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FISH HABITAT MAPPING

Salinity and temperature as factors controlling the spawning and catch of *Parapenaeus longirostris* along the Moroccan Atlantic Ocean

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Abstract The deep-water rose shrimp, *Parapenaeus longirostris* (Lucas 1846, Decapoda: Penaeidae) is one of the main target species of the demersal fishery in the Moroccan Atlantic region. However, in the last decade, there is a severe decline of shrimp fisheries in the area without the existence of any management plan. The purpose of this article is to investigate the relationships between the spawning of the deep-water rose shrimp and environmental factors in order to provide basic information for any future management measure. The spatial distribution of mature females is investigated through statistical techniques on data collected in the Moroccan Atlantic Ocean from bottom trawl surveys during 1981–2004. The geographic distribution of mature females is jointly analyzed in association to the spatial distribution of salinity and temperature at the depth of species catch. The study reveals a strong relationship between locations of spawning females and high salinity. Most spawning occurrences are observed in high salinity 'islands' (35.6–36.5 psu) or in the boundaries of higher-lower salinity patterns in the specific range of 36.2–36.4 psu in shallower (75–200 m) and deeper zones (250–500 m). Spawning occurs mostly in the shallower zone from spring to summer while during winter, it occurs in both depth zones. Temperature seems to be important on catch levels of the species.

Keywords Deep-water rose shrimp · Environment · Ecology · Atlantic · Morocco

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Essential Fish Habitat Mapping in the Mediterranean

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Introduction

The deep-water rose shrimp, *Parapenaeus longirostris*, thereafter rose shrimp, is one of the three species of the genus *Parapenaeus* that inhabits the Atlantic Ocean (Perez-Farfante & Kensley, 1997). It has a wide geographical distribution in the Eastern Atlantic, from the north of Spain (Olaso, 1990) to south Angola (Crosnier et al., 1968), as well as in the Mediterranean and its adjacent seas (Karlovac, 1949;

Maurin, 1960; Massuti, 1963; Audoin, 1965). Rose shrimp is targeted by a large fishing fleet in eastern Atlantic waters, south of Spain and Portugal (Pestana, 1991; Sobrino et al., 1994), Morocco, Mauritania, Senegal, Guinea Bissau, Gabon, and Angola (Cervantes & Goni, 1986; Cervantes et al., 1991; Sobrino & Garcia, 1991, 1992a, b).

In Moroccan waters, rose shrimp is one of the main target species of the Moroccan Atlantic demersal fisheries representing one of the most valuable species in fishery markets. The species is targeted by a coastal fleet operating between the coast and 150 m and by a deep sea fleet operating between 150 and 700 m. The catch of the coastal fishery is always landed fresh for local consumption mainly in Casablanca, Larache, and Agadir. The catch of the deep sea fishery is landed frozen in Tangier and Agadir ports and it is exported to Europe. The rose shrimp represents 98% of the landing species of the deep sea fishery. During the last decade, the shrimp fisheries in Moroccan Atlantic fishing grounds have been characterized by a severe decline (FAO, 2004, 2005). However, the exploitation pattern of this species has not been defined within a management plan (Belvèze et al., 1982; Benchoucha, 2005).

Although the commercial importance of this resource is high and despite being a species with wide geographical distribution, especially in African Atlantic fishing grounds, studies on the biology, ecology, and exploitation aspects of the rose shrimp are limited and fragmented. Based on multiyear sampling (1988–1994), obtained from Spanish fishing fleet landings at Spanish ports but operating in Moroccan Atlantic waters, the rose shrimp showed a continuous spawning during the year with two spawning peaks, one at early summer and another at the beginning of autumn (Sobrino & Garcia, 1994). This spawning pattern is similar to that found in the south of Portugal by Ribeiro-Cascalho & Arrobas (1983), who reported two peaks, one in June and another in October. In more recent studies (Ribeiro-Cascalho & Arrobas, 1987; Pestana, 1991), spawning peaks were established between June and July and between January and February by obtaining a first maturity size of 26 mm cephalothorax length (sexual maturity length), for the fishing grounds exploited to the south Portugal. This area is influenced by Mediterranean outflow, indicating species growth at smaller sizes during the gonadal maturation process. Length–weight ratio is similar at minor sizes, nevertheless, beyond a certain value, females at the same size weigh more than males; this deviation starts at around 24 mm of cephalothorax length. The rose shrimp prefers sandy and muddy bottom substrates and its size and male presence are positively correlated with depth (Froglia, 1982). Sobrino et al., (2000) and Relini et al., (1999) reported that mature females are generally present in all seasons with reproduction starting in winter and maturity reached in autumn and early winter.

In the Gulf of Cadiz, spawning of rose shrimp occurs throughout the year with two peak periods in late spring and early autumn. Here, the species is characterized by a differential growth pattern, with females reaching a larger size, having a life cycle of 2–3 years. Individuals reach sexual maturity at 8–10 months at varying sizes, depending on the area (cephalothorax length 20–28 mm in females) and have an average fecundity of 90,000 eggs. The species feeds on a great variety of prey with main preference in annelid worms (polychaetes) and foraminiferans (Sobrino et al., 2005). In the Mediterranean, (central-southern Tyrrhenian coasts), the species has been caught between 61 and 587 m with higher abundance indices observed from 200 to 450 m and average cephalothorax length increasing significantly with depth (Spedicato et al., 1996). Similar results were also reported by D'Onghia et al. (1998) for the Ionian Sea (Central Mediterranean). In the Sea of Marmara (located between the Mediterranean and the Black Sea), the mature individuals of the species with fully developed eggs were found throughout the year with the highest gonadosomatic index values obtained in September, October, December, April, and May. The total length at which 50% of the population reaches maturity is calculated to be 9.7 cm. Among the individuals caught, females at 10–11 cm and males at 9–10 cm formed the dominant size groups (Bayhan et al., 2005). In Egypt, spawning occurs throughout the year in deep waters, with pick occurrence during November. Immature individuals were found from January to September (Abdel Razek et al., 2006).

In 2003, the Moroccan production of rose shrimp reached 10,866 tones in weight and 60,947,250 USD in value (4,917 tones and 14,702,250 USD by the coastal fleet and 5,949 tones and 46245000 USD by the deep-water fleet) (Official statistics, ONP-Morocco). The abundance of rose shrimp constitutes 57% of all shrimp species occurring in Morocco. The number of females (63%) is far larger than that of males (37%). Cephalothorax length is 23.44 mm corresponding to 6.41 g weight and 0.44 years of age. Stock evaluation shows that rose shrimp is dramatically over exploited, the stock is deteriorated and the biomass is continually decreasing with most exploited sizes belonging to juveniles (FAO, 2007).

