Faculdade de Ciências do Mar e do Ambiente

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"Fecundity of the spiny lobster *Panulirus regius* De Brito Capello, 1864 (Decapoda, Palinuridae) in the Northwest Islands of the Cabo Verde Archipelago (Central-East Atlantic)"

Relatório de Estágio de Licenciatura em Biologia Marinha e Pescas

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RESUMO

A amostragem da lagosta verde *Panulirus regius* foi realizado durante as visitas regulares ao mercado de peixe e em botes comerciais de pesca de mergulho com escafandro, durante os anos de 2001 a 2003. Foram registados vários dados relativos a tamanhos, sexo, medidas morfométricas e foram colhidas amostras de ovos de lagostas. Foi amostrado um total de 852 lagostas (429 machos e 423 fêmeas), 50,1% das fêmeas encontravam-se ovadas, ocorrendo durante todo o ano. Para o estudo da fecundidade foram contados os ovos de 68 fêmeas obtidas de Agosto a Setembro de 2001 e de Outubro de 2002 a Abril de 2003.

O tamanho de primeira maturação sexual, menor fêmea ovada e fecundidade foram comparados com outras populações de *P. regius*. A relação entre o número de ovos (NO - milhares de ovos) – comprimento da carapaça (CC, mm) foi estabelecida ($NO=1{,}59\times CC^{2{,}77}$) para fêmeas da lagosta verde capturadas nas ilhas Noroeste de Cabo Verde, não tendo sido encontradas diferenças significativas de ano para ano.

O índice do potencial reprodutivo (IPR) estimado, indica que fêmeas nas classes de 100-105 a 115-120 mm produzem metade do total de ovos produzido pela população e têm índices de produtividade similares. O comprimento estimado de 50% de maturação de fêmeas foi 87,9 mm CC.

Tendo em conta os valores de fecundidade encontrados é proposta uma revisão do tamanho mínimo de desembarque, promovendo assim, um melhor recrutamento e é discutida a possibilidade de introdução de um tamanho máximo de desembarque.

ABSTRACT

The green lobster (*Panulirus regius*) from Cabo Verde was sampled from 2001 to 2003 by going out with local fisherman who use SCUBA or snorkelling and by visiting local ports regularly. Biological data on size, sex, body measurements and egg samples were collected. A total of 852 lobsters (429 males and 423 females) were sampled. Some 50.1% of the females were ovigerous, and occurred thoughtout the year. For the fecundity study 68 berried females were obtained in August-September 2001 and October 2002 to April 2003 and the eggs were counted.

Size at the onset of sexual maturity (50% maturity), smallest berried female and fecundity were compared with other *P. regius* populations. The brood size-carapace length (BS, thousands eggs – CL, mm) relationships ($BS=1.59 \times CL^{2.77}$) of female *P. regius* from Northwest Islands of Cabo Verde, was examined and no significant differences were found for the two sampling periods.

The estimated index of reproductive potential (IRP) indicate that females in the size class between 100-105 and 115-120 mm CL produced half of the total eggs in the population and have similar indices of productivity. Estimated size of 50% maturity for females was 87.9 mm CL.

Considering the results obtained here, a modification of the minimum landing size is proposed. The introduction of a maximum landing size is also discussed.

INTRODUCTION

The species of interest in this study, *Panulirus regius* De Brito Capello, 1864 is a tropical spiny lobster, occurring in the Eastern Atlantic, from approximately 28ºN and 15ºS (African Continent), between Cape Juby (Morocco) and Namibe (Angola), including Cabo Verde Islands, and some Western Mediterranean populations (East coast of Spain, South coast of France) (Fischer et al., 1981; Holthuis, 1991). Clotilde-Ba et al. (1997) considered *P. regius* an Atlantic-Mediterranean spiny lobster species with one of the greatest geographical ranges among the palinurids of commercial importance.

From the socio-economic point of view, *P. regius* fishery is of great importance to Cabo Verde, accounting for 71% of the shallow-water lobster species caught in the Northwest Islands. Lobsters are caught with traps (among the reefs and around islands with a narrow island shelf) to depths of 10-55 m, while in shallow waters they are caught by divers (skin-diving or SCUBA diving), using a gaff to extract lobsters from their dens (Dias, 1993). In Cabo Verde, *P. regius* is one of 4 commercial species of lobsters, with the other three being *Scyllarides latus* (Latreille, 1802) and *Panulirus echinatus* Smith, 1869 (shallow water species) and *Palinurus charlestoni* Forest & Postel, 1964 (an endemic deep-water species) (Holthuis, 1991; Dias, 1992).

