Crustaceana 62 (1) 1992, E. J. Brill, Leiden

INSHORE-OFFSHORE MOVEMENTS OF PELAGIC RED CRABS *PLEURONCODES PLANIPES* (DECAPODA, ANOMURA, GALATHEIDAE) OFF THE PACIFIC COAST OF BAJA CALIFORNIA SUR, MEXICO

BY

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RÉSUMÉ

Le galathéide pélagique *Pleuroncodes planipes* est très abondant au large des côtes occidentales de Basse-Californie. Afin de déterminer les changements saisonniers possibles dans la fréquence et la biomasse de ces crustacés sur le plateau continental, où se tient une grande partie de la population, une recherche à long terme a été entreprise, incluant la surveillance de son abondance. C'est au total 198 chalutages sur le fond, avec des filets à crevettes, qui ont été effectués de juillet 1987 à septembre 1990, couvrant ainsi toutes les saisons. Les crustacés étaient présents sur tout le plateau continental en hiver et au printemps (au moment de la reproduction). Une abondance moyenne maximale de 450 kg/Ha a été atteinte à la fin du printemps, à 51-100 m de profondeur. Quand la température au fond montait jusqu'à 16°C (été-automne), fréquence et abondance décroissaient l'une et l'autre à tous les niveaux, avec une disparition complète au-dessus de 50 m de profondeur. Ce n'est qu'à plus de 151 m que la fréquence de *Pleuroncodes* était relativement haute. L'abondance décroissait en été dans les profondeurs de moins de 100 m (0-200 kg/Ha), alors qu'elle croissait entre 100-200 m (400 kg/Ha). Les présentes observations suggèrent que les adultes ont un cycle migratoire: ils gagnent les eaux plus profondes au printemps et en été pour revenir occuper la totalité du plateau continental en hiver. Pendant l'été *Pleuroncodes* s'étend aussi vers le talus continental, jusqu'à 500 m au moins. Les crustacés occupent également le fond et la colonne d'eau, de nuit comme de jour, en dépit des mouvements nocturnes signalés du fond vers la surface.

INTRODUCTION

Pelagic red crabs (*Pleuroncodes planipes* Stimpson, 1860), have been considered as the most abundant component of the pelagic nekton off southern Baja California (Blackburn & Thorn, 1974). Accordingly, it is the most important grazing organism in the coastal upwelling areas at the southern end of the California current (Longhurst et al., 1967).

Changes in red crab biomass during day and night plankton collections, with higher abundance at night, were considered a reflection of vertical migration (Boyd, 1967). The movements are not, however, a rule (Boyd, 1967; Blackburn, 1977; Alvariño, 1976), with occasional diurnal surfacing swarms reaching up to 100 crabs/m^2 in some areas (Boyd, 1967).

Latitudinal changes of red crabs have also been reported. During normal years the red crab population is found from 20° to 30° N (Boyd, 1967), but in warm years (e.g., El Niño), these crustaceans can be found as far north as Monterey Bay, California (36° N) (Glynn, 1961; Boyd, 1967; Longhurst, 1966; Longhurst, 1968), carried there by a stronger transport of the Davidson current, favored by a debilitated California current during warm years (Alvariño, 1976). Dispersal of the pelagic phase of red crabs has been documented from coastal to oceanic waters areas (Boyd, 1967; Longhurst & Siebert, 1971; Alvariño, 1976).

The breeding season extends from December to March (Boyd, 1960; Longhurst, 1968), though ovigerous females have been found in other months (Kato, 1974). The center of breeding occurs mainly between 24° and 26° N, off Bahia Magdalena (Boyd, 1967), but oceanic breeding as far as 700 miles southwest of Cabo San Lucas was reported (Longhurst & Siebert, 1971). Most of the research on this species has been focused on biology and ecology of larvae and the so-called ''pelagic phase'', i.e., the time spent by red crabs in the water column, because they move to the bottom during the day time. In contrast, few studies were concentrated on the benthic phase, and mostly undertaken to estimate relative abundance limited temporal and spatially (Boyd, 1967; Ehrhardt et al., 1982; Arvizu et al., 1974). Avariño (1976) suggested that population movements of red crabs do not occur on bottom areas between 225 to 475 m depth, and she found that two red crab populations were present off Punta Eugenia (28° N): an epipelagic population inhabiting the water above 200 m depth, and a mesopelagic from 475-200 m, possibly also occupying the bottom. This interpretation was based on collections in the water column.

We herein analyzed information of bottom trawlings from different seasons during 1987, 1988, 1989 and 1990, conducted in a region bordered between 24° and 26° N on the continental shelf (the area of higher abundance). Information collected by two other research vessels in the same area (''Bonn'' and ''Weser''; Schulz, 1976) were included in the analyses. The information suggests seasonal inshore-offshore movements of the benthic organisms which are related to oceanographic conditions.