Based on long-term data from experimental trawling along the north Atlantic Moroccan coast, the aims of this study are to provide knowledge on the bathymetric distribution of the species and catch areas and to investigate the relationship between environmental factors (salinity and temperature) and rose shrimp spawning and catch in the Moroccan Atlantic waters aiming to contribute to any future and informed management decisions.

Materials and methods

The investigated area (Fig. 1) is located in the eastern part of the subtropical North Atlantic gyre off Morocco (NW Africa) influenced by the connection of the Gulf Stream via the Azores Current and the Canary Current with the North Equatorial Current. The study area belongs to one of the major eastern boundary upwelling systems of the world (Carr, 2002). Upwelling is predominant in summer and early fall due to the trade wind belt that is intensified during summer (Abrantes et al., 2002).

Fisheries data were collected during 40 experimental trawl surveys carried out during 1981–2004 in the North Moroccan Atlantic waters at a depth range 20–1,000 m. The duration of each survey was between 15 and 20 days. All stations were sampled during day-time in order to avoid rose shrimp considerable upward migrations during night-time. Two similar research vessels were used, 'Ibn Sina' during 1981–1986 and 'Charif Al Idrissi' during 1987–2004 surveys (Table 1). The two vessels were equipped with a trawl of 40 mm stretched mesh size at the cod-end.

The investigations covered two study areas: Larache–El Jadida (north zone) and Essaouira–Agadir (south zone) (Fig. 1). The bottom type in the region between these two zones is rocky, thus no investigation by trawling occurred there. The depth covered by the surveys was ranging from the coast (20 m) to 1,000 m depth with stratums of 0–100, 101–200, 201–500 and 501–1,000 m considered. Surface area (km^2) for each sampling stratum is shown in Table 2.

A stratified random sampling design (Fig. 1) was adopted with allocation of hauls proportional to the area of the strata (Cochran, 1963; Fogarty, 1985).

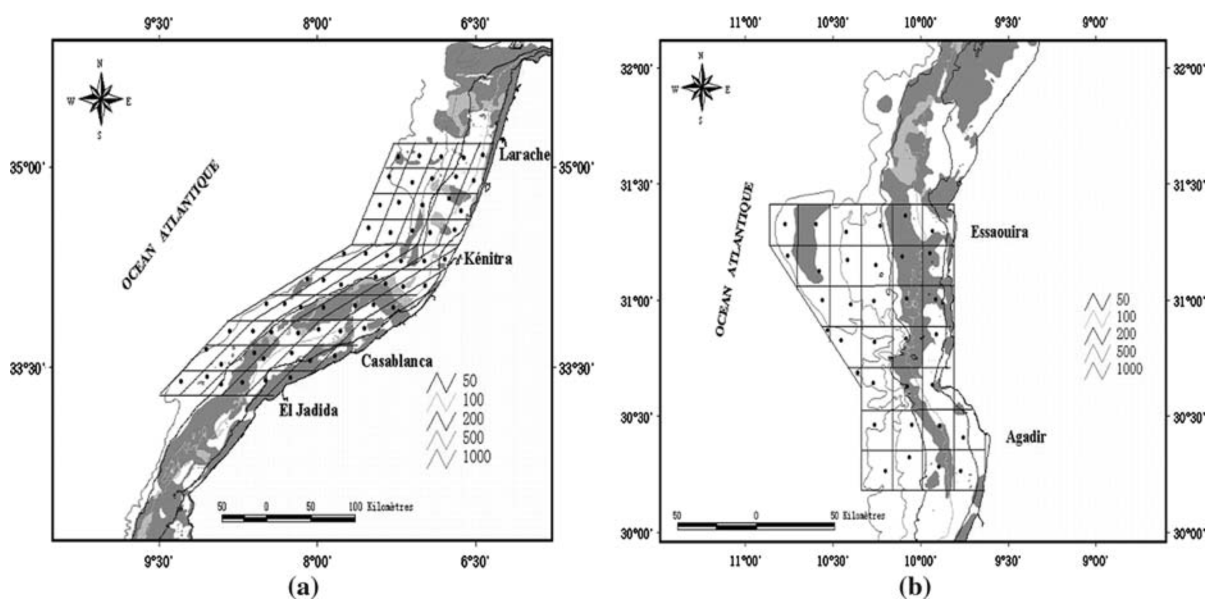

Fig. 1 Map of the study area Moroccan Eastern Atlantic: Stratified sampling adopted in each survey (**a**): North zone (Larache–El Jadida) and (**b**): south Zone (Essaouira–Agadir)

Table 1 Calendar of all *Parapenaeus longirostris* surveys realized during 1981–2004

Time	Research vessel	Type of trawl	Type of panel	Zones investigated	Sampling
Dec81	Ibn Sina	Calypso	Morgeres	North–South	16
Apr82	Ibn Sina	Calypso	Morgeres	North–South	33
Oct82	Ibn Sina	Calypso	Morgeres	South	6
Dec82	Ibn Sina	Calypso	Morgeres	South	4
Apr83	Ibn Sina	Calypso	Morgeres	North–South	18
Aug83	Ibn Sina	Calypso	Morgeres	North–South	29
Dec83	Ibn Sina	Calypso	Morgeres	North–South	29
Mar84	Ibn Sina	Calypso	Morgeres	North–South	66
Dec84	Ibn Sina	Calypso	Morgeres	North–South	40
May85	Ibn Sina	Calypso	Morgeres	North–South	40
Sep85	Ibn Sina	Calypso	Morgeres	North–South	37
Apr86	Ibn Sina	Calypso	Morgeres	North–South	33
Nov86	Ibn Sina	Calypso	Morgeres	North–South	36
Nov87	Charif Al Idrissi	Shrimp	Japenese	North–South	39
Mar88	Charif Al Idrissi	Shrimp	Japenese	North–South	40
Jun89	Charif Al Idrissi	Shrimp	Japenese	North–South	35
May91	Charif Al Idrissi	Shrimp	Japenese	North	16
July92	Charif Al Idrissi	Shrimp	Morgeres	North–South	24
Dec92	Charif Al Idrissi	Shrimp	Japenese	North	8
Apr93	Charif Al Idrissi	Shrimp	Morgeres	North–South	44
Jun94	Charif Al Idrissi	Shrimp	Morgeres	North–South	53
Sep94	Charif Al Idrissi	Shrimp	Morgeres	North–South	37
Dec94	Charif Al Idrissi	Shrimp	Morgeres	North	25
Apr95	Charif Al Idrissi	Shrimp	Morgeres	North–South	48
July95	Charif Al Idrissi	Shrimp	Morgeres	North–South	67
Dec95	Charif Al Idrissi	Shrimp	Morgeres	North	54
May96	Charif Al Idrissi	Shrimp	Morgeres	North–South	70
July97	Charif Al Idrissi	Shrimp	Thyboron	North	52
Dec97	Charif Al Idrissi	Shrimp	Thyboron	North–South	77
July98	Charif Al Idrissi	Shrimp	Thyboron	North	53
Dec98	Charif Al Idrissi	Shrimp	Thyboron	North–South	71
Mar99	Charif Al Idrissi	Shrimp	Thyboron	North–South	50
Nov99	Charif Al Idrissi	Shrimp	Thyboron	North–South	68
Nov00	Charif Al Idrissi	Shrimp	Thyboron	North–South	72
Apr01	Charif Al Idrissi	Shrimp	Thyboron	North–South	82
Nov01	Charif Al Idrissi	Shrimp	Thyboron	North–South	70
May02	Charif Al Idrissi	Shrimp	Thyboron	North–South	76
June03	Charif Al Idrissi	Shrimp	Thyboron	North–South	83
June04	Charif Al Idrissi	Shrimp	Thyboron	North–South	80

