ANALYSIS OF POPULATIONAL STRUCTURE OF THE HERMIT CRAB *DARDANUS INSIGNIS* (ANOMURA: DIOGENIDAE) NEAR COASTAL ISLANDS IN SOUTHEASTERN BRAZIL: A STUDY OF 14 YEARS AGO

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ABSTRACT

Analysis of populational structure of the hermit crab *Dardanus insignis* (Anomura: Diogenidae) near coastal islands in southeastern Brazil: a study of 14 years ago. Braz. J. Aquat. Sci. Technol. 17(2):17-25. eISSN 1983-9057. DOI: 10.14210/bjast.v17.n2.p17-25. The goal of this paper was the comparison of the population structure and the reproductive period of *Dardanus insignis* from two islands in a subtropical area of the Brazilian coast. A total of 795 hermit crabs were obtained at Couves Island, being 56.4% males, 27.3% non-ovigerous females, 3.8% ovigerous females, and 12.5% juveniles; at Mar Virado Island a total of 336 specimens were captured, being 59.5% males, 31.8% non-ovigerous females, 4.7% ovigerous females, and 4.5% juveniles. The sex-ratio was statistically different from 1:1 in favor of males during all study period in both sites. The reproductive period is seasonal in both sites and the juveniles' recruitment occurred at the first two winter months. Only males were found in the largest size classes. Despite of the distance and environmental and biological features of each site, both populations of *D. insignis* showed similar characteristics.

Key words: absolute abundance, size frequency distribution, sex-ratio, demographic group, recruitment, reproduction.

INTRODUCTION

Hermit crabs are an important macrozoobenthic group at the intertidal and sublittoral zones, with a high diversity in tropical and subtropical regions (Sumida & Pires-Vanin, 1997). The hermit crab *Dardanus insignis* (Saussure, 1858) is the most abundant hermit crab of soft bottom littoral at Southeastern Brazil (Fransozo et al., 2011; 2012), being classified as one of the species that structuring the benthic mega fauna, from shallow regions to depths greater than 100 meters at southeastern of Brazilian coast (Pires, 1992). One of the main factors in the success of the hermit crabs is the flexibility of the feeding behavior (omnivorous-detritivorous) that characterizes them as opportunistic feeders, allied to the gastropod shell utilization, which promote their adaptation to any environment (Hazlett, 1981).

In Brazil, the last decades have been marked by a reasonable number of studies on hermit crabs and anomuran communities (Negreiros-Fransozo & Nakagaki, 1998; Turra & Leite, 2000; 2001; Fransozo et al., 1998; 2008; Mantelatto & Garcia, 2002) and particular features of each species such as population structure, reproduction, relative growth and shell occupation (Negreiros-Fransozo et al., 1992; Reigada & Santos, 1997; Bertini & Fransozo, 1999a; 2000; Garcia & Mantelatto, 2001; Turra et al., 2002; Frameschi et al., 2013). Recent studies have described some features of *D. insignis*, including the post-embryonic development (Hebling & Mansur, 1995), population dynamics (Branco et al., 2002; Fernandez-Goés et al., 2005) and fecundity (Miranda et al., 2006). Studies on the population structure based on size classes' distribution, sex-ratio, recruitment, migration and reproduction are of fundamental importance in the understanding of the dynamic of the animals' life cycle.

According to Dugan & Davis (1993), areas that function as a source of recruits due to the presence of shelters, as islands of Ubatuba region, positively affect fisheries resources in nearby areas. As stated by Norse (1993), such areas are fundamentally important for the conservation of all local biodiversity. Thus, studies such as this, with information about biological features of distinct populations of one same species are of basic importance in order to suggest monitoring programs for species conservation. The studies of the NEBECC research group, which has operated in the Brazilian southeast region for over 20 years, have provided supporting information for the implementation of Marine Protected Areas (MPA) such as the creation of the Cunhambebe sector on the northern São Paulo coast, in 2008 (proclamation No. 53525, October 8, 2008), a site that is still the object of studies on biodiversity. The aim of this study was to investigate population characteristics of *D. insignis* from two islands (populations) of southeastern Brazil taking into account: the size distribution, abundance, size range, sex-ratio, reproductive period and also their relationship with the environmental features.

