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# ASPECTS OF THE BIOLOGY AND FISHERY OF THE EUROPEAN SPINY LOBSTER (*PALINURUS ELEPHAS*) FROM THE SOUTHWEST COAST OF PORTUGAL

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ABSTRACT

The biology and fishery of the lobster, *Palinurus elephas* from the SW coast of Portugal was studied during two distinct periods 10 years apart in 1993-1994 (March 93 to March 94) and during 2003 (May to July). The landings at the port of Sagres, representing half of the catch of the country for this species, were sampled twice a week. The ovigerous season extends from September to March, with an individual incubation period of five months. Considering the ovigerous condition as an indicator of maturity in females, 50% of the females were mature at carapace length of 110 mm. Females below this size represent 95% of the population and account for 41% of the egg production. Females above 50% maturity, representing only 5% of the population, provide 59% of the eggs, showing the importance of larger individuals in the reproduction of this species. Most biological parameters estimated are within the range of values reported for this species in other areas with the exception that in our study the total length was smaller in relation to carapace length, so that females of a given carapace length carried fewer eggs. Parameters were estimated for the following relationships: total length and carapace length, weight and carapace length, weight and total length, maturity at size (carapace length) and fecundity at size (carapace length). It is suggested that a set of measures including catch control, effort control, gear control and protected areas are combined to allow the recovery of this resource.

## INTRODUCTION

The spiny lobster *Palinurus elephas* (Fabricius, 1787), previously known as *Palinurus vulgaris*, is common along the Northeast Atlantic coasts (Ireland and South of England), Azores and down into the Mediterranean to the Greek Islands (Chace and Dumont, 1949; Marin, 1985; Hunter, 1999). It is a temperate water species living on the continental shelf at depths varying with age and latitudinal distribution, being common in waters to depths of 160 m with higher concentrations between 10 and 70 m (Bouvier, 1940; Ficher et al., 1987). It has been occasionally found in deeper waters (Campillo and Amadei, 1978).

Reviews by Hunter (1999) and Goñi and Latrouite (2005) summarize the published literature on the biology and fisheries of this species. For the Portuguese coast only one study has been published to date (Vasconcellos, 1960) resulting from sampling landings in the port of Sines from mid July to early October in 1958.

This species is an important resource in the SW coast of Portugal. Baldaque da Silva (1891) made the first reference to the commercial exploitation of the lobster. At that time it was already considered a valuable resource, supporting the fishing activity of both Portuguese and French fleets.

The study area, referred to as Southwest coast (Fig. 1) extends from Sines to Cape St. Vincent on the west coast and along the South coast from Cape St. Vincent to Lagos. Over the past 20 years the SW coast has accounted for 75-90% of the national spiny lobster landings, with the higher values in most recent years. The most important port is Sagres where over half the national catch is landed. Landings from the SW coast have declined steadily from an average of 14 metric tons per year between 1988 and 1993 to five tons per year between 1998 and 2003. Over this last six years catches have decreased every year falling to a minimum of two tons in 2003 (landing statistics from General Directorate for Fisheries and Aquaculture, Lisbon Portugal).

Since the fleet is mainly artisanal, landings tend to occur in ports close to the fishing grounds; the increase in the importance of the SW coast shows that, at present, catches are not only declining but also restricted to areas around Cape St Vincent (where catches of lobster were always higher), suggesting a reduction in the geographical distribution of the species.

The fleet registered in Sagres and targeting lobsters has decreased from 27 to 21 vessels between 1993 and 2003 accompanied by slight declines in gross tonnage and engine power. However, the average age of the vessels dropped from 22 to 13 years, due to the large investments made in the modernization of the fleet in recent years.

On a per kilogram basis the spiny lobster is the most valuable species landed in Portugal, reaching its highest first sale prices in ports of the SW coast (42 USD in Sagres for 2003). For the period 98-03 (where the value of individual vessel landings is available), spiny lobster sales decreased in importance from 9% to 4% (landing statistics from General Directorate for Fisheries and Aquaculture, Lisbon Portugal).

Changes also occurred in the gear used: these boats are allowed to use several gear types but when targeting spiny lobsters, most use nets set on the bottom. The switch from traps to fixed nets started in the early 1970s and today only a few boats use traps to capture lobsters (Serafim, unpublished data, based on a questionnaire survey of the fisherman in Sagres). Lobster traps are built using a metal frame of rectangular or semi-circular section, with two openings and baited with sardine (Costa e Franca, 1982). Tangling nets

