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Nota Científica

Podding of juvenile king crabs *Lithodes santolla* (Molina, 1782) (Crustacea) in association with holdfasts of *Macrocystis pyrifera* (Linnaeus) C. Agardh, 1980

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ABSTRACT. Underwater photographic records and sampling were carried out in Steamer Bay, Strait of Magellan, Chile, to study the spatial distribution patterns of juvenile king crabs *Lithodes santolla* during late winter and early spring in 2006. Observations were made on the relationship between these crabs and the holdfasts and stipes of the large kelp *Macrocystis pyrifera*. Dense aggregations, known as "pods", of juvenile king crab (34-75 mm CL) were observed and photographed for the first time in specific areas of the embayment in relation to *Macrocystis*; pod abundance varied between 2 and 70 ind·m^{-2}. Maximum abundance was detected on plants having holdfasts > 15 cm in diameter and abundant stipes and sporophylls. The ratio between male and female abundance was nearly 1:1. This study attempts to bring attention to previously unknown ecological roles of the kelp *M. pyrifera* in relation to its associated benthic fauna in habitats near the southern tip of South America as background information on the ecological functions of this species prior to allowing its industrial-scale exploitation.

Key words: subantarctic benthos, seaweed-animal relationship, *Lithodes santolla*, shallow water, Strait of Magellan, Chile.

Agregaciones de juveniles de centolla *Lithodes santolla* (Molina, 1782) (Crustacea) en asociación con discos de fijación de *Macrocystis pyrifera* (Linnaeus) C. Agardh, 1980

RESUMEN. Se efectuaron registros fotográficos y colecta de muestras en bahía Steamer, estrecho de Magallanes, Chile, para estudiar los patrones de distribución espacial de juveniles de la centolla *Lithodes santolla* durante fines de invierno y comienzo de la primavera en 2006. Las observaciones fueron realizadas en relación a presencia de centollas juveniles en discos de fijación y estipes de la macroalga parda *Macrocystis pyrifera*. Se observaron y fotografiaron por primera vez, densas agregaciones de juveniles de centolla (34-75 mm LC), conocidas como "pods", en áreas específicas de la bahía relacionadas con *Macrocystis*. La abundancia varió entre 2 y 70 ind·m^{-2}. Las mayores abundancias se detectaron en plantas con disco de fijación con diámetros > 15 cm y con presencia de abundantes estipes y esporofilas. La proporción de abundancia entre machos y hembras fue cercana a 1:1. El presente estudio pretende llamar la atención de los roles ecológicos, previamente desconocidos, del alga *M. pyrifera* en relación a la fauna bentónica asociada a hábitats distribuidos en el extremo sur de Sudamérica básica para conocer las funciones ecológicas de esta macroalga antes de permitir su explotación a escala industrial.

Palabras clave: bentos subantártico, relación alga-animal, *Lithodes santolla*, aguas someras, estrecho de Magallanes, Chile.

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King crab life-history studies indicate that the early post-settlement age classes exhibit cryptic behavior and have restrictive habitat requirements (Lovrich & Vinuesa, 1995; Loher & Armstrong, 2000). Nursery habitats provide refuge from predation by benthic fishes and invertebrates (Barshaw & Lavalli, 1988) and the extent and availability of such habitats can exert a strong influence on settlement patterns and early post-settlement survival. Thus, the lack of suitable nursery habitats may define the most restrictive population "bottleneck" faced by some crustaceans such as the lobster *Homarus americanus* and have a greater influence on recruitment patterns than do absolute levels of larval supply (Wahle & Steneck, 1991).

