

Population biology of *Panulirus echinatus* Smith, 1869 (Decapoda: Palinuridae) from São Pedro and São Paulo archipelago, Northeastern Brazil.

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Abstract

Spiny lobsters are one of the main economic resources for the fisheries industry in the northeastern region of Brazil. However, this resources has been dramatically depleted in the last decades as a result of illegal and predatory fishery activities. Increase in the fishery effort is due mainly to its high economic value added to the lack of appropriate legislation to protect the stock. This study address some biological aspects of *Panulirus echinatus*, a species heavily harvested in northeastern of Brazil. A total of 1,494 specimens were obtained during July/1998 and September/1999 from São Pedro and São Paulo archipelago. The sex ratio skewed significantly from 1:1. The analysis of the population structure indicated that males reach larger length and weight than females. The differences between sexes in the sex ratio, in the size classes, and in the population structure are possibly related to different reproductive behavior between sexes.

Key words: *Panulirus echinatus*, sex ratio, morphometry, northeastern Brazil.

Introduction

Spiny lobsters are one of the most important economical resources of the fishery sector in northeastern Brazil. Different methodologies have been used to capture these crustaceans, which are frequently harvested in depths from 10 to 60m, such as, traps, nets, and diving (Paiva, 1995). The continental fleet commonly employed the first method during the 1980's, but due to the insignificant yields, the latter technique is the most popular nowadays despite the fact that it is not legally regulated. As a result, throughout the northeastern region, lobster catch is greatly decreasing due to the reasons outlined above in addition to overfishing of specimens below the minimum size legally protected (Lins Oliveira *et al.*, 1993; Fonteles Filho, 1994; Vasconcelos *et al.*, 1994; Vasconcelos and Lins Oliveira, 1996).

The spatial distribution of different species of lobsters is determined by environment parameters, substrate conditions, and inter and intraspecific competitions. The Caribbean spiny lobster *Panulirus argus* (Latreille, 1804) is larger, exhibits a wider distribution, and occupies deeper bottoms than its congener *P. echinatus* Smith, 1869 and *P. laevicauda* (Latreille, 1817). The smooth tail spiny lobster *P. laevicauda* is distributed along coastal shallow waters. However, both *P. argus* and *P. laevicauda* require clean, warm and well oxygenated water, and calcareous substrate containing algae and gravel, whereas the brown spiny lobster *P. echinatus* prefers offshore regions with rocky substrates (Paiva, 1995).

Except for habitat preferences, biological information on *P. echinatus* remains scarce, probably because it preferentially inhabits offshore areas of difficult access, such as Rocas Atoll, Fernando

de Noronha Archipelago, São Pedro and São Paulo Archipelago. To date, *Panulirus echinatus* is the only species of spiny lobster commercially harvested in northeastern Brazil that is not considered by the fisheries legislation. With the decline in catches of *P. argus*, the fishing fleets have turned their attention to *P. laeviscauda* and *P. echinatus*. However, biological information for *P. echinatus* is lacking and it would be required to set up fisheries policies to protect the stock.

The determination of sex ratio is a useful tool to understand the composition of an investigated stock as well as variations in its abundance. In general, this parameter is estimated by the numerical ratio of males to females, and it can be expressed as a coefficient or percentage (Aguilar and Malpica, 1993). Biometric relationships provide regression equations that correlate linear body measurements with body weight which can be used to infer dependent variables that are necessary to manage the fishing (Ivo, 1996).

Within this framework, this study provide basic information on population structure, morphometry and sex ratio of *P. echinatus*. It is expected that the data presented here may be useful in designing legal guidelines to protect the stock of this species.

Material and Methods

São Pedro and São Paulo archipelago (29° 20' 44" W: 00° 55' 01" N) is the unique group of Brazilian oceanic islands in the Northern Hemisphere. Of volcanic origin, these islands are approximately 1000 km offshore of Natal, Rio Grande do Norte State, their nearest continental city (Fig. 1).

Fifteen expeditions were carried out from June/1998 to September/1999 to collect specimens of *P. echinatus* in the archipelago. Fish traps, commonly called 'covo' by fishermen, were set around the islands and in small coves between them. Collecting sites ranged from 10 to 50 meters deep to minimize a possible stratification due to depth.