MATERIALS AND METHODS

A long term project to explore and evaluate potential fish stocks off the Pacific coast of Baja California (fig. 1), includes the pelagic red crab (langostilla in Spanish). Since most trawling effort during the past four years was devoted to the area between 24° and 26° N, and because this area has been considered as the main region of *Pleuroncodes* distribution (Boyd, 1967), the data here reported represent the behavior of the Baja Californian population.

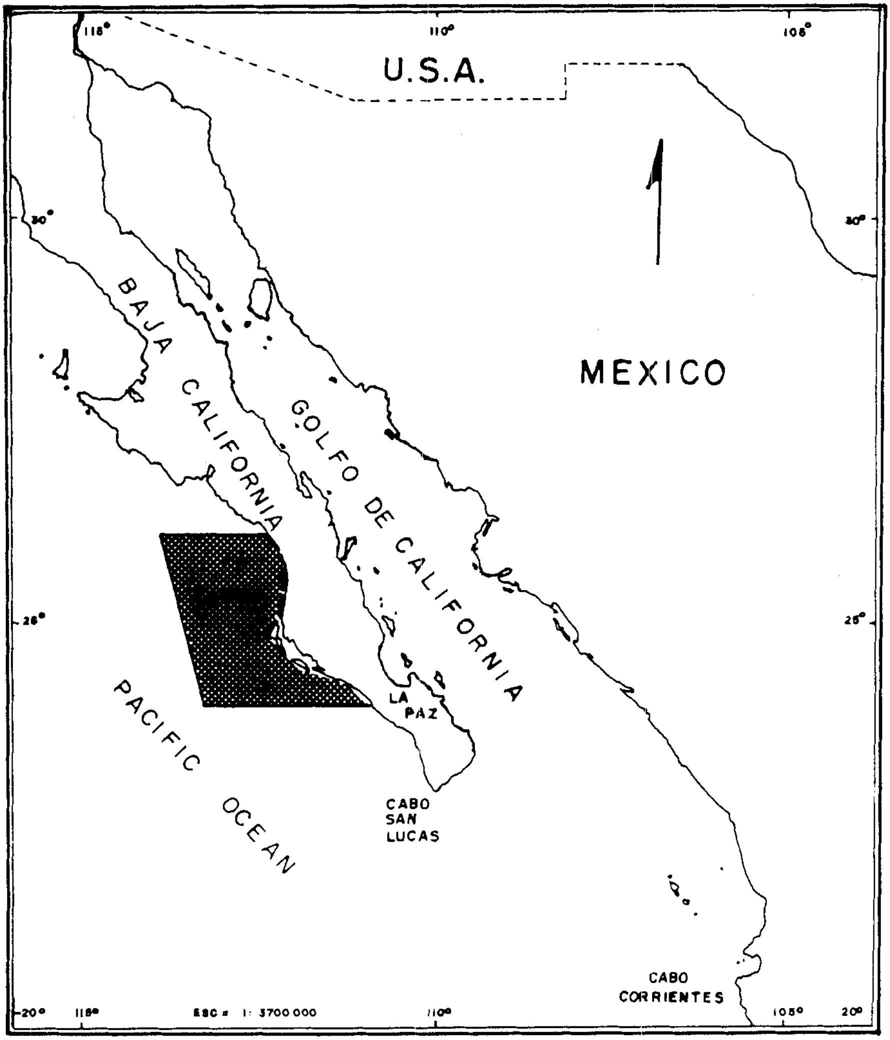

Fig. 1. Study area limited by the 24° and 26° N. and 0-200 m depth. This area contains most of the pelagic red crab stock off Baja California.

Many hours were spent searching for suitable bottoms during the first cruises. Echosonic exploration to detect stations of positive (not risky) trawling, according to bottom outline, was made using a Simrad sounder. Once the geographic position of the stations was established and recorded, the bottom suitability was verified by sampling the type of substrate with a Smith-McIntyre grab. Ship positioning on the same stations in subsequent trips was achieved with a satellite navigator.

Two ships were used to conduct the trawling; the first being the R/V "El Puma" owned by the Universidad Nacional Autonoma de México, using a stern-trawling equipment. The second was a commercial shrimp boat "MARSEP XVI", using twin bottom trawls. The nets in both cases are those used in the typical shrimp fishery with a mesh size of 3 cm. The net used in the "El Puma" had a 20 m mouth and those used in the "MARSEP" had a 13.5 m width. Trawling time and speed were recorded to estimate the area swept by the net (AS). The shrimp boat speed was standarized to 4 km/h (2.2 knots) while for the "El Puma" this was 5.4 km/h (3 knots). For each boat, the area swept was calculated as follows;

MARSEP: AS = (13.5 × 2) (4000m/h) × time.

