

Reproduction, population dynamics and production of *Nereis falsa* (Nereididae: Polychaeta) on the rocky coast of El Kala National Park, Algeria

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Abstract The polychaete *Nereis falsa* Quatrefages, 1866 is present in the area of El Kala National Park on the East coast of Algeria. Field investigations were carried out from January to December 2007 to characterize the populations' reproductive cycle, secondary production and dynamics. Reproduction followed the atokous type, and spawning occurred from mid-June to the end of August/early September when sea temperature was highest (20–23°C). The diameter of mature oocytes was approximately 180 µm. Mean lifespan was estimated to about one year. In 2007, the mean density was 11.27 ind. m⁻² with a minimum of 7.83 ind. m⁻² in April and a maximum of 14.5 ind. m⁻² in February. The mean annual biomass was 1.36 g m⁻² (fresh weight) with a minimum of 0.86 g m⁻² in December and a maximum of 2.00 g m⁻² in June. The population consisted of two cohorts distinguishable from size frequency distributions. One cohort corresponded to the recruitment of 2006 and the other appeared during the study period in September 2007. The annual production of

N. falsa was 1.45 g m⁻² year⁻¹, and the production/biomass ratio was 1.07 year⁻¹.

Keywords Nereididae · Population dynamics · Production · Reproduction

Introduction

The polychaete *Nereis falsa* Quatrefages, 1866 has a wide geographical distribution. This species has been recorded along the coast of the Atlantic Ocean [Atlantic coast of Morocco (Fadlaoui and Retière 1995), Namibia (Glassom and Branch 1997) and South Africa (Day 1967), North American Atlantic coast (Posey et al. 2002, 2006), Florida Bay (Vittor 1997a, 1998), north coast of the Gulf of Mexico (Vittor 1984), Galveston Bay in the Gulf of Texas (Vittor 1997b), north-east coast of Venezuela (Arana and Diaz 2006), Colombian Caribbean coast (Baez and Ardila 2003)] and the Mediterranean Sea [Algésiras Bay in Spain (Sanchez-Moyano et al. 2001), Cueta harbour in Morocco (Guerra-Garcia et al. 2003; Guerra-Garcia and Garcia-Gomez 2004), Circeo National Park on the Italian Adriatic coast (Andrea and Giancarlo 2003), Izmir Bay/Turkey (Ertan Çinar et al. 2008), on floating debris in the Ligurian Sea (Alliani and Meloni 1999) and on current metre moorings deployed in the Corsica Channel (Alliani and Meloni 1999)]. Moreover, this species lives as epibiont on loggerhead turtles (*Caretta caretta*) nesting on the coast of Georgia, USA (Pfaller et al. 2006), and on mussels *Mytilus galloprovincialis* in Izmir Bay, eastern Mediterranean (Ertan Çinar et al. 2008). The species is a facultative rafter; i.e. it typically lives in benthic habitats but may become dispersed while being associated with floating items (Thiel and Gutow 2005).

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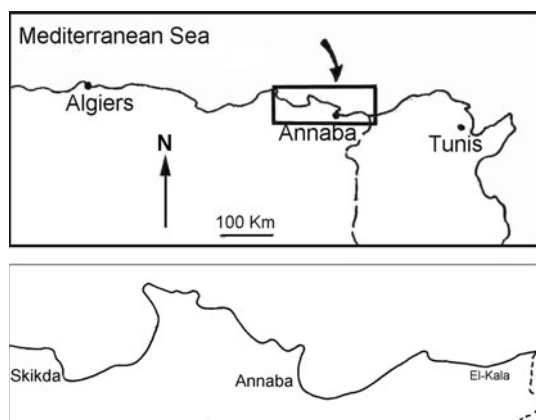


Fig. 1 Study area and location of sampling station

A preliminary study of the species' distribution on the Algerian east coast (between Skikda and El Kala, (Fig. 1) revealed its presence only in the area of El Kala National Park. The reproductive biology and population dynamics of this species are poorly documented. So, this study was conducted to obtain information on the cycle of reproduction, secondary production and dynamics of a population of *N. falsa* on a rocky shore on the Algerian east coast (Mediterranean Sea). This work is part of a research programme dedicated to the identification of indicator species of pollution on the Algerian east coast (Abdenour et al. 2000, 2004; Bouzeraa et al. 2004; Beldi et al. 2006; Sifi et al. 2007).