MATERIAL AND METHODS

Hermit crabs were monthly collected from January 1998 through December 1999 in two sites at the Ubatuba region, on the Northern coast of the state of São Paulo, Brazil. The sites were located near two islands as reference point: the Couves Island (23°24'45''S; 44°51'27''W) and Mar Virado Island (23°33'25''S; 45°09'37'') (Figure 1). Samplings were performed using double-rigged nets, with an aperture of 4.5m and mesh size of 20mm in the main body of the net and 15mm at the cod end. Samplings were taken at sea in front of the continent and covered an approximate area of 18000m^2 in 30 minutes.

Both sediment and hermit crabs sampled material were kept in thermo boxes with flake ice until the transport to field laboratory and maintained refrigerated until the analysis. Monthly measurements of bottom and surface temperature and salinity were recorded using a mercury thermometer and an optical rephractometer, respectively.

In the laboratory, the sediment was dried at 70°C for 72h in an oven. The sediment organic matter content (%) was obtained through ash-weighing: 3 aliquots of 10g each per station were placed in porcelain crucibles and incinerated for 3h at 500°C. After that, samples were then weighed again for organic matter content calculation. In general, these procedures followed those of Mantelatto & Fransozo (1999). The sediment remaining after analysis of the organic matter was re-dried and passed through a series of sieves with graduated mesh sizes, following the Wentworth (1922) scale. All procedures for sediment analysis followed Håkanson & Jansson (1983) and Tucker (1988).

Hermit crabs were identified according to Melo (1999), and after sex determination, specimens were dissected for gonad development observation. The specimens were classified according to the maturity conditions based on gonad size, shape, and coloration in relation to the hepatopancreas (Lancaster, 1988). All hermit crabs had their cephalothoracic shield length (CSL) measured using a caliper (0.01mm). After that, they were grouped in ten size classes with 2mm intervals. The size frequency distributions were tested for normality by means Kolmogorov-Smirnov test. For relative abundance evaluation between populations, the samples were standardized using the capture per unit effort, number of specimens by 100m^2 in each trawl. The mean size of hermit crabs in each demographic category was compared by means the Mann-Whitney test (Zar, 1996). The comparison of the abundance of hermit crabs between populations was performed by Kruskall-Wallis test.

The reproductive period of the populations were determined based on the frequency of ovigerous females in relation to adult non-ovigerous females, and also on adult specimens with gonad in developed stage in relation to immature ones. The monthly and year sex-ratio were calculated by means the binomial test (Wilson & Hardy, 2002).

In order to evaluate some possible association among the environmental factors (bottom temperature, salinity and organic matter content of sediment) and hermit crab frequence, it was used the Spearman cor-

