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Fishing of Norway lobster *Nephrops norvegicus* (Linnaeus, 1758) (Decapoda Nephropidae) in Algerian western waters

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ABSTRACT A frequently occurring species with high market value in Algeria, the Norway lobster *Nephrops norvegicus* (Linnaeus, 1758) (Decapoda Nephropidae) has attracted the interest of many professional fishermen. Fishery for this species has been growing rapidly in recent years. In this work, we collected data on the eco-biology, production, and monitoring of fishing effort and calculated yields. Our main objective is to provide an introduction to the fishing activity of this crustacean decapod in western Algeria, to provide a database for further studies of the lobster stock, and to contribute to the improvement and development of lobster fishery in Algeria.

KEY WORDS Algeria; capture; effort; eco-biology; *Nephrops norvegicus*; performance.

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INTRODUCTION

In Algeria, due to the absence of any form of crustacean farming, the total shrimp production corresponds to over 90% fishing. Three shrimp species of high commercial value are caught that, in order of abundance, are: *Aristeus antennatus* (Risso, 1816) (Aristeidae), *Parapenaeus longirostris* (Lucas, 1846), and *Penaeus kerathurus* (Forskål, 1775) (Penaeidae).

Due to the considerable economic value, some crustaceans have attracted the interest of many professional fishermen. This is the case for the Norway lobster *Nephrops norvegicus* (Linnaeus, 1758) (Decapoda Nephropidae) which leads a demersal life, living on sandy mud bottoms (Sarda & Aguzzi, 2012). Its bathymetric distribution is wide, ranging from 15 m to 800 m (Farmer, 1972) but, typically, from 180 to 500 m (Abello & Sarda, 1982; Dintheer, 1982; Orsi Relini & Relini, 1985).

On the biology and fishing of *N. norvegicus*, several studies have been published for the Mediterranean Sea in Spain by Sarda (1998), Sarda et al., (1998), and Aguzzi et al. (2004, 2009a), in France by Fontaine & Warluzel (1969), Morizur et al. (1981), Morizur (1983), and Macher et al. (2008), and in Greece by Castro et al. (1998).

In Algeria, *N. norvegicus* is abundant in the extreme West (from Ghazaouet to Bouzedjar) and a first estimate made in 1982 on the level of this marine zone reveals a high biomass (ISTPM, 1982). In this coastal area of western Algeria, this crustacean is found on the continental shelf edge between 180 and 550 m depth, with a higher density between 280 and 400 m (CGPM/GFCM, 1982; Massuti et al., 2003). However, this Arthropod becomes gradually scarce as we move from Habibas Islands (western Algeria) towards the eastern country coast.

We tried to get as much information as possible on the eco-biology and fisheries of *N. norvegicus* in order to exploit the results as a data basis for future studies and contribute to the improvement and the management of these crustaceans fisheries in Algeria.

MATERIAL AND METHODS

Study area

In Algeria, the lobster is caught in the western region of the country, which extends on approximately 5000 m^2 all along the 80 km of coastline limited to the West and the East respectively by the meridian lines 2°00'E and 2°30'E and 2°00 E and 2°30'E and North by the parallel 35°20'N and 35°40'N (Fig. 1).

Sampling

Twenty-one sea trips have been carried out on a professional trawler operating in a regular way from June 2011 to April 2012 on our study area (Cape Noe until Habibas Islands; Fig. 1) with 617 specimens gathered.

Data collection on fishing for this lobster is based mainly from surveys and personal investigations in the field, obtained from personal commercial fisheries statistics, and also gathered from the concerned management and fishing resources services (DPRH). The information on the capture sites and the sorting characteristics, as well as other data on the lobster fishery, were collected from some skippers. These data provided additional information to those presented in Table 1 on the various areas restricted for the Norway lobster fishing activity and bathymetric limits (Table 1). The preliminary treatment of collected specimens were carried aboard a trawler. After sorting by sex, each individual was measured using a caliper and weighed by a precision balance. For females, the ovaries stages maturity was determined by macroscopic observation according to the Farmer scale (1972, 1975). We adopted three gonadic stages (Table 2).