Generally, a range of 50–84 30-min hauls were carried out during each survey. The vessel speed, measured by GPS, was maintained at 3.0 knots. The horizontal net opening (20 m) was measured by means of a SCANMAR sonar system. For each station, the zoological collection has been sorted to species and length measurements were made. The abundance index (in kg/h) by zone or by stratum was calculated as the mean of the catch by species for all hauls in the zone or in the stratum.

Table 2 Surfaces (in km^2) of zones investigated

Bathymetry zone	North zone		South zone	
	Strata	Surface (km^2)	Strata	Surface (km^2)
0–100 m	Stratum 1	3254.574	Stratum 5	1583.148
101–200 m	Stratum 2	6296.902	Stratum 6	1462.023
201–500 m	Stratum 3	2435.297	Stratum 7	1553.021
501–1000 m	Stratum 4	5402.358	Stratum 8	3029.324

Table 3 Deep-water pink shrimp females' stages scale (Laboratory of Invertebrates, Russian Institute)

Stage I	Juvenile stage, ovaries are completely transparent or hardly discernible the other organs.
Stage II	Ovaries are fine or relatively big very detachable the other parts of the body. They are flasks, semi transparent, letting suspect the other organs.
Stage III	Ovaries are big, opaque, can be of slightly greenish color or blue; these can be distinguished by transparency through the shell. The previous digitations of ovaries do not recover the stomach.
Stage IV	Previous stage of spawning, the ovaries are big, opaque, of green color. Gonads are visible through the shell. The previous digitations of ovaries recover the lateral parts of the stomach.
Stage V	Stage of spawning. At this stage, the ovaries distinguish themselves from the precedent only by their color which oscillates between the brown and the dark green.

Rose shrimp cephalothorax length was measured (in mm) from rear of ocular indent to posterior dorsal margin of cephalothorax. Sex and maturity stage were assigned according to the Atlantniro Russian Institute scale (Laboratory of Invertebrates) (Table 3). Female maturity stages were considered as immature (stages I and II) and mature (stages III–V). In order to depict the geographic distribution of mature females, we selected those halls where both more than 50% of females and more than 50% of mature females were present and assumed as spawning females.

In order to examine the effect of environmental factors (salinity and temperature) on the spawning distribution of rose shrimp, we obtained 3-dimensional environmental data through NOAA's National Oceanographic Data Center (NODC) website (http://www.nodc.noaa.gov/OC5/WOA01/qd_ts01.html). The environmental data source is the high resolution (1/4°) temperature and salinity analyses (climatology) of the world's oceans (Boyer et al., 2005). Environmental data were processed under a Geographic Information System (GIS) environment and were superimposed to the distribution of spawning females of the species. Each spawning location was assigned an environmental value according to sampled month and depth. In order to examine whether factors such as depth and time (month, year or a combination of both) affect spawning frequency or catch, we used the analysis of variance (ANOVA) and in case of violation of the assumptions of ANOVA, its non parametric equivalent, the Kruskall-Wallis test. The Pearson and Spearman correlation coefficients were used to check for linear relationships between the catch or spawning variables and the environmental variables. Generalized additive (GAM) and linear regression models were also built to assess the influence of the environment and the relative importance of the variables. All statistical analyses were implemented in R language (R Development Core Team, 2005).

The study of the spatial distribution of spawning females was carried out under the implicit assumption of statistics that the structure of the investigated variable was stable in time, at least for the duration of each survey. This hypothesis seems to be realistic, considering the greater speed of the survey with respect to some possible biomass displacements. Moreover, catchability was not structured through space as the daylight sampling guaranteed that the catches were not affected by vertical migratory movements (Pestana & Ribeiro-Cascalho, 1991).

Results

The study area and the distribution of all haul surveys as well as the distribution of spawning females are shown in Fig. 2. Rose shrimp population shows a wide distribution as it was present at almost 80% among all

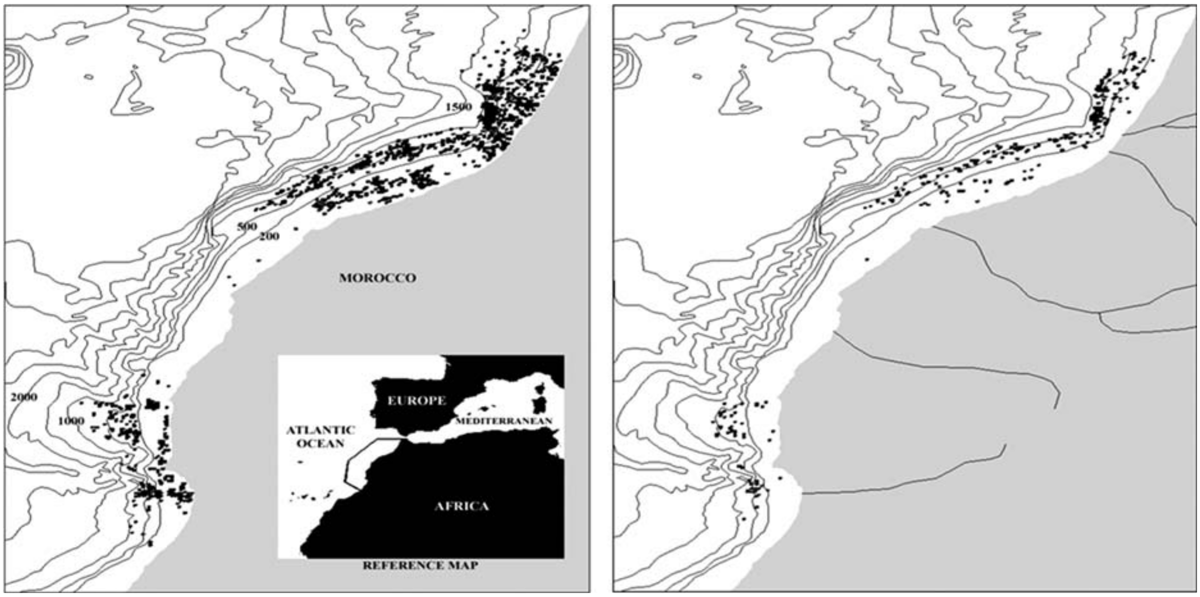

Fig. 2 Moroccan Atlantic Ocean: geographic distribution of all surveys (left) and distribution of *Parapenaeus longirostris* spawning females (right)