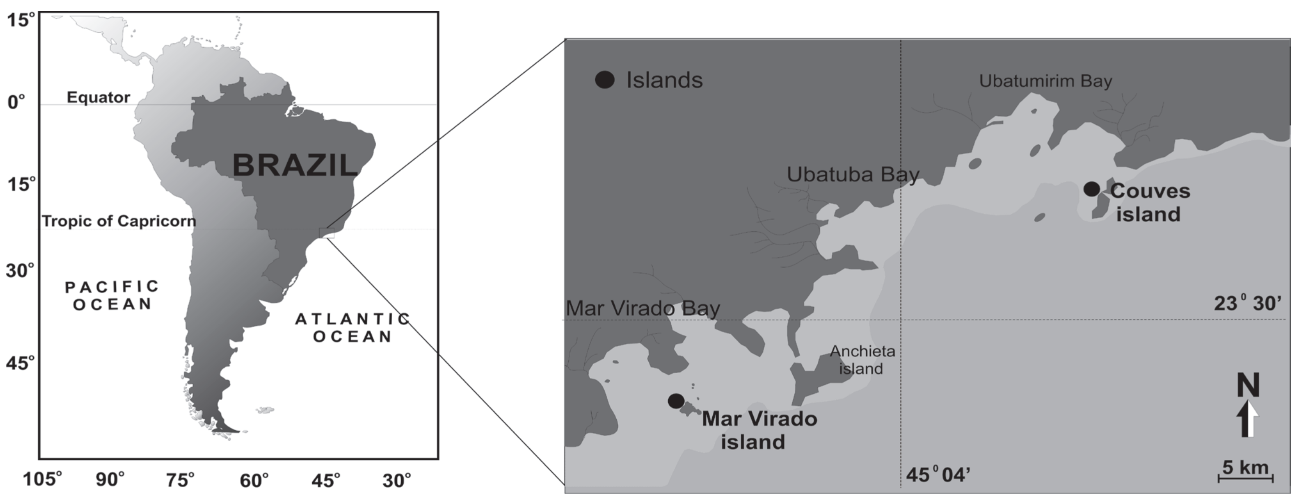

Figure 1 - Map indicating the location of the Couves and Mar Virado Islands.

relation analysis (Zar, 1996). All statistical tests utilized in this paper followed the significance level of 5%.

RESULTS

Distinct pattern of variations were verified in the environmental factors in both sampled sites. The bottom and surface temperatures showed higher variation during summer and spring at Couves than Mar Virado Island (Figure 2). Concerning both studied years, the major variations were registered in 1998 for both sites, with only bottom salinity showing monthly variations all studied period, mainly in Mar Virado Island (Figure 3). The organic matter content (%) was higher in Couves than Mar Virado Island, with peaks in both sites during summer 1999 (Figure 4). With reference to the sediment composition, the MarVirado Island showed finer sediment grains than those found in the Couves Island (Figure 5). During sampling period, there were correlations only between hermit crabs and organic matter content. The results of the Spearman test of correlation for hermit crabs and environmental factors are presented in Table 1.

At Couves Island, a total of 795 specimens of *D. insignis* were obtained, from which 448 were males (56.35%), 217 non ovigerous females (27.30%), 30 ovigerous females (3.77%) and 100 juveniles (63 males and 37 females; 12.58%) (Table 2). At Mar Virado Island, a total of 336 specimens were obtained, being 200 males (59.52%), 107 non-ovigerous females (31.85%), 14 ovigerous females (4.17%) and 15 juveniles (9 males and 6 females; 4.46%) (Table 3). The abundance of hermit crabs between islands differed statistically, being higher in Couves Island (H=5.778; $p < 0.05$).

In 1998, it was captured a larger number of hermit crabs compared to 1999 in both islands. In Couves Island (Figure 6) there was a peak on July 1998 and in Mar Virado Island (Figure 7), there was a peak on March 1998. The total mean size of the hermit crabs from Couves Island (6.76±1.90mm of CS) was significantly larger than (Z=-8.02; p=0.00) those from Mar Virado Island (7.88±2.56mm of CS). In the comparison of the mean size of hermit crabs from Couves

Table 1 - Results of Spearman correlation analysis for the relationship between environmental factors and the frequency of occurrence of individuals for each island (r_s = Spearman correlation coefficient).

Environmental variables	Couves		Mar Virado	
	r_s	p	r_s	p
Surface temperature	-0.16	0.46	0.04	0.82
Botttom temperature	0.11	0.59	0.13	0.56
Salinity	0.09	0.67	0.18	0.40
Organic matter	-0.60	0.00	-0.62	0.00

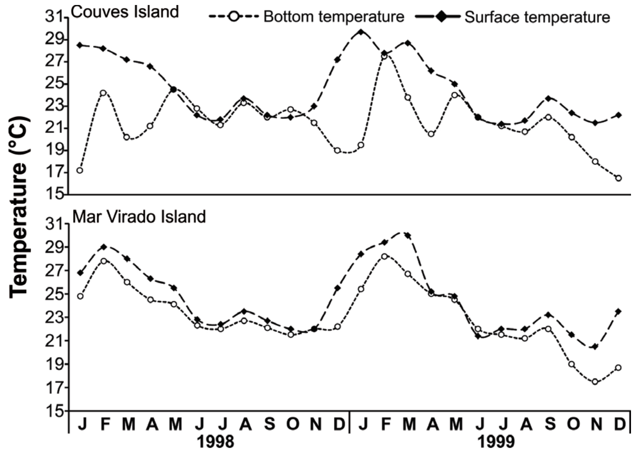

Figure 2 - Monthly values for bottom and surface temperature in each sampled site along the studied period.