"El Puma" AS = (20 m) (5400m/h) × time.

Total biomass for each trawl and specific biomass (red crab versus associated fauna), was transformed to density by dividing this by the area swept. The catch was divided in several taxonomic groups with special emphasis on species of commercial and ecological importance, but for the present analyses only red crab biomass will be considered.

Depth was recorded with the Simrad sounder aboard the "El Puma", and a Furuno sounder on the "MARSEP". Temperature at three levels (surface, midwater, and bottom) was recorded with Van Dorn bottles, substrate temperature was directly taken from grab samples. Weight of capture was measured using a 100 kg dynamometer with ± 1 kg error. Dates for each cruise and depths at which trawls were conducted are summarized in table I.

Data obtained from the "Bonn" and "Weser" were used only to determine presence and frequency of red crabs by depth. Abundance estimates were not readily available since they were published as kg/hour.

RESULTS

A total of 233 experimental trawlings was conducted off the Pacific coast of Baja California. From these 198 were located between 24° and 26° N (fig. 1). All seasons were covered in the 15 cruises analyzed (table I). The data on the red crab biomass were arranged by 50 m depth strata from 0 to 200 m; also the influence of the seasons was noted.

Bathymetric frequency of benthic red crabs. — In the stratum of 0-50 m depth, frequency of red crabs (occurrence in trawl samples) diminished throughout the year from the first months of the year to the period from June to November when no trace of red crabs was found (fig. 2).

In the 50-100 m stratum, the frequency of red crabs decreased later in the year (July-August), when about half the total trawls yielded red crabs. In September and October, the frequency of red crabs was the lowest recorded but increased again in November (fig. 2). A similar trend was recorded at depths between 100 and 150 m.

TABLE I

List of cruises from which data were available for the red crab study in the area between 24° and 27° N.

Cruise	Date	Depth range m
BONN-7411	12-17 November 1974	40-380
WESER-7411	12-13 November 1974	40-500
BONN-7501	6-11 January 1975	44-300
WESER-7501	7- 9 January 1975	25-260
EP-8707	7-19 July 1987	60-226
EP-8710	5-20 October 1987	40-221
MARSEP-8804	25-30 April 1988	16-81
MARSEP-8805	25-30 May 1988	13-65
MARSEP-8806	28 June-1 July 1988	18-50
MARSEP-8807	21-23 July 1988	50-165
EP-8807	24 July-6 August 1988	30-180
EP-8810	1-10 October 1988	30-200
EP-8902	25 February-5 March 1989	25-178
EP-8907	5-12 July 1989	30-228
EP-9009	2-12 September 1990	36-218

Note: Data from several cruises were combined when months of sampling were the same or very close in order to increase sample size. Combinations were as follows; MARSEP-8804 and MARSEP-8805; MARSEP-8806 and MARSEP-8807; EP-8707, EP-8807 and EP-8907; EP-8710 and EP-8810; BONN-7411 and WESER-7411; BONN-7501 and WESER-7501.

The depths between 150-200 m, also showed a diminishing frequency of red crabs from July to November, but this decrease was less drastic as compared to the three shallower strata.

In a general scope, red crabs occurred in all depths of the continental shelf from at least January to June-July. It is possible that the end of December marks the return of red crabs to the depths from 0-150 m, but no data were available for that month. However, the trend of increasing red crabs in depths from 50 to 200 m in November, and the presence of red crabs in all depths in January, lead to suggest, that pelagic red crabs start the return to the shallower waters in December.

As shown by fig. 2, red crabs do not leave the continental shelf completely during the summer, since they are found between 150 and 200 m depth around the year. In the movement to deeper waters, the red crab population invade at least the depths up to the 500 m, as shown by trawls conducted by the "Bonn" and "Weser" (Schulz, 1976).

Bathymetric changes in benthic red crab biomass. — If red crab frequency decreased from shallow to deep waters with the advance of the year, abundance should have followed the same trend. However, mean values of abundance or red crab density (kh/Ha), could be expected to have a higher variation, since