stations sampled. Spawning females in all surveys are distributed in various depths and throughout the year. Maximum spawning occurs in the region of Loukkos and deeper in the north of Agadir city, where sand and mud dominate the seabed. Spawning occurs generally between the isobaths of 100 and 500 m.

The distribution of the abundance index of rose shrimp for the surveys May 2002, June 2003, and June 2004 is shown in Fig. 3. Although some differences in abundance levels of rose shrimp among the years are observed, two sub-areas with high density of the species are observed. The geographical areas characterized by a high level of abundance are mainly localized between Moulay Bousselham and Rabat and in Agadir surrounding region, at depths ranging from 20 to 500 m, with some intrusions in the deeper levels. However, the maximum of abundance is always situated in the Loukkos region (Larache-Kénitra).

The spatial distribution of spawning females is superimposed to the spatial distribution of salinity distribution at catch depth. Salinity-spawning distributions in various depth zones are shown in Fig. 4. In most cases, spawning occurrences are observed in high-salinity 'islands' or in the boundaries of higher-lower salinity patterns.

The distribution of the spawning and its associated salinity is shown in Fig. 5. Most spawning occurrences are observed in the salinity range of 36.2–36.4 psu (the general salinity range for spawning is 35.6–36.5 psu). The case of June 2003 presents a tongue of homogeneous salinity range and 3 cases of high spawning occurrences in 150, 300 and 500 m depth zones. Overall, there are 2 depth zones where spawning is mostly observed. These are the shallower zone (75–200 m) and the deeper zone (250–500 m). Spawning occurs mostly in the shallower zone from spring to summer (March–July) while during winter (November–December) it occurs in both depth zones.

In an exploratory approach, statistically significant linear correlations were observed between catch variables (frequency, min, max, mean, and sum) and the variability (standard deviation—std) of temperature, as well as between min catch and min temperature, and min catch and std of salinity. The spawning frequency showed a statistically significant correlation to maximum salinity (Table 4, Fig. 6a and b).

A generalized additive model describes the relationship between landings and the environmental parameters. Temperature, along with depth and time-related variables (year and month) explain 15% of the variability of landings. An interaction between temperature and month was also statistically significant in this model (Fig. 7). Maximum salinity performs better than its minimum and mean values in terms of Akaike

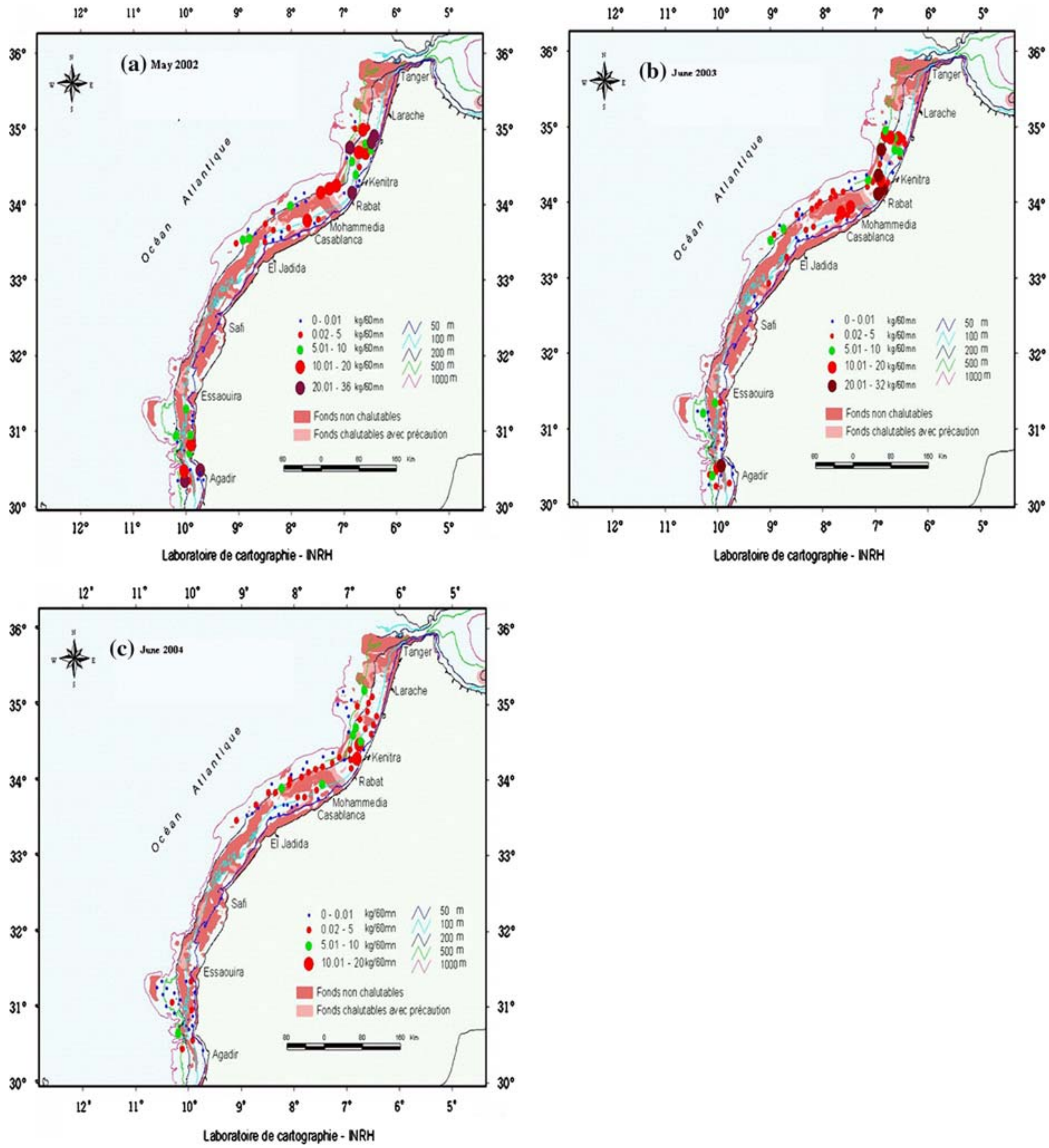

Fig. 3 Geographic distribution of the abundance index (kg/h) of *Parapenaeus longirostris* in Moroccan Atlantic Ocean during selected surveys

Information Criterion (AIC, Akaike, 1973; Burnham & Anderson, 2002) and percentage of the variability explained. A better proportion of the variability of the number of spawning females, namely 33%, is explained by means of a linear model that uses salinity and depth as explanatory variables (Fig. 8).