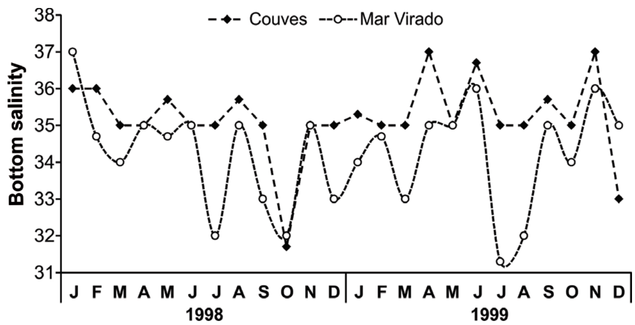

Figure 3 - Monthly values for bottom salinity in each sampled site along the studied period.

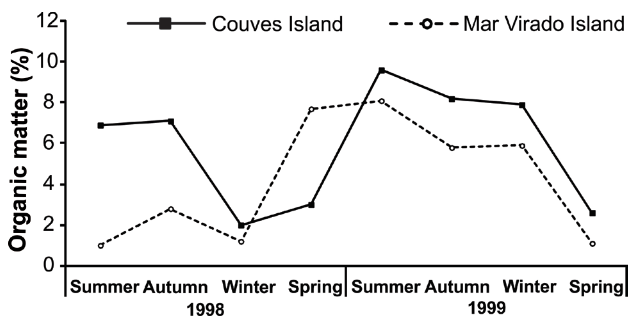

Figure 4 - Mean values for organic matter content by each year season in both sites.

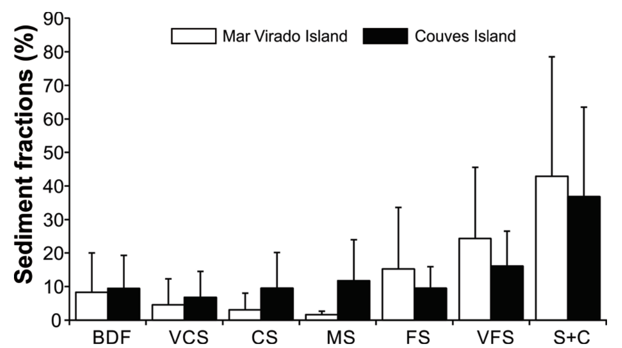

Figure 5 - Texture of sediment in Couves and Mar virado Islands. (BDF = biodetritus fragments; VCS = very coarse sand; CS = coarse sand; MS = mean sand; FS = fine sand; VFS = very fine sand and S+C = silt+clay).

Table 2 - Monthly distribution of the number of specimens by sampling period, including demographic groups and sex-ratio results for Couves Island population (AM = adult males; AF= Adult non-ovigerous females; J = Total juveniles, representing immature males and females; M:F = ratio of males and females ratio) (*p < 0.05).

	1998						1999					
	AM	AF	OF	J	Total	M:F	AM	AF	OF	J	Total	M:F
January	16	4	1	14	35	1:0.8	11	4	0	1	16	1:0.4
February	14	5	1	2	22	1:0.6	1	0	0	0	1	-
March	11	7	0	4	22	1:0.8	8	2	0	0	10	1:0.2
April	11	4	0	3	18	1:0.4	0	0	0	0	0	-
May	36	20	0	10	66	1:0.7	1	2	0	0	3	1:0.2
June	50	45	0	12	107	1:1.0	6	9	0	0	15	1:1.2
July	31	13	0	3	47	1:0.5*	2	3	0	4	9	1:1.0
August	91	58	0	29	178	1:0.7*	7	3	0	6	16	1:0.6
September	22	21	4	0	47	1:1.1	27	4	9	4	44	1:0.2
October	19	3	7	2	31	1:0.5	11	0	1	1	13	1:0.4*
November	25	2	2	1	30	1:0.2*	17	1	4	2	24	1:0.4
December	21	6	1	2	30	1:0.3*	10	1	0	0	11	1:0.1*
Total	347	188	16	82	633	1:0.7*	101	29	14	18	162	1:0.5*

Island, males (7.20±2.03mm of CS) were significantly larger (Z=7.95; p=0.00) than femaels (6.07±1.20mm of CS); while in Mar Virado Island, males (8.40±2.98mm of CS) were also larger (Z=4.53; p=0.00) than females (7.03±1.29mm of CS). Comparison between sites showed males (Z=-5.63; p=0.00) and females (Z=-6.63; p=0.00) larger in Couves Island than in Mar Virado Island. Males from Couves Island were significantly larger than adult non-ovigerous females (Z=5.80; p<0.01); while sizes of adult males and ovigerous females did not show significant difference (Z=1.34; p=0.180). In Mar Virado Island it was verified a same relation concerning size differences among demographic groups. The descriptive measures of hermit crabs and comparisons are shown in Table 4.

