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Feeding habits of the false southern king crab *Paralomis granulosa* (Lithodidae) in the Beagle Channel, Tierra del Fuego, Argentina*

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SUMMARY: Stomach contents of 282 false southern king crabs (*Paralomis granulosa*), between 10 to 90 mm CL from the Beagle Channel (Golondrina Bay and Roca Mora), Argentina, were examined by the frequency of occurrence method of analysis and by a food index. Roca Mora is an area where juveniles (<50 mm CL) dominate and in Golondrina Bay adults (>60 mm CL) are common; in this last area sexual segregation was also observed. The principal food groups for crabs of Golondrina Bay were algae, molluscs, crustaceans, bryozoans and foraminiferans; for crabs from Roca Mora the natural diet consisted of three major food groups: hydrozoans, echinoderms and foraminiferans. The relative frequency of different prey groups varied in relation to the size, season and sex. There were no significant differences in the quantity of food consumed by sexes in both areas. Generally small crabs (<40 mm CL) contained more food than large crabs (>50 mm CL). Juveniles consumed a greater amount of food during winter and spring. In summer (moulting period), juveniles had the highest vacuity index. Adults consumed minor amounts of food during autumn, before the spawning-moulting-mating period when the vacuity index was higher (spring).

Key words: Feeding habits, natural diet, crabs, *Paralomis granulosa*, stomach contents, Lithodidae.

RESUMEN: HÁBITOS ALIMENTARIOS DEL CENTOLLÓN *PARALOMIS GRANULOSA* (LITHODIDAE) EN EL CANAL DEL BEAGLE, TIERRA DEL FUEGO, ARGENTINA. – Se analizaron 282 contenidos estomacales de centollón (*Paralomis granulosa*), comprendidos entre 10 mm y 90 mm de largo de caparazón (LC), provenientes del Canal del Beagle (Bahía Golondrina y Roca Mora), Argentina. El análisis se basó en la frecuencia de presencia de los grupos que conforman la dieta y el peso relativo del contenido estomacal. Roca Mora es un área dominada por juveniles (<50 mm LC) y Bahía Golondrina por adultos (>60 mm LC). En esta última se observó segregación sexual. Los principales grupos que conforman la dieta de los individuos de Bahía Golondrina fueron algas, moluscos, crustáceos, briozoos y foraminíferos; mientras que para los de Roca Mora la dieta natural comprende tres grupos principales: hidrozoos, equinodermos y foraminíferos. Las frecuencias relativas de los diferentes grupos variaron en relación a la talla, época de muestreo y sexo. No se detectaron diferencias significativas en la cantidad de alimento consumido en relación al sexo en ambas áreas. Generalmente los cangrejos pequeños (<40 mm LC) contenían más cantidad de alimento que los mayores (>50 mm LC). Los juveniles consumieron mayor cantidad de alimento durante el invierno y primavera. Durante el verano (período de muda) se determinó el mayor índice de vacuidad. Los adultos consumieron mayores cantidades de alimento durante el verano, después del período de desove-muda-apareamiento cuando el índice de vacuidad fue mayor (primavera).

Palabras clave: Hábito alimentario, dieta natural, cangrejos, *Paralomis granulosa*, contenido estomacal, Lithodidae, centollón.

INTRODUCTION

The false southern king crab, *Paralomis granulosa* (Jacquinot, 1847), commonly called “centollón”, is a commercial species in Chile and Argentina since the early 1970’s. For Argentina the largest catches were recorded in 1995 when they amounted to 320 metric tons. This species inhabits the Pacific Ocean from Paso Tenaún, Chile, to Cape Horn, Argentina, and the Atlantic Ocean from 56°S to the

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Golfo San Jorge, including the Malvinas Islands at depths of up to 50 m (Macpherson, 1988).

Studies on the biology are scarce (Campodónico, 1977; Campodónico and Guzmán, 1981; Campodónico *et al.*, 1982; Vinuesa *et al.*, 1989; Comoglio *et al.*, 1990; Lovrich and Vinuesa, 1993). Food habits have been analyzed for numerous crab species, including *Chionoecetes bairdi* (see Paul *et al.*, 1979; Jewett and Feder, 1983), *Paralithodes camtschatica* (Tilesius, 1815) (see Mc Laughlin and Hebard, 1961; Takeuchi, 1968; Feder and Paul, 1980; Feder and Jewett, 1981; Jewett and Feder, 1982), *Callinectes sapidus* Rathbun, 1896 (see Ryer, 1987; Ropes, 1988) and *Lithodes santolla* (Molina, 1782) (see Comoglio and Amin, 1996).