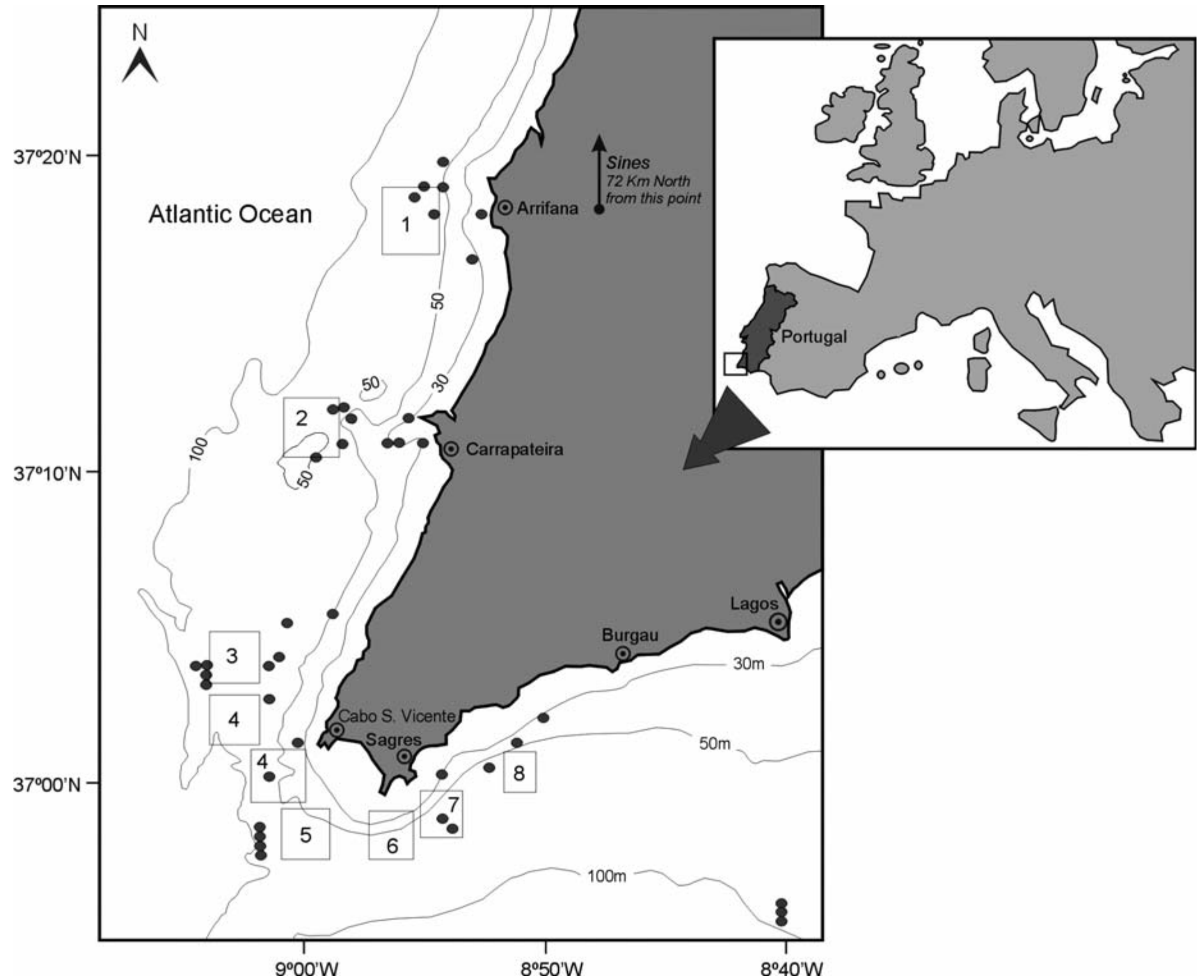


Fig. 1. Location of spiny lobster *Palinurus elephas* fishing grounds off the SW coast of Portugal. The squares indicate the fishing grounds identified on a map by the fisherman during the 1993-94 sampling. The dots indicate the position of individual nets sampled on board during 2003. 1-Arrifana, 2-Carrapateira, 3-Ponta Ruiva e Pedra do Cajado, 4-Cabo de São Vicente, 5-Tonel, 6-Fortaleza, 7-Legítimo and 8-Barranco.

and trammel nets are set on the bottom between 30 and 90 meters depth. Fishing is more intense between March and October due to better weather conditions.

At present, the only management regulations aimed specifically at the lobster consist in the prohibition of landing ovigerous females and a minimum legal size (MLS) of 95 mm carapace length. This MLS was increased from roughly 80 mm in 2003 (average carapace length for males and females with 20 cm total length). Lobster fishing does not involve special licensing, and an unestimated portion of the catch is sold outside official control. There is no assessment of this stock. Apart from a decrease in the declared landings, the only factor that signals some cause for worry is the disappearance of lobsters from depths less than 30 meters. It has been suggested that this may be related to the action of divers (Saldanha, 1980). The regional importance of this resource justifies a better assessment and management of the lobster stocks. Given that only one other study exists for the area of interest (Vasconcellos, 1960), data from this author was used to compare with the present study, taking into consideration that in the late 1950s lobsters were caught only by traps.

## Materials and Methods

### Sampling

The spiny lobster population of the SW coast of Portugal was sampled in the port of Sagres during two periods, ten years apart: 1) March 1993 to March 1994, and 2) May to September 2003 (Table 1). The first sampling period was defined to get an indication of the fishing regime, the catch composition and biological aspects of the species, in particular the ones related with growth (molting season and morphometrics) and reproduction (ovigerous season and fecundity). The second period was chosen to coincide with the annual peak of catches and aimed at obtaining information on the changes in the fishery during the past ten years, and in addition to determine how port sampling reflects catches at sea. Catches were sampled in the port on the same days as sampling on the fishing boats (from boats other than those sampled at sea).

Landings were sampled 2-3 times a week. In some occasions (1993-94 period) it was not possible to sample all the lobsters landed. In this situation the sampled length frequencies were raised to the total catch of the boat. During 2003 the catches were never large enough to require sub-sampling either on board or in the port.

The carapace length was measured with calipers from tip of the rostrum to mid point of the lower border of the cephalothorax (Hepper, 1966). The length measurements were registered to the mm below. During 1993-94 individual lobsters were weighed to the nearest gram.

During 1993-94, a total of 4341 lobsters were measured, representing 2.6 tons and 23% of the total landings from the fishing grounds on the

Table 1. Description of sampling strategy used to obtain data in this study, n indicates numbers sampled before extrapolation to monthly samples.

| Sampling period | n | Trips sampled | Location | Data collected | Strategy |
|---|---|---|---|---|---|
| March 1993-March 1994 | 4341 | 310 | Port of Sagres | Length (carapace and total), weight. Sex, ovigerous condition, hardness. Vessel, fishing grounds (from captain). Biological sample for fecundity. | Twice/week, all landings sampled |
| May 2003-July 2003 | 172 | 11 | On board (boats from port of Sagres) | Length (carapace). Sex, ovigerous condition, hardness. Fishing grounds (GPS), gear (fleet size and number, mesh). | Twice/week (weather permitting) |
| May 2003-July 2003 | 422 | 45 | Port of Sagres | Length (carapace). Sex, ovigerous condition, hardness. Vessel. | Twice/week, all landings sampled |

SW coast of Portugal. During 2003, 594 individuals were measured, representing 264 kg and 22% of the total landings in Sagres (estimated to correspond to 15% of the SW coast).