The size frequency distribution by cephalothoracic shield length of the obtained specimens evidenced a not normal distribution pattern, being unimodal for Couves Island population (KS=0.17; p<0.01) (Figure 8) and Mar Virado Island population (KS=0.17; p<0.05) (Figure 9).

The sex-ratio verified for Couves Island population was biased for males in the months: July 1998 (p=0.03), August 1998 (p=0.01), November 1998 (p=0.00) and December 1998 (p=0.00) and October 1999 (p=0.01), November 1999 (p=0.04) and December 1999 (p=0.00). The sex-ratio of each studied year for Couves Island population was also biased for males (1M : 0.66F; p=0.00 1998 and 1M : 0.54F; p=0.00 1999) (Table 2). The sex-ratio verified for Mar Virado Island population was biased for males in the months: June 1998 (p=0.03) and December 1998 (p=0.04), and in August 1999 (p=0.02). The sex-ratio of both studied years for Mar Virado Island was similar (1M: 0.65F; p=0.00 1998; and 1M: 0.46F; p=0.00 1999) (Table 3). With respect to the size frequency distribution, sex-ratio is biased for males as size class increase, verifying a similarity of sex-ratio in the first size classes, after the

Table 3 - Monthly distribution of the number of specimens for sampling period, including demographic groups and sex-ratio results for Mar Virado Island population (AM = adult males; AF= Adult non-ovigerous females; J = Total juveniles, representing immature males and females; M:F = ratio of males and females ratio) (*p < 0.05).

	1998						1999					
	AM	AF	OF	J	Total	M:F	AM	AF	OF	J	Total	M:F
January	10	3	1	0	14	1:0.4	4	1	0	0	5	1:0.2
February	21	12	0	2	35	1:0.6	1	1	1	0	3	1:2.0
March	28	19	0	0	47	1:0.7	0	2	0	0	2	-
April	10	10	0	3	23	1:0.9	4	1	0	0	5	1:0.2
May	22	17	0	0	39	1:0.8	1	1	0	0	2	1:1.0
June	14	6	0	2	22	1:0.4*	5	1	0	5	11	1:0.6
July	3	4	0	0	7	1:1.3	0	0	0	0	0	-
August	17	18	0	1	36	1:1.1	8	1	0	0	9	1:0.1*
September	14	4	3	1	22	1:0.5	4	2	0	0	6	1:0.5
October	3	0	1	0	4	1:0.3	11	0	7	1	19	1:0.6
November	4	1	1	0	6	1:0.5	6	1	0	0	7	1:0.2
December	7	1	0	0	8	1:0.1*	3	1	0	0	4	1:0.3
Total	153	95	6	9	263	1:0.6*	47	12	8	6	73	1:0.5*

