

REPRODUCTIVE ECOLOGY OF THE BLUE CRAB, *Callinectes danae* SMITH, 1869 IN THE CONCEIÇÃO LAGOON SYSTEM, SANTA CATARINA ISLE, BRAZIL

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(With 8 figures)

ABSTRACT

Abundance of ovigerous females, size of the first gonadal maturation and the possible migration, route of the blue crab *Callinectes danae* from the Conceição Lagoon system, Santa Catarina Isle, Brazil, are described. This lagoon is connected with the coastal area through a canal. A total of 1,124 crabs was caught during a 19 month sampling period. The reproduction and recruitment of juveniles occurred all year-round, with two peaks of abundance (February and September), correlated with the presence of ovigerous females (June and January). The mean carapace width at which the crabs attained gonadal maturity for the first time was 9.4 cm in males and 8.4 cm in females. The Conceição Lagoon is a growth, reproduction, and spawning area for the species. However, egg eclosion occurs outside the lagoon following migration of ovigerous females to the open sea. After hatching the eggs, some females return to the lagoon, but males stay there for most of their life cycle.

Key words: *Callinectes danae*, reproductive ecology, Portunidae.

RESUMO

Ecologia reprodutiva de *Callinectes danae* Smith, 1869 na Lagoa da Conceição, Ilha de Santa Catarina, Brasil

Neste trabalho são analisados a abundância de fêmeas ovígeras, o tamanho de primeira maturação gonadal e a possível rota de migração do siri azul *Callinectes danae* na Lagoa da Conceição, Ilha de Santa Catarina, Brasil. A lagoa está conectada com a área costeira por meio de um canal. Um total de 1.124 siris foram coletados durante 19 meses de amostragens. A reprodução e o recrutamento de juvenis ocorrem ao longo do ano, com dois picos de abundância (junho e janeiro). A largura média de carapaça que os siris atingem o tamanho de primeira maturação gonadal foi estimado em 9,4 cm para machos e 8,4 cm para fêmeas. A Lagoa da Conceição funciona como uma área de crescimento, reprodução e desova para a espécie. Entretanto, a eclosão das larvas ocorre fora da lagoa com a migração das fêmeas ovígeras para mar aberto. Após a eclosão, algumas fêmeas retornam para a lagoa, enquanto os machos permanecem na lagoa ao longo da vida.

Palavras-chave: *Callinectes danae*, ecologia reprodutiva, Portunidae.

INTRODUCTION

The Conceição Lagoon system supports an important fishery for penaeid shrimps, fishes and crabs, among which the blue crab, *C. danae* Smith, 1869, is the second species in the ranking of fishing produce. Besides this economic aspect, the lagoon is also considered a scenic and archaeological patrimony that is vulnerable to human impact (Sierra de Ledo, 1990).

Despite the wide distribution of *C. danae* along the Brazilian Atlantic coast, from Paraíba to Rio Grande do Sul (Melo *et al.*, 1989), on its ecology is from in the Mundaú Lagoon, Alagoas State (Pereira-Barros & Travassos, 1975), in Santos Bay, São Paulo State (Pita *et al.*, 1985; Moreira *et al.*, 1988), and reproductive cycle in the Ubatuba region (Costa & Negreiros-Fransozo, 1998).

In overseas countries, recent information about population studies of portunids crabs is based mainly on *Callinectes sapidus* from various estuaries of the North Atlantic (Montfrans *et al.*, 1991; Steele, 1991; Fitz & Wiegert, 1991, 1992; Hsueh *et al.*, 1993; McClintock *et al.*, 1993; Steele & Bert, 1994).

Previous work on the population structure of *C. danae*, designated the Conceição Lagoon as a local where individuals developed from juveniles to adult specimens. Also, mating activities occur inside the lagoon (Branco & Masunari, 1992). There are two abundance peaks due to recruitment of juveniles inside the lagoon, but it was possible to detect the coexistence of seven cohorts in the lagoon population (Branco & Masunari, 1993).

The average fecundity of *C. danae* was estimated to be 598.885 eggs per female, and there is a direct correlation between the average number of eggs (or egg mass weight) and female size (Branco & Avila, 1992). Based on the condition factor and gonadosomatic index of the species, Branco *et al.* (1992) reported as May, November, January and March, as the most frequent months of spawning.