Materials and methods

Study site and collection of material

Individuals were collected in the area of El Kala National Park, Algerian east coast. Worms were found among red algae covering hard bottoms. Rocks are metamorphic and are composed of gneiss and quartzite. The maximum tide is small (0.9 m).

Individuals were collected monthly from January to December 2007. The region sampled corresponded with the area of greatest density of individuals. The individuals occur in the lower intertidal zone and extend down into the subtidal. We used bleaching liquid (10% in sea water) to force individuals out of their algal mats in order to obtain undamaged whole individuals. Approximately 6 m² of hard bottom has been monitored each month in order to collect enough individuals for the population dynamics study.

In our study site, *N. falsa* coexists with two other species of nereidid polychaetes, *Perinereis cultrifera* and *Platynereis dumerilii*. For a correct identification to species

level, using the diagnostic patterns of paragnaths on the proboscis, worms were made to evert their proboscis by generating pressure some distance behind the head.

The number of collected specimens varied between 47 in April and 87 in February. A total of 812 worms were collected and examined. At each sampling date, air and sea water temperature were recorded.

Reproduction

For the study of the reproductive cycle, the individuals were fixed in the laboratory with 8% neutral formalin and examined for the presence sexual products in the coelom. A short incision was made in the body wall at about the twentieth chaetigerous segment and a drop (~1 ml) of the coelomic fluid was taken out with a Pasteur pipette and examined under a binocular microscope. If possible, forty oocytes each were measured using a calibrated eye piece graticule. The longest and the shortest diameter of oocytes were determined, and the average value was used as an estimate of oocyte size.

Population dynamics

After species identification, the fresh weight of each individual was measured. Weight frequency histograms were treated by FISAT II FAO software, which is used for the identification of parameters of a mixture of distributions (Gayanilo et al. 2005) and replaces the methods based on the analysis of modes of histograms (Gayanilo et al. 1988; Gayanilo and Pauly 1989). The secondary production (P) was estimated by the method of Crisp (1971) using the equation $P = (Nt_1 + Nt_2)/2(Wt_2 - Wt_1)$ with Nt_1 and Nt_2 representing numbers of individuals in a cohort at times t_1 and t_2 and Wt_1 and Wt_2 representing the mean fresh weights of a cohort at times t_1 and t_2 . The secondary production and the production/biomass ratio (P/B) were calculated for the year 2007.

Results

Temperature at the study site (Fig. 2)

During the study period from January to December 2007, air temperature varied between 10°C in December and 34°C in August (average: 21.08 ± 9.40°C). Sea water temperature measured during low tide ranged between 8°C in January and 23°C in August (average: 16.08 ± 5.01°C).

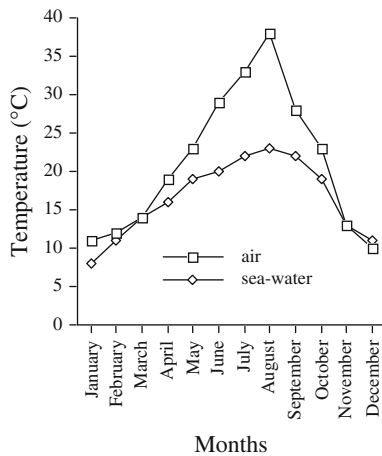


Fig. 2 Monthly sea water and air temperature in the studied area

Reproductive biology

Cœlomic punctures of each female showed a homogeneous aspect with oocyte diameters being appreciably equal. Thus, ovogenesis was considered to be synchronous. The mean oocyte diameter frequency histograms of individuals collected from January to December 2007 are shown in Fig. 3. Most of the histograms are unimodal and can be considered to show a single cohort.

The study of the changes in average oocyte diameters (Fig. 4) allowed us to reveal the female sexual cycle. The mean oocyte diameter varied between $42.44 \pm 11.19 \mu\text{m}$ in September and $166.27 \pm 16.06 \mu\text{m}$ in August. From January to May, the mean oocyte diameter ranged between 80 and 100 μm . We recorded a steady increase of the mean oocyte diameter from May to July, with maximal mean