Specimens of *Panulirus* spp. were identified according Melo (1999). Sex was identified based on external morphology (*e.g.*, presence of pleopods on abdomen in females). The following measurements were taken: total wet weight (Tw), cephalotorax weight (Cw) and abdomen weight (Aw) (using a digital scale, 0.1g precision); total length (Tl), cephalotorax length (Cl) and abdomen length (Al) (using a caliper, 0.1 mm precision) (Fig. 2).

The determination of size and weight classes, in which both sexes were grouped, were based on the total length (15 mm intervals) and total weight (50g intervals). For the purposes of analyzing sex ratio, a proportion test, according to the package STATISTICA version 5.0 (StatSoft), was applied to each size class and in the total of sampled population.

Shapiro-Wilks test, kurtosis and symmetry evaluated the normality of total length data. Homogeneity of variances was tested using Levene's method (Zar, 1999). Total length differences between males and females were evaluated by Mann-Whitney test. Finally, results of all statistical tests were evaluated at $\alpha = 0.05$ of significance level.

Results

A total of 1,494 lobsters were obtained throughout the collection period, in which 840 were males, and 654 were females. Their size (Tl) varied from 57 to 250 mm, and they were grouped into 15 length classes within 15 mm intervals (Fig 3). Weight varied from 6 to 664 g, and they were grouped into 14 classes within 50 g intervals (Fig 4).

Population structure

The frequency distributions of *P. echinatus* revealed that males were distributed in bigger size and weight classes than females (Fig. 3 and Fig. 4). Total length distributions did not fit as normal and comparisons between male and female lengths (Tl, Cl, and Al) showed that they were statistically different (Table I).

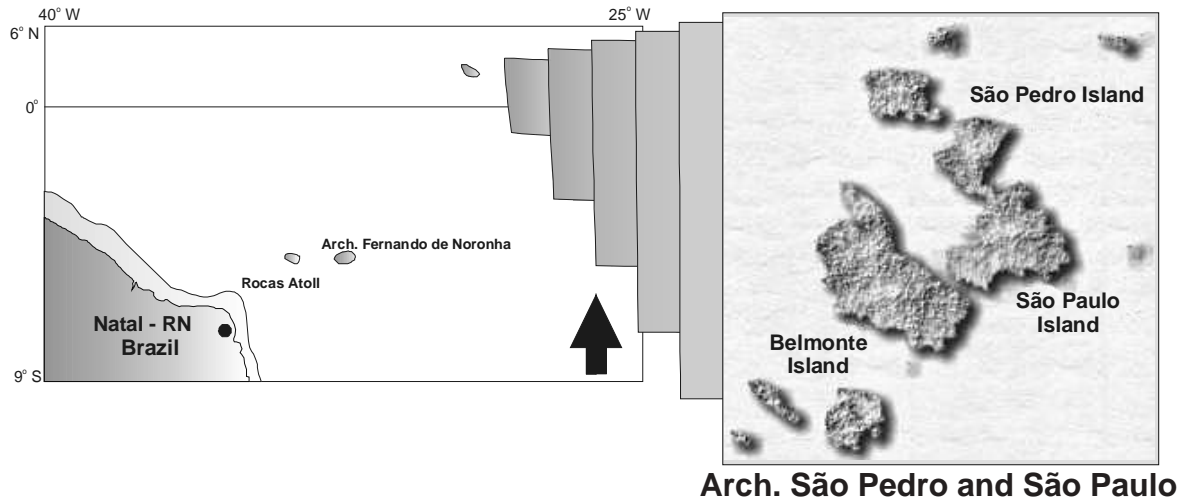


Figure 1: Location of the São Pedro and São Paulo Archipelago.