The present paper describes the reproductive ecology of *C. danae* in terms of abundance of ovigerous females, annual fluctuation of the condition factor, size (carapace width) at which the crabs attain gonadal maturity for the first time, and the probable migration route in the Conceição Lagoon system and the open marine area, in an attempt to understand the life history of the

species and to plan a regulated coastal management in the future.

MATERIAL AND METHODS

The study site includes a coastal lagoon (Conceição Lagoon) and a sandy beach (Barra Beach) on the eastern side of Santa Catarina Isle, in southern Brazil (27°30'30"-27°37'15"S, 48°00'00"W), near the city of Florianópolis (Fig.1). The lagoon is 13.5 km long and its width ranges 0.15-2.50 km, accounting for an area of 19.2 km² and a water volume of 40 x 10⁶ m³ (Knoppers *et al.*, 1984; Caruso-Gomes Jr., 1989). There is a connection with the coastal area at Barra Beach through a canal 2 km long, 20 m wide and 2 m deep. Three subsystems have been recognized in the lagoon, North, Central and South, based on their physico-chemical properties, geology and bathymetry (Branco & Masunari, 1992). Nine sampling stations inside the lagoon and one at Barra Beach (coastal area) were established (Fig.1). A quantitative sample of crabs was taken monthly from each collection station at night with the aid of illumination by a gas lantern, from January 1988 through July 1989, except for April/88, November/88 and April/89. Temperature and salinity of the surface water were measured monthly from January 1988 through March 1989, except for April/88 and November/88. The crabs were caught with a conic hand net with a mouth diameter of 30 cm and a 5.0 mm mesh. The "catch per unit effort" (CPUE) was the number of crabs caught in 30 minutes covering an area of 100 m². The depth range of the sampling sites was 20-150 cm.

The collected animals were pooled per station for analysis of population characteristics. Each blue crab was identified and sexed; ovigerous females, mating couples and molting individuals were also noted.

Determination of the gonadal maturation stage followed Taissoun (1969). For each crab, the carapace width (Wid) between the tips of the two lateral spines was measured to the nearest 0.1 mm with calipers (Mitutoyo), and total weight (Wt) was also measured. For further details of methodology see Branco & Masunari (1992). Every month the mean fitted condition factor of both sexes was calculated, according to Santos (1978). The carapace width at the first gonadal maturation also Vazzoler (1981).