Panulirus regius, the royal spiny lobster is the most important crustacean species in the region. However, little is known about its basic biology, reproduction and fecundity in west Africa (Dias, 1993; Reis, 1997) despite earlier contributions (Marchal & Barro, 1964; Postel, 1966; Giudicelli, 1971; Maigret, 1978). Reis (1997) described the fishery of *P. regius* in Cabo Verde, referred as “lagosta verde” (green lobster), at present heavily fished in most of the islands (Foueré, 1981; Dias, 1993; Reis 1997).

P. regius has different reproduction seasons at different latitudes, from June to September in the northern hemisphere and January to March in the southern hemisphere, requiring 23–25ºC for egg maturation and 26ºC for spawning (Giudicelli, 1971). The same author reported reproductive migrations in adult *P. regius* females on the Senegal shelf, with lobsters moving from 2-20 m to 20-55 m from June to August, the period corresponding to peak reproductive activity (copulation) when the lobsters follow cooler waters.

Like other tropical *Panulirus* species (Fonseca-Larios & Briones-Fourzán, 1998), *P. regius* spawns all year-round, with a spawning peak from June to September in Cabo Verde (Dias, 1993).

The fecundity of a palinurid lobster is usually evaluated by counting the number of external eggs carried externally on the pleopods of a female (Chubb, 2000). The term "brood size" can also be used, specifically for decapod species that spawn repetitively during a breeding season (Pollock & Goosen, 1991). Other measures of fecundity are: potential fecundity (the number of oocytes in the ovary), actual fecundity (number of eggs on the pleopods at the time of capture) and effective fecundity (estimated number of eggs on the pleopods at the time of hatching) (Tuck et al., 2000).

If fecundity studies are directed at attempting to understand the relationship between stock and recruitment, as suggested by Chubb (2000), then the reproductive capacity of a lobster population cannot be simply measured by the number of eggs produced. Other parameters, such as the average reproductive potential (Correa-Ivo & Vasconcelos-Gesteira, 1995) and the index of reproductive potential (Kanciruk & Herrnkind, 1976) need to be considered. These indicators combine size specific fecundity with the size structure of the population of reproducing females.

Fecundity of palinurid lobsters is high, usually up to some 700,000 eggs per spawning (Morgan, 1980). These values are achieved through large broods of small eggs produced over a relatively short adult lifespan (Pollock & Melville-Smith, 1993); the smaller the egg size, the higher the fecundity (Pollock, 1995).

The fecundity of *P. regius* females has been studied throughout its geographical range (Marchal & Barro, 1964; Maigret, 1978; Clotilde-Ba et al., 1997). Recently, Freitas et al. (2005) determined an index of reproductive potential (IRP), the brood size (BS) and estimated the relationship BS=*f*(CL) from 35 *P. regius* females from Cabo Verde Islands (CL, carapace length).

The present work aims at improving fecundity estimates for *P. regius* in Cabo Verde, as well as of brood size, egg size, "actual" fecundity as a function of CL, size of onset of maturity and IRP, specifically for the population of the Northwest Islands of Cabo Verde, and compare them with studies conducted elsewhere for this and other *Panulirus* species.

MATERIALS AND METHODS

STUDY AREA — Cabo Verde is located in the Eastern Atlantic (14º50' - 17º20'N, 22º40' - 25º30'W) about 750 km west of Senegal. It is composed of 10 islands and 5 islets with an area of 4033 $km^{2.}$ The coastline is 965 km long but the island shelf (depths less than 200 metres) is only 5934 km^2 (Bravo de Laguna, 1985; DGMP, 1998; Menezes, et al., 2004). The samples were obtained from the shelves of the Northwest Islands of the Cabo Verde Archipelago: Santo Antão, São Vicente and Santa Luzia (Fig. 1).