### Length Frequencies

Because of relatively small sample sizes in 2003 length frequencies were smoothed using a running average of three 1 mm size classes. The size frequencies for the months of May to July in 1993 and 2003 were compared using a Smirnov test for two independent distributions (Conover, 1971), considering only size classes larger than 80 mm to avoid bias introduced by on-board sampling during 2003.

Molting frequencies and seasons are not well identified with the sampling strategy defined here. Soft individuals do not have commercial value and are frequently very damaged by the gear. Their behavior (reduced feeding and movement) naturally decreases their catchability. Consequently, only individuals with partially hardened carapaces, that can still be deformed when pressed, were considered to indicate a recent molt.

The lobsters were caught with trammel nets placed between 30 and 90 meters depth. The nets were composed of sections 50 meters long and 2.5 to 4 meters high. Each net had 80 to 200 sections (total length of 4 to 10 km).

Data published by Vasconcellos (1960) for the same area of this study are referred to frequently. Since most biological parameters reported by this author were expressed in total length rather than carapace length, the conversion to carapace length was made using the parameters obtained in this work.

### Morphometric Relationships

The following morphometric relationships were studied:

$$TL = a + b\ CL \tag{1}$$

$$W = a\ CL^b \tag{2}$$

$$W = a\ TL^b \tag{3}$$

where CL = Carapace length (mm), TL = Total length (mm), W = Weight (g) and 'a' and 'b' are parameters. For equations 2 and 3 parameters were estimated by applying a linear regression model to the $\log_{10}$ transformed equations.

### Female Maturity at Size

The presence of external eggs was used as an indicator of maturity. Although ovigerous females were present from September 93 to March 94, only data from the months corresponding to the centre of the ovigerous season (November to January) were used to estimate the parameters of the relationship between size and sexual maturity, in order to avoid bias due to incomplete hatching (earlier months) or initiated spawning (later months). A logistic model was used with the form:

$$MAT = \frac{1}{1 + \exp(a - b\ CL)} \times 100 \tag{4}$$

where MAT = percent of mature females, CL = carapace length (mm) and 'a' and 'b' are parameters (length of 50% maturity is –a/b). The parameters of the model were estimated using a non-linear least-squares technique (PROC NLIN, SAS Institute Inc., 2000).

### Fecundity

The number of eggs in the pleopods was used as a measure of fecundity. The eggs were separated from the previously measured and weighed females. The total weight of the eggs was recorded, and from each ovigerous mass three samples of 0.5 grams of eggs were taken. These eggs were counted and the total number of eggs was estimated by extrapolating to the total weight of the ovigerous mass. A total of 19 females caught during the ovigerous season and covering 60% of the range of lengths in the catch were observed. The number of eggs was related to the size of the female using a linear relationship (Campillo and Amadei, 1978; Morgan, 1980):

$$E = a\ CL - b \tag{5}$$

where E = number of eggs, CL = Carapace length (mm), 'a' and 'b' are parameters.

In order to compare the fecundity of this species with values estimated for the same area over 30 years earlier (Vasconcellos, 1960), data on egg counts from this author were used to estimate the parameters of equation 5. The two regressions were compared using analysis of covariance after testing for equal slopes (Snedecor and Cochran, 1980).

### Reproductive Potential

The reproductive potential or larval production potential was studied for each length class (1993-94 period) using a simplification of the methodology proposed by Kanciruk and Herrnkind (1976) and involving the estimation of the following indices:

a) Reproductive potential index ($D_i$):

$$D_i = A_i\ B_i\ C_i/1000 \tag{6}$$

where $A_i$ = length frequency for class i, expressed in percentage of the total, $B_i$ = proportion females in class i that are ovigerous, $C_i$ = average number of eggs for class i. $D_i$ expresses the total number of eggs (in thousands) produced by class i. $D_i$ expresses the total number of eggs (in thousands) produced by class i for a standardized female population of 100 individuals.

b) Contribution of each length class to the egg production (E):

$$E_i = 100(D_i/\Sigma D_i) \tag{7}$$

where $E_i$ = contribution of class i for total egg production and $D_i$ = reproductive potential index for class i.

## Results

The length distributions for males and females for the 1993-94 period are presented in Fig. 2. In all months the length distribution shows a well-represented group with lengths from 75 to 115 mm carapace length. The maximum sizes caught (carapace length) were 162 mm for females and 177 mm for males. The population of interest was studied only once before, in 1958 (mid July to early October) by Vasconcellos (1960). This author reported that females tended to dominate the larger sizes and accounted for 60%

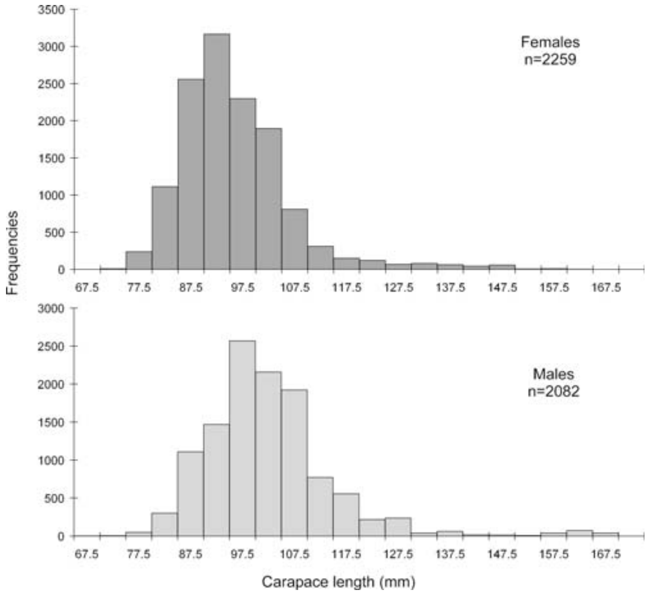


Fig. 2. Size structure of the catch for the first period sampled, March 1993 to March 1994. The data represent the total catch for the port of Sagres. Frequencies are grouped in 5mm classes and sex and season.

of the catch. This was not observed in the samples of 1993 and 2003, where the proportion of females decreased to 52% and 41% (Fig. 2) and the larger classes are dominated by males. The modal classes decreased from 120 mm carapace length in females and 140 mm in males (Vasconcellos, 1960) to 90-100 mm in both sexes in this study (comparison of all studies for the Portuguese coast presented in Table 2).