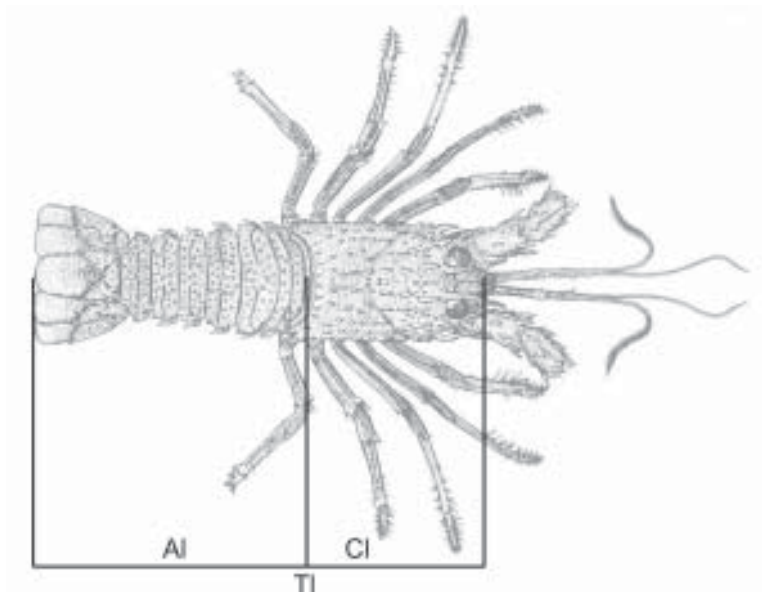


Figure 2: *Panulirus echinatus* (modified from Melo, 1999). Illustration indicating land marks from morphometric parameters were obtained. *modified from Melo, 1999.

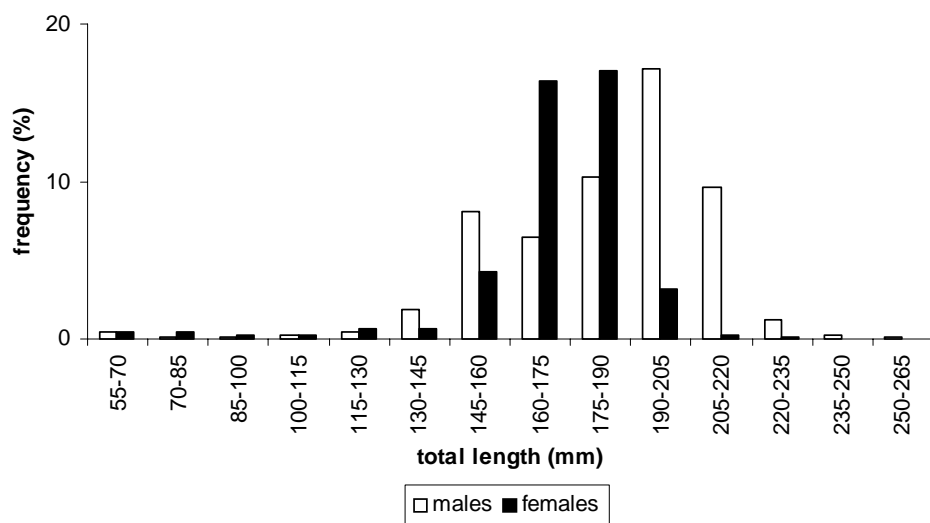


Figure 3: Total length classes distribution for males and females of *Panulirus echinatus* from São Pedro and São Paulo Archipelago between June 1998 and September 1999.

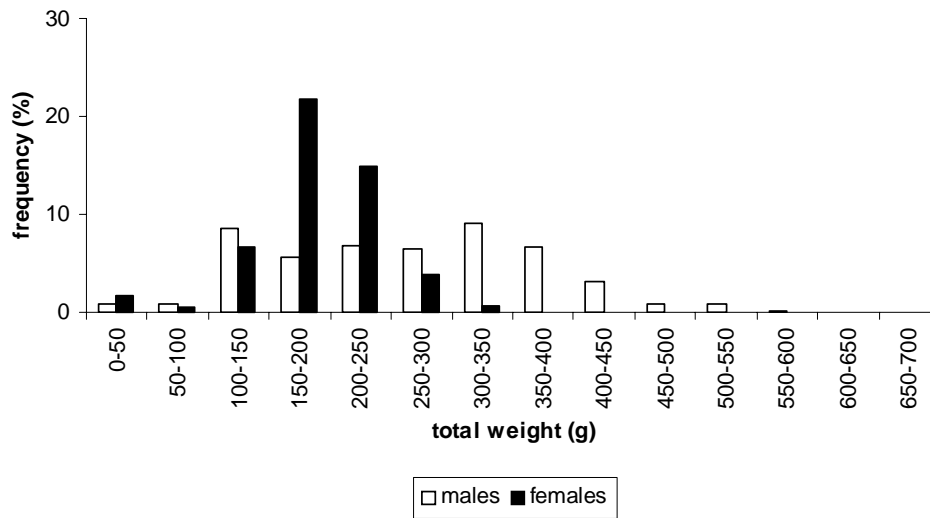


Figure 4: Total weight classes for males and females of *Panulirus echinatus* from São Pedro and São Paulo archipelago between June 1998 and September 1999.