The shredding of prey by mouthparts and further mastication by the gastric mill makes identification of prey species difficult (Stevens *et al.*, 1982). However, a study of the food habits of the crab is of considerable importance because food availability and utilization may play important roles in the distribution, migration and moulting patterns of the crabs.

This report indicates the types of organisms that contributed to the diet of *Paralomis granulosa* in terms of the frequency of occurrence and the amount of food in the stomachs.

MATERIAL AND METHODS

Specimens of *Paralomis granulosa* were collected during 1988-1989 (N=282) in Golondrina Bay (40.78%) and Roca Mora (59.57%) (Fig. 1), by SCUBA. In the laboratory, crabs were measured (CL, carapace length, defined as the distance from the posterior margin of the orbital indentation to the mid-point of the posterior marginal indentation, in mm), weighed (WT, wet weight, in g) and sexed.

Foreguts were isolated immediately and contents, when present, were removed and weighed to the nearest 0.01 g, then fixed in 10% buffered seawater formalin. Prey organisms were identified to the lowest possible taxonomic level using a dissecting microscope.

For size comparisons, crabs were divided into 8 size classes of 10 to 19.9 mm; 20 to 29.9 mm; etc., then analyzed as 8 discrete samples. The percentage frequency of occurrence (F) for each prey taxon identified in the stomachs was calculated.

The Wilcoxon Signed Rank test and Kruskal-Wallis test were used in analyzing the relative food weight of crabs (stomach content weight/body weight) by a classification factor. A P-value was calculated and if found to be less than 0.05, a third pro-

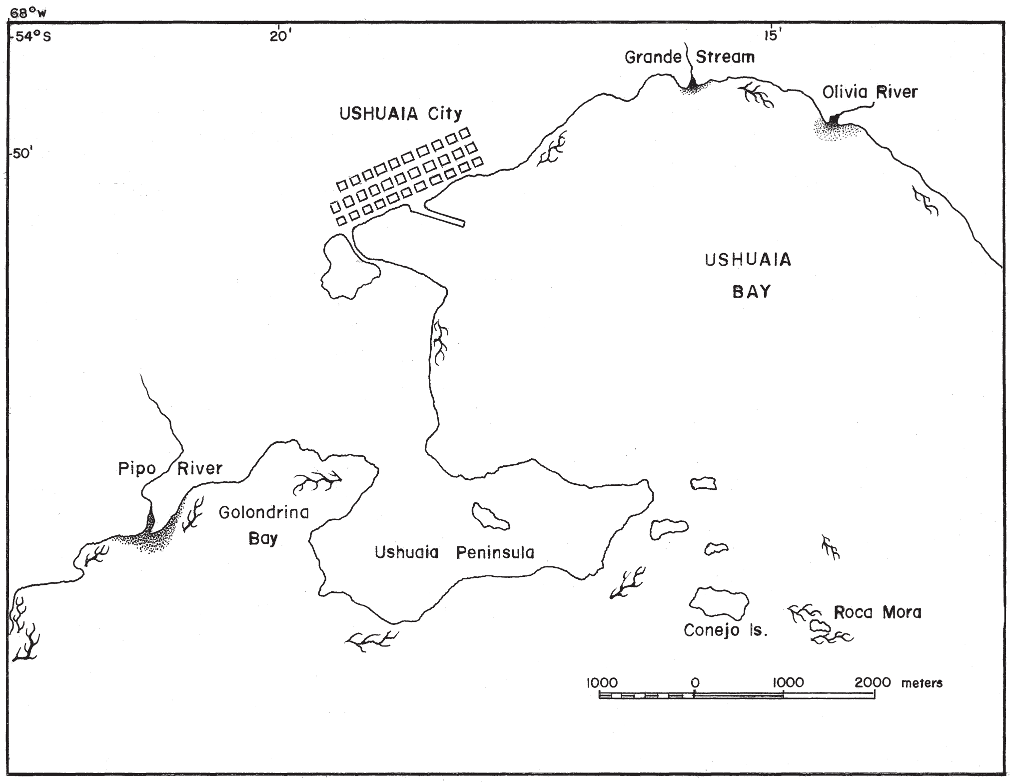

FIG. 1. – Locations where false king crabs, *Paralomis granulosa*, were collected for stomach analyses.

TABLE 1. – Number of crabs with food by sampling areas, sexes and size classes.