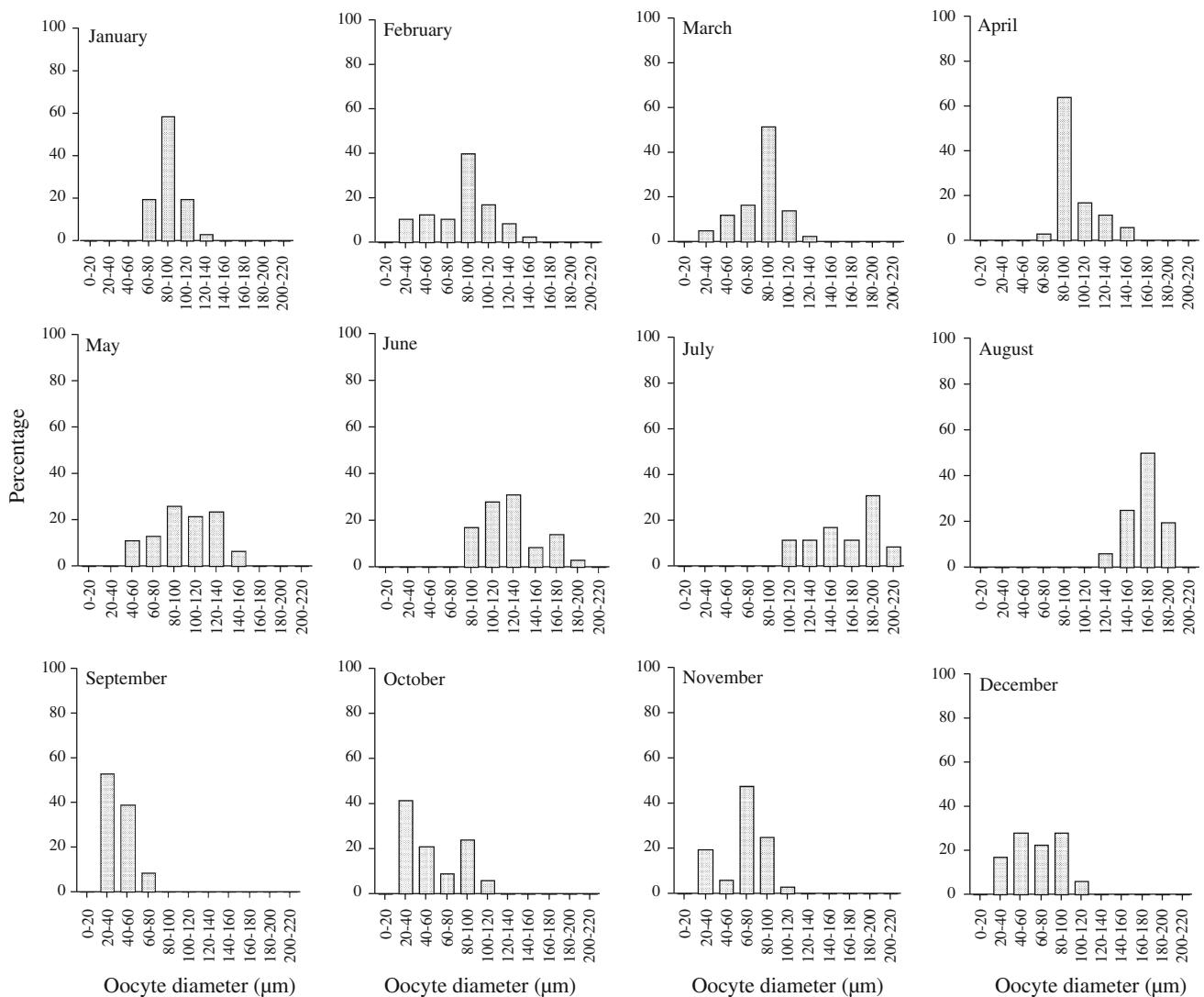


Fig. 3 Size distribution frequency of oocytes between January and December 2007

values of 155 μm . The first mature oocytes (diameter greater than 160 μm) occurred in the coelomic fluid of females collected in mid-June. From July to August, oocyte growth was weak and the mean oocyte diameter became maximal (166.27 μm). The coelomic fluid of females collected in early August contained a majority of large oocytes (diameter between 120 and 200 μm) (Fig. 3), while the coelomic fluid of females collected in September contained only small oocytes indicating that the spawning period was finished. So, the spawning season begins in mid-June and spreads out until the end of August or early September. From September to December, the mean oocyte diameter ranged between 40 and 60 μm and remained relatively constant. Oocytes took less than one year to develop fully (Fig. 4).

During the whole study period, we did not find large mature males or females showing morphological modifications characteristic of epitoky. In consequence, individuals seem to reproduce exclusively in the atokous state and neither of sex appears to survive spawning. A comparison of Figs. 2 and 4 shows that spawning occurs when sea water surface temperature is highest (20–23°C).