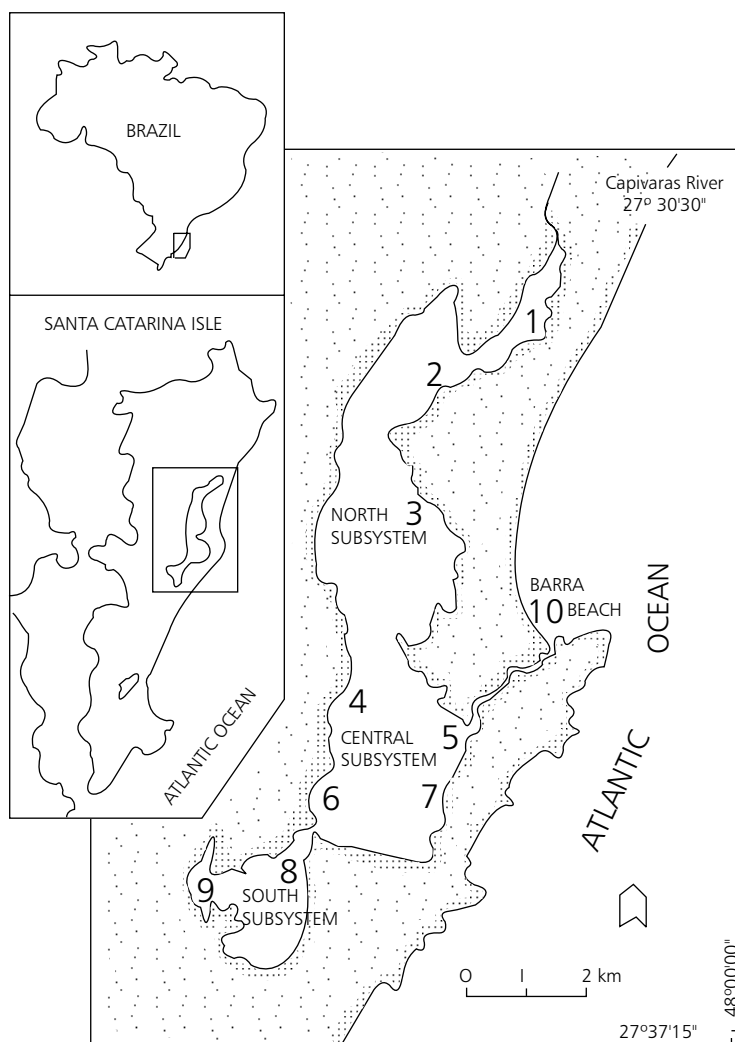


Fig. 1 — Conceição Lagoon system. Station locations (arabic numerals) inside the lagoon and at Barra Beach.

RESULTS

The temperature of the surface water showed a well defined seasonal fluctuation in the three subsystems: high values in summer months and lower ones in late autumn and early winter. The mean surface temperature in the Central subsystem varied from 13.0°C (June) to 26.0°C (January). In the South subsystem the fluctuation ranged from 12.5°C to 27.6°C and in the North subsystem, from 12.3°C to 27.8°C (the fluctuation range surpassed 15.0°C). Differences in excess of 2°C were not observed among the subsystems in any sampling month, with the exception of the North subsystem

in January/89 (Fig. 2). The value was then about 5°C lower than in the Central and South subsystem.

The overall fluctuation of the surface water salinity ranged from 26.0 ‰ (February) to 35.5 ‰ (March). Higher values in the Central subsystem followed by those in the North and South subsystems from January/88 to January/89 were observed and appeared to reflect their proximity to the coastal area. After January/89, salinity was highest in the North subsystem. In this subsystem, salinity oscillated from 28.5 ‰ to 35.5 ‰, the widest range observed. Except for June/88, in each month the difference in salinity values among the three subsystems was always at least 1.0 ‰ (Fig. 3).

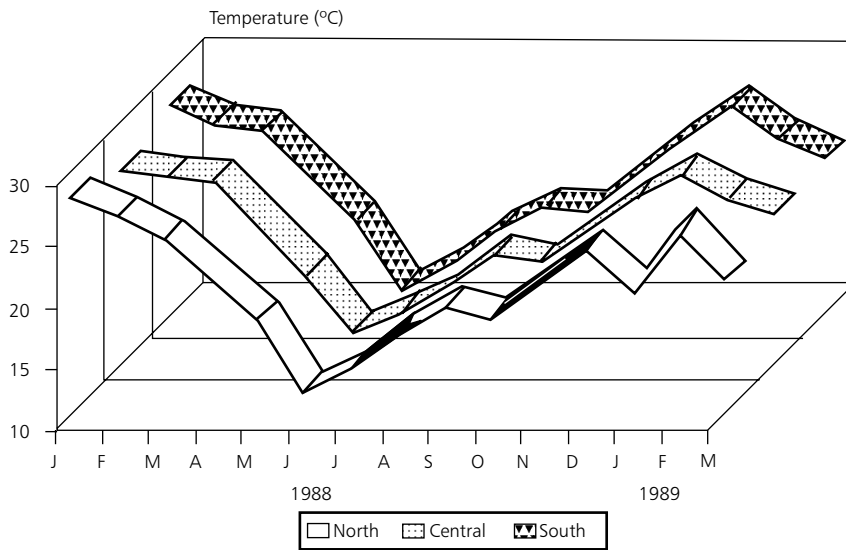


Fig. 2 — Conceição Lagoon. Annual fluctuation of monthly mean temperature ($^{\circ}\text{C}$) of surface water in the North, Central and South subsystems during the study period. There were no collections in April/88 and November/88; the data of these months were interpolated.