Discussion

As in any marine resource, the knowledge of the biology and the ecology of the rose shrimp constitute a fundamental asset for the management of the species. In spite of the economic importance,

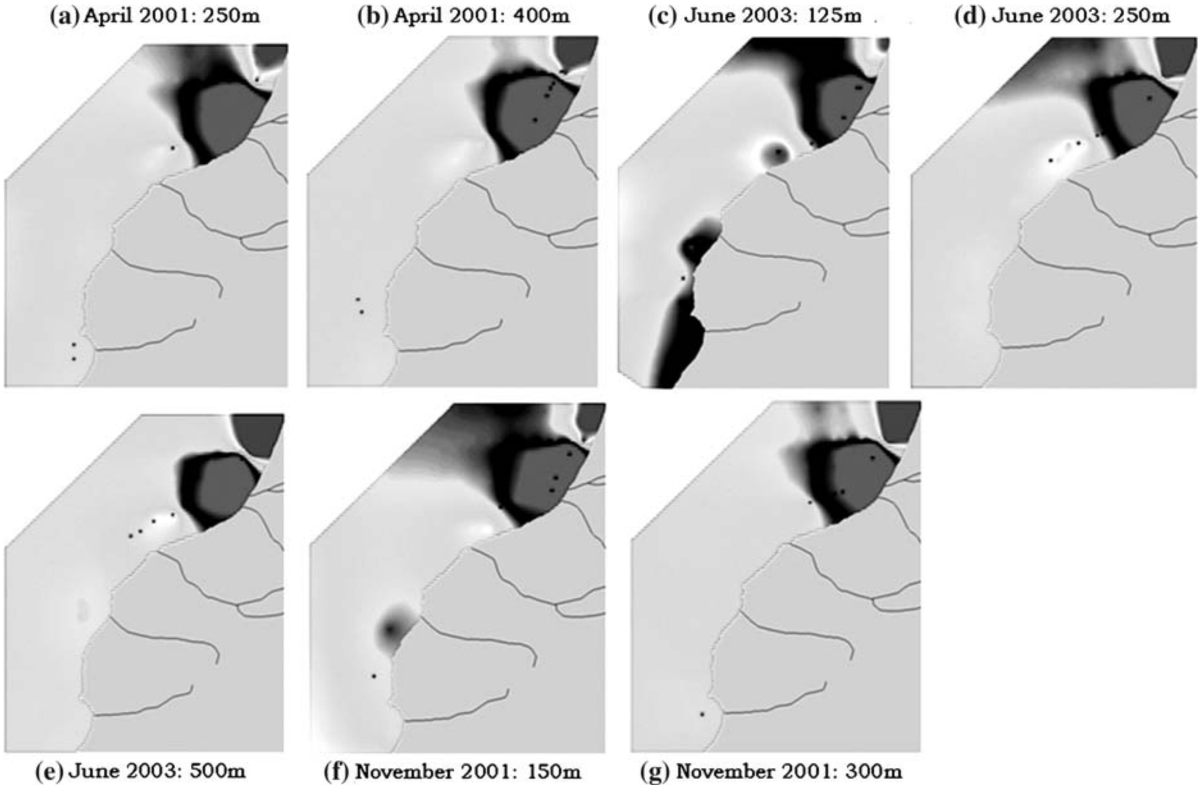

Fig. 4 Geographical distribution of salinity and *Parapenaeus longirostris* spawning occurrences in various depth zones

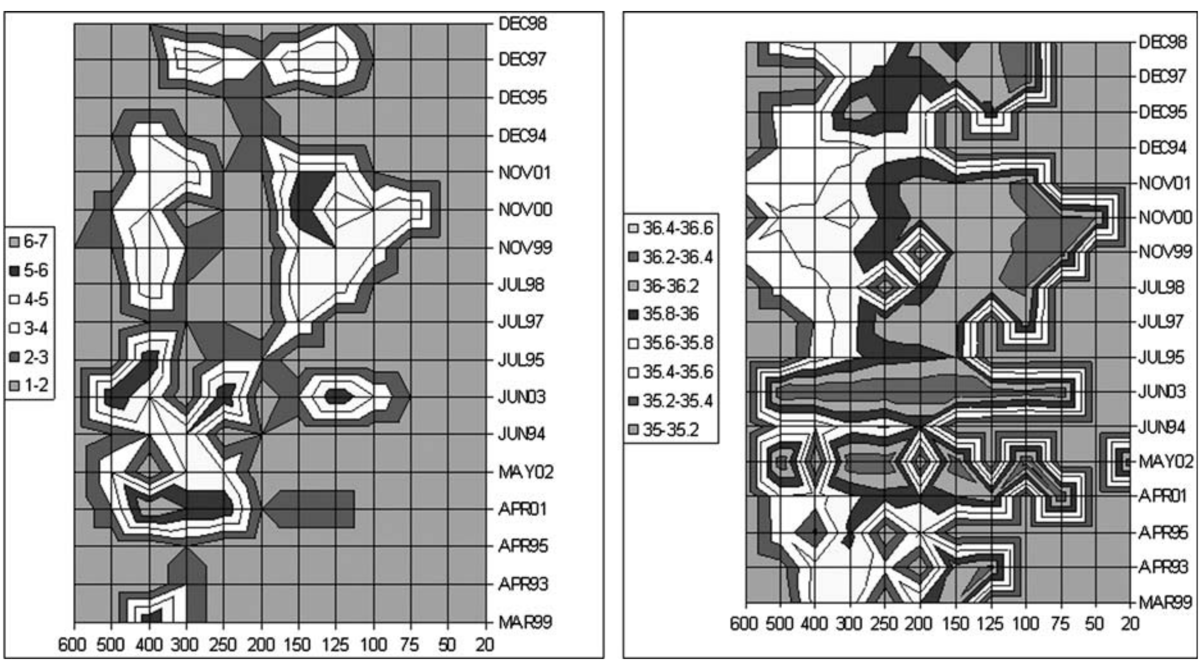

Fig. 5 Spatial distribution of spawning *Parapenaeus longirostris* (left) and associated salinity (right) during all surveys