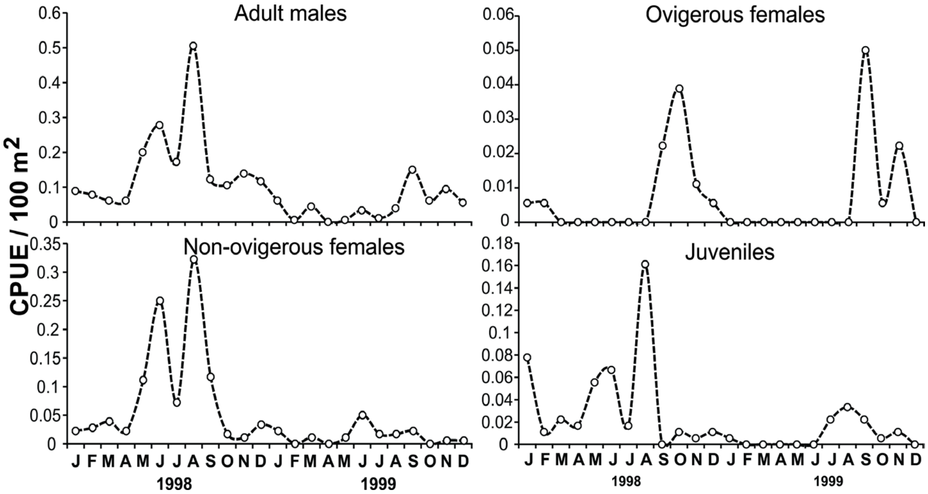

Figure 6 - Monthly distributions of specimens (catch per unit effort / 100m²), in each demographic group for Couves Island population.

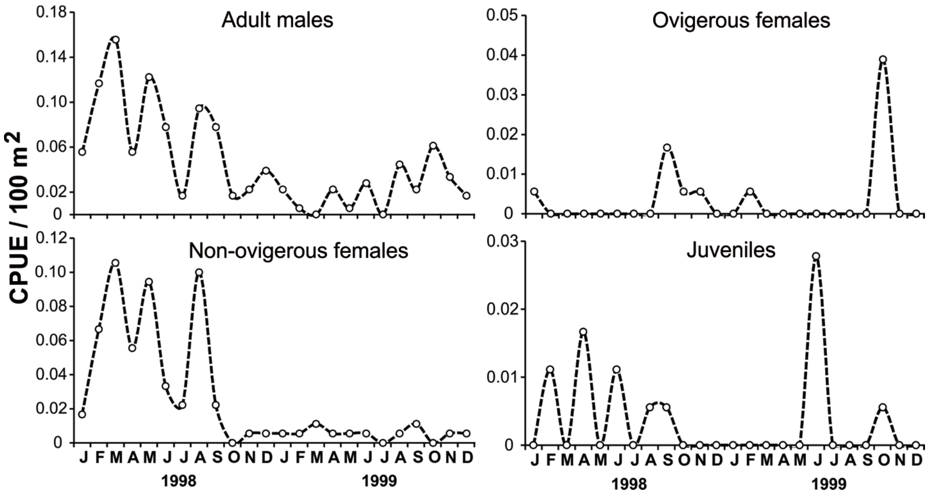

Figure 7 - Monthly distributions of specimens (catch per unit effort / 100m²), in each demographic group for Mar Virado Island population.

5th size class 100% of individuals captured were males for both populations.

The reproductive period of *D. insignis* was similar for both populations, beginning in the middle of winter with the increase of the percentage of females with developed gonad and ending in the end of the summer. There were no ovigerous females in March for both places, characterizing a seazonal reproductive pattern for the species. The recruitment differed between sites, occurring with major intensity in summer and winter for Couves Island population and during autumn and winter for Mar Virado Island population. Reproduction and recruitment data are presented in Figure 10.

Table 4 - Minimum (Min), maximum (Max), mean and standard deviation (SD) of cephalothoracic shield length (CSL) for demographic groups of *Dardanus insignis* in each island (AM = adult males; AF= adult non-ovigerous females; JM = juveniles males; JF = juveniles females; OF = ovigerous females).

	Couves Island			Mar Virado Island		
	Min.	Max.	Mean±SD	Min.	Max.	Mean±SD
AM	4	19.4	7.4 ± 1.9	4.9	24.2	8.6 ± 2.9
JM	4	4.6	4.4 ± 0.4	2.7	4.9	4.2 ± 0.7
AF	4.4	9.9	6.5 ± 1.2	4.5	9.2	7.1 ± 1.0
JF	4.4	4.6	4.3 ± 0.4	2.8	4.7	3.7 ± 0.8
OF	4.2	9.6	6.6 ± 1.3	6.2	9.8	7.6 ± 0.9

DISCUSSION

Biological information from past years may reveal changes in the structuring of populations allied to current environmental conditions. Several studies with old information was recently published with this purpose (Fransozo et al., 2011; 2012; Andrade et al., 2013a, b, c; Baeza et al., 2013; Furlan et al., 2013; *herein*). In this study, it was found that the environmental factors showed distinct variations for both sampled sites, being the SACW evidenced by means the decrease in the water surface temperature values at the Couves Island during spring and summer (Mantelatto & Fransozo, 1999; Negreiros-Fransozo et al., 1991). At Mar Virado Island, due to the proximity with the