Size classes	Golondrina Bay			Roca Mora		
(CL in mm)	Male	Female	Total	Male	Female	Total
10-19.9	0	0	0	11	9	20
20-29.9	0	0	0	42	42	84
30-39.9	0	0	0	12	6	18
40-49.9	3	0	3	0	0	0
50-59.9	4	3	7	1	7	8
60-69.9	18	11	29	9	7	16
70-79.9	27	8	35	0	0	0
80-89.9	13	0	13	1	0	1
90-99.9	1	0	1	0	0	0
Total examined	65	22	87	76	71	147
(%)	74.71	25.29		51.7	48.3	

cedure was employed to make multiple comparisons using the rank sums (Daniels, 1978).

RESULTS

General considerations

The overall vacuity index (percentage of empty stomachs) was 11.0%. The crabs examined ranged from 10 mm to 99.9 mm CL (Table 1). 17 crabs (6.0%) with food in their stomachs were damaged and were discarded without further analysis.

Crabs (N = 234) were analyzed taking into account the different areas. Roca Mora is an area where we principally found crabs <40 mm CL, and few crabs with CL>50 mm (only during summer months). In Golondrina Bay specimens were principally CL>60 mm. The percentage of females was 25.3% for Golondrina Bay and 48.3% for Roca Mora.

Natural diet

Some species of molluscs that could be determined in the stomach contents were *Mytilus edulis chilensis* Hupe, 1854, *Aulacomya ater* Molina, 1782, *Hyatella solida* (Sowerby, 1834), *Margarella violacea* (King and Broderip, 1831), *Calliostoma nudum* (Phillippi, 1845) and *Fissurella picta* (Gmelin, 1791).

Bryozoans were only represented by *Membranipora isabelleana* (d'Orbingy, 1847) and echinoderms by the sea urchin *Pseudechinus magellanicus* (Bernasconi, 1953).

Foraminiferans were represented by 26 species, among them *Bucella peruviana* (d'Orbingy, 1839), *Cibicides* sp., *Elphidium* sp., *Discorbis peruvianus* (d'Orbingy, 1839), *Cribrostomoides* sp., and *Trochammina* sp., which are commonly found in this area (Lenna, 1966; Boltovskoy *et al*., 1983).

TABLE 2. – Natural diet of *Paralomis granulosa* from the Beagle Channel. Frequency of occurrence (%) of food groups in the stomach of crabs by sexes and by sampling areas.

	Golondrina Bay			Roca Mora		
Prey groups	Males	Females	Total	Males	Females	Total
Foraminifera	40.00	63.64	45.98	50.00	43.66	46.94
Bryozoa	41.54	63.44	47.12	27.63	35.21	31.29
Hydrozoa	21.54	36.36	25.29	63.16	56.34	59.86
Mollusca	55.38	86.36	63.22	39.17	39.44	39.46
Echinodermata	15.38	9.09	13.79	50.00	43.66	46.94
Algae	72.31	59.09	68.97	19,74	15.49	17.69
Polychaeta	30.77	31.82	31.03	9.21	5.63	7.48
Crustacea	53.85	31.82	48.28	9.21	12.68	10.88
Number of stomachs with food	65	22	87	76	71	147
Chi-square		9.35		56.21		
Significance level		0.23 (**)		8.59E-10		

Taking into account the sampling areas, the principal food groups for crabs of Golondrina Bay were algae (69.0% frequency of occurrence), molluscs (63.2%, principally bivalves 43.7% and gastropods 39.1%), crustaceans (48.3%), bryozoans (47.1%) and foraminiferans (46.0%). For crabs collected in Roca Mora the natural diet belonged to four major food groups: hydrozoans (59.9%), echinoderms (46.9%), foraminiferans (46.9%) and molluscs (39.5%, principally gastropods 26.5%) (Table 2).

There was no significant difference between sexes in the frequency of occurrence of the principal prey items for crabs from Roca Mora, but for Golondrina Bay significant differences occurred (Chi-

TABLE 3. – Statistical results. Wilcoxon signed-rank test for *Paralomis granulosa* relative food weight by sexes. a) Golondrina Bay, b) Roca Mora.

a) Golondrina Bay		
Sexes	Stomachs with food Number	Average rank sum of contents
Males	65	41.12
Females	21	50.86

Calculated test statistic= 2.41. Calculated P-value= 0.12.

b) Roca Mora		
Males	67	65.08
Females	59	61.67

Calculated test statistic= 0.083. Calculated P-value= 0.77

TABLE 4. – Natural diet of *Paralomis granulosa* from the Beagle Channel. Frequency of occurrence (%) of food groups in the stomach of crabs by size classes.