We then analyzed the various data obtained through different models and equations below: the overall sex ratio, the sex ratio according to size, and the sex ratio according to seasons.

It has been calculated a $\chi 2$ heterogeneity test, the risk of a degree of freedom and p <0.05 significance, using the STATISTICA Software (StatSoft Inc., 2001) to determine whether the predominance of each sex in each class size and during all sampling months are significant or not.

The length at first maturity (L 50) is the length at which 50% of females are mature (Fontaine & Warluzel, 1969; Conand, 1977). To provide details on the reproductive cycle and the lobster laying, L 50 was calculated as follows:

$$L_{50} = \frac{S_1}{S_2}$$

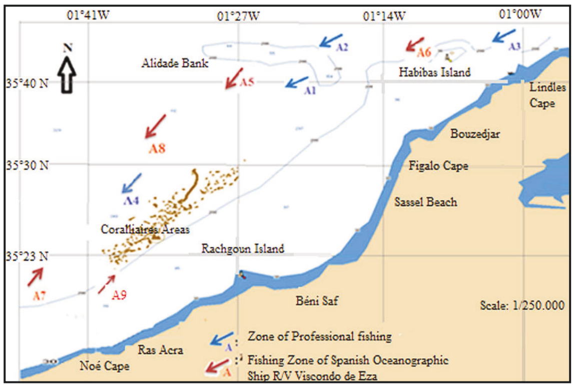

Figure 1. The *Nephrops norvegicus* geographical distribution in western Algeria with the fishing areas.

A1	35° 41' 000'' N	01° 21' 600''W	336	357
A 2	35° 41'565'' N	01° 21' 770''W	362	383
A 3	35° 41'000'' N	01° 22' 560''W	430	455
A 4	35°47' 107'' N	01° 15'967'' W	330	463
A5	35° 45' 165'' N	01° 19'461'' W	626	650
A6	35° 47' 107'' N	01° 15'967'' W	530	863
A7	35° 30' 917'' N	01° 38'692'' W	376	380
A8	35° 37' 820'' N	01° 37'274'' W	441	454
A9	35° 22' 025'' N	01° 49'970'' W	321	359
A10	35° 40' 113'' N	01° 28'464'' W	404	419

Table 1. Fishing areas for *Nephrops norvegicus* in the bay of Beni Saf (western Algeria).

Stage	ovarian Color	Other characteristics
1	White	- Threadlike(filiform) ovaries, well separated
2	Pale green	- Ovaries having developed lateral wings - Visible oocytes - Vitellogenesis
3	White and green mottled	- Ovaries during shrinkage - Oocytes being resorbed

Table 2. Summary outline of maturity stages applied to *Nephrops norvegicus* females and the equivalent macroscopic characteristics.

Growth study

The objective of this part is to determine the characteristic of living organisms, such as population size structure, growth and age of *N. norvegicus* in the targeted area of this study. There are several mathematical models to express the growth in crustaceans. A detailed review was made by Beverton & Holt (1957), Ursin (1967), Gulland (1983), Sparre & Venema (1996) and Pauly & Moreau (1997). However, the most common model is that of Von Bertalanffy (1938):

$$Lt = L\infty\left[1 - e^{-k\left(t - t_o\right)}\right]$$

L∞ is the theoretical maximum height (in mm), Lt is the size (in mm) at age t, while k is the growth coefficient.

For the assessment of these parameters, the program LFDA (Kirkwood et al., 2001)was applied to monthly catches body length using ELEFAN method. As the calculations of k and L∞ growth are correlated, we will determine Ø using the formula of Pauly & Munro (1984):

$$\Phi = 2.\log L_{\infty} + k$$

Fleet and fishing effort

To identify the best fishery (fleets and fishing effort), we consulted archives at the Fisheries and Fish Resources Department (DPRH) and two fishing antennas at both Bouzedjar and Beni Saf fishing ports located in our study area (Fig. 1).