Fig. 3 presents the size structure for the months of May to July sampled in 1993 and 2003. The comparison of the total length distributions between both periods (males and females added and considering carapace lengths larger than 80 mm) showed significant differences (Smirnov test $P$-value $< 0.05$) though these differences do not correspond to marked changes in the length composition over the ten year period. For both samples there is a mode at around 97.5 mm carapace for males and 92.5 mm for females. The mean carapace size of the catch was 96 mm for females and 102 mm for males in 1993 and 95 mm and 99 mm in 2003.

Fig. 4 shows the length frequencies for 2003 resulting from on board and port sampling. These distributions reveal the lack of compliance with the MLS regulation, and that differences are only seen for carapace lengths below 60 mm. Lobsters of this size were very rare in the catches (on board sampling). The comparison of port and onboard samples showed that port samples represented the catch well, in the absence of compliance with MLS legislation. Compliance with the present MLS of 95 mm would reduce the catches dramatically.

Changes in the sex ratio in samples taken during the 1993-94 period are presented in Fig. 5. The sex ratio, expressed as percentage of females in the catch, varied between minimum values of 38% in October 1993 to a maximum value of 75% in February 1994. The values were around 50% during Spring and Summer 1993 followed by greater oscillations during the following months. Overall, the sex ratio of the catch was 52%. For 2003 (months of May to July only) the sex ratio was 41%. Considering the same months for 1993 this value was 48%, suggesting a decrease in the proportion of females over time.

Parameter estimates for morphometric relationships are presented in Table 2. The results confirm that for the same total length females have shorter cephalothorax and wider abdomen than males, an attribute that has been related with egg carrying (review in Hunter, 1999). Sexual differentiation also occurs in relation to the weight-length relationship. For the same total length males are heavier than females, whereas for the same carapace length females are heavier than males.

The molting season for females is from March to June, with a peak during the month of June (Table 3). For males there was no clear molting season; molting occurred along the whole year with higher values in December.

The mating season could not be defined because there were no females found with spermatophores. The spermatophores may have been lost when the lobsters were tangled in the net. The first ovigerous females were found in September, with eggs at an early stage of development. Most females spawn in November. The evolution of the percent females with eggs is presented in Fig. 6. In the beginning of February, some females already had eggs in advanced stages of development, with embryos with visible eyes, and around 11% had reduced ovigerous masses with signs of eclusion of most of the larvae (long ovigerous setae with no eggs). In March, only 7 of the observed females had some eggs left. The ovigerous season lasted from September to March. The smallest ovigerous female caught had a carapace length of 84 mm.

In the absence of data on gonad development, the presence of eggs in the pleopods was used as the only

Table 2. Morphometric relationships for *Palinurus elephas*. TL = total length (mm), CL = carapace length (mm), W = weight (g).

| Sex | Indep. variable | Depend variable | Range of indep. var.* | Range of dep. var.* | a Intercept | b Slope | n | $r^2$ | $P$-value |
|---|---|---|---|---|---|---|---|---|---|
| F | TL | CL | 180-410 | 72-162 | −14.321 | 2.641 | 2259 | 0.97 | < 0.0001 |
| M | TL | CL | 165-410 | 67-177 | 18.363 | 2.188 | 2082 | 0.97 | < 0.0001 |
| F (no eggs) | $\log_{10}$ (W) | $\log_{10}$ (TL) | 180-1820 | 180-400 | −4.088 | 2.821 | 2195 | 0.96 | < 0.0001 |
| F (with eggs) | $\log_{10}$ (W) | $\log_{10}$ (TL) | 300-2150 | 210-410 | −4.300 | 2.913 | 64 | 0.98 | < 0.0001 |
| M | $\log_{10}$ (W) | $\log_{10}$ (TL) | 150-2300 | 165-410 | −4.491 | 3.000 | 2082 | 0.97 | < 0.0001 |
| F (no eggs) | $\log_{10}$ (W) | $\log_{10}$ (CL) | 180-1820 | 72-156 | −3.427 | 3.051 | 2195 | 0.97 | < 0.0001 |
| F (with eggs) | $\log_{10}$ (W) | $\log_{10}$ (CL) | 300-2150 | 84-162 | −3.431 | 3.058 | 64 | 0.98 | < 0.0001 |
| M | $\log_{10}$ (W) | $\log_{10}$ (CL) | 150-2300 | 67-177 | −3.034 | 2.834 | 2082 | 0.97 | < 0.0001 |

* range of variable prior to log transformation.