Morphometry

From the relationship between weight and length, power functions were derived for males ($T_w = 0.0251 T_l^{3.1779}$) and females ($T_w = 0.404 T_l^{2.9649}$). Pearson correlation coefficients related to each equation ($r = 0.99$ and $r = 0.98$ for males and females, respectively) are presented (Figure 5). The same tendency for population structure, in which males were larger than females, was obtained by morphometry. This demonstrated a sexual polymorphism linked to size of individuals (Table I).

The linear equations representing the relationships among $Cl \text{ vs. } Tl$, $Al \text{ vs. } Tl$, $Cl \text{ vs. } Al$, and respective coefficients of determination for both sexes are listed in Table II.

Mean proportions between Cl/Tl , Al/Tl , and Cl/Al suggested that while the abdomen accounted for 2/3 of an individual's length, it only represented 1/3 of an individual's weight (Table III).

Sex ratio

The total sex ratio measured for *P. echinatus* was 1.3:1 favoring males, which was statistically different from the expected value 1:1. Evaluating the sex ratio from smaller size classes suggested that one would expect a value of 1:1. However, evaluating size after gonadal maturity ($Tl > 14.0$ cm; Pinheiro unpub. data) indicated that this ratio differed significantly from the expected (Fig. 6).

Table I: Morphometric parameters for *Panulirus echinatus* from São Pedro and São Paulo archipelago between June 1998 and September 1999. Comparison of total length (Tl), cephalotorax length (Cl) and abdomen length (Al) between males and females (Mann-Whitney test $p < 0.05$ for all comparisons).

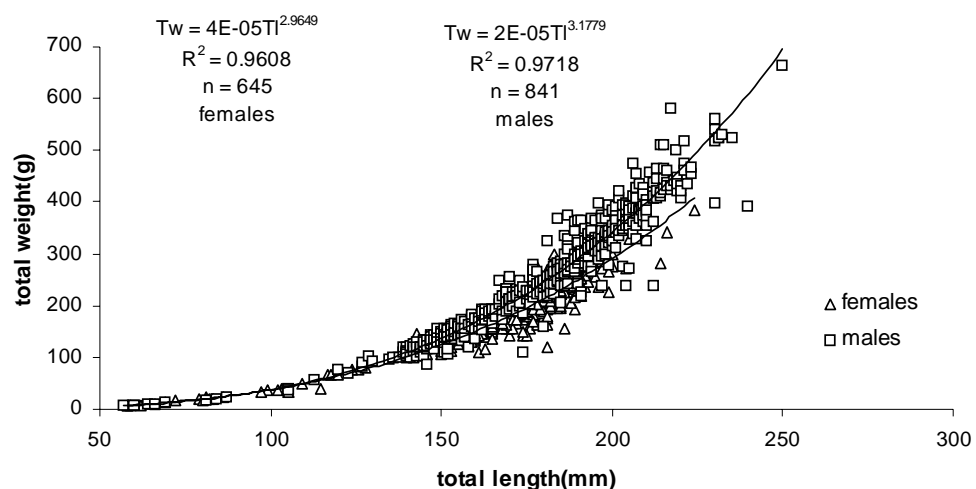
Length (mm)		male	female	total
	Tl	183 ± 0.94	170 ± 0.82	177 ± 0.66
Mean ± error	Cl	70 ± 0.48	61 ± 0.42	64 ± 0.36
	Al	125 ± 0.38	109 ± 0.13	119 ± 0.23

Table II: Obtained equations (CI vs. TI), (AI vs. TI) and (CI vs. AI) with the determination coefficients for specimens of *Panulirus echinatus* from São Pedro and São Paulo archipelago between June 1998 and September 1999.

