Population Dynamics and Fisheries of Squat Lobsters, Family Galatheidae, in Chile

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Two species of squat lobsters, *Cervimunida johni*, Porter, and *Pleuroncodes monodon*, Milne Edwards, family Galatheidae, are harvested commercially off Chile. A commercial fishery began by exploiting the first species but has gradually shifted to harvesting the second. The fishery for *Pleuroncodes* began in 1966 off San Antonio (L. 33°35"S) but has gradually moved southward and now extends to Talcahuano (37°S). There are two possible explanations for this shift in fishing area; (1) increased fishing pressure, and (2) changes in the natural environment. Some support for the second explanation is seen by simultaneous changes observed in other species which may be due to cyclic changes in the environment.

Data on the fishery has been collected from 1966 to the present from the area between Coquimbo (30°S) and Talcahuano by the Fisheries Development Institute of Chile (Instituto de Fomento Pesquero, IFOP) by monitoring the fleet at landing ports and from research surveys. From 1979 to 1983 research surveys of the fishing ground were conducted in an area from 35° to 27°S between depths of 70 to 350 m and using bottom trawls designed for catching squat lobsters.

Results of studies to date have provided information on the life history of each species, including reproductive patterns, minimum size at sexual maturity and an estimation of growth rate. Oceanographic factors hypothesized to affect *Pleuroncodes* population dynamics are discussed.

Deux espèces de galathées (*Cervimunida johni*, Porter et *Pleuroncodes monodon*, Milne Edwards, famille des galathéidés) font l'objet d'une pêche commerciale au large du Chili. Une pêche commerciale visant tout d'abord la première espèce s'est graduellement modifiée pour porter sur la seconde. La pêche des *Pleuroncodes* a débuté en 1966 au large de San Antonio (33° 35′ S de lat.) mais s'est par la suite déplacée vers le sud; elle atteint maintenant Talcahuano (37° S). Ce déplacement des aires de pêche peut s'expliquer de deux façons : 1) une augmentation de la pression de pêche et 2) une modification du milieu naturel. Des modifications observées simultanément chez d'autres espèces et pouvant être causées par des changements cycliques du milieu appuient, du moins en partie, la deuxième hypothèse.

Des données sur cette pêche sont recueillies depuis 1966 dans la région s'étendant de Coquimbo (30° S) à Talcahuano. Les données ont été obtenues par l'Institut de développement des pêches du Chili (Instituto de Fomento Pesquero, IFOP) qui effectue des contrôles de la flottille aux ports de débarquement de même que des relevés de recherche. De tels relevés des fonds de pêche ont été réalisés de 1979 à 1983 dans la région comprise entre 35° et 27° de latitude sud. Ils ont été réalisés à des profondeurs variant de 70 à 350 m à l'aide de chaluts de fond conçus pour la capture des galathées.

Les études effectuées ont permis d'obtenir des renseignements sur le cycle vital de chaque espèce, notamment sur les caractéristiques générales de la reproduction, la taille minimale à maturité sexuelle et le taux de croissance estimé. Les auteurs traitent des facteurs océanographiques que l'on suppose avoir un effet sur la dynamique de la population des *Pleuroncodes*.

Introduction

Galatheids are part of the anomura sea fauna off Chile. Five genera have been described: *Galathea* Fabricius, *Pleuroncodes* Stimpson, *Cervimunida* Benedict, *Munida* Leach, and *Munidopsis* Whiteaves. Of 16 species, 8 are endemic to Chilean waters but only two species, *C. johni* Porter and *P. monodon* H. Milne Edwards are of economic importance (Fig. 1). *Munida gregaria* Fabricius[1] and *M. subrugosa* White[1] may become economically important in the near future and *M. montemaris* Bahamonde and López may have some