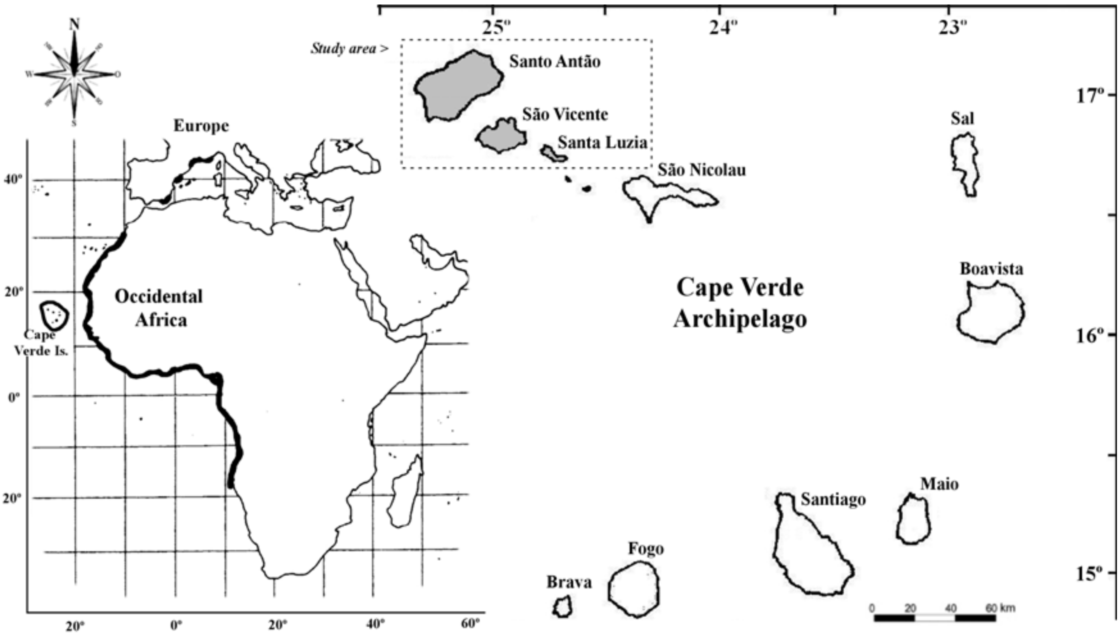

Figure 1 – Map showing the geographical distribution of *P. regius* in the eastern Atlantic (thick coastline) and the area were the samples were obtained in the northwest Islands of Cabo Verde Archipelago (darker islands) (adapted from Holthuis, 1991).

The climate in the region is tropical, with two weather regimes (seasons) alternating along the year: moderate cold season (December to June, 22-23ºC average) and a warm season (26-27ºC) (Almada, 1993).

LOBSTER SAMPLING — Sampling took place from May to November 2001, April to December 2002 and April to June 2003. The ovigerous females used in the fecundity study were selected from lobsters catches landed at Mindelo's Fish Market and Padik's SCUBA group (São Vicente Isl.) on August-September 2001 and October 2002 to April 2003. Because the season closed to fishing is from 1 July to 30 September, lobsters in this season were obtained with SCUBA, permitted for scientific purposes, at depths of 13-22 m (Freitas, 2002).

Carapace length (CL) was chosen as an indicator of body (measured from between the rostral horns to the posterior dorsal edge of the carapace, ± 0.1 mm below, using callipers). Other measurements were also obtained: total length (TL), abdominal width at the fifth abdominal somite (AW) and presence or absence of external eggs. When external eggs were present, the development stage of the embryos was registered according to the scale proposed by Franca et al. (1959) based on the presence of visible eye spots and colour of the egg mass: newly excluded eggs (orange eggs and absent eye spots), intermediate (dark orange eggs with vestigial eye spots) and about to hatch (brown eggs with eye spots clearly visible). The maturity condition of the females was also evaluated using the presence of well-developed filamentous ovigerous setae on the endopodites of the pleopods as an indicator of maturity.

ESTIMATION OF BROOD SIZE — Following DeMartini et al. (2003), very late embryonic developmental stages, observed in three females bearing brown eggs with degrading egg masses, were not included in the study of the relationship BS = *f* (CL).

In the absence of an electronic egg counter, we used gravimetric methods, which are still employed and give accurate estimates of BS (Chubb, 2000). As suggested by Morgan (1972) and Gracia (1985), and applied in studies such as Fonseca-Larios & Briones-Fourzán (1998) and Briones-Fourzán & Contreras-Ortiz (1999), the pleopods of ovigerous females containing the egg mass were cut and removed from the abdomen and fixed in 70% ethanol. Later, they were air dried until the eggs could be easily stripped from the pleopodal setae and the egg mass weighted (± 0.001 g). After this, two similar methods for the estimation of brood size were used: one for ovigerous females captured during the 1^{st} sampling period (August-September 2001) and another for the females captured during the 2^{nd} sampling period (October 2002 to April 2003). In the first situation, the egg masses were dried (at 45ºC for 48 h using an oven) before obtaining three subsamples (about 0.01 g each), where the eggs were counted (after being sieved through a 1mm mesh to remove extraneous matter); in the second case, the subsamples (about 0.03 g) were obtained from the alcohol preserved egg masses, and the eggs was separated using a solution of bleach (one to four parts of water). In both cases the number of eggs of the subsamples were counted using a ×10 stereo microscope and extrapolated to the total egg mass to obtain the particular individual brood size.