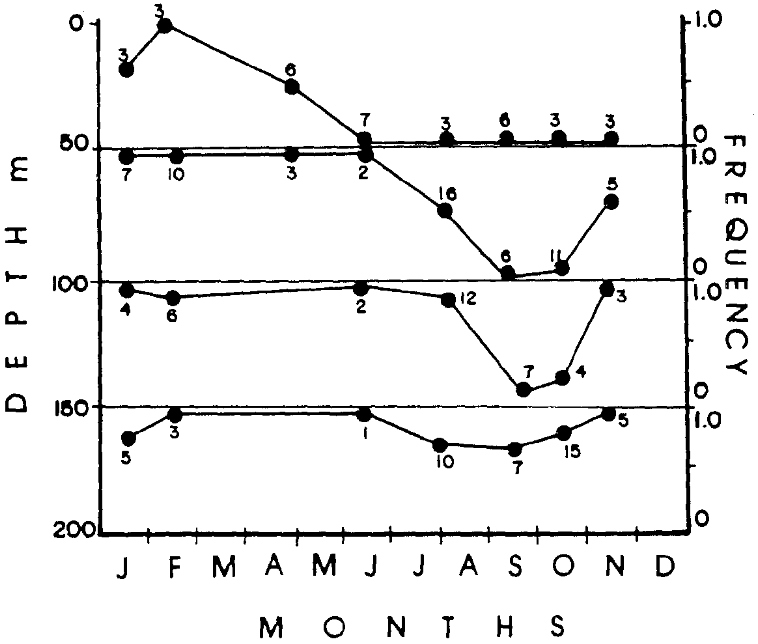

Fig. 2. Relative frequency of red crabs (ocurrences/hauls) throughout the year. February was the month of major dispersal on the bottom of the continental shelf, after which the frequency decreased from shallower to the deeper strata. Red crabs return to invade the whole area in November-December.

spatial distribution of red crabs is not homogeneous, but is in form of patches. In some areas the sounder recorded large groups of red crabs in contrast to nearby sites where the crustaceans were virtually absent.

The bathymetric changes in red crab biomass (kg/Ha) throughout the year are shown in fig. 3. In February, the mean red crab density was relatively low, in spite of the higher red crab frequency (fig. 2). The mean density for all strata ranged from 70 to 140 kg/Ha. In April-May, the red crab abundance was the highest recorded (only stations in the first 100 m depth). For the following months (June through October), red crab biomass did fall to zero in the 0-50 m stratum, while a relative increase after June was noted in deeper waters (fig. 3). The red crab density diminished for all strata in September, which was the month with lower red crab frequency and biomass. Apparently, the peak of red crab biomass detected in July-August between 50 and 200 m depth, could be a reflection of the red crab population coming from the shallower strata (0-50 m).

Changes in bottom temperature and red crabs. — In spite of the supposed eurythermic characteristics of *P. planipes* (cf. Blackburn & Thorne, 1974), a relative preference for temperatures between 13° and 16°C was apparent (fig.