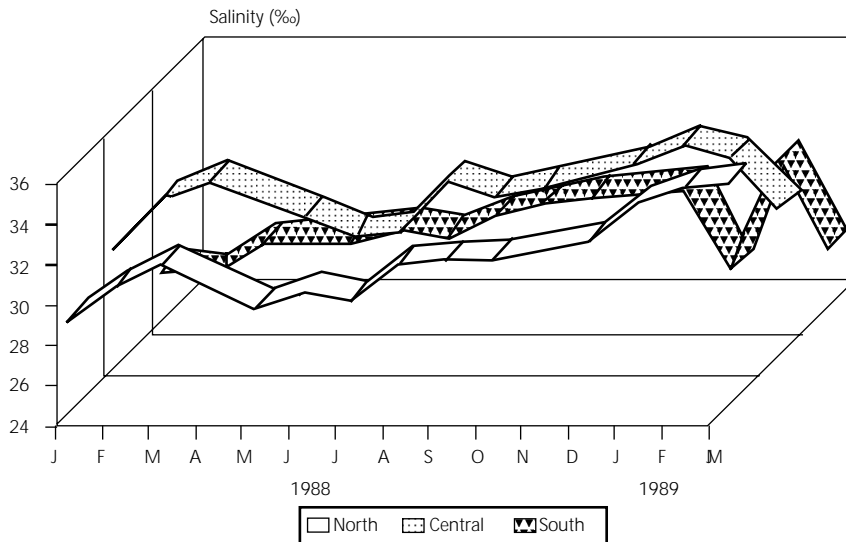


Fig. 3 — Conceição Lagoon. Annual fluctuation of monthly mean salinity (‰) of surface waters in the North, Central and South subsystems during the study period. The data were interpolated in April/88 and November/88.

During the 19 month sampling period, a total of 1.124 individuals of *C. danae* was collected (613 males and 511 females). The carapace width of the males ranged from 1.5 to 13.5 cm accounting for 13 classes of 1.0 cm interval, and that of the females from 2.0 to 11.5 cm, with 10 classes (Fig. 4). There

was overlap in carapace width of the juveniles and adults for both sexes. The overlap range in males was larger than in females. Male classes larger than 11 cm and female classes larger than 10 cm always. Ovigerous females occurred months, suggesting reproductive activity of the species almost all year

round (Fig. 5), but showed main peaks during the former year: in June/88 (88.2%; winter peak), January/89 (84.6%; summer peak), June (80.0%) and July/89 (85.7%; winter peak). Except for October/88, the other frequencies were lower than 50.0%.

The monthly variation of the mean fitted condition factor of males and females ranged from 0.067 (March/89) to 0.094 (September/88) for males, and from 0.068 (May/89) to 0.080 (July/89) for females (Fig. 5). The curve of the mean condition factor for males showed two peaks: the first in January/88 (0.091) and the second in September/88 (0.094). In the remaining months, the values fluctuated slightly at much lower levels: from 0.067 in March/89 to 0.080 in October/88

(Fig. 5). No correlation was found between mean condition factor and the developmental stage (juvenile or adult) of the males: high proportions of juveniles were related both to high values of condition factor (Jan/88 and September/88, for example) and low values (March/89, for example) (Fig. 5, Table 1). For females, the curve of mean condition factor showed high values related to high proportions of ovigerous females only in winter peak (June/88 and July/89) and a high proportion of non-ovigerous adult females (March/89). On the other hand, the lowest values of mean condition factor were related to a high proportion of juveniles (August/88, September/88 and February/89 (see Fig. 5 and Table 1).

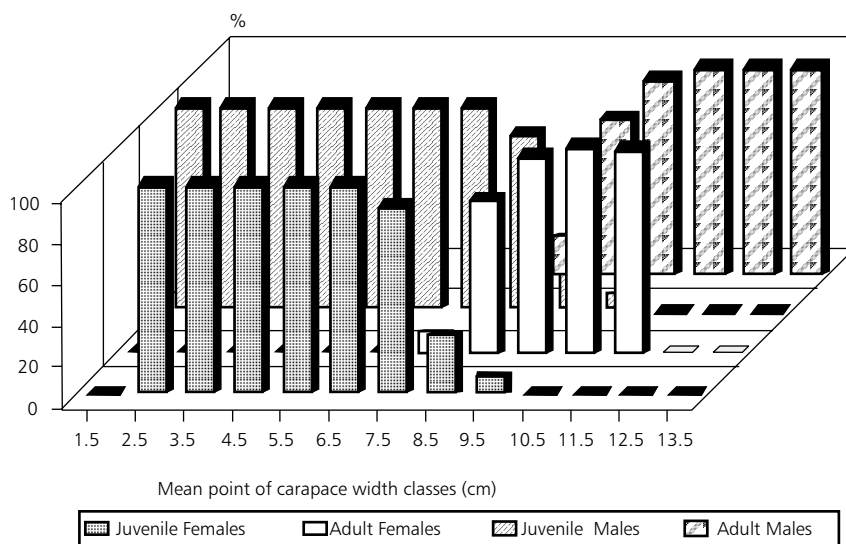


Fig. 4 — *Callinectes danae*. Distribution of relative frequencies of captured crabs ($N = 1,124$) during the period from January/88 to July/89, in carapace width classes (cm).