For the relationship BS=*f*(CL), recommendations proposed by Somers (1991) were followed. A linear regression on the logs of both variables was used to produce scale-independent regressions slopes, and to stabilize the BS variance. In this study, regression equations were fitted for different sampling periods and egg separation methodologies and these effects were evaluated using analysis of covariance (ANCOVA) with significance considered for $p<0.05$.

The relationships of BS=*f*(CL) were compared for each one of the sampling periods (August-September 2001, n = 35, and October 2002 to April 2003, n = 30; based on results of the previous tests (no differences between sampling periods were found), a regression for the total data was obtained.

RELATIVE EGG WEIGHT — An indicator of individual egg weight was used, modifying an earlier index presented by Fonseca-Larios & Briones-Fourzán (1998). Those authors considered the number of eggs in 0.01 g of dry weight of egg mass as an indicator of egg size, referring to "relative egg size". The problem with this index is that its value is inversely related to individual egg size (the higher the number of eggs in a standard egg mass the smaller the eggs), making the interpretation and discussion of values difficult. In this work we suggest an alternative index, designated as relative egg weight, and obtained by using the formula:

$$REW = \frac{\sum_{k=1}^{k=3} w}{\sum_{k=1}^{k=3} n} \times 10^5 \qquad \text{eq. 1}$$

where REW is the relative egg weight, w is the individual weight of each one of the subsamples and n the number of eggs counted. This index in directly related to egg weight and the higher the index the heavier the individual eggs. Egg weight is not necessarily related to egg size. In later developmental stages the eggs are larger, but not necessarily heavier, because the yolk consumed along the egg maturation is denser than the larval tissue. Therefore, an index based on weights cannot be correlated to egg size.

Since some eggs were counted on dry egg masses and others on wet egg masses, all weights were converted to dry weights. In 12 egg fractions both dry and wet weights were obtained and the regression of wet weight (w_w) on dry weight (w_d) estimated ($w_d=0.0005 + 0.2944\ w_w$, n=12, $r^2=0.985$).

Relative egg weight was compared for different embryo stages (newly excluded eggs, intermediate, and about to hatch) and female size (3 carapace length classes, CL<80, 80≤CL<100 and CL≥100 mm), using Kruskal-Wallis tests for the null hypothesis; median of all groups compared is the same (Zar, 1999). Rejection was considered for $p\leq0.05$.

REPRODUCTIVE POTENTIAL — The index of reproductive potential (IRP, Kanciruk & Herrnkind, 1976) is used to establish the size classes of breeding females contributing most to the egg production of the populations. IRP = (A×B×C)/D, where A = proportion of females in a particular size class per total number of females in the sample, B = proportion of ovigerous females in the size class, C = estimated mean brood size in the size class. D is a constant, which is obtained by setting standard IRP = 100 for a selected class (in this work the size class where 75% of the females are ovigerous). The total egg production per size class per year (e/y) was also calculated (e/y = C x number ovigerous females in the size class). Total egg production relative to 100:

$$E = \frac{e/y}{\sum e/y} \times 100 \qquad \text{eq. 2}$$

and index of individual contribution of a female in a given size class

$$F = \frac{E}{n^{o}\ \text{females in size class}} \qquad \text{eq. 3}$$

were also estimated.

For estimation of the reproductive potential of the population, we used CL data from 423 females and 5 mm carapace length classes were considered.

SIZE AT ONSET OF SEXUAL MATURITY — The size at onset of maturity (SOM) in female *P. regius* was considered to be the size at which 50% of the females are mature, estimated by fitting a logistic model to the proportion of egg-bearing females per size-class (Groeneveld & Melville-Smith, 1994; Tuck et al., 2000).

RESULTS

SIZE FREQUENCY AND SEX RATIOS — From May 2001 to June 2003, a total of 852 *P. regius* were sampled (373 taken to the laboratory); 429 were males (50.4%), and 423 were females (49.6%), i.e., the sex ratio was 1.01 males per female.

Females ranged in size from 47.1–137.3 mm CL (mean ± SD = 87.3 ± 17.2 mm), and males from 42.5–185.0 mm CL (95.8 ± 27.3 mm). Of the 423 females, 212 (50.1%) were ovigerous. The size of berried females was 61.9–137.3 mm CL (95.8 ± 15.4 mm), with predominance of classes between 85 to 110 mm CL (51.9%). Clear size dimorphism was observed, with males reaching larger sizes than females. Figure 2 represents the size frequencies of males, and ovigerous and non-ovigerous females.