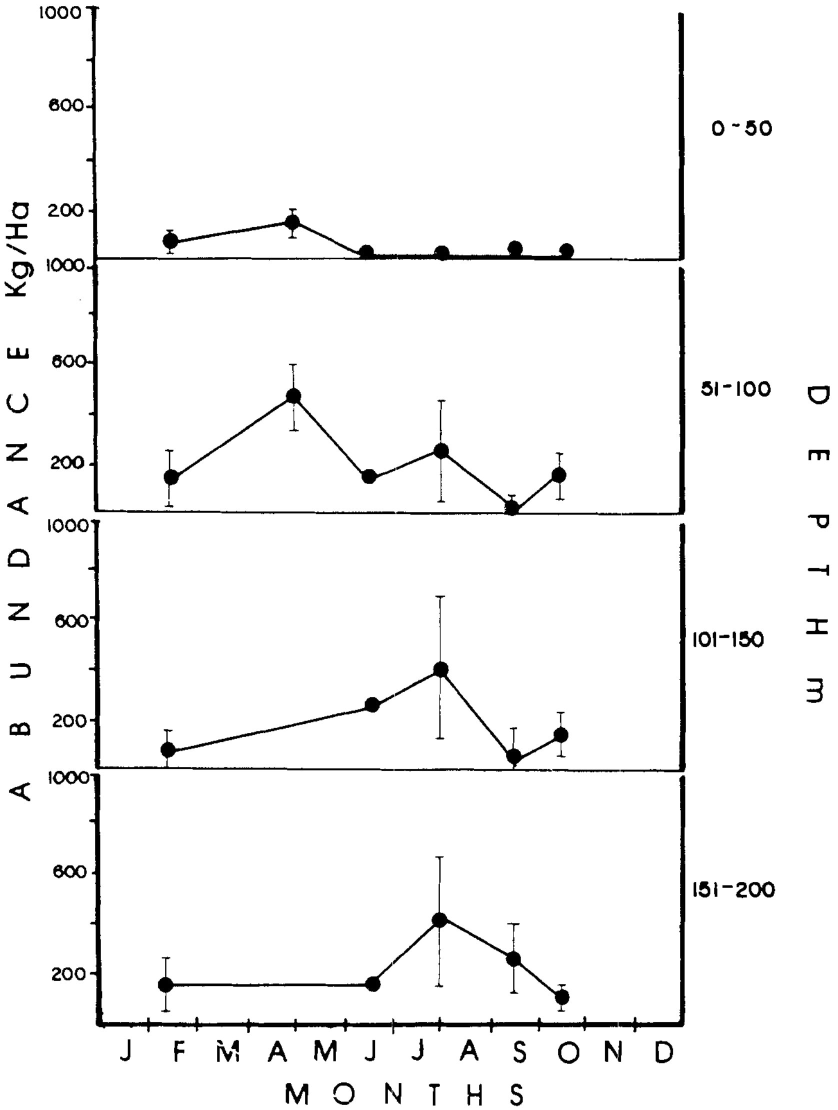

Fig. 3. Seasonal and depth related red crab biomass (kg/Ha). In shallow waters (0-100 m) biomass reached its highest abundance (400 kg/Ha) in April-May. Similar concentrations were detected at deeper stations in subsequent months.

4). Particularly, frequency of red crab occurrences were the highest in bottom temperatures between 13° and 14°C.

The values of red crab abundance (kg/Ha) organized by relative frequency in temperature ranges (fig. 5), suggested also higher probability of finding larger concentrations of red crabs (100 kg/Ha or higher) with bottom temperatures between 13° and 14°C.

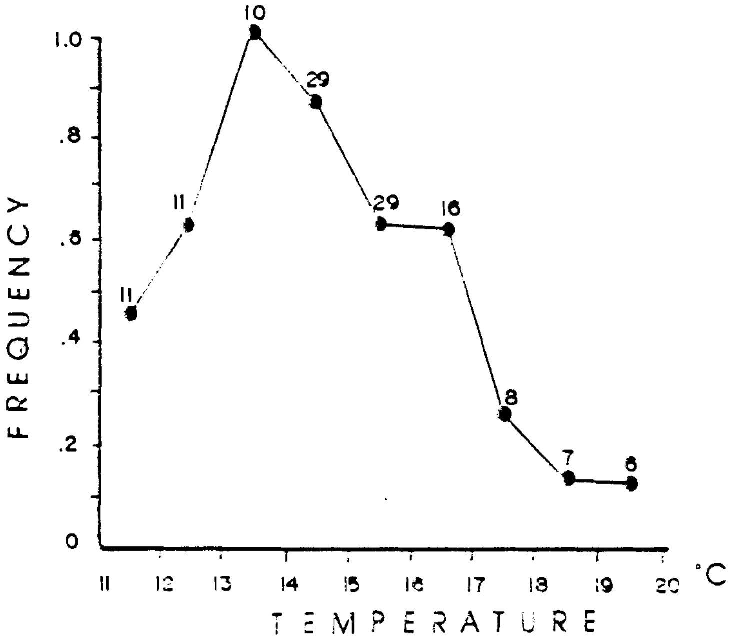

Fig. 4. Relative frequency of pelagic red crabs relative to bottom temperature. Hauls conducted in areas where bottom temperatures were between 13° and 15° C, had the highest red crab occurrences. Frequency decreased when temperatures were lower or higher than this range

A steady decrease in the occurrence of high densities of red crabs was noted from 13°-14°C to 19°-20°C. Red crab abundances of 500 kg/Ha or higher were only recorded between 13° and 17°C. From figs. 4 and 5, it seems clear that either frequency or abundance decreased at temperatures lower than 13°C or higher than 17°C.

Bottom temperatures were also combined and ordered by depth strata (fig. 6). Strata from 0-50 and 51-100 depth, showed a trend of increasing bottom temperature from February through October. In the two deeper strata (100-200), bottom temperature increased from February to July-August, then had a drop in September to increase again in October (fig. 6). There is no explanation for this sudden decrease.

The annual variation in bottom temperature in the strata 0-150 m deep, was higher than in the deeper strata. Accordingly the red crab frequency was more variable at these depths. In the stratum from 150 to 200 m, where the bottom temperature varied from 13° to 15°C (fig. 6), the red crab frequency was never under 30%.