Population dynamics

The mean density and biomass of *N. falsa*, at the study site between January and December 2007, were 11.27 ± 2.09 ind. m^{-2} and 1.36 ± 0.38 g m^{-2} , respectively. From one month to another, *N. falsa* density and biomass varied considerably (Fig. 5a, b). Nevertheless, the biomass tended to be higher in summer than in winter (Fig. 5b), with the highest value recorded in June ($B = 2$ g m^{-2}) and the lowest in December ($B = 0.86$ g m^{-2}).

The mean individual fresh weight was maximal during spring and summer (March to August). It decreased at the end of summer (September) and was minimal during

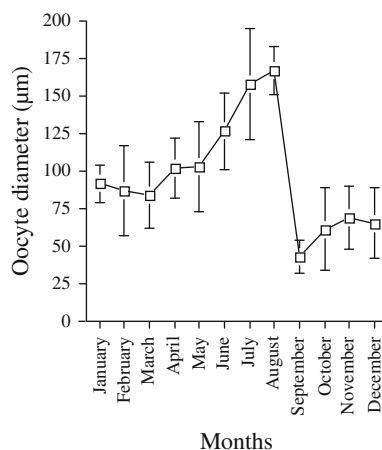


Fig. 4 Changes in oocyte size from January to December 2007. Each data point represents mean \pm SD of the mean

autumn and winter (October to February) (Fig. 6), reflecting the mortality of adults and recruitment of juveniles. The temporal variation in biomass is largely explained by the variation in mean individual fresh weight.

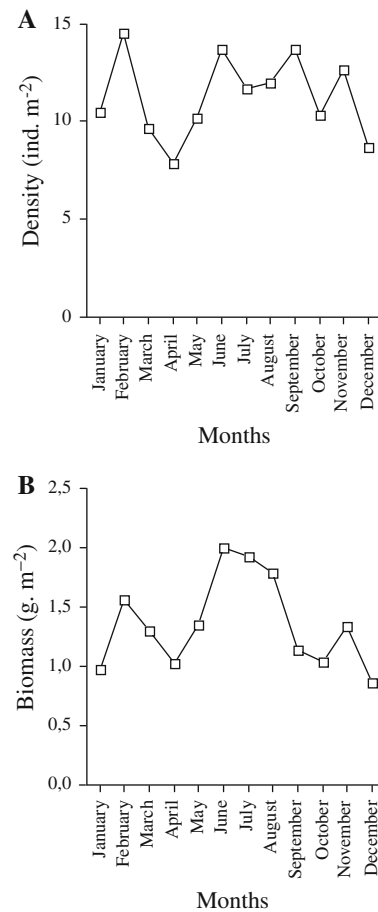


Fig. 5 Temporal variations in the density (ind. m^{-2}) (a) and in the biomass (fresh weight g m^{-2}) (b) of the studied population of *Nereis falsa* at El Kala, Algeria

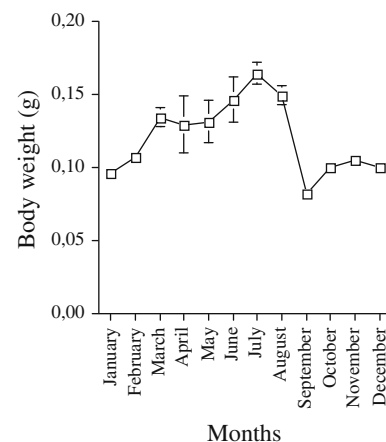


Fig. 6 Changes in the mean individual fresh weight from January to December 2007. Each data point represents mean \pm standard error of the mean

Recruitment pattern

The weight frequency histograms of *N. falsa* collected from January to December 2007 are shown in Fig. 7. Two cohorts (C_1 , C_2) can be distinguished. One cohort (C_1) could be followed over eight months from January to August 2007. This cohort represents the older (I-group) individuals. Its members showed a progressive increase in mean individual weight from January to August (Fig. 6). During summer, this cohort was well represented by large females with large oocytes ranging from 140 to 190 μm in diameter in August. In September, the mean individual weight decreased, related to the disappearance of the large individuals after reproduction (C_1)

and the appearance of another cohort (C_2). This cohort could be followed for the rest of the sampling period into December. It corresponded to a new generation of individuals (0-group; i.e. individuals hatched during the sampling year) which had just settled in the study area. This cohort was represented by females with small oocytes ranging from 30 to 70 μm in diameter in September. All frequency histograms showed a unimodal distribution (Fig. 7).