Relationship	Sex	Equations	r ²
CI vs. TI	male	CI = 0.243TI ^{1.16}	0.96
	female	CI = 0.296TI ^{1.07}	0.95
AI vs. TI	male	AI = 0.838TI ^{0.889}	0.94
	female	AI = 0.703TI ^{0.968}	0.97
CI vs. AI	male	CI = 0.452AI ^{1.14}	0.83
	female	CI = 0.519AI ^{1.03}	0.86

Table III: Morphometric ratios for *Panulirus echinatus* from São Pedro and São Paulo Archipelago between June 1998 and September 1999.

Relationship	AI/TI		CI/TI		Aw/Tw		Cw/Tw	
	male	female	male	female	male	female	male	female
Proportions (%)	62.3	64.4	38.7	36.0	26.6	36.4	71.4	61.4

**Figure 5:** Relationship between weight and length for males and females of *Panulirus echinatus* from São Pedro and São Paulo archipelago between June 1998 and September 1999.

Discussion

Population structure and morphometry

The results of this study pointed to a possible sexual polymorphism in *P. echinatus*. Ivo (1996), studying *P. argus* and *P. laevicauda* from the coast of Ceará, found the same pattern, (i.e., males larger than females). Kanciruk (1980) *apud*. Vasconcelos and Vasconcelos (1994) assumed that males of palinurids reach considerably greater total length than females. On the other hand, Vasconcelos and Vasconcelos (1994) observed a trend in which males of *P. laevicauda* attain larger dimensions, while for *P. argus* they observed opposite tendency in the coastal areas of Rio Grande do Norte. In addition, in most metazoan species, females attain larger body sizes than do males. This generality was established for many groups by Darwin (1874), and has been supported and extended by subsequent authors (Shine, 1988).

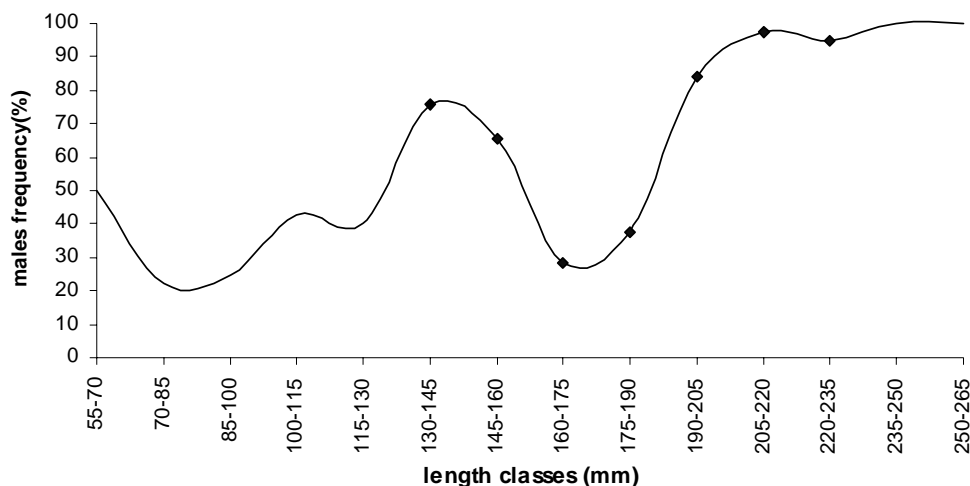


Figure 6: Sex ratio within the length classes of *Panulirus echinatus* from São Pedro and São Paulo Archipelago between June 1998 and September 1999. (* = $p < 0.05$).