Table 4 Linear correlations (statistically significant in bold) between catch, spawning and environmental variables

A

Pearson correlation coefficient (*P*-value)	Depth	Minimum salinity	Maximum salinity	Standard deviation salinity	Minimum temperature	Maximum temperature	Standard deviation temperature
Frequency	−0.344 (0.228)	0.075 (0.8)	0.412 (0.14)	0.145 (0.62)	−0.38 (0.18)	0.17 (0.59)	**−0.758 (0.002)**
Min catch	−0.2 (0.47)	0.445 (0.11)	−0.07 (0.8)	−0.42 (0.13)	**0.69 (0.006)**	0.23 (0.41)	**0.636 (0.014)**
Max catch	−0.33 (0.24)	−0.04 (0.9)	0.42 (0.14)	0.18 (0.53)	−0.48 (0.08)	−0.05 (0.85)	**−0.746 (0.002)**
Mean catch	−0.48 (0.08)	0.25 (0.38)	0.323 (0.26)	−0.15 (0.6)	−0.255 (0.38)	0.085 (0.77)	**−0.549 (0.042)**
Sum catch	−0.39 (0.17)	0.14 (0.62)	0.39 (0.17)	0.04 (0.89)	−0.38 (0.17)	0.18 (0.52)	**−0.757 (0.0017)**

B

Spearman rank correlations (*P*-value)	Standard deviation temperature	Standard deviation temperature	Standard deviation temperature	Minimum temperature	Standard deviation salinity	Standard deviation temperature	Standard deviation temperature
Frequency	**−0.7511 (0.0068)**						
Maximum catch		**−0.7152 (0.0099)**					
Mean catch			**−0.6425 (0.0205)**				
Minimum catch				**0.6273 (0.0237)**			
Minimum catch					**−0.718 (0.0096)**		
Minimum catch						**0.6786 (0.0144)**	
Sum catch							**−0.7239 (0.0091)**

C

Spearman rank correlations (*P*-value)	Minimum salinity	Maximum salinity	Mean salinity
Spawning	−0.0384 (0.686)		
Spawning		**0.855 (0.0064)**	
Spawning			0.11 (0.246)

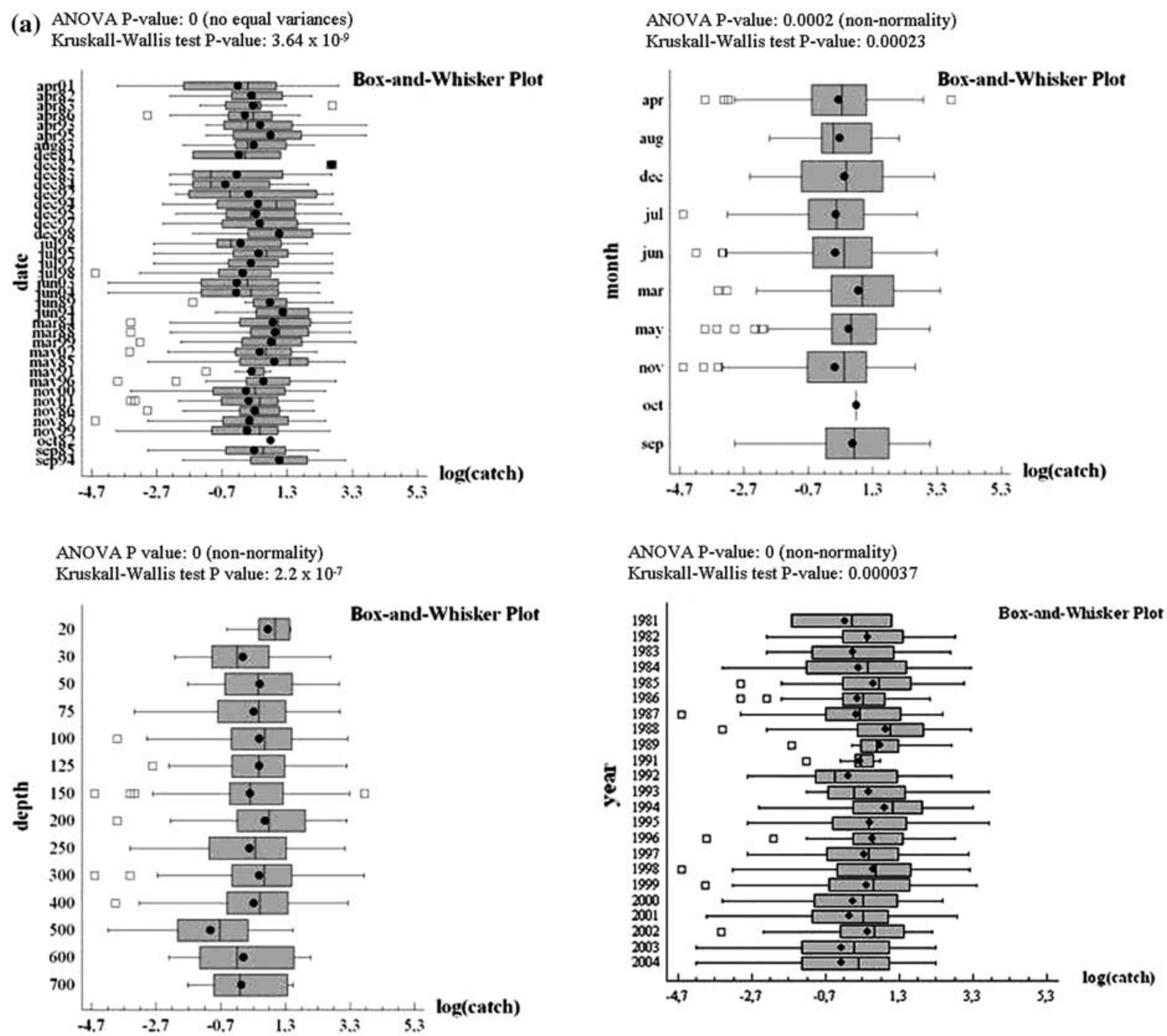

Fig. 6 (**a**) Analysis of variance and Kruskall-Wallis test *P*-values between catch and time-depth variables. (**b**) Analysis of variance and Kruskall-Wallis test *P*-values between spawning and time-depth variables

published papers on the rose shrimp are mainly based on commercial sampling in landings ports. The present study, based on multiannual data obtained by experimental trawling surveys brings useful elements for the management of this marine resource in Morocco.