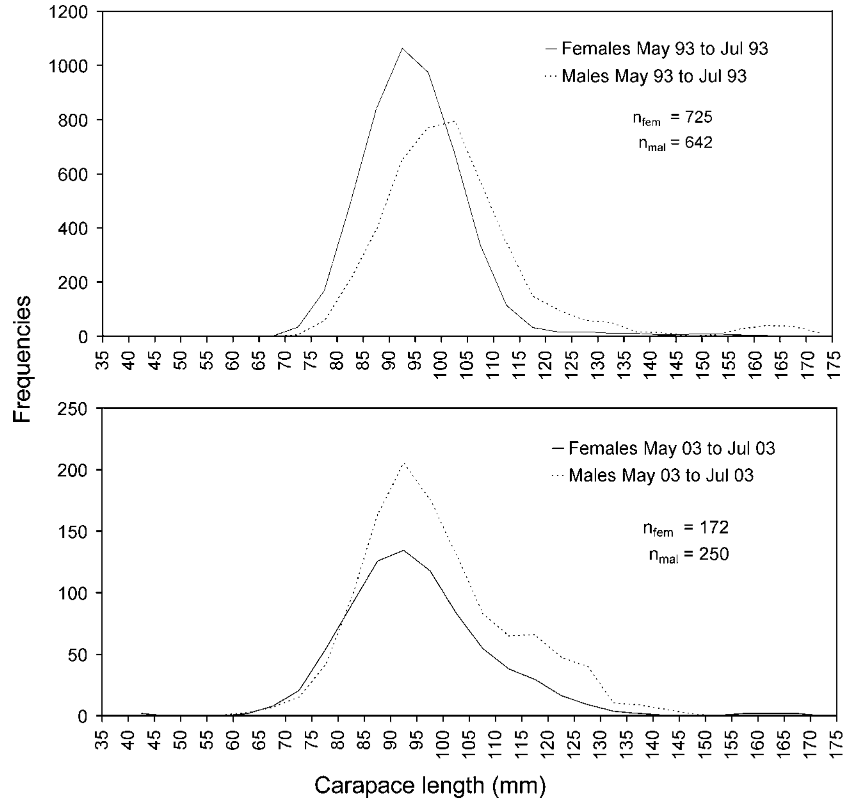


Fig. 3. Comparison of the size structure for 1993 and 2003, for the months of May to July, when catches are higher. The frequencies represent the extrapolation of the sample to the landings in Sagres. Moving averages of three 1 mm size classes were applied.

indicator of maturity. Only data for the middle of the ovigerous season (November to January) were used. The frequencies for these months were added and the percentage mature in each 5 mm carapace length class was calculated. The result of fitting of a maturation ogive to these data is presented in Fig. 7. The estimated parameters for equation 4 are $a = -13.57$ and $b = 0.13$, corresponding to a size at 50% maturity of 110 mm carapace length.

As in all other studies for the same species, a regression line expressing number of eggs (E) as a function of carapace length (CL) (equation 5) was found: $E = 3355\ CL - 283832$. The same relationship was established for data presented by Vasconcellos (1960): $E = 2520\ CL - 196225$. No changes in fecundity were detected between the two studies, 25 years apart (ANCOVA $F = 2.28$, $P$-value $= 0.14$; Fig. 8).

Values for the reproductive potential for each size class are presented in Table 4. Females below 50% maturity (110 mm carapace length), representing 95% of the female population, contribute with 41% of the eggs. The remaining larger females, only 5% of the population, are responsible for 59% of the eggs.

## Discussion

Considering the two studies where information for this stock was obtained (Vasconcellos, 1960 and the present work) the decrease in mean length and representation of larger sizes (mostly females) is likely to be mostly, but not exclusively, the result of increasing fishing pressure. Fishing areas have remained essentially the same (Serafim, unpublished data, based on a questionnaire survey of the fisherman in Sagres) but there were changes in the gear, from traps to fixed nets. Goñi et al. (2003a) reported differences in the efficiency of traps and fixed nets, with traps having lower catch rates for larger males only. This can explain the loss of dominance of females in larger classes from 1958 to 1993-2003, and should be taken into consideration when interpreting variations in maximum and average sizes and sex ratios. The importance given by Vasconcellos (1960) to the dominance of females in larger classes also has to do with using total length rather than carapace length, to study the structure of the population; Table 5 shows the maximum values converted to carapace length and they are very similar for both sexes (190 and 193 mm for females and males, corresponding to total length of 495 and 435 mm, respectively). Nevertheless, if females have similar size-selective properties for both traps and fixed nets (Goñi et al., 2003a), the data suggests a considerable decrease in mean length from 1958 to the present.

Minimum and maximum sizes also indicate a decrease in the range represented in the catch from 1958 to 1993-94, although such data need to be considered with caution. Data from 2003 are not relevant because they include measurements of sub-legal sizes made on board (Table 5). A comparison with values presented by other authors (review in Hunter, 1999) is difficult because sampling strategies and sizes are not reported. Minimum sizes may be affected by regulation of minimum legal size (MLS), maximum sizes are associated with rare individuals and are affected by