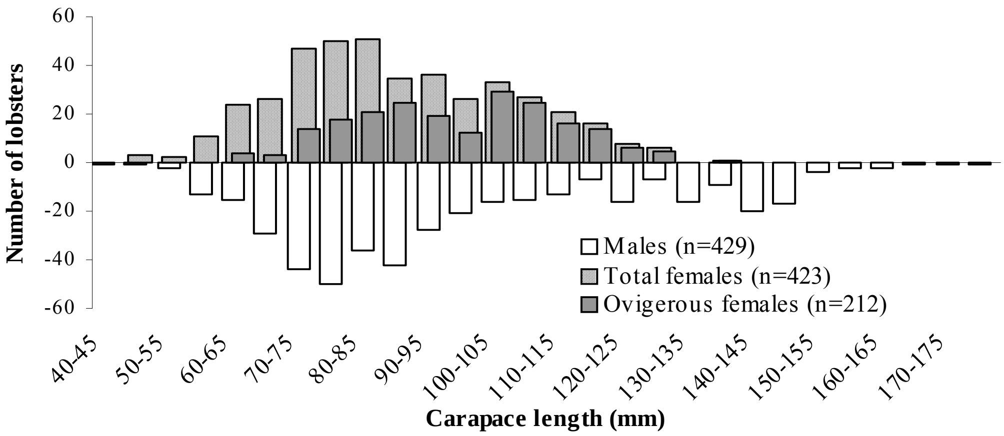

Figure 2 – Size distribution of males, ovigerous females, and total females of *P. regius* for the sampling period (May 2001 to June 2003).

ONSET AT SEXUAL MATURITY — Figure 3 presents the result of fitting the logistic model to the proportion of ovigerous females per size class. The estimated size at 50% maturity was 87.9 mm CL.

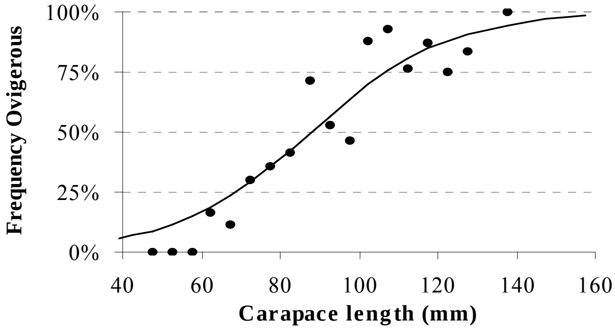

Figure 3 – Relationship of proportion of ovigerous females and carapace length (mm) for *P. regius*.

CARAPACE LENGTH–BROOD SIZE RELATIONSHIPS — The total number of females where eggs were counted was 65 (35 sampled in 2001 and 30 between 2002 and 2003), ranging from 66.4 to 125.8 mm CL. Data for the fecundity based on external egg numbers is included in Table 1.

Table 1 – Range in carapace length (CL) in mm, mean size, sample size, regression equation of log of brood size as a function of log (CL), coefficients of determination (r^2) and p-value of the ANOVA regression (H_0: slope=0) for each sampling period and total.

Period	Size range (CL, mm)	Mean size (CL, mm)	N	Regression equation	r^2	p-value
2001	66.4–115.8	84.9	35	Log BS=3.0759(log CL)-0.3913	0.78	<0.001
2002-03	73.5–125.8	95.1	30	Log BS=2.5287(log CL)+0.6726	0.74	<0.001
Global	66.4–125.8	89.6	65	Log BS=2.7683(log CL)+0.2003	0.78	<0.001

No significant differences in BS-CL regressions were found between 2001 and 2002-03. The partial ANCOVA results were: test for $\beta_1=\beta_2$ not rejected (F=1.90, df=61 and p-value=0.173) and test for $\alpha_1=\alpha_2$ (equal elevations), not significant either. The data for the 65 females from both sampling periods was combined to obtain a single regression (Table 1 and Figure 4).