The rose shrimp shows a wide geographical distribution in the study area with a bathymetric distribution related to size due to the migration of juveniles from the continental shelf to the slope, a pattern that is, however, common in many species of the family Penaeidae (Heldt, 1938). In Moroccan Atlantic, the distribution of rose shrimp is reported between 20 and 700 m, though the species is more abundant between 70 and 400 m (Holthuis, 1987), with adults mainly observed between 150 and 350 m and juveniles between 100 and 180 m (Ardizzone et al., 1990). Generally, smaller specimens are more frequently caught on the upper part of the continental shelf (50–200 m) while larger ones are mainly distributed along the slope at depths exceeding 200 m (Ribeiro-Cascalho & Arrobas, 1987).

Geographic areas characterized by high level of abundance are mainly located between Moulay Bousselham and Rabat and in Agadir surrounding region, at depths ranging from 20 to 500 m, with

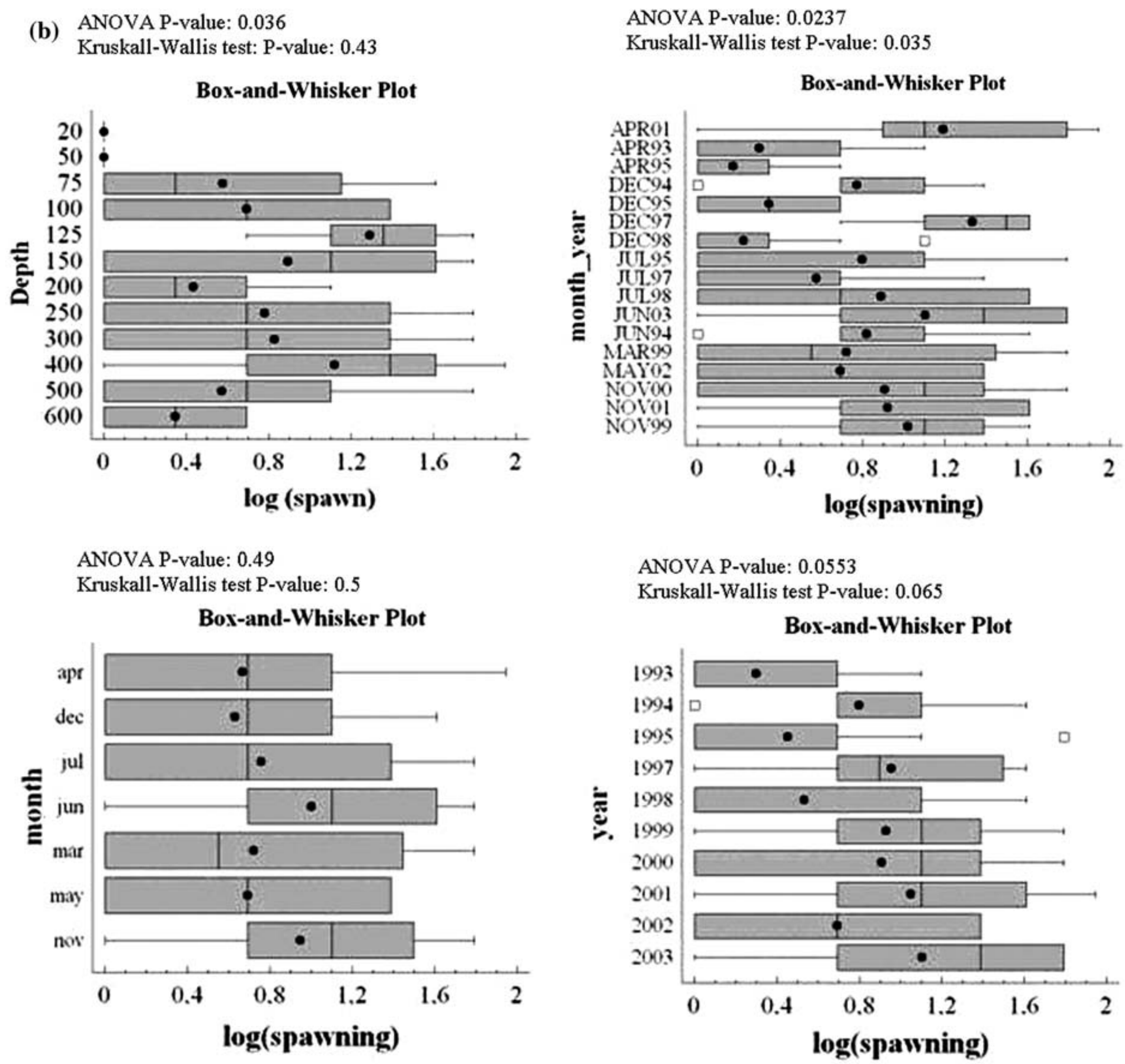

Fig. 6 continued

some intrusions in the deeper levels. Such distribution of the abundance of the rose shrimp might indicate a catch composition in which small sized shrimps prevail in some areas, as it can be argued by the knowledge on the bathymetrical partitioning of the different fractions (juveniles and adults) of the species population in the same basin (Ardizzone et al., 1990; Spedicato et al., 1996). Rose shrimp abounds in two zones: Larache–El Jadida and Essaouira–Agadir (Fig. 3). Maximum species abundance is always situated in the Loukkos region (Larache-Kénitra), probably due to the presence of extended muddy seabed and the increased productivity in this area, and consequently, the abundance of food. Benthic bio-sedimentary characterization of the north Atlantic Moroccan shelf between Tangier and El Jaida revealed an extended central region of mud, bounded on the coastal side by medium or fine sands and offshore by biogenic muddy or coral formations. An increased gradient in terms of biomass was highlighted with pure mud or sandy mud being highly productive (Bayed & Glémarec, 1987).