A similar bottleneck may be faced by the Alaskan king crab *Paralithodes camtschaticus* (Loher & Armstrong, 2000) and also the subantarctic *Lithodes santolla*, based on their early life habits. For approximately two years post-settlement, termed the "early benthic phase" (EBP; Wahle & Steneck, 1991), individual king crabs live a cryptic, solitary existence (Karinen, 1985; Stone *et al*., 1993). The EBP is ecologically distinct from the social-aggregative behavior, termed "podding" displayed by older juveniles (Powell & Nickerson, 1965; Dew, 1990; Lovrich, 1997; Loher & Armstrong, 2000). Pods are social aggregations of individuals of a determined age or size, as previously described for lobster species (Wahle & Steneck, 1991) and gastropods (Avendaño *et al.*, 1998) and may help members locate other members of the opposite sex, reduce predation, and increase opportunities for feeding and mating. During a study describing the ecological recruitment cycle of king crab *Lithodes santolla* on the brown seaweed *Macrocystis pyrifera* beds located in a shallow, sandy-rocky embayment (Famine Bay; < 5 m depth) of the Strait of Magellan, Chile, podding of *L. santolla* individuals was discovered around the holdfasts and stipes/sporophylls of this kelp. In spite of the economic importance of *Lithodes santolla* and a long history of research on the exploited fraction of its population, few studies have been done on its early benthic stages and population biology (Lovrich, 1997), in part due to difficult working conditions in the field.

The formation of pods in crustaceans is a type of behaviour that is occasional, and associated with different stages in their life history such as moulting, mating, and the incubation period. The function of podding in a particular species may vary depending on the type of specimens that comprise the pod (*e.g*. maturity stage, sex, intermoult stage) and possible changes in habitat conditions such as water temperature or the presence of predators (Sampedro & González-Gurriarán, 2004). Previous studies have cited podding in king, tanner, and spider crabs (Dew, 1990; Stevens *et al*., 1992a; Stone *et al.*, 1993; Zhou & Shirley, 1997; Sampedro & González-Gurriarán, 2004). Nevertheless, this type of aggregational behavior has not been reported for southern king crabs. Previously, this type of behaviour has been studied by means of direct observations while diving, remotely operated vehicles (ROV) carrying video or still cameras, or submersible vehicles carrying observers (Zhou & Shirley, 1997). In Chile, little work has been done using underwater images, remote vehicles, and submersibles, except for the observations of megabenthic communities in the Strait of Magellan by Gutt *et al*. (1999). The present data, obtained by diving, represents the first observations of the aggregate behaviour of juvenile *Lithodes santolla* associated with the kelp *Macrocystis pyrifera*, and our interpretation of its ecological significance.

Field expeditions were made in August and September 2006 to observe the benthic behaviour of juvenile *Lithodes santolla* in Steamer Bay (53°36'50"S; 70°55'45"W). This bay is a small coastal indentation on the N shore of the eastern portion of the Strait of Magellan (Fig. 1). The bay is only 400 m long and 150 m wide, with an average depth of 5 m. The area closest to the coastline consists of a band of rocks and boulders, changing with depth to shelly sands. A *Macrocystis pyrifera* kelp bed occupies the bottom in a band parallel to the coast from depths of 3 to 5 m. A few plants of *Gigartina skottsbergi* were scattered around the area.

Observations of *L. santolla* were made during the day by SCUBA diving, and photographed using a Nikon Coolpix 995 digital camera in a Sealux CX 995 underwater housing and subtronic strobes. Data were obtained on crab density and sex, the size of the plants with which the crabs were associated, number of stipes per plant, and presence of sporophylls (spore-bearing fronds) on the plants. Reconnaissance of a large portion of the bay was done to determine the extent of podding behaviour. Since the patches of *M. pyrifera* were not homogeneously distributed thoughout the bay, we established six sampling points (one-m^2 quadrat) within a total area of about 150 m^2 of the *M. pyrifera* band, separated from each other by distances varying between 2 and 30 m.