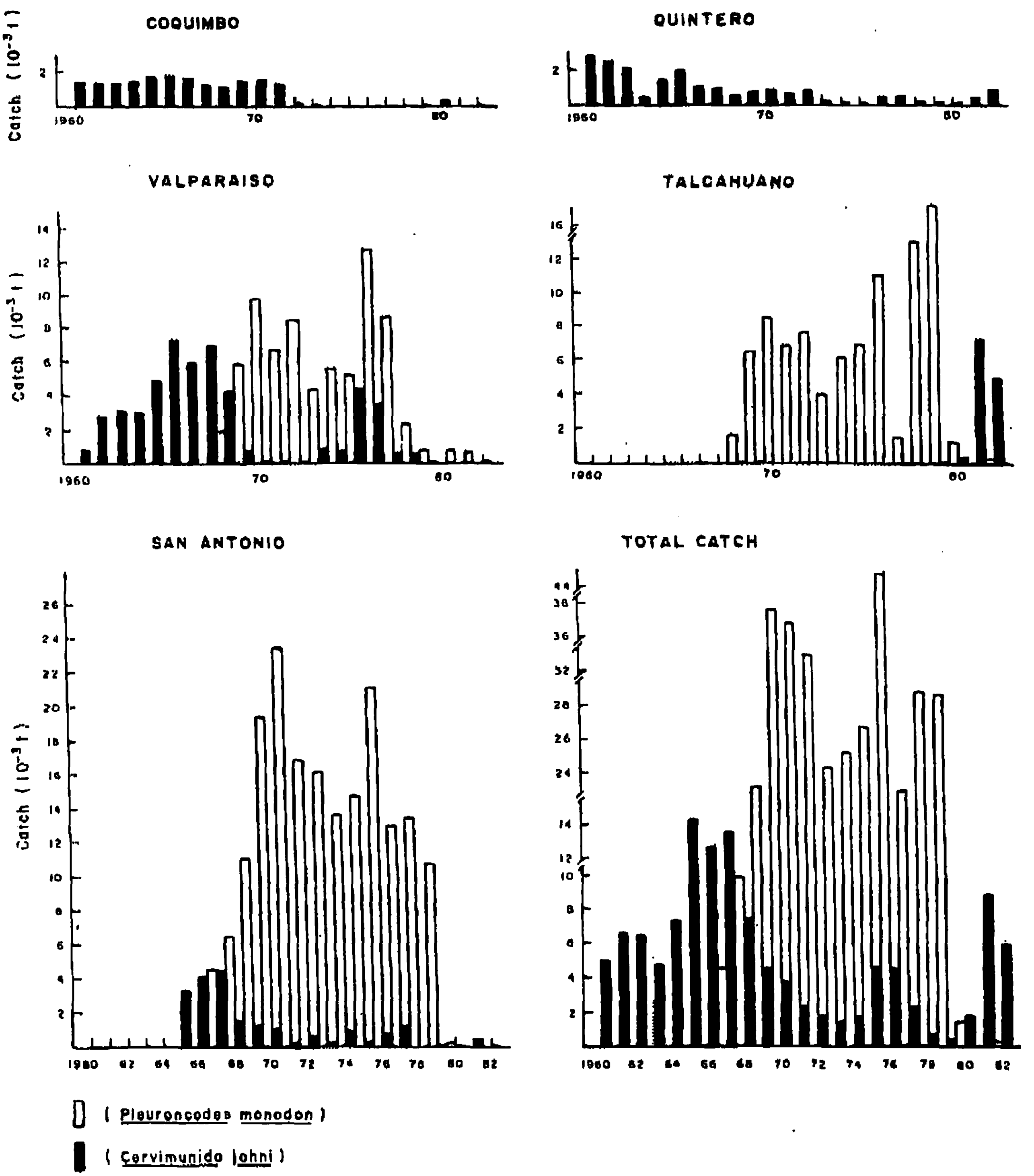

FIG. 1. Annual landings of *Pleuroncodes monodon* and *Cervimunida johni* by port and total national landings in Chile (1960–82).

importance in the distant future. The remaining species in Chilean waters are only of scientific interest.