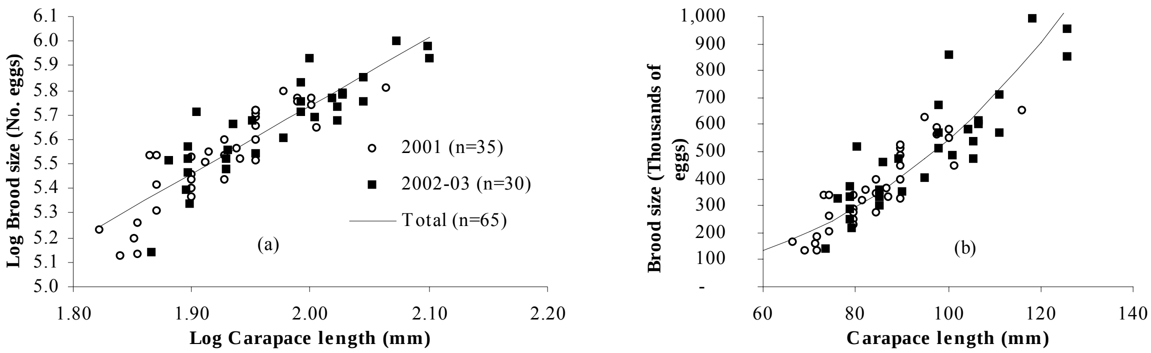

Figure 4 – Data plot for carapace length (CL, mm) vs. brood size (BS, number of eggs) relationship in female *P. regius*. (a) With the log-transformed data; (b) with the exponential raw data [equation for (a): Log BS=2.7683(log CL)+0.2003 and for (b): $BS=1.59\times CL^{2.77}$].

Brood size ranged from 133,979 for a 69 mm CL female, to 995,179 eggs for a 118.2 mm CL female.

RELATIVE EGG WEIGHT — Descriptive data for relative egg-weight are presented in Table 2. Number of broods observed, mean value and variance of egg-weight are included by size group and egg developmental stage.

Table 2 – Descriptive statistics for relative egg-weight (weight of eggs / number of eggs x 10^5, by embryonic developmental stages and carapace length classes.

Embryo stages		Carapace length (CL, mm) CL<80	80≤CL<100	CL≥100	Total
Orange	n	10	8	5	23
	mean	2.68	2.72	2.46	2.64
	variance	0.284	0.329	0.253	0.277
Dark orange	n	8	17	10	35
	mean	2.23	2.72	2.71	2.60
	variance	0.300	0.158	0.122	0.212
Brown	n	3	3	1	7
	mean	2.88	2.64	2.03	2.65
	variance	0.012	0.082	-	0.122
Total	n	21	28	16	65
	mean	2.53	2.71	2.59	2.62
	variance	0.301	0.186	0.177	0.220

The results of the Kruskal-Wallis test indicate that there are no differences with respect to embryonic stage (χ^2=27.43, df=2, p-value=0.808) and female size (χ^2=1.33, df=2, p-value=0.514).

REPRODUCTIVE POTENTIAL — To estimate IRP, 423 females were used (212 ovigerous). The constant D was 400.56, obtained by setting the IRP value of the 100-105 mm class to 100. This class was chosen as the standard because it has a high percentage of ovigerous females, was well represented in the population (Table 3) and was close to the estimated 75% maturity (106.9 mm CL, Fig. 3).

Table 3 – Estimation of the index of reproductive potential (IRP). IRP = (A×B×C)/D, where A = percentage of females in each 5 mm CL class, B = percentage of berried females in a given size class, C = estimated brood size of the mid-point of the size class ($\times 10^{-3}$ eggs), and D = a constant (400.56) used to standardize the most productive size class to 100% (Kanciruk & Herrnkind, 1976). e/y = number of eggs produced/spawn/year ($\times 10^{-3}$); E = % of total egg production; F = E/A, a class-specific index of egg productivity. Values in bold signal particular classes discussed in the text.

Size class (CL, mm)	Total no. of females	No. of ovig. females	A	B	C($\times 10^{-3}$)	IRP	e/y	E	F
<60	16	**0**	3.8	0.0	80	0.0	0	0.0	0.00
60 - 65	24	**4**	5.7	16.7	149	3.5	594	0.5	0.10
65 - 70	26	**3**	6.1	11.5	184	3.3	551	0.5	**0.08**
70 - 75	47	14	**11.1**	29.8	224	18.5	3,136	2.9	0.26
75 - 80	50	18	**11.8**	36.0	269	28.6	4,850	4.4	0.37
80 - 85	51	21	**12.1**	41.2	320	39.7	6,728	6.1	0.51
85 - 90	35	25	8.3	71.4	377	**55.6**	9,426	8.6	**1.04**
90 - 95	36	19	8.5	52.8	440	49.3	8,355	7.6	0.89
95 - 100	26	12	6.1	46.2	509	36.0	6,105	5.6	0.90
100 - 105	33	29	7.8	**87.9**	584	**100.0**	16,944	**15.4**	**1.98**
105 - 110	27	25	6.4	**92.6**	667	**98.4**	16,665	**15.2**	**2.38**
110 - 115	21	16	5.0	**76.2**	756	**71.4**	12,096	**11.0**	**2.22**
115 - 120	16	14	3.8	**87.5**	853	**70.5**	11,938	**10.9**	**2.87**
120 - 125	**8**	6	1.9	**75.0**	957	33.9	5,742	5.2	**2.76**
≥125	**7**	6	1.7	**85.7**	1,128	39.9	6,769	6.2	**3.72**
Total	423	212	100.0				109,898	100.0	

The smallest berried female in this sample was 61.9 mm CL and the classes 70- to 80- mm CL had the highest percentage of females while the classes over 100- CL had the highest proportions of ovigerous females. Like in Kanciruk & Herrnkind (1976) for *P. argus* in the Bahamas, we assumed only one spawning per year throughout the size range of the females when estimating IRP in *P. regius*.