Of the 150 m^2 area surveyed, only about 5 m^2 contained important king crab aggregations. Considerable concentrations of crabs were associated with only a few of the kelp holdfasts in the reconnaissance area (Fig. 2, Table 1). This table shows the results from the quadrat used to estimate the abundance of the juvenile *L. santolla* associated with the *Macrocystis*. Plant abundance within the quadrat ranged from 1 to 5 individuals, with the greatest crab abundances occurring where the

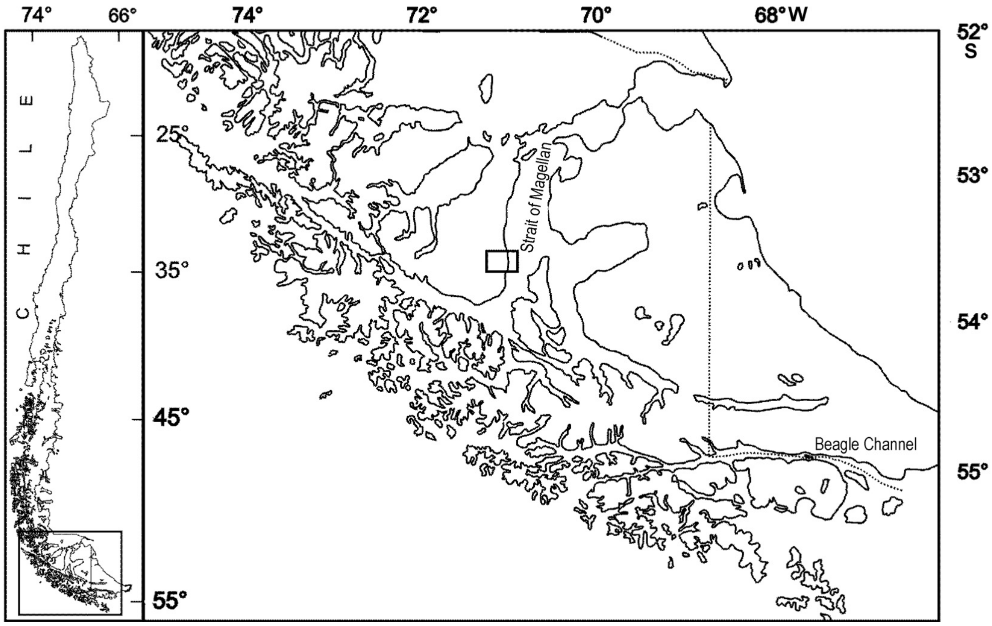

Figure 1. Location of the study area in Steamer Bay, Strait of Magellan, Chile, visited by diving in August and September 2006.

Figura 1. Ubicación del área de estudio en bahía Steamer, estrecho de Magallanes, Chile, donde se desarrolló el buceo en agosto y septiembre de 2006.

Table 1. Quantitative data on podding of the subantarctic king crab *Lithodes santolla* on the kelp *Macrocystis pyrifera* in Steamer Bay, Strait of Magellan, Chile, in September 2006. Quadrat size = 1 m^2.

Tabla 1. Antecedentes cuantitativos para describir el proceso de agregaciones en *Lithodes santolla* sobre el alga parda *Macrocystis pyrifera* en bahía Steamer, estrecho de Magallanes, Chile, durante septiembre, 2006. Tamaño cuadrantes = 1 m^2.

Sampling site	Number of *M. pyrifera* plants/ quadrat	Number of stipes	Holdfast diameter (cm)	Number of king crab/ quadrat
A	1	5	12	5
B	1	3	15	2
C	2	25, 12	30, 20	54
D	3	4, 6, 4	15, 25, 22	58
E	2	10, 18	30, 32	34
F	5	6, 8, 15, 12, 7	No data	8

plant density was 2 to 3 plants per m^2. The highest crab abundances occurred around the plants with the greatest number (3-25) of stipes, coinciding with the largest holdfast diameters (15-32 cm). Holdfasts of > 15 cm diameter could host 5 to 58 king crab juveniles m^{-2}. Aggregations of the crabs were associated with the holdfasts, particularly in plants bearing sporophylls on the upper region of the holdfast. No crabs were associated with plants without sporophylls.