The data collected was used to get catches per unit effort equal to the fishing effort split by the boats number or E = weight in ton/day.

In addition, daily monitoring (personal observations of the trawler landings) was used to calculate the standardized CPUE.

Associated fauna

The study of the associated fauna allowed, first, to make an inventory and to know the captured species and, secondly, to determine the species composition and calculate their relative abundance which is equal to the number of the individual species on the total number of all species in percentage.

RESULTS

According to Kartas & Quignard (1984), the sex ratio is one of the parameters that helps, within a certain limit, the reproductive capacity of species in their natural environments. In other words, this index represents the abundance of one sex compared to another.

In our sample of 617 Norway lobsters, the sex of each individual has been determined (431 males and 186 females). The total sex ratio is 69.85%, with a total femininity rate of 30.15% clearly indicating a sex-ratio in favor of males. From the populations and from females and males percentages in *N. norvegicus* by size class, we illustrate the size abundance curves in figure 2. Figure 3 represents graphically the monthly variations of sex ratio; we noted that the males percentage remains quite dominant during the year.

Based on closer examination of the ovaries structure on a yearly cycle (June 2011-April 2012), we can say that the species spawning period studied in Beni Saf area takes place from November to April with a maximum phase of gonads maturation in March (Fig. 4).

The conclusion that emerges from figure 4 is that the size at first maturity is relatively variable depending on the geographical zone (Table 3), according to Cartes et al. (1993).

The analysis focuses on the distribution of the total sampled catches during the 11 months of work (June 2011 - April 2012). The LFDA Software (subroutine ELEFAN) (Kirkwood et al., 2001) was used for the calculation of the growth parameters values. The Tables 4 and 5 gives the values of L∞, K and t0 estimated for the target species, and then replaced in the Von Bertalanffy equation, as well as Ø calculated in the present study.

Figures 5 and 6 show the fleet evolution at the two ports: Beni Saf and Bouzedjar fishing with bottom trawls over a period from 2002 to 2012. We noticed from the two previous figures that the trawlers number during this period of 10 years of operation has increased from 11 to 48 at the Bouzedjar port. However, and for the same period in the Beni Saf port, the number fell from 39 to 36: the reduction is due to an operational fleet transfer of 3 trawlers from Beni Saf to Bouzedjar port.

Annual landings from 2007 to 2012 (Fig. 7) and lobster catch per unit effort (CPUE) (Fig. 8) for fishing with bottom trawling increased from 2 to 24.5 tons, respectively, and from 0.4 to 4.1 tons per boat every year in the respective way. Furthermore, the average standardized CPUE for the port of Beni Saf showed a similar tendency, with higher values in summer and autumn.

Despite the imperfection of quantitative appreciations that can be drawn from a study of associated fauna (Fig. 9) by trawling (from a sea trip to another catch the number of individuals and the number of species are highly variable), the analysis of the results reveals that the Norway lobsters are the most abundant species, especially in the median area of the continental shelf between a depth of 250 and 400 meters. The captured fish in these bottoms relates for the most part to the Gadidae family: the most common species are *Merluccius merluccius* (Linnaeus, 1758), followed by *Phycis blennoides* (Brünnich, 1768). The most common cephalopod being the *Octopus vulgaris* (Linnaeus, 1758) and, for crustacean fauna, the *Parapenaeus longirostris*. Lastly, only commercial species smaller than the stated size, as the dogfish *Scyliorhinus canicula* (Linnaeus, 1758), remain.

DISCUSSION AND CONCLUSIONS

Our study was conducted over a period of 11 months (12 June 2011–11 April 2012) with a total sample of 617 Norway lobster specimens. We noted a difference in the sex ratio in favor of males during the sampling period (total male proportion = 69.85%, females = 30.15%), with males being significantly more frequent than females and from size Lc= 47 mm we found only males. This could result in a slightly faster growth for males. Charuau (1978) formulated the hypothesis that female growth would be slowed due to less frequent molts. Another explanation of the difference in the sex ratio in favor of males would be due to the low proportion of females in the catch, because they are less active and often hide in burrows (Jukic, 1971; Froglia & Gramitto, 1981; Orsi Relini et al., 1998; Ungaro et al., 1999).