Vertical migration versus bathymetric movements. — It could be suggested that the vertical migration reported for this species (Boyd, 1967; Kato, 1974),

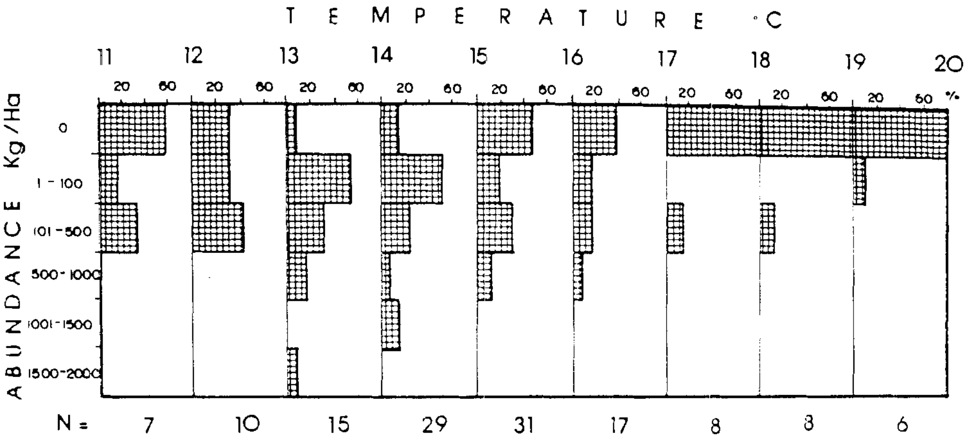

Fig. 5. The effect of temperature on red crab frequency and abundance is noted; red crab biomass had its maximum (1000-2000 kg/Ha) in localities with bottom temperatures between 13° and 15°C. Frequency and density decreased steadily as the bottom temperature increased to 20°C. The same trend is shown for decreasing temperatures.

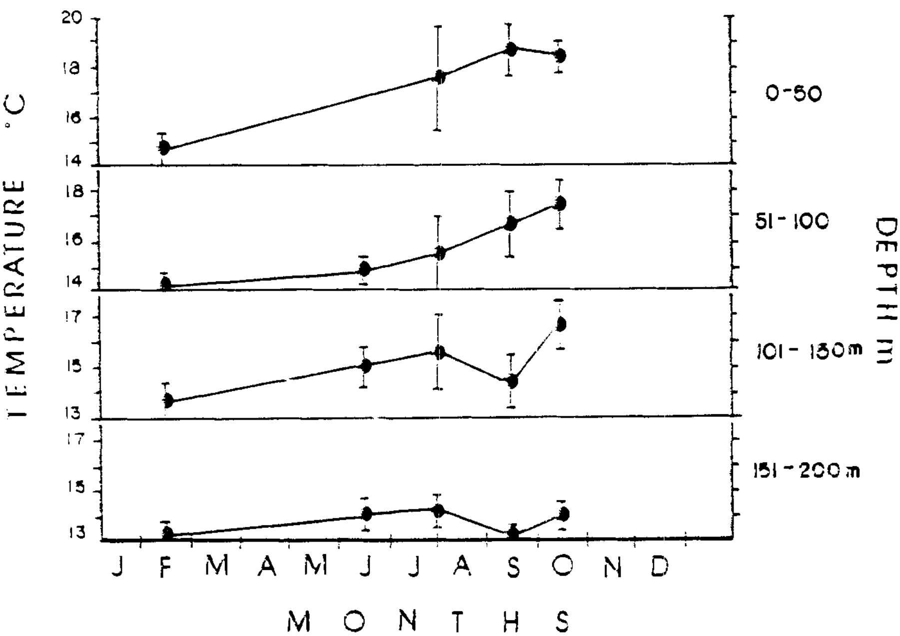

Fig. 6. Bottom temperature trend for some months at all depths studied. Except for waters from 151-200 m deep, where temperature did not change markedly, an increase in mean temperature was noted from June through October. July-August showed the maximum variation in waters from 0 to 150 m depth. This period coincides with a rapid increase in bottom water temperature and red crab movements to avoid these waters (cf. figs. 2, 3).

has an effect on the bathymetric changes recorded on the bottom, since red crabs move to the surface at night. Even assuming a circadian migration in which the total population leaves completely the bottom at night, the total absence of red crabs from the 0-50 m benthos at daytime from July to November cannot be explained.

Out of 198 trawls, 82 were conducted at night (19:00 to 06:00), and 116 in the day time (06:01 to 18:59). When the mean densities of red crab in night (156.2 kg/Ha) and day trawls (79.1 kg/Ha) are compared, the results suggest that in spite of the vertical movements of red crabs, they are found at night on the bottom in high density. Thus, only a fraction of the benthic red crabs migrate toward the sea surface at night. Several of our graphic echosoundings recorded at different stations support this notion. The unexpected higher abundance of red crabs at night on the bottom, could be due to a higher vulnerability of these crustaceans in the dark, but this remains unclear at the present time.

DISCUSSION

Benthic inshore-offshore movements. — Adult pelagic red crabs seem to perform inshore-offshore movements off the Pacific coast of Baja California. During the cold season, from December through April, red crabs show higher frequency in shallow waters (fig. 2), which coincides with the breeding season. As water temperature increased, the red crabs moved to deeper areas where the temperature still remained relatively cold (fig. 6).