Growth curves (Fig. 8) have been constructed using the means of fresh weight for each cohort shown in Fig. 7. The mean lifespan was estimated to be one year using the appearance and disappearance of modes in the cohort analysis.

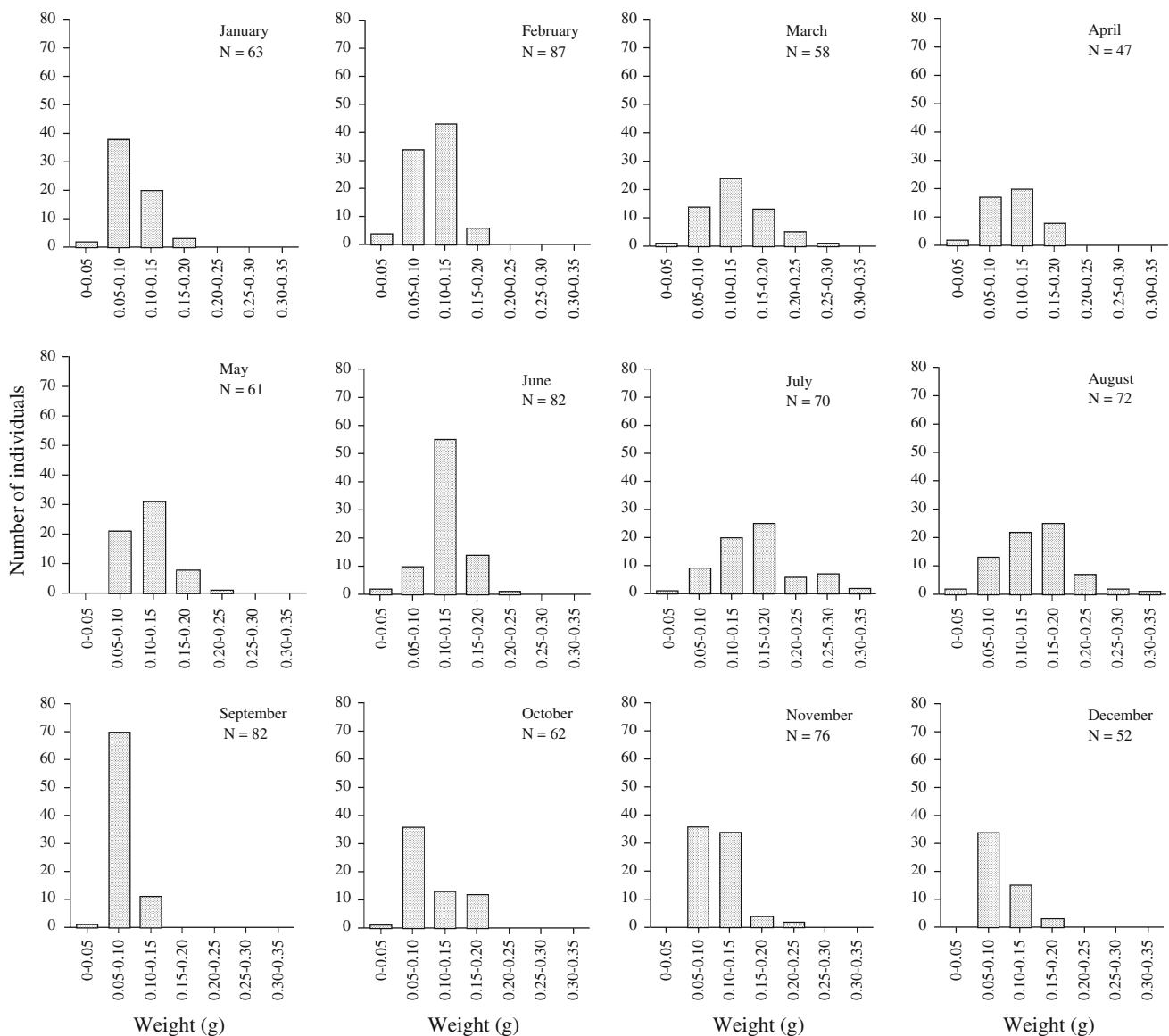


Fig. 7 Weight frequency histograms of *Nereis falsa* at El Kala between January and December 2007