P. monodon is distributed from Lobos de Afuera in Peru to the Bay of Ancud in Chile (Haig 1955) and occurs in depths between 20–40 m off Antofagasta (Gutierrez and Zuñiga 1977) and from 200 to 400 m off Valparaiso (Arana and Pizarro 1970) (Fig. 2). *C. johni* has a more restricted distribution and occurs between Coquimbo and Isla Mocha at depths between 200–400 m.

The Chilean squat lobster fishery began in 1953 on *C. johni* and in the last three decades, there have been numerous studies on the biology of exploited species (*C. johni*: De Buen 1957; Fagetti 1959, 1960; Alegría et al.

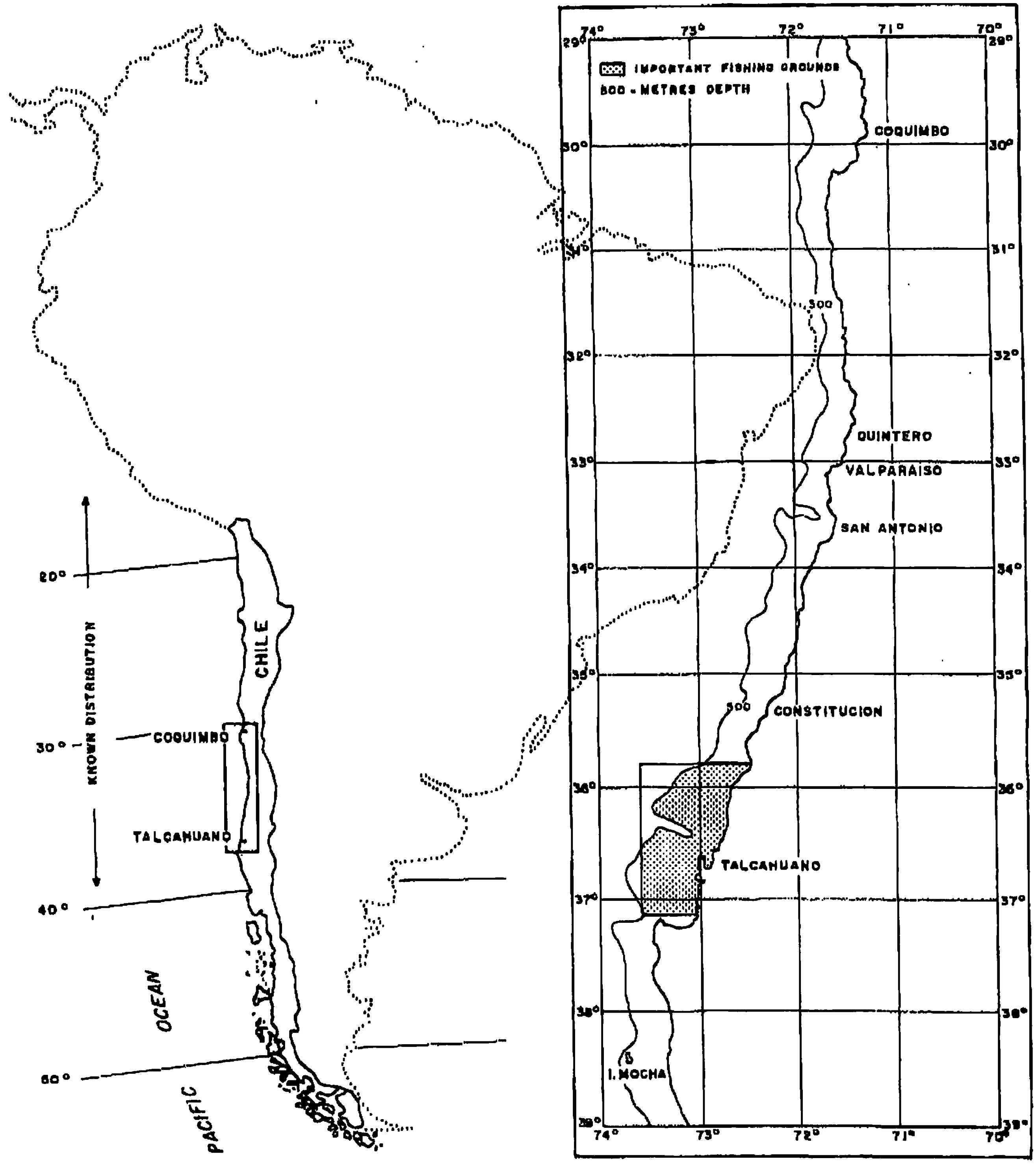

FIG. 2. Geographical distribution and main fishing areas for *Pleuroncodes monodon* in Chile.

1963; and Bahamonde 1965. *P. monodon*: Henriquez and Bahamonde 1964; Arana and Pizarro 1970; Fagetti and Campodónico 1971; Gutierrez and Zuñiga 1977 Henriquez 1979). In 1965 the Fisheries Development (Instituto de Fomento Pesquero, IFOP) began biological and economic studies of squat lobster fisheries to investigate additional exploitation of these resources (Mistakidis and Henriquez 1966). This resulted in a number of internal reports, mostly on *P. monodon*, many of which have not been published although the most important points have been summarized. In recent years, (G. Henriquez, unpubl. data) research has focused on why areas of highest abundance of *P. monodon* are located between 36° and 37°S (this represents a relatively small area at the southern extremity of its latitudinal range) and possible causes of the decrease in average commercial catch since 1970.