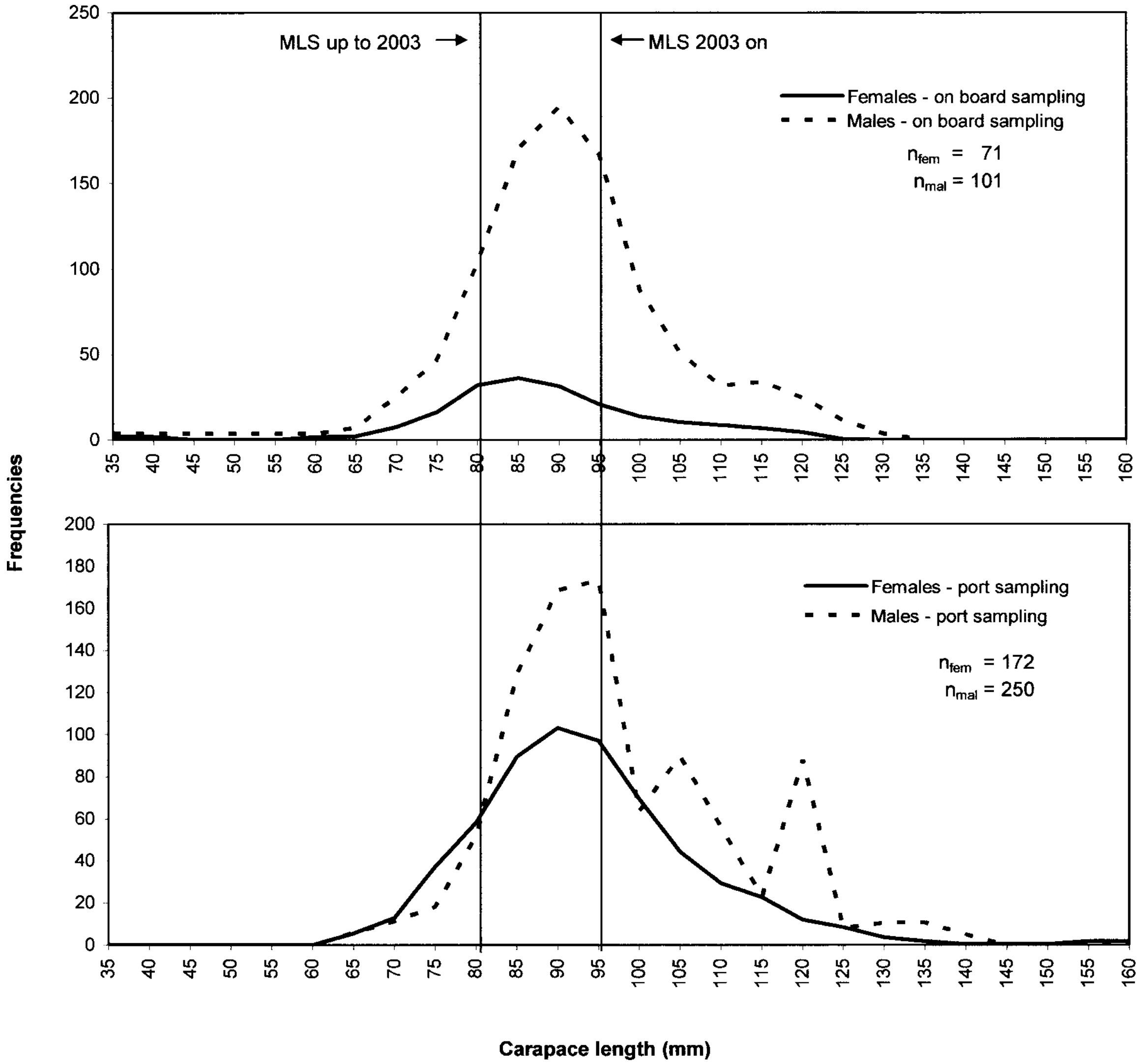


Fig. 4. Comparison of the size structure of the catch for on board and port samples in 2003. The frequencies represent the extrapolation of the sample to the landings in Sagres. Moving averages of three 1 mm size classes were applied. Vertical lines indicate the minimum legal legal size (MLS) in place when the samples were taken (roughly 80 mm carapace corresponding to 200 mm total length) and the MLS (95 mm carapace) in place after 2003.

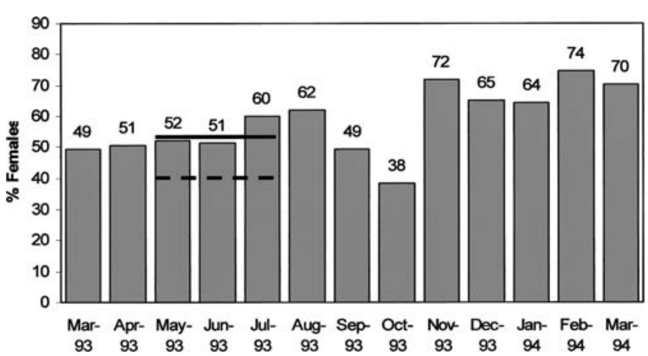


Fig. 5. Sex ratio expressed as percentage of females for each month sampled. Vertical bars correspond to seasons for 1993-94. The horizontal lines indicate the percentage of females for May to July 1993 (solid line - 53%) and 2003 (dashed line - 41%).

sampling effort. For northern European populations maximum sizes vary from 151 mm to 180 mm for females and 165 mm to 193 mm for males. The data obtained in this work are within this range for 1993-94. Data for 2003 shows the smallest maximum size reported for males, 141 mm carapace.

As expected, molting frequencies were zero for females during the ovigerous period. Soft males were found throughout the year but with higher incidence in winter. Considering both sexes together (for the purpose of comparison with other authors) molting throughout the year was observed in the Mediterranean populations (Hunter, 1999). Molting for both sexes is concentrated from April to August in Irish waters, while in the UK both sexes molt later, from June to December. The population from the SW coast of Portugal seems to present an intermediate situation between these two groups, with males molting throughout the year and females molting during the spring and early summer.

Table 3. Frequency of molting individuals expressed in numbers per thousand, for March 1993 to March 1994.

| Month | Males | Females |
|---|---|---|
| MAR 93 | 0 | 1.9 |
| APR 93 | 2.5 | 0 |
| MAY 93 | 2.3 | 4.6 |
| JUN 93 | 16.7 | 15.8 |
| JUL 93 | 0 | 0 |
| AUG 93 | 0 | 0 |
| SEP 93 | 12.7 | 0 |
| OCT 93 | 23.2 | 0 |
| NOV 93 | 0 | 0 |
| DEC 93 | 285.7 | 0 |
| JAN 94 | 0 | 0 |
| FEB 94 | 0 | 0 |
| MAR 94 | 196.1 | 16.7 |

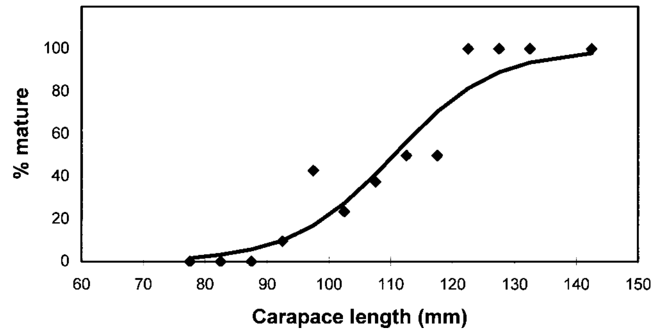


Fig. 7. Maturation curve representing the percentage of females with eggs for each size class. The observed values were calculated using only the information at the center of the ovigerous season, November 1993 to January 1994.