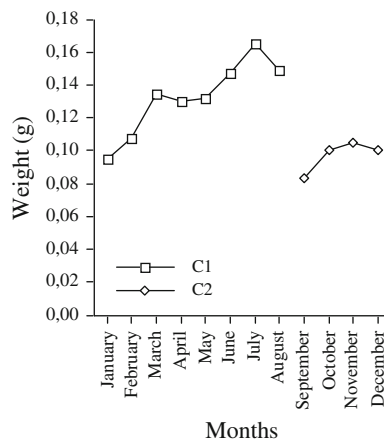


Fig. 8 Growth curves of the cohorts of *Nereis falsa* at El Kala between January and December 2007

Production estimates

Estimates for the production by the two cohorts of *N. falsa* during the study period are shown in Table 1. The annual secondary production in 2007 was $P = 1.45 \text{ g m}^{-2} \text{ year}^{-1}$ at a mean annual biomass of $B = 1.36 \text{ g m}^{-2}$. Thus, the ratio P/B amounted to 1.07 year^{-1} .

Discussion

The reproduction of *N. falsa* in the El Kala National Park (Mediterranean, eastern Algeria) follows the atokous type.

Table 1 Secondary production of the cohorts of the population

Cohort	W_t	$W_{t_2} - W_{t_1}$	N_t	$N_{t_1} + N_{t_2}/2$	Production (g for 6 m^2)
January	0.095	–	63	–	–
February	0.108	0.013	87	75	0.975
March	0.135	0.027	58	72.5	1.957
April	0.130	–0.005	47	52.5	–0.262
May	0.132	0.002	61	54	0.108
June	0.147	0.015	82	71.5	1.072
July	0.165	0.018	70	76	1.368
August	0.149	–0.016	72	71	–1.152
Total C1					4.066
September	0.083	0.083	82	41	3.403
October	0.100	0.017	62	72	1.224
November	0.105	0.005	74	68	0.340
December	0.100	–0.005	52	63	–0.315
Total C2					4.652
Total					8.718

W_t mean weight variation of a cohort between t_1 and t_2 , W_{t_1} and W_{t_2} mean fresh weights of a cohort at times t_1 and t_2 , N_t number of individuals in a cohort at times t , N_{t_1} and N_{t_2} numbers of individuals in a cohort at times t_1 and t_2

Data on the species' mode of reproduction are very scarce and based on old and incomplete observations. To our knowledge, the present study is the first providing on the life cycle of *N. falsa*. Fauvel (1923) stated that the species reproduces in an epitokous state. However, ecological plasticity in the mode of reproduction has been observed for several species of polychaetes and particularly for nereidid polychaetes (see review by Giangrande 1997). For example, individuals of *Perinereis cultrifera* reproduce with or without the morphological modifications which are characteristic of epitoky depending on geographical origin. This species is particularly interesting since it occupies the same habitat as *N. falsa* (rocky shores) and is present in our study site. The reproduction of *P. cultrifera* in the English Channel and the French Atlantic coast is of an epitokous type and has been observed from May to June and sometimes July (Fauvel 1916; Herpin 1925; Fage and Legendre 1927; Durchon 1951; Cazaux 1965; Scaps et al. 1992). In the Arcachon Basin (Cazaux 1965) and on the north coast of Brittany, *P. cultrifera* (Scaps et al. 1992) has a 3-year lifespan. Along the Atlantic coast of El Jadida (Morocco), the reproduction of *P. cultrifera* is of an atokous type and spawning occurs from April until the end of May (Rouhi et al. 2008). In the Mediterranean Sea, mature specimens are atokous in Marseille (Peres and Rancurel 1948) and on the west coast of Algerian in the Bay of Algiers (Durchon 1957; Marcel 1962; Rouabah et al. 2008). In the Bay of Algiers, the lifespan of the species probably does not exceed two years and the reproductive period spans most of the year, but reproduction is most intense in spring from March to May (Rouabah et al. 2008). Reproduction of *P. cultrifera* is of an epitokous type in the Venice lagoon in Italy (Ansaloni et al. 1986), at Salammbô near Tunis (Zghal and Ben Amor 1989) and at Annaba on the east coast of Algeria near the Tunisian border (Rouabah and Scaps 2003a). At Annaba, *P. cultrifera* has a 3-year lifespan and spawning occurs in late April/early May (Rouabah and Scaps 2003a, b). The existence of two modes of reproduction in this species (atoky and epitoky) led Marcel (1962) and Zghal and Ben Amor (1989) to split the species into two physiologically different subspecies ("races"), while the observations of Scaps et al. (2000), Rouabah and Scaps (2003b) and Rouabah et al. (2009) indicated that "*P. cultrifera*" may represent a complex of species.