Initially in 1953 the squat lobster fishery was based entirely on landings of *C. johni* made at Coquimbo, Valparaiso and San Antonio (Fig. 2). Landings peaked at 14 365 t in 1965, and in 1966 fishing ranged from Coquimbo (19°30"S) to Punta Iloca (34°57"S) (Mistakidis and Henriquez 1966). Subsequently landings of *C. johni* declined gradually and in 1970, 3 812 t were harvested (Fig. 1). Abundance of *C. johni* gradually decreased in the area between Coquimbo and Valparaiso but catches of *P. monodon* increased as the fishing fleet moved further south. In 1967 landings of the latter species amounted to 4 583 t, increasing to 9 961 t in 1968. The best squat lobster fishing grounds were located in an area from 29° to 35°S where catches of 2 $t \cdot h^{-1}$ were made (Hancock and Henriquez 1968). In 1970, 37 678 t of *P. monodon* were caught, and fishing effort increased to 1 257 $\times 10^3$ BHP (Brake Horse Power) per fishing day (Henriquez and Avilés 1977).

The decline in *P. monodon* landings between 1970–75 (Table 1) was due to political-economic conditions and not to a decline in abundance of *P. monodon*. The fishery concentrated on *P. monodon* when the industry began to market a processed product in 1976, and this accounted for peak landings of 49 729 t that year and an average effort increase to 1 329 000 BHP per fishing day (Table 1). An analysis of catch and effort data provided by the industry showed that from 1970 to 1976 there was a steady increase in catch per unit effort, but since 1977, catch has decreased while effort has continued to increase (Labra and Lederman 1980).

In 1978 landings were 29 400 t and effort was 1 700 000 BHP·d; 61% of the fleet was concentrated in 1 294 km^2 at Punta Achira Fig. 3 (Henriquez et al. 1980). The size of animals declined and the mean cephalothoracic length (CL) decreased from 39 mm in 1967 to 27 mm in 1978 as the fishery moved southward (Peñailillo 1981) (Fig. 3 and 4). Consequently in 1979 the Corporación de Fomento de la Produción (CORFO) requested IFOP to undertake an evaluation of this resource.