The spawning of the species occurs in the entire Moroccan coast throughout the year as it is shown by

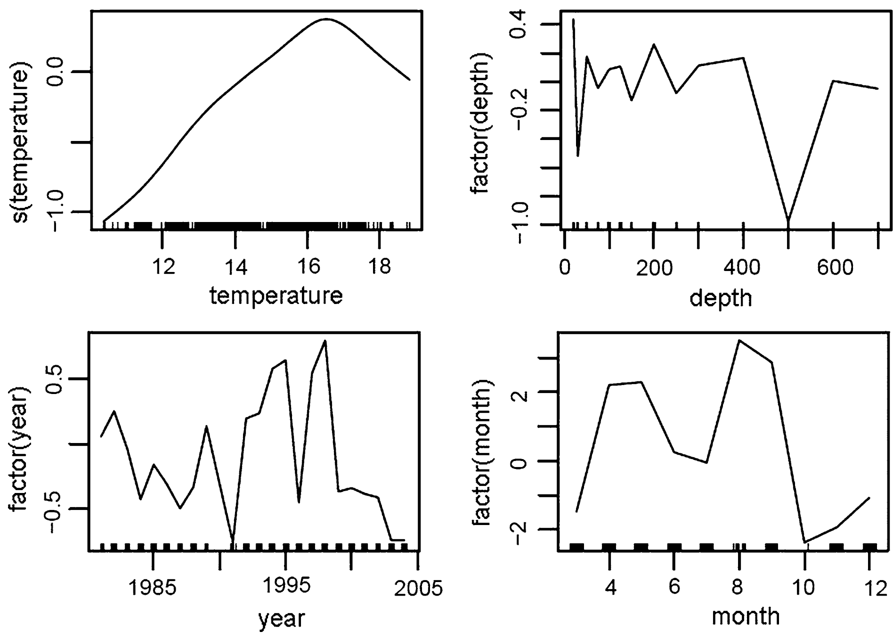

Fig. 7 Generalized Additive Model plots for time and temperature variables in relation to catch levels of *Parapenaeus longirostris* in the Moroccan Eastern Atlantic

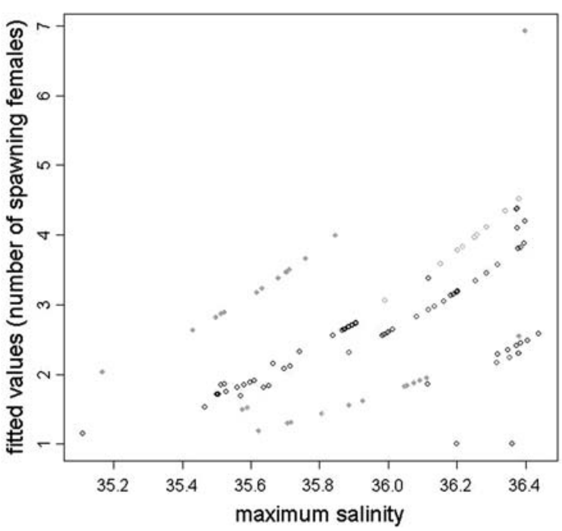

Fig. 8 Linear regression model between maximum salinity and spawning females of *Parapenaeus longirostris* in the Moroccan Eastern Atlantic

the wide distribution of mature females along the Moroccan Atlantic coast. However, two spawning zones are observed: the coastal spawning band where the depth is between 75 and 200 m and the deeper spawning band where the depth ranges from 250 to 500 m. Female rose shrimp comprise the major proportion of the catch. Individuals in stage I have a smaller mean size, than stage II, which are smaller than those of stage III. This indicates that there is growth at smaller sizes during the gonadal maturation process (Ashton, 1972).

As the spectrum of climatic variability is not identical at the equatorial and tropical or moderate zones, abundance of the stocks of shrimps in these regions varies considerably. Our intention here is to draw the attention on the diverse types of possible variations and their combinations because the consequences on fisheries management and research programmes for an optimal strategy of resource exploitation are different. Several laboratory and survey studies depict this. Charmantier-Daures et al. (1988), conducted laboratory experiments on survival under different salinity–temperature combinations using post-larvae of *Penaeus japonicus* and *P. chinensis*. Low temperature (10–14°C) decreases the tolerance of *P. japonicus* post-larvae to low salinity levels while this influence is less important in *P. chinensis*. Williams (1969) showed the relation between the 'thermal contents' of 1 year and the abundance of shrimps. Warm years correspond sharply to high species catch. In fact, the global abundance of shrimps is proportional to the species annual thermal balance sheet. Berry & Baxter (1969) showed the existing connection between the timing of the peak annual migration of juvenile *P. aztecus* toward offshore areas and air temperature in April of the same year. In addition, Barrett & Gillespie (1973, 1975) indicated that the catch of *P. aztecus* during

May depends on the temperature in April. Perez-Farfante (1982) underlined the relationship between shrimp catches and rainfall (as indication of salinity levels). Such studies show that temperature influences the survival of larvae and post-larvae by increasing or decreasing the rate of metabolic processes for the absorption of food. However, the complex behavior of shrimps in relation to temperature and salinity variations remains unknown. It is evident that any study on the effect of environmental factors on the physiological and biological processes would allow the improvement of any management measures. In Morocco, the maximum of spawning is observed in the salinity range of 36.2–36.4 psu. In June, the observed gradient of salinity appears homogeneous, possibly as a result of increased riverine outflow in the region. Thus, in June 2003, the spawning occurrences are observed in various depths: 150, 300 and 500 m.

The main environmental factor governing the spawning of deep-water shrimp is salinity while temperature seems to be important on catch levels. A statistically significant linear correlation is observed between the catch variables (frequency, minimum, maximum, mean and sun) and the standard deviation coefficient of the temperature. A high linear correlation is also observed between the minimal catch and the standard deviation of the temperature and the salinity. The catch is low when the temperature is minimal. The minimal catches also depend on the variation of the salinity. The frequency and the maximum of spawning are strongly correlated and depend mainly on the maximal salinity. The spawning is maximal when the salinity is maximal. The frequency of the spawning seems to be affected by the depth and by the combination year–month but it is not affected by the year and the month taken separately. The catches are affected by all the examined factors.

The studying of the spatial correlations of the distribution of mature females and salinity-temperature variables can provide useful information for a better understanding of the biology of the rose shrimp and its stock assessment and comprise a distinct indication for suggesting advice to fisheries management. The protection of spawning areas, as well as the nursery areas, through limitation of the fishing pressure throughout the year could be considered as an effective, complementary regulation tool for a short-lived species like the rose shrimp. In fact, information on the spatial distribution of abundance index and of spawning females, if coupled with analysis of the geographical distribution of salinity and temperature, could be of importance in stock assessment, allowing some variant application of the composite surplus production models (Munro, 1980; Caddy & Garcia, 1982). Such an approach may help evaluating the status of resources exploitation in regions where multiyear time series of abundance data are available (Relini & Piccinetti, 1996; Bertrand et al., 1997).

Conclusion

This study revealed the high relationship between the spawning females of the deep-water rose shrimp (*Parapenaeus longirostris*) and the high salinity levels in Moroccan Atlantic Ocean. High salinity levels seem to activate spawning of this species while temperature seems to affect the catch levels of the species. These results provide useful information for a better understanding of the biology of the rose shrimp, for improvements in stock assessment while comprising a distinct indication for suggesting advice to fisheries management.

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