A total of 91 ovigerous females accounted for 47.6% of the total adult females Table 1. Their CPUE value was the highest in the coastal area, followed by the Central and North subsystems; no ovigerous female was captured in the South subsystem; in winter, number of collected ovigerous females in the coastal area was 52 times greater than that of the Central subsystem (Fig. 6). Females from the North and Central subsystems showed yellowish eggs, whereas, in the coastal area the eggs were brownish, and therefore more developed. The curves in the Fig. 7 was plotted based on the

relative frequencies of juveniles and adults of both sexes. The mean carapace width at which the crabs attain gonadal maturity for the first time was estimated by Figure 7: $Wid_{pm} = 9.4$ cm (for males), $Wid_{pm} = 8.4$ cm (for females).

The probable migration route of *C. danae* during their life cycle in the Conceição Lagoon system is reproduced in Fig. 8, based on previous studies (Branco & Masunari, 1992 and 1993) and the present data. In Conceição Lagoon juveniles of *C. danae*, approximately four months old, reach a mean carapace width of 2.5 cm.

TABLE 1
Distribution of number of males and females of *Callinectes danae* during the sampling period (1988-1989) from Conceição Lagoon system. Relative frequency (%) of ovigerous females (RFOVI) is also presented. JU = juveniles; ADU = adults; OVI = ovigerous females.

MONTHS	MALES		FEMALES				TOTAL
	JU	ADU	JU	ADU	OVI	RFOVI	
January/88	13	5	9	5	3	37.50	35
February	94	39	60	29	17	36.95	239
March	35	14	31	4	1	20.00	85
May	11	18	7	2	2	50.00	40
Jun	17	16	1	4	30	88.23	68
July	17	3	10	2	1	33.33	33
August	27	2	13	1	1	50.00	44
September	69	7	78	1	1	50.00	156
October	50	10	36	5	7	58.33	100
December	5	14	14	8	2	20.00	43
January/89	17	10	13	2	11	84.61	53
February	48	9	23	1	1	50.00	82
March	19	11	17	33	3	8.33	83
May	9	2	3	2	1	33.33	17
Jun	9	4	3	1	4	80.00	21
July	6	3	1	1	6	85.71	17
TOTAL	446	167	319	101	91		1124

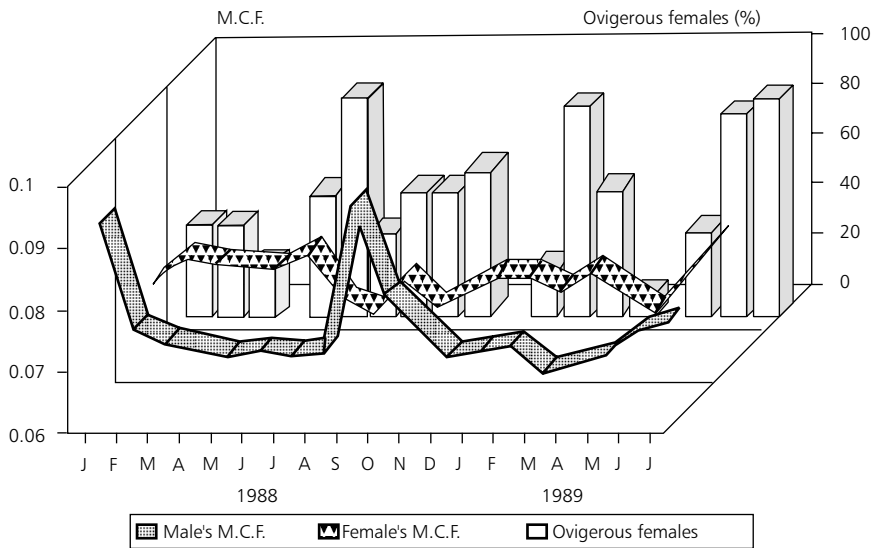


Fig. 5 — *Callinectes danae*. Fluctuation of the relative frequency (%) of ovigerous females (histogram) inside Conceição Lagoon and Barra Beach (coastal area) during the study period. Annual fluctuations of the mean condition factor (M.C.F.) of males and females are also showed (curves). The data were interpolated in April/88, November/88 and April/89.