Food groups	Size classes 1	2	3	4	5	6	7	8
Foraminifera	50	38	50	67	60	62	37	54
Bryozoa	50	32	39	67	40	45	34	31
Hydrozoa	45	56	67	0	47	45	34	23
Mollusca	20	29	56	33	67	70	71	46
Echinodermata	35	44	39	33	47	34	14	15
Algae	10	6	28	67	73	66	54	77
Polychaeta	0	4	17	0	13	30	40	23
Crustacea	0	7	6	33	33	43	54	46
Number of stomachs with food	20	84	18	3	15	47	35	13

square test, see Table 2). The food weight to body weight relationships of males and females was not significantly different (Wilcoxon signed-rank test: P=0.12 for Golondrina Bay and P=0.77 for Roca Mora) (Table 3). Thus, food data for both sexes were combined for the analysis of quantity of food consumed. Cannibalism was not recorded in the present study.

Size classes of crabs

There were differences in the frequency of occurrence of food groups among size classes (Table 4). Molluscs had higher frequencies in size classes between 50 and 80 mm CL. Algae and crustaceans were present in higher frequencies in classes >40 mm CL. Foraminiferans, hydrozoans and bryozoans were present in all classes with similar frequencies. Echinoderms had higher frequencies in organisms <70 mm CL.

The converted weight of food consumed differed significantly among crab size groups (Table 5). The smaller crabs (CL<40 mm) contained significantly more (P<0.05) food than did large crabs.

TABLE 5. – Statistical results. Kruskal-Wallis one-way ANOVA for *Paralomis granulosa* food weight by crab size groups.

Size classes (CL in mm)	Stomachs with food Number	Average rank sum of contents
10-19.9	13	137.92
20-29.9	75	156.11
30-39.9	17	143.97
40-49.9	3	111.33
50-59.9	13	70.15
60-69.9	45	75.04
70-79.9	34	53.97
80-89.9	13	44.92
90-99.9	1	12

Calculated test statistic= 113.32. Calculated P-value=0 assuming a χ^2 distribution with 8 DF.
Pairs significantly different (P<0.20). Multiple comparison test (Daniels, 1978). 10-19.9; 20-29.9; 30-39.9 > 50-59.9; 60-69.9; 70-79.9; 80-89.9

Sampling period

The diet of *P. granulosa* differed in terms of frequency of occurrence between areas and sampling periods (Table 6). For Golondrina Bay, there were few crabs collected in winter and during spring the vacuity index was high. Therefore for these periods

TABLE 6. – Natural diet of *Paralomis granulosa* from the Beagle Channel. Frequency of occurrence (%) of food groups in the stomach of crabs by sampling periods and areas (GB: Golondrina Bay; RM: Roca Mora).

Prey groups	Summer GB	Summer RM	Autumn GB	Autumn RM	Winter GB	Winter RM	Spring GB	Spring RM
Foraminifera	50.79	56.25	5.88	19.05	100	41.30	100	59.38
Bryozoa	55.56	16.67	11.76	42.86	40	43.48	100	28.13
Hydrozoa	15.87	89.58	41.18	66.67	60	41.30	100	37.50
Mollusca	66.67	47.92	35.29	28.57	100	41.30	100	31.25
Echinodermata	15.87	54.17	5.88	28.57	20	43.48	0	53.13
Algae	88.89	33.33	17.65	14.29	20	4.35	0	15.63
Polychaeta	33.33	12.50	17.65	4.76	40	8.70	50	0
Crustacea	44.44	25.00	64.71	9.52	40	2.17	50	3.13
Unidentified material	11.11	45.83	47.06	23.81	0	34.78	0	46.88
Number of stomachs with food	63	48	17	21	5	46	2	32
Vacuity index (%)	0	18.64	10.53	0	28.57	0	85.71	11.11

we only list the following food groups as being present without rank in importance: foraminiferans, hydrozoans, bryozoans, molluscs, crustaceans and polychaetes. In this area, during summer the principal prey groups were algae (88.9%), molluscs (66.7%), bryozoans (55.6%), foraminiferans (50.8%) and crustaceans (44.4%). In crabs collected during autumn the principal food groups were crustaceans (64.7%), hydrozoans (41.2%), molluscs (35.3%) and a higher percentage of undetermined material (47.1%).