The greatest crab aggregations occurred in small areas at depths of less than 3 m, with as many as 60 crabs hidden in holdfasts covered with sporophylls. Less than 3 juveniles m^{-2} were observed beneath boulders or loose algal fronds. There were very few or no crabs associated with plants outside the area where the crab accumulations were observed. The largest crab abundances (146 specimens) were associated with plants that were within a 50 m^2 area.

Another noteworthy observation from the present reconnaissance was that some of the crabs climbed to the upper parts of the kelp, reaching heights of up to 100 cm above the bottom. The sizes (carapace length = CL) of the specimens observed ranged from 34.8-75 mm for males (n = 24) and 34-69 mm for females (n = 28). The males weighed from 18.5 to 204.9 g (mean = 54.9 g) and the females 12.7 to 150.3 g (mean = 56.1 g). Of 52 crabs analysed, the male : female ratio was 0.46 : 0.54, and no ovigerous females were present.

The preliminary information presented here is the first report on "podding" in the Chilean king crab *Lithodes santolla*. Podding refers to the formation of structurally dense, socially organized groups of organisms living in aggregations; most individuals in pods are in physical contact with each other and stacked atop one another (Stone *et al*., 1993). The results of this study underline the importance of plant/animal interactions during the early life of this valuable subantarctic crustacean.

Podding behavior is probably a generalized characteristic of the lithodids, previously cited for *Paralithodes* (Loher & Armstrong, 2000). This behavior has also been well documented for the Majidae, including *Chionoecetes bairdi* (Zhou & Shirley, 1997), *Chionoecetes opilio* (Comeau *et al.*, 1998), *Hyas lyratus* (Stevens *et al*., 1992b), and *Maja squinado* (Sampedro & González-Gurriarán, 2004). Various reasons were proposed for the aggregation behaviour in the majids, including protection during moulting, location of mates, aid in food capture, and protection from predation (Powell & Nickerson, 1965; Stevens *et al*., 1994; Zhou & Shirley 1997; Gardner, 1999). Observations of *M. squinado* by Sampedro & González-Gurriarán (2004) suggested that this behaviour was based on protection from predation. The authors indicated that pods could vary in form and structure depending on the species, time of year, and area where the pods formed, as well as the characteristics of the individuals that form them (maturity stage, intermoult stage). A protective function has also been suggested for juvenile aggregations of spiny lobsters (Eggleston *et al.,* 1990; Smith & Herrnkind, 1992; Butler *et al.,* 1999).

Although *L. santolla* juveniles presented a sex ratio of about 1:1, which is typical of mating aggregations, most crabs forming the aggregations in the present study were smaller than the normal size at sexual maturity (Campodónico *et al.*, 1974; Vinuesa, 1984). This suggested that the aggregations were not related to reproductive behaviors.

Despite descriptions in the literature that king crabs consume algae (*e.g.* Comoglio & Amin, 1996, 1999), none of the crabs were observed to be feeding on the kelp, nor did they appear to have adversely affected the integrity of the kelp plants (Fig. 2). There were no drift algae associated with the kelp, which would suggest a potential food source. Since numerous other plants were present in the area that did not host aggregations of juvenile king crabs, this study poses the important question of why the crabs prefer to gather around one kelp plant over another.

Some previous observations (Dew, 1990) have suggested that the kelp provides a shaded refuge at different times of the day. This was somewhat supported by our observations, as aggregations were more commonly seen at midday and in the morning. However, night observations are required to confirm this situation. Our 2005 and 2006 observations showed that aggregations began to appear at the end of winter (September) as reported for other lithodids at other latitudes (Powell & Nickerson, 1965; Stevens *et al*., 1993). The limited nature of these observations, however, calls for more detailed reconnaissance to be done throughout the year as well as diurnally in order to develop a more detailed description of this behavior.