Females in size class 100- to 115- CL produced 52.5% of all eggs and had the highest IRPs. The size at 50% maturity (87.9 mm) is included in class 85-90, also presenting a high IRP (Table 3). The relative reduction of IRP for smaller and larger females was related with poorer representation of ovigerous females and large females in the samples. In any case, the three largest classes have the highest indices of productivity but are poorly represented, showing in this case, the importance of large females for the production of eggs in the populations. The 105- class had one of the highest productivity indexes (F = 2.38), resulting from relatively high fecundity and good representation of ovigerous females in the sample, making this class 29 times more productive than the recently mature class (65- CL, F = 0.08 and including the L25%=68.8) (Table 3 and see Fig. 3).

DISCUSSION AND CONCLUSION

The sex ratio is well balanced in the studied population. Kanciruk (1980) reported that the sex ratio in palinurids can vary considerably. The method of capture used in this work, diving, is highly efficient and unselective, and may justify the absence of significant deviations from a balanced sex ratio.

The size structure of both sexes is different, with males reaching larger sizes than females. Kanciruk (1980) suggested that this is likely due to differential growth or molting rates between sexes, longer male lifespan, or increased metabolic demands on females during egg production.

Data on fecundity of *P. regius*, including the present study and previous ones, are presented in Table 4. Although samples were very small in some of the studies, variations in fecundity and reproduction parameters from region to region are observed, a situation that should be expected in palinurids (Chubb, 2000). Chittleborough (1974) found variability by almost 30 mm in L50% for a coastal population of *Panulirus cygnus*. Wenner et al. (1974) considered the size at which crustaceans become sexually mature a very useful indicator of environmental effects on field populations. Early maturity can be indicated by smaller sizes of first maturity (MOF) and size at 50% maturity (L50%) and is usually correlated with higher water temperatures (Sutcliffe, 1953). Since *P. regius* experiences a wide range of climatic and oceanographic conditions along the African coast (28ºN to 15ºS and 15 to 28ºC) (Postel, 1966), variation in all biological parameters for this species should be expected.

Table 4 – Comparison of some reproductive parameters in *P. regius*. 1 - Minimum carapace size of ovigerous females; 2 - size at onset of maturity for females (criteria not defined in most cases); 3 – maximum number of eggs per female (observed).

Species/ Study Area	MOF[1] (CL in mm)	SOM[2]	Brood size ($\times 10^3$)	n	e/y max [3]	References
Panulirus species			300–550 (90 mm CL)		1.2×10^6	Pollock (1995)
Panulirus regius						
Ivory Coast	57	58-73	416 (81 mm CL)	1		Machal & Barro (1964)
Benin	75					Giudicelli (1971)
Angola	67					Franca (1966)
Mauritania		53	1,300 (129-140 mm CL)		1.3×10^6	Maigret (1978)
Senegal	67.2		93–309	3		Clotilde-Ba et al. (1997)
Cabo Verde	**61.9**	**87.9**	**$BS=1.59\times CL^{2.77}$**	**65**	**1.0×10^6**	**This Study**

To analyse the data from different areas included in Table 4, three regions were defined: North of the Gulf of Guinea (Mauritania, Senegal and Cabo Verde), Gulf of Guinea (Ivory Coast and Benin) and South of the Gulf of Guinea (Angola). Considering MOF values, these are similar for Cabo Verde and Senegal (CL 61.9 and 67.2 mm), but the two extremes of the range for the species are precisely from the studies coming from the Gulf of Guinea region, from two areas that are close and where conditions are expected to be very similar. Variation in MOF cannot be explained by latitude either. Factors other than water temperature can explain changes in maturity parameters. These include genetic selection, biomass of available food, intense fishing effort (Leocádio, 2004), density-dependent phenomena (Chubb, 2000) and physiological adjustment to differing photoperiods (Quackenbush & Herrnkind, 1981).

One relevant aspect for fecundity studies is the average number of spawning episodes per adult female per year. Major field studies of tropical palinurid lobsters have established that rapid and repetitive brood cycles are common, with up to 5 broods per year (Junio, 1987, for *Panulirus penicillatus* in the Philippines waters). Quackenbush (1993) suggested that larger females spawn more frequently than smaller lobsters, because they may skip the annual molt. Protracted spawning seasons (Briones-Fourzán & Lozano-Alvarez, 1992) and high indexes of egg productivity (high number of eggs at L50%) (Fonseca-Larios & Briones-Fourzán, 1998) may imply multiple spawning.