For the determination of the reproductive cycle and the laying period, based on the ovaries structure observation over a complete cycle (June 2011–April 2012), we can say that the *N. norvegicus* spawning period in Beni-Saf area occurs from November to April with the maximum gonads maturation phase in March. Our results are practically similar to those obtained by other cited authors. These clearly define the spawning period in the Spring and early Summer. This situation is common to the Mediterranean shore (Karlovac, 1953; Morizur et al., 1978; Froglia & Gramitto, 1979, 1981; Sarda, 1985; Sarda & Cros, 1984; Sarda, 1983a, b, 1985, 1991; Froglia & Gramitto, 1988; Orsi Relini & Relini, 1989; Sarda & Valladares, 1990; Sarda & Lleonart, 1993; Mc Quaid et al., 2006; Morello et al., 2009).

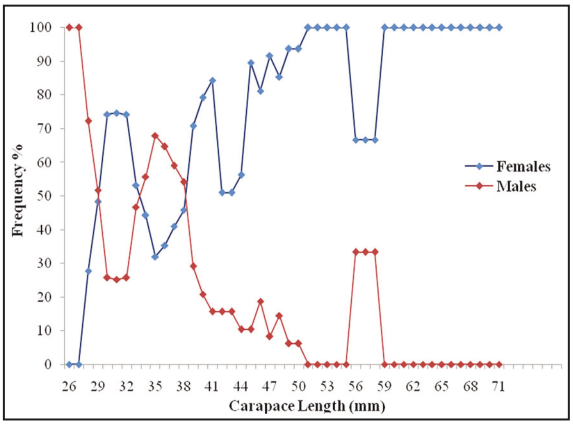

Figure 2. The *Nephrops norvegicus* males and females abundance curve vs size. The results of $\chi 2$ test highlight the predominance of the sexes according to the fishing months (* p<0.05 significance).

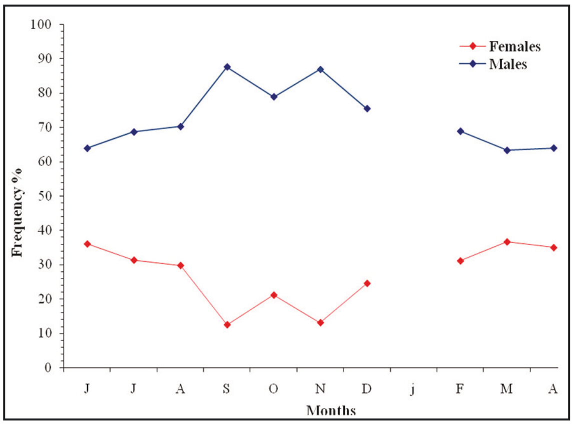

Figure 3. The *Nephrops norvegicus* males and females abundance curve vs size. The results of $\chi 2$ test highlight the predominance of the sexes according to the fishing months (* p<0.05 significance).

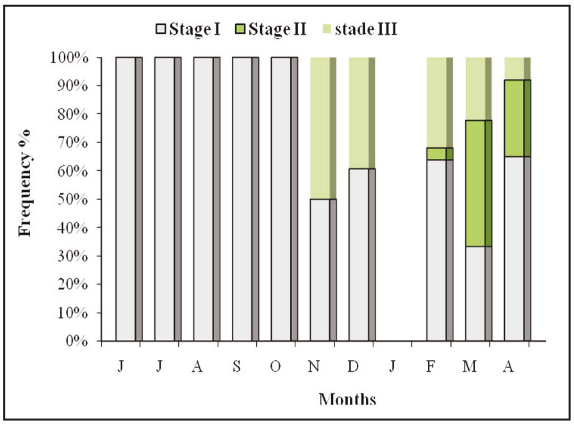

Figure 4. Percentages of different stages of sexual maturity in *Nephrops norvegicus* females.