The podding behavior of *L. santolla* was similar to that reported for *P. camtschatica* (Zhou & Shirley, 1997) in that individuals > 80 mm in CL were not present in the pods. Crab podding in general was not previously reported as occurring in relation to algae, which makes the present report of particular interest regarding the potential harvesting of kelp, which is currently being contemplated in this region. Podding behaviour may represent a key step in the life cycle of the king crab, which could be adversely affected by disturbing the kelp population, making our observations of direct interest for managing both the crab fishery and kelp harvesting. This is particularly applicable to the recruitment dynamics of these crabs (Tapella & Lovrich, 2006). We thus recommend that authorities responsible for the management of artisanal fisheries in the region develop direct evaluations that extend our observations and may aid in making predictions related to king crab recruitment.

In the future, studies are required to improve estimates of the abundance of the non-exploited segment of the southern king crab population in order to determine its state of conservation. The podding process needs to be included as a potentially crucial part of the behavioral suite of the population, as

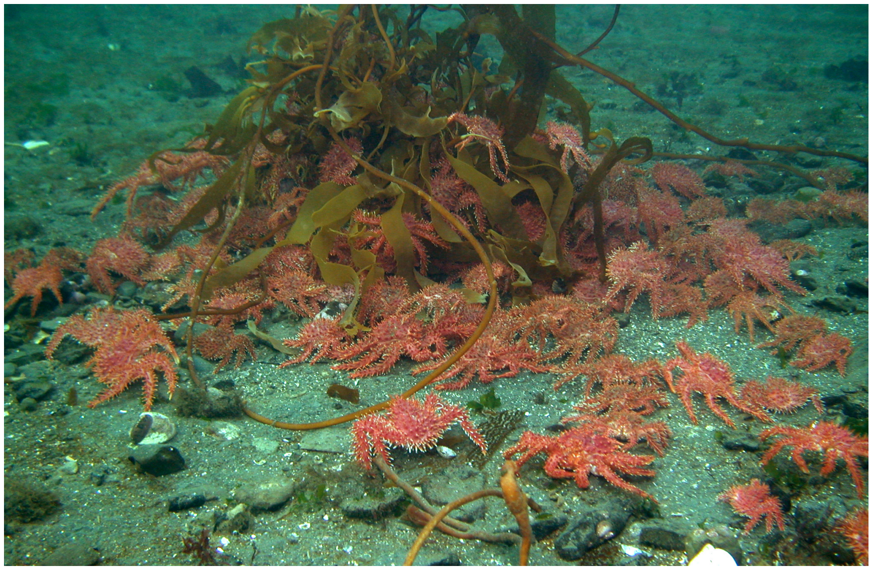

Figure 2. Aggregation (podding behaviour) of juvenile king crabs *Lithodes santolla* (34 to 75 mm CL) on a *Macrocystis pyrifera* holdfast, representing about 70 ind·m^{-2}. Photograph taken August 13, 2006 in Steamer Bay, Strait of Magellan, Chile, at 3 m depth.

Figura 2. Agregación (podding) de juveniles de centolla *Lithodes santolla* (34 a 75 mm LC) en un disco de fijación de *Macrocystis pyrifera*, representando alrededor de 70 ind·m^{-2}. Fotografía tomada el 13 de agosto de 2006 en bahía Steamer, estrecho de Magallanes, Chile, a 3 m de profundidad.

the occurrence of aggregations of individuals could introduce errors into broad population evaluations. Furthermore, if this life history stage indeed faces a habitat bottleneck, as has been suggested for the juveniles of other commercially exploited crustaceans (e.g. Wahle & Steneck, 1991), it is particularly important to protect the juveniles of *L. santolla* and their habitat.

Finally, this research is part of a long line of studies that highlight the importance of kelp forests for local biodiversity as breeding habitats for many species and thereby demonstrates that kelp forests require the highest conservation status in temperate marine environments.

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