In this study we assumed that females spawn only once a year, but more detailed studies need to be undertaken. Observations made in Cabo Verde suggests that the reproductive season coincides with the increase in water temperatures. Although the climate in Cabo Verde has minor fluctuations along the year, leading Franca et al. (1959) to suggest that *P. regius* in Cabo Verde did not have reproductive migrations, there are periods of the year when temperature rises creating condition similar to Spring (Dias 1993). This can explain some synchronicity in the reproductive cycle of Cabo Verde lobster species, with a peak ovigerous season from June to September. In the absence of more detailed information on the life cycle of *P. regius,* we assumed only one spawning per female and year. Marking studies need to be done in this population to understand if small females begin breeding early in the season, while the larger lobsters extended the breeding year-round, as recognized in *Panulirus inflatus* and *Panulirus glacilis* (Briones-Fourzán & Lozano-Alvarez, 1992).

Fecundity values estimated here are in agreement with studies in geographically close areas. Maigret (1978) for *P. regius* in Mauritania estimated the average brood size of 129-140 mm CL females to be 1,300,000, while in our study, the estimated number of eggs for the same sizes is 1,104,000 (CL 129 mm) and 1,385,000 (CL 140 mm) (average 1,124,000 eggs), suggesting that Cabo Verde populations may have smaller brood sizes. Higher fecundity was also reported for the Ivory Coast where one female with CL 81 mm had roughly 416,000 eggs (Marchal & Barro, 1964), where as the estimated value for the same CL for the Cabo Verde population is 304,000. It should be stressed that fecundity estimates for the Mauritania and Ivory Coast populations were based on very small sample sizes.

A review of palinurid life-history patterns (Pollock, 1995) gives the range for fecundity (standardized to 90 mm carapace length) to be 300,000-550,000 eggs. In this study, we obtained a value of 408,000 eggs, that is closer to the upper values for the other palinurids.

With respect to relative egg weight, our results showed no differences with egg development and female size. In nature, eggs about to hatch may be significantly larger in diameter than recent oviposited eggs (Gracia, 1985) but lighter, with the reduction in weight due to the consumption of the dense yolk material during development (Briones-Fourzán & Contreras-Ortiz, 1999). It is therefore expected that late development stages will give higher values of relative egg weight. The results obtained in this work are in agreement with information presented previously (Aiken & Waddy, 1980; Chubb, 2000). Studies on *P. argus* suggest that larger females should actually have smaller eggs, because they can have multiple spawnings in the same year, leading to smaller eggs in second or later egg-masses (Fonseca-Larios & Briones-Fourzán, 1998). The results obtained here should therefore be considered with caution, and more studies are necessary to clarify these aspects of fecundity of *P. regius*.

When determining the reproductive potential, several aspects need to be considered in order to avoid biased estimates. Knowledge of the period of spawning is of relevance to estimates of size-fecundity relationships when evaluating regional variation in reproductive potential (Lizárraga-Cubedo et al., 2003). Specific fecundity can vary along the year, depending mainly of the variation of the number of individuals in the age groups and food availability in the periods that precede the reproduction (Correa-Ivo & Vasconcelos-Gesteira, 1995). In this work, fecundity was estimated leaving out egg masses in late development stages (likely to have suffered egg losses) and the population structure was estimated from intensive sampling, occurring over 3 fishing seasons. Size specific maturation values and percentage of ovigerous females are therefore likely to represent the population of interest.

The indexes of reproductive potential (IRP) estimated here indicate that females in the size class 100- to 115- (CL in mm) produce half of the total eggs and have similar indices of productivity. Although single spawning was assumed due to lack of precise information, multiple spawnings may occur in large females, i.e., CL>115 mm; a reasonable management measure for this species would be the protection of large females, introducing a maximum landing size, in addition to the minimum landing size already in place.

The minimum landing size (MLS) for the green lobster in Cabo Verde is 200 mm total length (TL), equivalent to 71.5 mm CL. This value is close to the size of 25% maturity estimated here (L25% = 68.8 mm). It is suggested that MLS should be moved to 250 mm TL, equivalent to 89.3 mm CL for females, and 96.6 for males; for females this value would be just above the estimated L50% estimated here (87.9 mm CL ≈ 246 mm TL). This would protect a large fraction of effective reproductive females, about 55.6% of IRP, and seems to be more realistic to a fishery partially based on SCUBA diving and traps. This measure would imply an adjustment of minimum landing weight, from 500 g (in place at this moment) to 600 g.

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