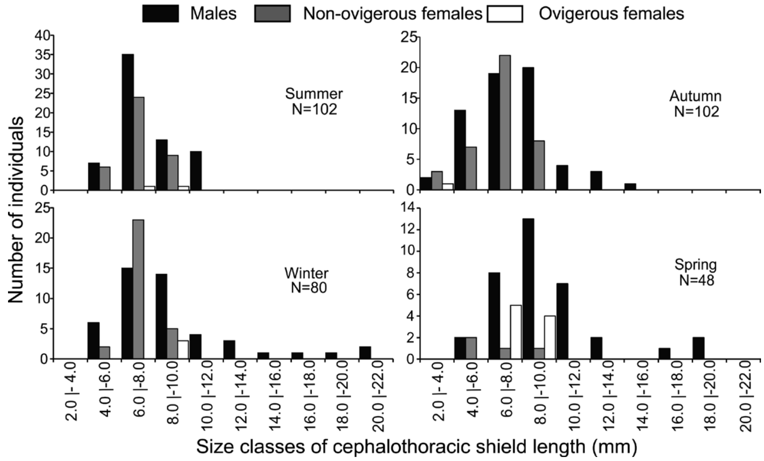

Figure 8 - Size frequency distribution of all hermit crabs captured in the Couves Island in each year season.

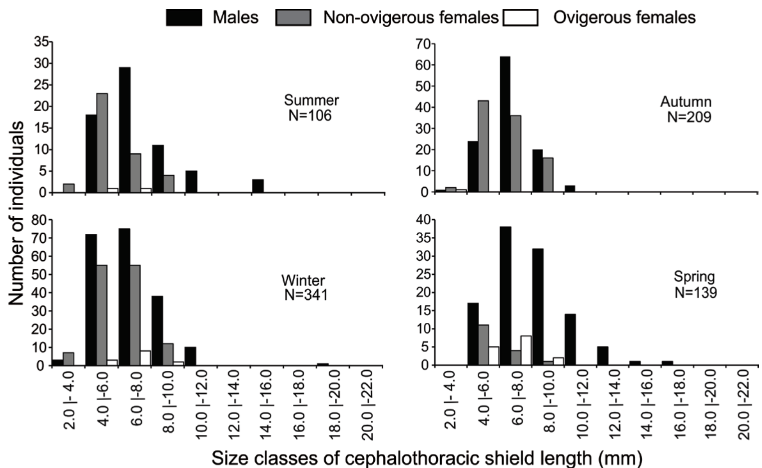

Figure 9 - Size frequency distribution of all hermit crabs captured in the Mar Virado Island in each year season.

São Sebastião Chanel, the SACW did not alter the water temperature values. The environment variations observed here, mainly concerning to temperature and sediment texture can be associated to the hydrodinamism of the water mass that acts in the south eastern Brazilian coast. The major ranges in the bottom and surface temperatures could be caused by the South Atlantic Central Water (SACW) that is formed by the submersion of the surface water in the subtropical convergence, where Brazilian and Falklands Current meeting occurs (Silveira et al., 2001). According to Odebrecht & Castello (2001), the SACW is the main source of nutrients transport in the State of São Paulo northern coast, increasing significantly the primary productivity. Considering that salinity also varied during spring, the decrease of this variable is probably to the entrance of SACW that is characterized by the difference between bottom and surface values of such environment variables. It was also observed that silt + clay in both sites were predominant that is characteristic of low hydrodinamism in the area causing finer sediment deposition (Mahiques et al., 1998). The finer sediment deposition can promote the permanency of