Low landings in 1980–82 (Fig. 1) were due to closed seasons imposed on fishing *P. monodon*; fishing for this species was only permitted as part of another fishery. Landings of *C. johni* were minimal because of low abundance. In 1983 fishing was permitted only for *P. monodon*.

The main objectives of this study are to review the present state of biological knowledge of Chilean galatheid fisheries, to outline the scientific basis for management of this resource in recent years and to discuss results of these management measures.

Research Survey Methods

This study is based on unpublished technical reports of IFOP resulting from research sponsored by the Under Secretariat of Fisheries of the Ministry of Economy, Development Corporation. Some fisheries statistics of IFOP and the National Fisheries Service have been used.

[1]Williams (1973) suggested from culture studies that these two species were actually extreme forms of one species, *M. gregaria* Fabricius (by precedence).

TABLE 1. Average fleet effort, catch and catch per unit of effort (CPUE) in *Pleuroncodes monodon* fisheries in Chile, 1968–78.

Years	Effort $\times 10^3$ (10^{-3} BHP[a]·d)	Catch (t)	CPUE (t)
1968	0.576	9 961	17,29
1969	1.032	23 277	22,56
1970	1.257	37 678	29,97
1971	1.094	36 804	33,64
1972	0.830	32 971	39,72
1973	0.580	24 444	42,14
1974	0.723	28 305	39,15
1975	0.770	26 805	34,81
1976	1.329	49 729	36,67
1977	1.443	33 087	22,93
1978	1.700	29 403	17,30

[a]BHP (Brake Horse Power) × fishing day.

The Fisheries Development Institute (IFOP) and the Catholic University of Valparaiso undertook a research survey in 1979 in the area between latitude 30°S (Coquimbo) and 38°20"S (Isla Mocha) at depths from 50 to 500 m. The main objectives of this survey were to:

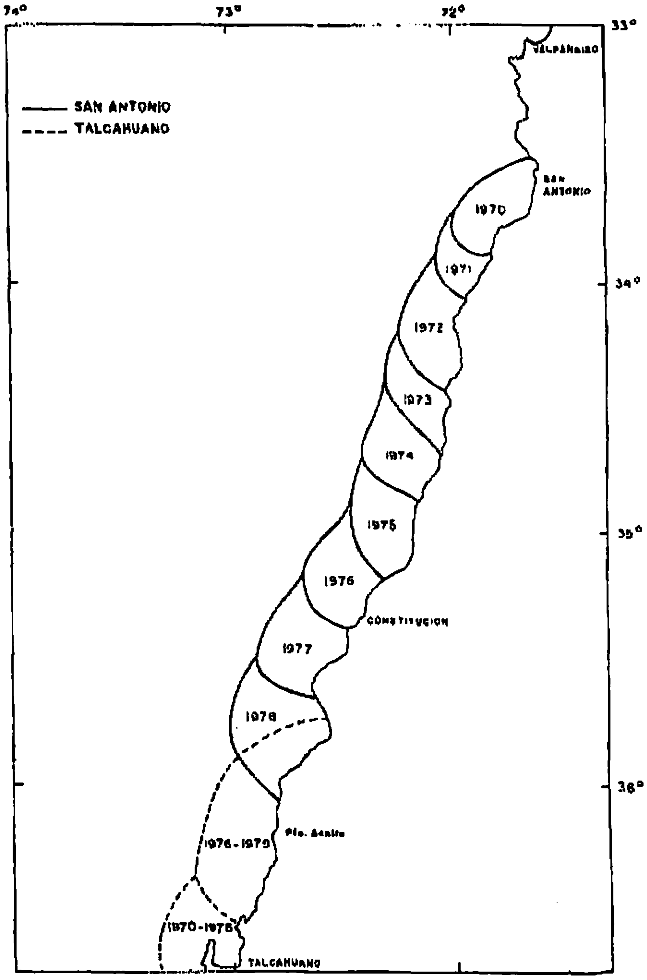

FIG. 3. Changes in fishing areas for squat lobsters in Chile (1976–79). Penailillo (1981).