Our study showed that *N. falsa* from the coast of El Kala has a synchronous oogenesis. Similar results have been obtained for other species of nereidid polychaetes such as *P. cultrifera* (Rouabah and Scaps 2003a) and *Platynereis dumerilii* (Fischer and Dorresteijn 2004). In contrast, Zribi et al. (2007) showed that *Perinereis macropus* from the Gulf of Gabes (Tunisia) has an asynchronous oogenesis, with the female individual bearing oocytes of quite different diameters.

Table 2 Comparison of the production/biomass ratio (P/B) in some species of polychaetous annelids

Family	Species	P/B	Site	Authors
Arenicolidae	<i>Arenicola marina</i>	1.14	Grevelingen estuary, North Sea	Wolff and Wolff (1977)
Nephtyidae	<i>Nephtys hombergii</i>	1.9	Lynher estuary, English Channel	Warwick and Price (1975)
Nereididae	<i>Nereis diversicolor</i>	3.9–4.6	Bou Regreg, Morocco	Gillet (1993)
	<i>Nereis diversicolor</i>	1.7–1.9	Oued Souss, Morocco	Aït Alla et al. (2006)
	<i>Nereis falsa</i>	1.07	El Kala, Algeria	Present work
	<i>Perinereis cultrifera</i>	2.3	El Jadida, Morocco	Rouhi et al. (2008)
Owenidae	<i>Owenia fusiformis</i>	0.89	English channel	Ménard et al. (1989)
Spionidae	<i>Scolelepis squamata</i>	2.0	Morocco	Bayed et al. (2006)

Data on the reproductive biology of nereidid polychaetes from the east coast of Algeria and the coast of Tunisia are very scarce. Nevertheless, Rouabah and Scaps (2003a) studied the life cycle and population dynamics of *P. cultrifera* in the area of Annaba, about 30 km west to our study site. It should be noticed that we did not find individuals of *N. falsa* in the site studied by Rouabah and Scaps in (2003a, b), while these two species co-occur on the coast of El Kala.

Nereis falsa has smaller mature oocytes (diameter of 160–210 μm , mean 165 μm) than *P. cultrifera* (diameter from 220 to, mean 250 μm). The reproductive period of *P. cultrifera* is short and spawning occurs from the end of April to early May; that of *N. falsa* is longer with spawning occurring from the end of July to early September. Oogenesis in *P. cultrifera* takes 16 months, while that in *N. falsa* takes less than one year. So, these two co-occurring nereids show clear differences in reproductive traits. The reproductive season of *P. macropus* stretches from March to June in the Gulf of Gabes in Tunisia, and mature oocytes range between 220 and 300 μm in diameter with a mean of 250 μm (Zribi et al. 2007). In contrast to *P. cultrifera* and *P. macropus*, which reproduce in spring at rising sea water temperature, *N. falsa* reproduces in summer when sea water temperature is at its maximum. In our study site, there are three species of nereids co-occurring in the same habitat (*N. falsa*, *P. cultrifera* and *P. dumerilii*) but only the life cycles of *N. falsa* and *P. cultrifera* have been investigated in this area. The life cycle of *P. dumerilii*, well known from some other geographical locations, remains to be studied for the coast of El Kala in order to compare all three species with respect to their reproductive characteristics.

The values of the mean annual biomass ($B = 1.36 \text{ g m}^{-2} \text{ year}^{-1}$) and the secondary production ($P = 1.45 \text{ g m}^{-2}$) of *N. falsa* at El Kala National Park are among the lowest recorded for polychaetes. The known P/B ratios of polychaete worms range between 0.89 and 4.6 year^{-1} (Table 2). The P/B ratio value of 1.07 year^{-1} for the *N. falsa* population of El Kala is similar to those reported

for *Owenia fusiformis* in the English Channel (0.89 year^{-1}) and *Arenicola marina* in the North Sea (1.14 year^{-1}) but is lower than those for polychaete worms from North Africa (e.g. P/B = 2.3 year^{-1} for *P. cultrifera* on the Atlantic coast of El Jadida, Morocco; Rouhi et al. 2008).

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