For Roca Mora, during summer and autumn hydrozoans (89.6% and 66.7%, respectively) were the most frequent prey, with a higher frequency than in other seasons. Others groups present in crabs during summer were foraminiferans (56.3%), echinoderms (54.2%) and molluscs (47.9%). During autumn a high percentage of bryozoans (42.9%) was observed. In winter, prey groups present had similar percentage of occurrence, bryozoans (43.5%), echinoderms (43.5%), foraminiferans, hydrozoans and molluscs (all with 41.3%). In spring, foraminiferans had a higher frequency (59.4%) and the next in occurrence was echinoderms (53.1%). In all periods a significant percentage of unidentified material occurred (between 23% and 47%).

Springtime was the principal period of high vacuity for crabs from Golondrina Bay (85.71%), and summer for crabs from Roca Mora (18.6%) (Table 6).

TABLE 7. – Statistical results. Kruskal-Wallis one-way ANOVA for *Paralomis granulosa* food weight by sampling periods.

a) Golondrina Bay Sampling period	Stomachs with food Number	Average rank sum of contents
Summer	63	49.06
Autumn	17	17.53
Winter	4	58.25
Spring	2	59.50

Calculated test statistic= 23.73. Calculated P-value= 2.84E-5 assuming a χ^2 distribution with 3 DF. Pairs significantly different (P<0.20). Multiple comparison test (Daniels, 1978). Autumn < Summer; Winter; Spring.

b) Roca Mora Sampling period	Stomachs with food Number	Average rank sum of contents
Summer	45	53.44
Autumn	12	42.42
Winter	40	77.61
Spring	31	72.11

Calculated test statistic= 14.36. Calculated P-value= 2.45 E-3 assuming a χ^2 distribution with 3 DF. Pairs significantly different (P<0.20). Multiple comparison test (Daniels, 1978). Summer; Autumn < Winter; Spring.

In autumn, crabs from Golondrina Bay contained significantly less food than crabs from other seasons. Crabs from Roca Mora consumed more food during winter and spring (Table 7).

DISCUSSION

The frequency of occurrence is an approximate method of analysis of gut contents, utilized when a broad description of food groups is required. Comoglio and Amin (1996) discussed the utilization of this method. This method is appropiate for most kind of foods, but overestimates the importance of unidentifiable material, sand and small animals occurring frequently, but in small amounts. For example, in the present study, foraminiferans occurred in >40% frequency of occurrence but from 1 to 4 individuals per stomach, presumably ingested incidentally while taking other prey items.

Paralomis granulosa has a diverse diet but the composition changes in relation to size of the predator and season. The results agree with Stevens *et al.* (1982) who determined that prey size was directly proportional to crab size and the optimum prey size increased with crab width. These authors concluded that crabs eat a representative selection of the benthos around them, that most feeding is opportunistic, and that little selection is evident.

Lovrich and Vinuesa (1993) determined that size at gonadal maturity in males is 50.2 mm CL and in females is 60.6 mm CL. Therefore, we established that Roca Mora is an area where juveniles are present while in Golondrina Bay adults are present.

As had been observed by Campodónico *et al.* (1982) we determined a sexual segregation in adults. In Golondrina Bay the size classes >60 mm CL were composed of males and in classes <40 mm CL in Roca Mora similar percentages of males and females were observed. Only 7.3% of the total crabs analyzed in Roca Mora were the size of maturity. These large crabs appeared only during summer, with this period being the time of greatest food consumption for adults, and the moulting period for juveniles. However, no cannibalism was observed.

In *Paralomis granulosa*, as in *Lithodes santolla* (see Comoglio and Amin, 1996), we observed that juveniles consumed more food than larger crabs, principally during winter and spring, before the moulting period (summer) when the highest vacuity index was observed.

During spring months, the vacuity index was higher for specimens of Golondrina Bay, in agreement with the observations of Lovrich and Vinuesa (1993) as the moulting-mating period of *P. granulosa*. Adults consumed minor amounts of food during autumn, before the spawning period.

As occurs with *L. santolla*, feeding generally occurs throughout the year, except during a few weeks of the moulting-mating period when feeding ceases or is at a minimum.

Additional data are essential to clarify the feeding biology of this dominant crab in Beagle Channel waters. Some parameters that should be addressed include the time required for the passage of food, the frequency with which prey are taken, and the caloric content of prey. It is only when the above information is adequately addressed that we will understand the feeding dynamics of these crabs.

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