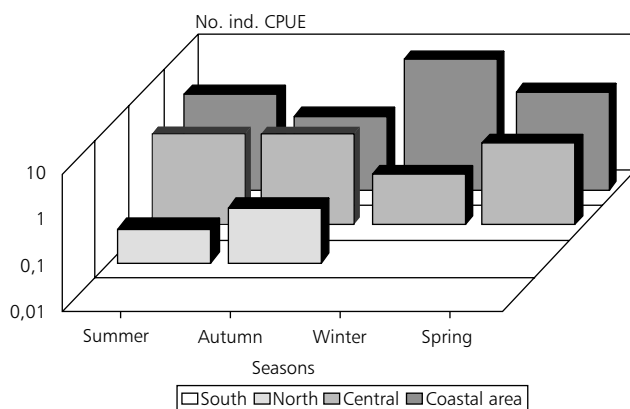


Fig. 6 — *Callinectes danae*. Distribution of ovigerous females (CPUE) in the lagoon subsystems and the coastal area during seasons of the year.

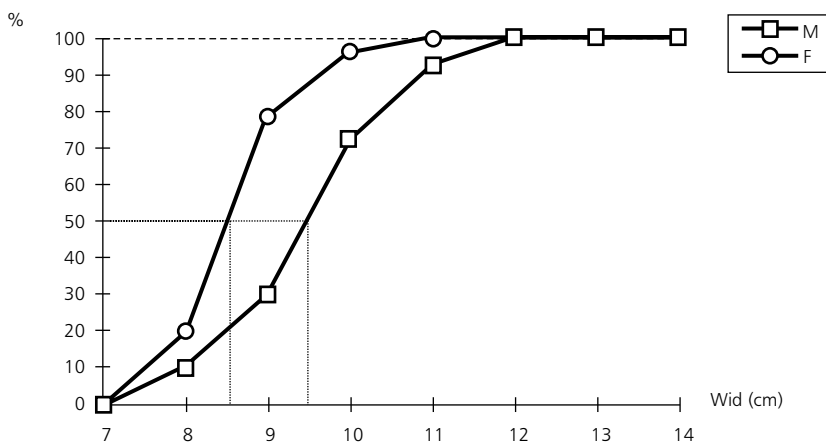


Fig. 7 — *Callinectes danae*. Distribution of the relative frequencies of adult males and females in carapace width classes. Wid_{pm} (mean carapace width at which males = 9.4 cm and females = 8.4 cm attain gonadal maturity for the first time).

After several moultings, young crabs develop into adults in about a year and half, when the males measure 9.4 cm and the females, 8.4 cm carapace width (Fig. 7).

Mating of the species probably occurs only inside the lagoon, as no mating couples were recorded outside. The presence of almost 100 % of sampled males inside the lagoon corroborates this hypothesis. The three subsystems of the lagoon function as a place for juvenile grow, adult mating, and female spawning (egg extrusion onto endopodites of the female pleopods). While males stay inside the lagoon, ovigerous females leave it through the canal and the larval hatching occurs in the saltier

waters or open sea. After planktonic life (zoea and megalopa), the juvenile crabs 1 or 2 enter the lagoon and complete their life cycle (Fig. 8).

Ovigerous females with a carapace width of 8.5 to 9.5 cm and 21 months old were frequent by caught inside the lagoon, suggesting that they stay after spawning within the lagoon. Immediately before the larvae hatch the ovigerous females leave the lagoon through the connecting canal toward the open sea. The high proportion of females carrying brownish egg masses in the Barra Beach area corroborates this assumption. Hatching probably occurs in the open sea, where salinity is higher than inside the lagoon.