In February red crabs were highly dispersed on the continental shelf (as reflected in figure 2). From 22 hauls conducted at this month, 21 (95%) yielded red crabs. However, the higher mean density (about 400 kg/Ha) was found in April-May. This high abundance occurred in waters 50-100 m deep, and similar figures were recorded months later (July-August) in the two deeper strata (from 100-150 and 150-200 m) (fig. 3). Not only the frequency but the biomass of red crabs diminished from coastal to oceanic waters from the cold to the warm season off Baja California. In October the red crab biomass was drastically reduced in all strata with no more than 150 kg/Ha from depths of 50 to 200 m, and no red crabs were recorded at all in the shallower stratum (0-50 m).

A schematic trend of the seasonal distibution of red crabs on the continental shelf is shown in fig. 7. The occurrence of these crustaceans on the continental slope was based on records by other authors (table II). On one hand, the red crab population aproaches the limits of the continental shelf during the warmer time of the year (summer), but does not leave the area completely. They start the return to shallow waters in the fall. On the other hand red crabs occupy the benthos of the continental slope throughout the year, which agrees with records from deeper waters (300-500 m; table II).

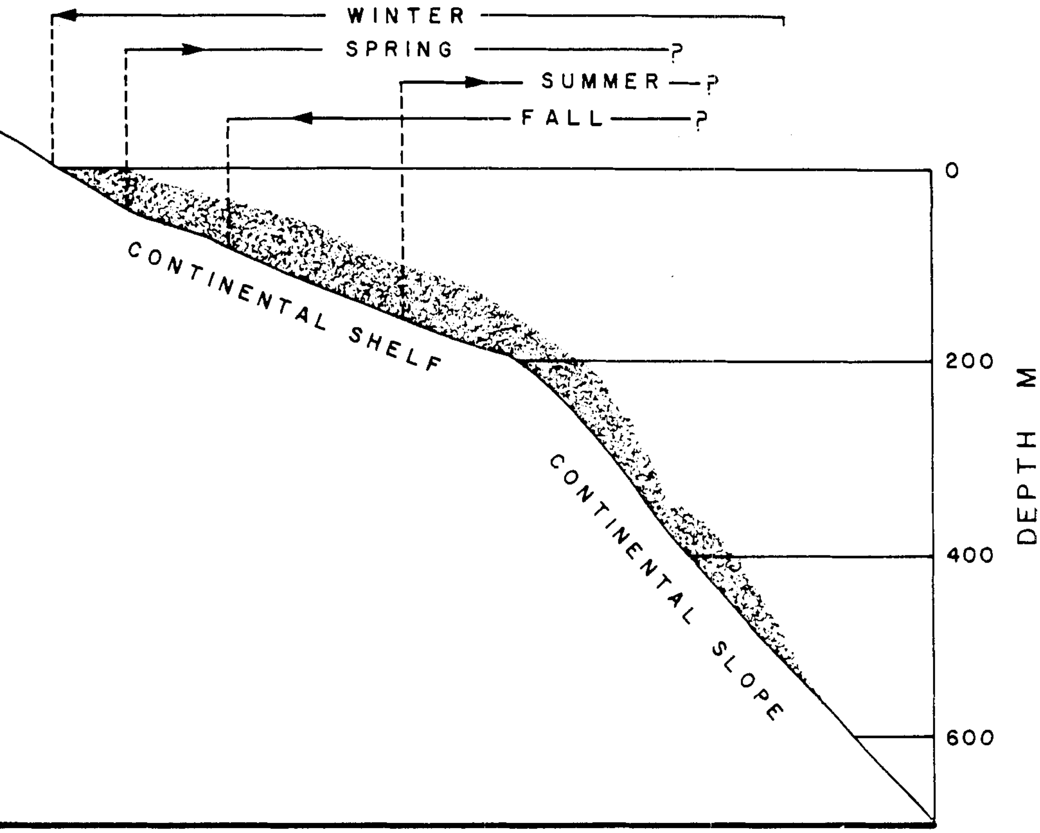

Fig. 7. Seasonal bathymetric occurrence of red crabs on the continental shelf off Baja California. The scheme represents the population movements from 24° to 26°. Lines for each season mark the space occupied by red crabs; arrows indicate the trend of the movements and interrogation marks indicate that at least up to 300 m depth red crabs have been found in other seasons, and suggest that they could also occur in deeper waters.