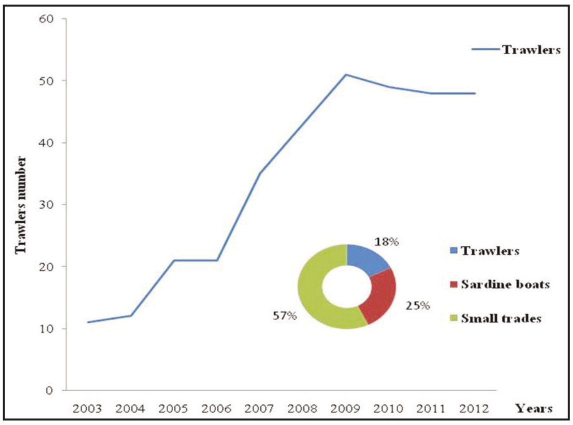

Figure 5. Annual evaluation of the trawlers number at Bouzedjar port.

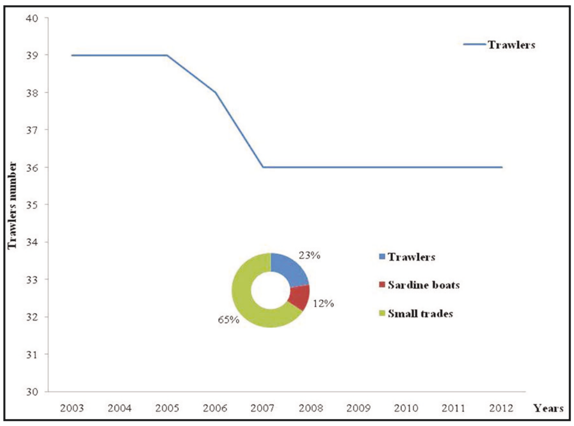

Figure 6. Annual evaluation of the trawlers number at Béni-Saf port.

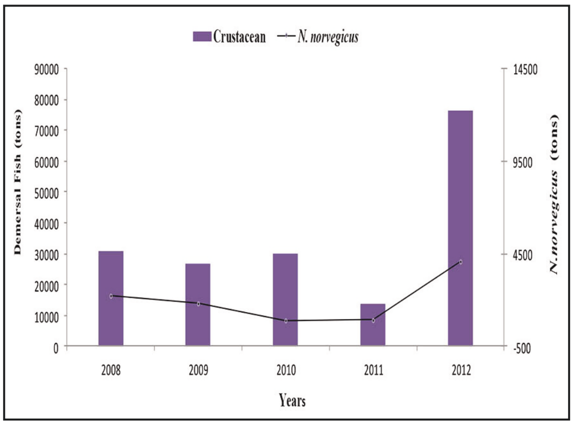

Figure 7. Annual unloadings of demersal fish and lobster *Nephrops norvegicus*.

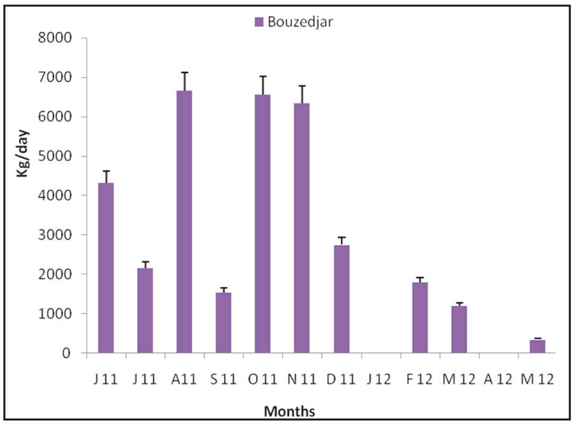

Figure 8. Monthly average of the standardized CPUE (with standard error) of Bouzedjar port.