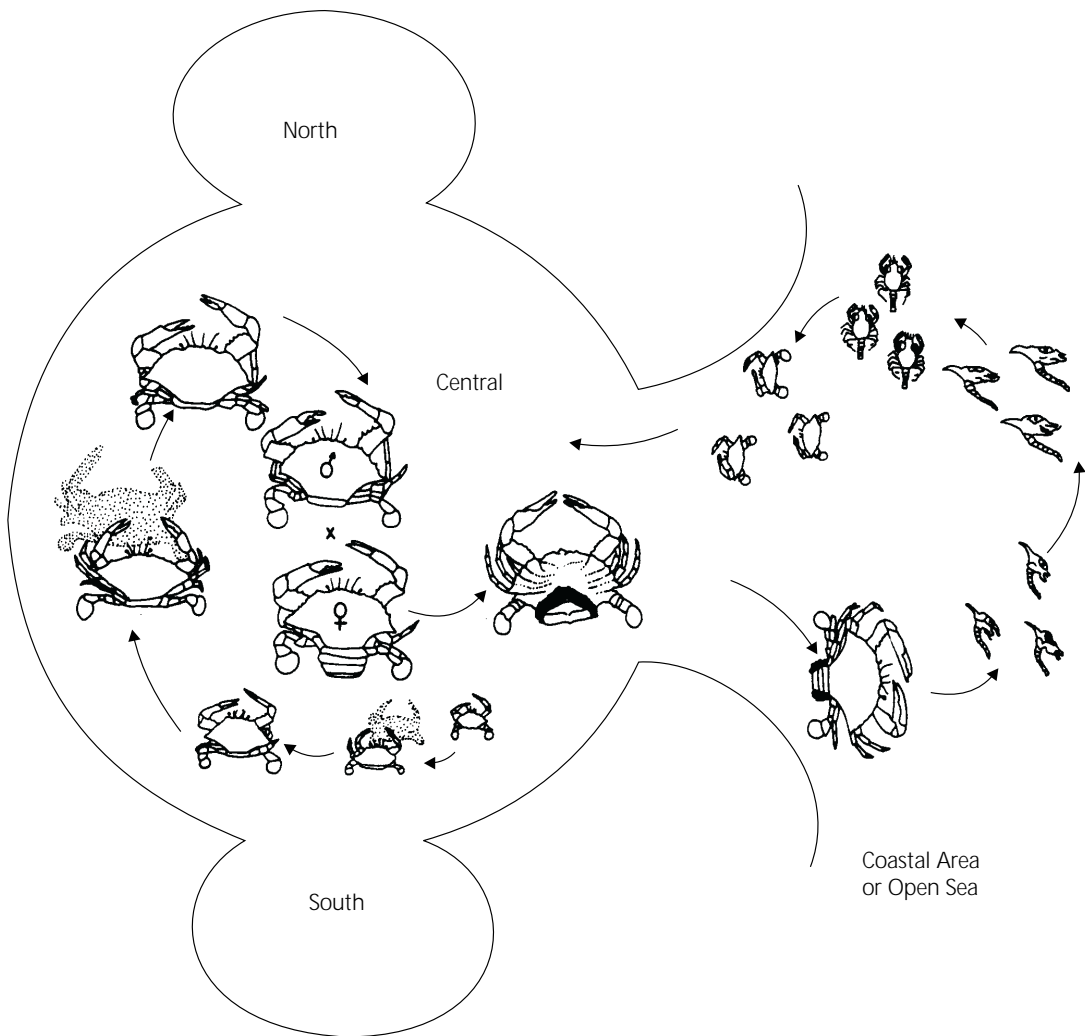


Fig. 8 — *Callinectes danae*. Probable migration route of various stages of development during life cycle in the Conceição Lagoon subsystems and the coastal area or open sea.

Systematic sampling with plankton nets along the canal failed to identify any planktonic larvae of *Callinectes* (Fig. 8). As the canal is the only opening to the lagoon system, it is assumed that populations of *C. danae* enter the lagoon as juvenile crabs with a carapace width of less than 10 mm. After egg hatch, many formerly ovigerous females return to the lagoon. Some females caught in the canal carried residual eggs attached to the pleopods and epizoic animals, such as barnacles, newly attached to their carapaces (Fig. 8). The males stay inside probably the lagoon overing their whole life time.

DISCUSSION

According to Koeppen (1918) the Santa Catarina Isle lies in a region of humid mesothermic climate type Cfa with rain distributed uniformly all year-round, and a hot summer. The Conceição Lagoon is within the isotherm of 20°C, where the air temperature has a mean annual variation of 7.9°C and a daily variation of 4.2°C. Temperatures higher than 40.0°C and lower than 7.0°C are registered only exceptionally (INEMET, 1980). The temperature of the surface water in Conceição Lagoon fluctuated as reported in previous studies