Red crabs, temperature and coastal upwelling. — Adult red crabs have been reported in wide temperature ranges; from 10° to 14°C (Boyd, 1967); 9°-14° (Parker, 1963); 10°-14° (Longhurst, 1967), and from 11° to 20°C (fig. 4). These wide temperature ranges were considered by Blackburn & Thorne (1974) as evidence that adult red crabs did not respond to temperature changes because they were eurythermal. However, temperatures between 13° and 16°C were associated with higher frequency and density of red crabs (figs. 4, 5). Water temperature is not likely to be the only cause of red crab distribution, but it is probably an associated factor to the oceanographic conditions by which red crabs find the maximum availability of food.

A more direct cause of coastal abundance of red crabs in the cold season could be the distribution and abundance of its main food. Although, red crabs

TABLE II

Depth records of *Pleuroncodes planipes* from different studies off Baja California, Mexico.

Locality	Month/Year	Depth of trawls m	Depth of occurrence m	Source
26°-25′	December 1960	50-300	75-300	1
22°-26°	October 1968	24-350	67-300	2
23°-28°	November 1974	40-500	70-500	3
23°-28°	January 1975	25-300	44-300	3
24°-28°	April-June 1980	18-300	18-300	4

1 = Boyd, 1960; 2 = Chavez & Padilla, 1974; 3 = Schulz, 1976; 4 = Erhardt et al., 1982.

have catholic feeding habits, food is mainly composed of phytoplankton (Longhurst, 1966; Longhurst et al., 1967). The abundance of red crabs in coastal waters off Baja California could be associated with the availability of food. Since the phytoplankton blooms in the area occur during the time of upwelling season (Longhurst, 1967; Blackburn, 1969), the best period of the year for red crab grazing should be that of the coastal upwelling. Coastal upwelling is seasonal and takes place in our study area in late winter and early spring (Roden, 1972), when red crabs breed and reach maximum coastal abundance. Red crab breeding season is probably strongly tied to the upwelling season because this ensures abundant food for their larvae. Blackburn (1969) demonstrated that red crabs showed higher abundance at sites where the levels of chlorophyll a, as a measure of phytoplankton abundance, were also higher.

Night versus day trawls. — Boyd (1967) reported that *P. planipes* lives to some extent on the bottom in its first two years of life but is also found as planktonic animal at this stage. The relative amount of time spent in these two environments was unknown but data from plankton collections indicate that there is some diurnal exchange between them (Boyd, 1967). Longhurst (1967) considered probable the existence of an alternation between pelagic and benthic phases in the life of a single individual.

Boyd (1967) reported, from a large number of plankton collections, that red crabs move toward the sea surface at night. Several sounder observations do support the existence of these movements (Kato, 1974; Aurioles, unpublished data), but the comparison of red crab density at the bottom in night and day trawls, suggests that even though these crustaceans disperse at night in the water column, a large portion of the swarm remains on the bottom.

The change from day to night biomass of red crabs at the bottom was however unexpected. If red crabs disperse at night, higher abundance should be found at daytime when as a consequence they are more concentrated, yet the mean bottom density of red crabs at night was twice the density during the day. Alvariño (1976), suggested a higher plankton collection efficiency for red crabs at night, mainly because a reduced visual capacity of the crustaceans in dark conditions. It is also probable that red crabs on the bottom are less able to avoid the trawl net at night, causing a relatively higher capture. However, there is no clear answer for this discrepancy.

The benthic and pelagic phases in *Pleuroncodes planipes* are now better understood: as larvae and juveniles, the red crabs are fully pelagic (Boyd, 1967; Longhurst, 1968); adult organisms between 18 and 31 mm standard carapace length (S.C.L.), that is in the first and second year (Boyd, 1967), occupy the continental shelf in the manner here explained (most individuals sampled in this study were in range of 18-30 mm ($\bar{x}$ = 24.5 S.C.L., n = >6000). Red crabs in this size range also move from the bottom to the sea surface, thus having an alternating benthic-pelagic phase. It is known that after the 32 mm S.C.L. (starting the third year of life), they adopt a strictly benthic existence (Boyd, 1967). Individuals larger than 32 mm S.C.L., were rarely seen on the continental shelf, supporting the findings of Boyd (1967).

ACKNOWLEDGEMENTS

Thanks are due to Consejo Nacional de Ciencia y Tecnologia de México for supporting this research through the grant no. P22OCC0R880518, and also for providing the R/V "El Puma" from 1987 to 1989 to conduct a great part of this research; also to the Secretaria de Educación Publica through Dirección de Ciencia y Tecnologia del Mar to provide the "MARSEP XVI" during 1988. Thanks also for the "El Puma" crew who always were willing to help during the different stages of the field work at the cruises conducted from 1987 to 1990, and to colleagues who helped during the laborious work on board.

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Received for publication 7 March 1991.