It appears that these commercially exploited palinurids exhibit sexual polymorphism based on the lengths of the individuals in the northeastern region of Brazil. This polymorphism related to size may result from differences in reproductive behavior. Females of *P. echinatus* carry eggs adhered to pleopods, and thus behave differently than males. During the reproductive period, females tend to hide to protected themselves from predators, which result in smaller activity and consequently reducing foraging time. Conversely, foraging behavior in males seems to be constant during the reproductive season. Another explanation can be put forward based on the suggestion males allocate energetic resources mainly to somatic growth, whereas females have to allocate a great amount of energy towards reproduction so that somatic growth and reproduction compete for resources (Hartnoll and Gould, 1988). Hence, the investment in somatic growth by males guarantee an advantage in intraspecies competition for mating and could explain the larger size observed in males of *P. echinatus*. This same pattern occurs frequently in several groups of decapods that posses in commom the incubation of eggs, such as swimming crabs, grapsidae crabs, hermit crabs, cleannig shrimps, and caridean shrimps (Guerao *et al.*, 1994; Zhang *et al.*, 1997; Pinheiro and Fransozo, 1998; Castiglioni and Santos, 2000; Moura *et al.*, 2000; Mantelatto and Martinelli, 2001).

Comparisons of the meaning cephalothorax length of the sampled individuals with those of other commercially harvested lobsters in northeastern Brazil suggested that *P. echinatus* is the smallest palinurid species among those found in that region (Table IV). This fact would explain why this species is not commercially harvested as the others species.

The morphometric equations obtained from the data available can be used as a powerful tool for setting guidelines to regulate fishery activities of *P. echinatus*. According to Ivo (1996), morphometric equations can be used to verify how a population answer to environmental modifications. Also external factors, such as fishing pressure, are known to modify population structure. Despite of the increase harvesting of *P. echinatus*, in São Pedro and São Paulo archipelago, the stocks of this species seems to be in equilibrium. However, it is necessary a close attention to modifications in the population structure to guarantee the sustainable management of this species.

Sex Ratio

It was observed that the sex ratio skewed significantly towards males of *P. echinatus*. The same pattern was observed in *P. argus* during the months of higher reproductive intensity, whereas

during periods lower reproductive intensity, sex proportions tended towards 1:1 (Soares, 1994). The same trend was observed in *P. argus* and *P. laevicauda* (Coelho *et al.* 1996). However, Ivo and Neto (1996) also found significant differences in *P. argus*, but the same was not observed in *P. laevicauda*. Wenner (1972) reported that differences in sex ratio between size classes are relatively common, and it may be explained by differences in longevity, mortality and growth. According to Lins Oliveira (1996), many hypotheses may be raised to explain differences in predominance of one sex; difference in growth rate and differential migration during the juvenile phase, natural mortality differences, and sexual reversal above a certain length. Góes and Fransozo (2000) suggest that these deviations may be directly related to collection procedures or sampling area chosen for analysis. Moreover, Mousseau and Fox (1998) point out that progeny sex can be influenced by biotic and/or abiotic factors. In many species mothers can manipulate or respond to their environment in a manner that suggests adaptive adjustment of progeny sex.

For *P. echinatus*, it is believed that the differences found in sex proportions are results of distinct behavior between the sexes. It is possible that females are less active during the reproductive period as they incubate the eggs adhered to abdomen. This behavior may change the probability of being captured. On the other hand, males do not change activity during the reproductive cycle, and thus they can be caught at the same rates throughout the year.

It is expected that the information provided by this study may help to draw protection policies for the northeastern stock of *P. echinatus* in Brazil. Information on L_{50} , reproductive season, fecundity, and overall maturity have been used to establish guidelines for legalization of a great number of fishery resources around the world (Aguilar and Malpica, 1993; Castilha, 2000; Groeneveld, 2000; Briggs *et al.*, 2001). After all, following up concepts of sustainable development and rational exploration of resources is the only guarantee we have to protect it for future generations.

Table IV: Comparisons between mean lengths of carapace within palinurids.

Species	Authors	Region	Mean length of carapace (mm)		
			male	Grouped	female
<i>P. argus</i>	Alvares and Negrete-Soto (1991)	Cuba	91.6		79.9
	Vasconcelos <i>et al.</i> (1994)	RN, Brazil	79.6	85.6	91.6
	Ivo and Neto (1996)	CE, Brazil		91.8	
	Ivo (1996)	CE, Brazil		96.9	
<i>P. laevicauda</i>	Vasconcelos <i>et al.</i> (1994)	RN, Brazil	70.1	73.6	77.2
	Ivo and Neto (1996)	CE, Brazil		71.2	
	Ivo (1996)	CE, Brazil		69.3	
<i>P. echinatus</i>	This study	RN, Brazil	55.9	52.2	48.8

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