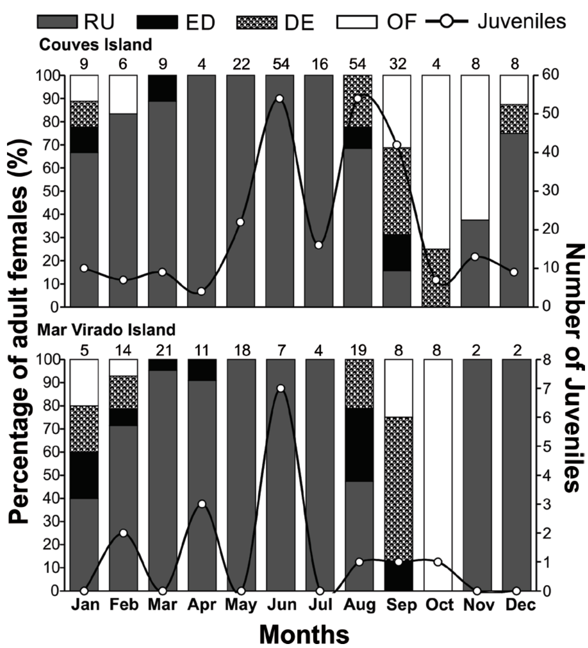

Figure 10 - Monthly variation of females percentage in each gonad development for each studied site. Number above each column indicates number of hermit crabs of each size class (RU= rudimentary; ED= developing; DE= developed; J =Total juveniles).

this species which has the habit of substrates revolving (Fernandes-Goés et al., 2005).

The unimodal size frequency of distribution is usually characterized by the occurrence of small monthly variations which can be generated due to a continuous recruitment of individuals, without the occurrence of empty size classes and mortality rates (Díaz & Conde, 1989). The size frequency distribution of *D. insignis* by environment factors size class indicated that both populations have similar behavior with respect factors variations. But it should be pointed that they also be influenced by biotic conditions, such as inter and intra specific relationships, territory defense, shell and food competiton, or mating and spawning adequate places (Hazlett, 1981). Both analyzed populations showed males reaching larger sizes than females. As mentioned by Abrams (1988), the reproductive success acquires a significant increase when males are larger than females because they got higher success in mating, being the energetic investiment between sexes driven in different conditions. Larger males trend to obtain more shells than smaller ones and also more females for reproduction.

The reproductive period was similar for both populations, being seasonal with the adult females showing developed gonad or egg mass from the late winter to all summer. Branco et al. (2002) in the southern Brazil, recorded the same reproductive pattern with a peak between the months of September and November. This discontinuous pattern was also recorded for other hermit crab species such as *P. diogenes* by Bertini & Fransozo (1999b) and *Paguristes erythrops* (Holthuis, 1959) by Garcia & Mantelatto (2001). As mentioned by Negreiros-Fransozo et al.(1992), hermit crabs from tropical and subtropical regions, concentrate their reproductive periods in the warmer months of the year, when the food resources for larvae are more abundant and the higher water temperatures accelerate the metamorphosis process. These conditions are extremely important for hermit crabs of the genus *Dardanus* (Paulson, 1875), as they pass through 8 zoeal stages before reach the megalopa stage, and should spend much time (approximately 40 days) in plankton before to metamorphoses (Hebling & Mansur, 1995). De Léo & Pires-Vanin (2006) verified that the northern coast of the State of São Paulo littoral shows an own productivity regime influenced by the SACW action, that provides food for larvaes favoring conditions for the breeding period.

The sex-ratio showed bias from the expected values (1 : 1; Fisher, 1930) in favour of males for each population. Similar results were found by Bertini & Fransozo (2000) for *Petrochirus diogenes* (Linnaeus, 1758); Bertini et al. (2004) for *Loxopagurus loxochelis* (Moreira, 1901) and by Fernandes-Goés et al. (2005) for *D. insignis* in the Ubatuba region. This ratio, according to Wenner (1972) is an anomalous pattern, commonly verified for marine adult crustaceans. Besides this, the sex-ratio could influence the size of population acting on its reproductive potential (Giesel, 1972).

Despite of the distinct environment features of Couves and Mar Virado Islands, mainly substratum (organic matter content and texture); it was verified similar abundance of *D. insignis* in the comparisons. Reproduction period was seasonal for both populations (from late winter to summer); juvenile recruitment occurred in summer, but less evident in Mar Virado Island. In short, both populations shared similar pattern concerning population structure and reproduction the islands studied. Such informations are useful for monitoring this species and, consequently, the environmental conditions found in the southeastern Brazilian islands.

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