In Algerian coast, Rouabah & Scaps (2003) indicated that the weight of the population of *P. cultrifera* varies between 0.4 and 0.8 g with a maximum number of parapodia of 125. For the population of El Jadida, the weight of adult individuals varies between 0.11 and 0.65 g, whereas, the number of chaetigers varies from 60 to 102 (Fig. 9). In comparison with the results of Scaps et al. (1992), the El Jadida female specimens of the studied population are less fertile. Indeed, according to these authors, the number of oocytes varies from 17000 to 130000 per female for worms of 0.8 and 4.8 g (against 1935 and 8920 for females of 0.23 and 0.64 g of the studied population). According to Durchon (1955), this polymorphism could have two origins: either internal and related to the genetics or the hormones, or external and depending on the abiotic factors (temperature, salinity, food...).

Several authors were interested in the mode of occupation of space by the various generations of the population of *P. cultrifera*. They clarified the variability of the dimensional structure according to the bathymetric level. Scaps et al., (1992) revealed that the large sexually differentiated individuals are dominant in the bottom of the zone with the algae *Fucus serratus*; whereas at the top it is the individuals of small size which dominate. The same observation was made by Miron & Desrosiers (1990) for *Nereis virens*, after a segmentary phase of growth at the top of the beach, the individuals start a migration downwards, where they settle in burrows until reproduction. In the present work, the study of the histograms of frequencies of weight as well as the curves of growth of the troops (Figs 6 & 7) showed the appearance of a new troop C_B in April (with an average weight of 0.182 ± 0.341 g), which allows to think that it is not only a question of one possible slope, but also of a new generation of specimens which has been

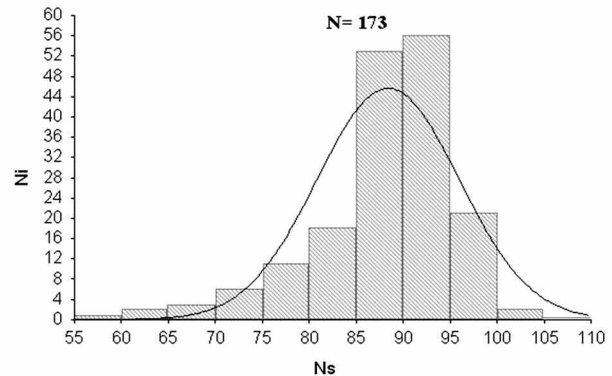


Figure 9. *Perinereis cultrifera*. Distribution of the number of chaetigerous in adult individuals (Ni: Number of individuals, Ns: Number of chaetigerous).

Figure 9. *Perinereis cultrifera*. Distribution du nombre de sétigères chez les individus adultes. (Ni : Nombre d'individus ; Ns : Nombre de sétigères).

just dwelt there installed. This last cohort was well represented by female individuals with oocyte diameters ranging between 220 and 300 μm in April (Fig. 8). However, it proves that the females of oocyte diameter average superior to 340 μm at the end of April are not represented in May. This observation makes it possible to deduce that this involves of a beginning of laying. The measurements related to the oocytes do not make it possible to consider the exact period of sexual differentiation. Indeed the first stages observed are those with oocyte diameters of 113 μm on average. That undoubtedly supposes that it begins in one month well before August. The unimodal structure of the population during this month confirms this observation. Consequently, the disappearance of the population after the laying could be explained only by the phenomenon of migration. After reproduction, the larval stages are pulled by water to the top of the zone of sampling and following a segmentary phase of growth, a migration is done to the bottom of the littoral zone in August (differentiated individuals) where grow until achieve sexual maturity. That is confirmed by the unimodal structure of the troops.

The comparison with *Nereis diversicolor*; which is more studied than *Perinereis cultrifera*, showed that two recruitment periods are generally observed in southern regions of Europe, as for example in the Bou Regreg estuary (Gillet, 1993) in the Canal de Mira (Abrantes et al., 1999) and in the Loire estuary (Gillet & Torresani, 2003). In more northerly European regions, the population of *N. diversicolor* generally have a short spawning period and only one recruitment period in east coast of England (Olive & Garwood, 1981) and in western Sweden (Möller, 1985).

Change in timing of spawning and life cycle of Polychaetes in different geographical regions could be a consequence of different local temperature regimes (Kristensen, 1984), since the inducing stimulus was reported to be a sharp temperature rise (Dales, 1950). In the case of the Atlantic Coast of El Jadida, differences in recruitment can be attributed to climatic factors.

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