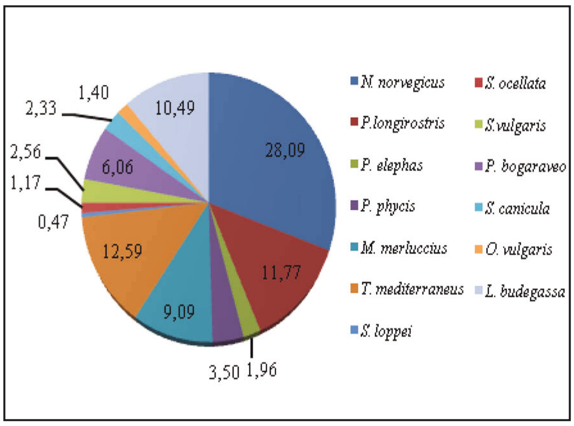

Figure 9. *Nephrops norvegicus* lobster associated fauna frequency.

In the present work, the size at first maturity (L 50) is estimated at 33 cm. These values are slightly overestimated because our samples come from commercial catches and not from experimental campaigns which operate on the whole bathymetric area. We can also add that the size at first maturity is relatively variable according to the geographical area (Cartes et al., 1993). Von Bertalanffy growth parameters are significantly different between the sexes, with higher values of the asymptotic length (L∞), growth coefficient (k), and the growth index (Φ) in favor of males. Therefore, the growth parameters estimated in the study area are in agreement with the low growth of the lobsters in the Mediterranean Sea (up to 25 to 32 years). This same model was also observed by Mytilineou et al. (1998), Sarda et al. (1998), Aguzzi et al. (2004), Cristo & Castro (2005), and Morello et al. (2008).

The results obtained in this study on the various aspects of the eco-biology of the *N. norvegicus* in Algerian western waters reveal that the life cycle of this species is similar to that observed in other Mediterranean areas.

Authors	Zone	Females (L_{50}) (mm)
Morizur, 1981	France	27 mm
Mc Quaid et *al*, 2006	Ireland	21 mm
Aguzzi et *al*, 2004	Spain	23 mm
Sarda et *al*, 1998	Spain	24 mm
Elisabetta et *al*, 2009	Italy	31 mm
Present work	Béni Saf (West Algeria)	33 mm

Table 3. Size of first sexual maturity (L50) of females in *Nephrops norvegicus*.

Sex	Males				Females			
Parameters	K	L∞	t_0	Ø	K	L∞	t_0	Ø
Results	0.16	77.50	-0.16	4.574	0.36	62.14	-0.67	4.030

Table 4. Results of growth parameters for females and males of *Nephrops norvegicus*.

Females	$Lc_t = 62.14(1\text{-}e^{-0.36\,(t+0,67)})$
Males	$Lc_t = 77.5(1\text{-}e^{-0.16\,(t+0,16)})$

Table 5. Von Bertalanffy growth Equations.

In addition, these results show that the fishing effort, implemented in the marine fishing area for Norway lobster in western Algeria, is significantly lower than that carried in other Mediterranean areas where the fishing power deployed is largely higher. In addition, the virtual absence of fishing pressure in the continental slope (depths beyond 400 m), resulted that the population of Norway lobsters at depths >400 m remains an unexploited source and a potential resource for the Algerian fishing.

Les us remind that the Norway lobster fishing is a recent activity which started only in the last decade. According to Mouffok et al. (2008), this species fishing grounds have remained untapped until the end of the last century because of their distances from the ports, weather conditions, and lack of suitable equipment (cables not sufficiently long, non-performing board equipment, poorly qualified crew, old fishing fleet, very high cost of spare parts, etc.). Fishing in the area under study was only for a particular type of shellfish: the white shrimp *Parapenaeus longirostris*.

Moreover, *N. norvegiucus* has discouraged the toughest fishermen because of its adaptation to great depths, using burrows as refuge and moving towards zones difficult to reach by trawlers (coral zones).

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