Data for morphometric relationships can be compared with other studies for this species summarized by Tidu et al. (2004). The derived total length for CL = 100 mm shows values lower than the range reported both for northern Europe and the Mediterranean: 250 mm total length for females (range of other studies 283-330 mm) and 237 mm for males (range of other studies 276-299 mm). This could imply lower fecundity for females with the same carapace length (shorter abdomens). Applying the parameters obtained in different studies (Table 6), the expected number of eggs (thousands) for a 120 mm carapace female is 106 and 119 for the SW of Portugal (Vasconcellos, 1960; and this work) and 142 and 134 for the Mediterranean (Spain, Western Mediterranean, Goñi et al., 2003b; and Corsica, Campillo and Amadei, 1978).

The first ovigerous females were found in September, with eggs at an early stage of development. Most females spawn in November. The ovigerous season extends until March (Fig. 6). These results are not in agreement with data presented by Vasconcellos (1960) for the same general area, who reported July as the month for the beginning of the spawning season but they are similar to values reported for other areas (Hunter, 1999), both for northern Europe and the Mediterranean. The data collected suggests that the individual ovigerous period lasts around 5 months, which is at the lower end of the range from 5 to 10 months (Hunter, 1999). Similar values for the incubation period were found in Corsica (Campillo and Amadei, 1978; Marin, 1985).

The minimum size of ovigerous females (84 mm carapace) is between other reported values for this species. This value is lower than those for northern Europe populations (90-121 mm, Hunter, 1999) and higher than values for the Mediterranean [67-71 mm, Hunter (1999) and Goñi et al. (2003b)]. Size at 50% maturity, 110 mm carapace length, is considerably higher than that of 76.5 reported for the Eastern Mediterranean (Goñi et al., 2003b).

The calculation of reproductive potential allows the estimation of the contribution of each size class for the reproduction of the population. In this study fecundity estimates were based on the number of external eggs. Females with carapace length larger than the size of 50% maturity, representing only 5% of the females contribute 59% of the egg production. The importance of larger females is also verified by Goñi et al. (2003b) for *P. elephas* in the western Mediterranean and Kanciruk and Herrnkind (1976) for *Panulirus argus* in the Bahamas. As suggested by these authors, the importance of very large animals for the reproduction of spiny lobster species should make us rethink the management strategies for these stocks. Protection of not only immature females but very large females as well should be considered; this may be achieved by setting aside areas where lobsters cannot be fished and are allowed to grow to

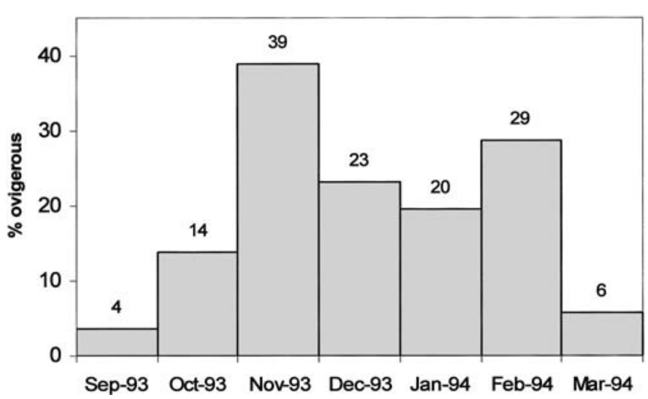


Fig. 6. Ovigerous season. This figure shows the evolution of the percentage of females with eggs for the period sampled (March 93 to March 94). Only the months that had some ovigerous females are represented.

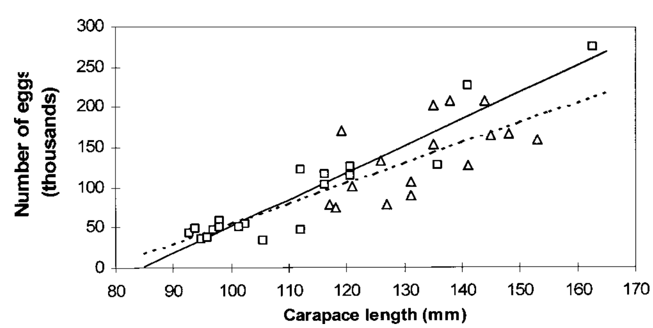


Fig. 8. Observed values and estimated relationship for the fecundity of *Palinurus elephas* obtained in this study (squares and solid line) and that of Vasconcellos (1960; triangles and dashed line). The slopes and intercepts of the two lines are not significantly different.