(Knoppers *et al.*, 1984; Odebrecht & Caruso-Gomes, Jr., 1987). The fluctuation of the surface water salinity documented in the present paper is according to Pritchard, 1967 *apud* Levinton, 1982 typical of estuarine lagoons. The fluctuation range was far from the lethal values observed in the laboratory for *C. danae*; at 0 ‰ salinity the death rate is 100% after five hours, and the gradual increase of salinity the death rate lessens from 2.0 ‰ to 35.0 ‰ (Pereira-Barros, 1987). However, the salinity range inside Conceição Lagoon seemed inadequate for the release of the larvae, as the females migrated to the coastal area. This migration of the ovigerous females from estuarine waters to saltier waters is a common behavior of other portunid crabs, such as *C. sapidus* (Mcclintock *et al.*, 1993) and *C. similis* (Hsueh *et al.*, 1993) from estuaries of the North Atlantic. Also, the males of both species stayed in the estuarine waters.

Steele & Bert (1994) described the habitat partitioning related to salinity by different developmental stages and sex of *C. sapidus* in Tampa Bay, Florida, a subtropical estuary in the Gulf of Mexico, where males prefer lower salinities. In Conceição Lagoon, we recorded the lowest salinities in the South subsystem (mean value 28.3 ‰), followed by the North (31.6 ‰) and Central (32.4 ‰) subsystems. No habitat partitioning was observed in the population of *C. danae*, and the absence of ovigerous females in the South subsystem may be related to the low salinities.

The canal connecting Conceição Lagoon and the coastal area constitutes an exit for migration for spawning females and an avenue for the return of juvenile crabs. In a parallel case, the Chesapeake & Delaware Canal between upper Chesapeake Bay and Delaware Bay (USA), has not been found to be a recruitment corridor (Miller *et al.*, 1975). This due to the length of this canal where the populations of juvenile and male crabs are supported and abundances fluctuated according to the season. In addition, that canal connects two estuaries, instead of an estuary and coastal area.

The difference between male and female condition factor is probably due to the higher weight of the female gonads. Nevertheless, as epizotic animals were more frequent among females, especially ovigerous ones, they may have contributed to a higher female condition factor.

According to Vazzoler (1981), the size of first gonadal maturity is an important parameter when a population is removed from its natural habitat, as it offers data for the analysis of how an exploratory activity affects the reproducing individuals. The carapace width at which *C. danae* attains gonadal maturity is highly variable, as is the time it takes to achieve it. Such variations were observed also in *C. sapidus* by Van Engel (1958) and Tagatz (1968a,b). The difference between the mean first gonadal maturity size of males and females observed in *C. danae* may have been due to a higher number of male moultings after gonadal maturation, in contrast with arrested growth of females, as is known in *C. sapidus* (Van Engel, 1958).

Despite the wide range of variation of first gonadal maturity size, based on the data presented, it is recommended that 9.4 cm for males and 8.4 cm for females must be established catch limits.

Probably, spawning of *C. danae* takes place inside the lagoon as the ovigerous females captured there carried egg mass, parallel with *C. similis* from the Gulf of Mexico (Garcia-Montes *et al.*, 1988). According to Van Engel (1958), hatching of *C. sapidus* occurs in the ocean; after six months the larvae reach to juvenile crab 1 and, thereafter, migrate to rivers and estuarine waters of Chesapeake Bay (USA). Crab 1 reaches sexual maturity through 18 or more ecdyses in a period of one year and a half. Assuming the same planktonic life period for *C. danae* from the Conceição Lagoon system, it is possible to infer that the two peaks in the ovigerous female abundance curve observed in June and January are related to the recruiting of juveniles in September and February, respectively. Then, larvae coming from the ovigerous females in June contribute to the juvenile population (5.5 cm of mean carapace width) in September, and larvae coming from ovigerous females in January to the juveniles in February: a period of about 12-15 months from hatching to the attainment of 5.5 cm carapace width.

The developmental stage in which *C. danae* enters Conceição Lagoon deserves an additional study: if megalopa or juvenile crab. Recent works on ecology of *C. sapidus* larvae suggest its probable settlement and re-invasion towards the estuary in the megalopa stage (Luckenbach & Orth, 1992; Boylan & Wenner, 1993; Hsueh *et al.*, 1993; DeVries *et al.*, 1994; Forward *et al.*, 1994; Olmi,

1994; Tankersley & Forward, 1994; Wolcott & DeVries, 1994; Lochmann *et al.*, 1995).

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