Table 4. Reproductive potential and productivity for each size class based on Kanciruk and Herrnkind (1976). The table also presents all the intermediate values necessary for the calculations. $A_i$ - Percentage of females in each size class, based on accumulated frequencies for the whole year sampled; $B_i$ - Proportion of females with eggs in each size class, based on the proportions of females with eggs in the middle of the ovigerous season; $C_i$ - Number of eggs per female of each size class, based on the fecundity equation estimated in this work; $D_i$ - Contribution of each size class for egg production: $A_i$ $B_i$ $C_i$/1000; $E_i$ - Percentage of eggs contributed by each size class: 100 ($D_i$ /$\Sigma$ $D_i$).

| Carapace length (Center of 5 mm class) | Relative frequency (%) $A_i$ | Proportion ovigerous $B_i$ | Number of eggs $C_i$ | Reproductive potencial index ($10^3$ eggs) $D_i$ | Contribution to egg production (%) $E_i$ |
|---|---|---|---|---|---|
| 67.5 | 0.06 | 0.01 | 0 | 0.0 | 0.0 |
| 72.5 | 1.82 | 0.01 | 0 | 0.0 | 0.0 |
| 77.5 | 8.56 | 0.02 | 0 | 0.0 | 0.0 |
| 82.5 | 19.68 | 0.03 | 0 | 0.0 | 0.0 |
| 87.5 | 24.38 | 0.06 | 10947 | 15.0 | 1.7 |
| 92.5 | 17.69 | 0.10 | 27802 | 48.8 | 5.6 |
| 97.5 | 14.60 | 0.17 | 44657 | 110.4 | 12.7 |
| 102.5 | 6.23 | 0.27 | 61512 | 104.9 | 12.1 |
| 107.5 | 2.39 | 0.41 | 78367 | 76.8 | 8.8 |
| 112.5 | 1.14 | 0.56 | 95222 | 61.3 | 7.0 |
| 117.5 | 0.92 | 0.70 | 112077 | 72.5 | 8.3 |
| 122.5 | 0.51 | 0.81 | 128932 | 53.8 | 6.2 |
| 127.5 | 0.61 | 0.89 | 145787 | 79.2 | 9.1 |
| 132.5 | 0.49 | 0.94 | 162642 | 74.6 | 8.6 |
| 137.5 | 0.33 | 0.97 | 179497 | 57.1 | 6.6 |
| 142.5 | 0.45 | 0.98 | 196352 | 86.5 | 9.9 |
| 147.5 | 0.03 | 0.99 | 213207 | 7.1 | 0.8 |
| 152.5 | 0.08 | 0.99 | 230062 | 18.0 | 2.1 |
| 157.5 | 0.02 | 1.00 | 246917 | 4.2 | 0.5 |

larger sizes (Goñi et al., 2003b) or by introducing landing controls that include, not only minimum legal size, but maximum landing size as well. The minimum legal size (MLS) increased from 80 to 95 mm carapace length in 2003, but is still clearly insufficient to promote an increase in egg production (less than 20% of the 95 mm carapace length females are mature).

In conclusion, the fishery of *P. elephas* off the SW coast of Portugal has declined consistently in recent years although the population structure has remained stable from 1993 to 2003. Data from 25 years before 1993 shows that larger individuals (CL greater than 140 mm) have become rare. The information available suggests this is a severely overfished fishery considering: 1) the low proportion of mature females in the catch, estimated to be 13% ($\Sigma A_i B_i$ in Table 4); 2) disappearance of large sizes from the catch (comparison of data from recent years with an earlier study by Vasconcellos (1960) and accounts from fisherman); and 3) consistent decrease in abundance (present catches are roughly one tenth of what they were in the late 80's and early 90's).

Table 6. Fecundity as a function of carapace length (parameters for data from Vasconcellos, 1960, estimated in this work) and another fecundity equation published for the Corsica population. Fecundity is expressed by the equation E = b CL − a, where E is the number of external eggs, CL the carapace length in mm and "a" and "b" are parameters.

| Area | Author | b | a | $r^2$ | n |
|---|---|---|---|---|---|
| Portugal, SW | This work | 3355 | 283832 | 0.89 | 19 |
| Portugal, SW | Vasconcellos, 1960 | 2520 | 196225 | 0.53 | 22 |
| France, Corsica | Campillo and Amadei, 1978 | 3033 | 229809 | 0.94 | 24 |
| Spain, W Mediterranean | Goñi et al. 2003b | 2428 | 148998 | 0.85 | 70 |

Factors other than overfshing may have contributed to low population levels, such as the degradation of coastal habitats necessary for post-larvae and juveniles, especially the decrease in algal coverage (collected by diver for agar and fertilizer production). Measures for stock recovery are urgent and should include identification of essential habitats for post-larva and juveniles with consequent designation of protected areas where fishing and/or algae collection is forbidden. One management option would be the reintroduction of traps in substitution of fixed nets. Traps are more selective for the species and can be designed to protect juveniles by introducing escapement grids. At this moment the fixed nets used can reach 10 km in length and each boat may operate several. It is also likely that the reintroduction of traps would translate in an effective reduction of fishing effort. Another management option could be the protection of large females through the introduction of a maximum size limit, which guarantee the survival of the most fecund females in the population.

It is obvious that many of the problems are related with non compliance with legislation already in place, such as disrespect of minimum legal size, permanence of the nets in the water during weekends and fishing too close to the coast. These are recognized by the fisherman and considered by them absolutely necessary for staying in the fishery, suggesting socio-economic considerations are essential for a management plan for this fishery.

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Table 5. Comparison of biological parameters obtained for the population of *Palinurus elephas* form the SW coast of Portugal in the present study and earlier work by Vasconcellos (1960). Values provided by this author were converted from total length into carapace length using the relationships estimated in the present study. The sampling period used in the earlier study was from mid July to early October, so only the data corresponding to the same months was used in this table for 1993.

| | | | Carapace length (mm) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Months | Sex | Minimum | Maximum | Mean | Smallest ovigerous | % females | n | Source |
| 1958 | July to October | F | 87 | 193 | — | 104 | 0.60 | 1658 | Vasconcellos, 1960 |
| | | M | 69 | 190 | — | — | – | 1096 | |
| 1993-1994 | March to March | F | 55 | 162 | 96 | 84 | 0.52 | 2259 | This study |
| | | M | 67 | 177 | 102 | — | – | 2082 | |
| 2003 | May to July | F | 40 | 161 | 95 | — | 0.41 | 243 | This study |
| | | M | 55 | 144 | 99 | — | – | 351 | |

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