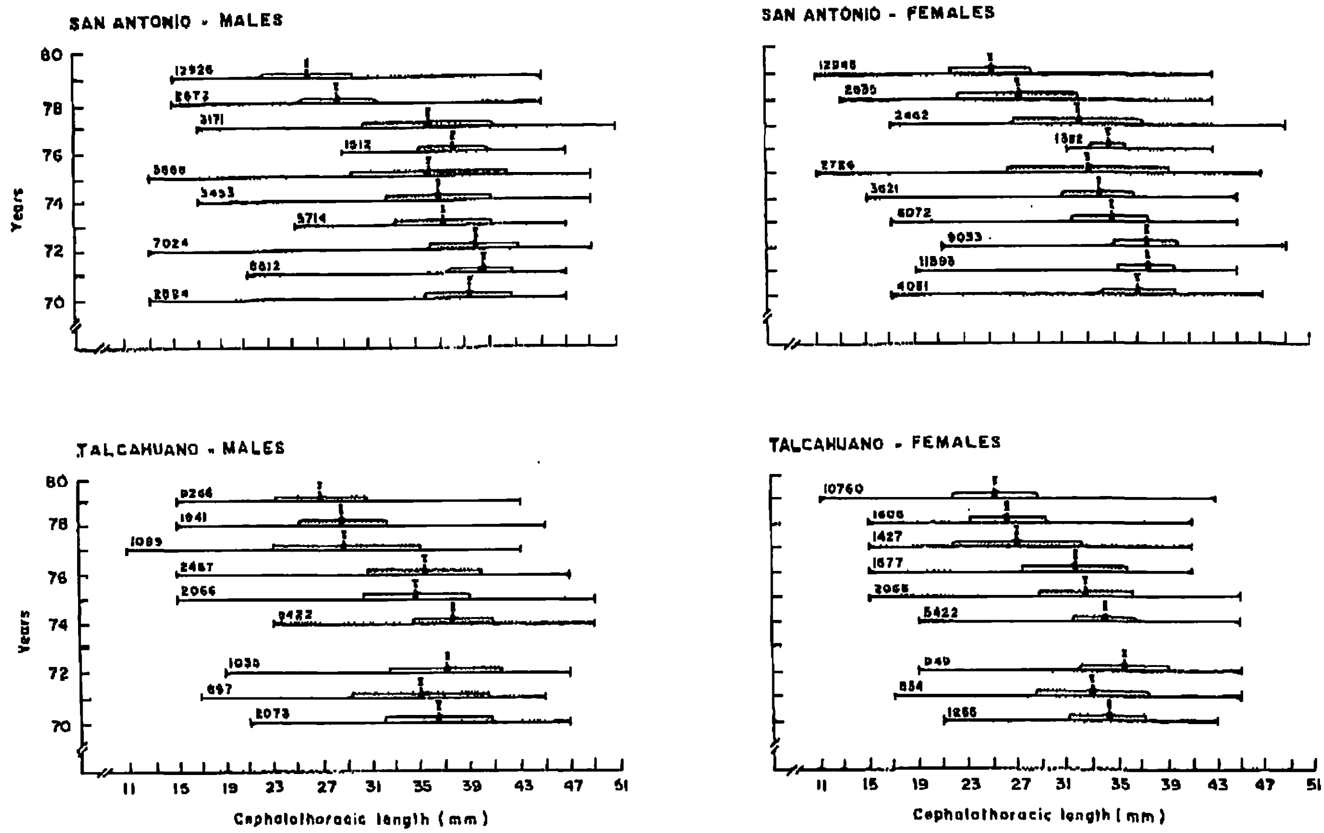

FIG. 4. Cephalothoracic length of male and female *Pleuroncodes monodon* from San Antonio and Talcahuano (1970–80). Peñaillo (1981).

(a) assess biomass of *P. monodon* in areas suitable for trawling
(b) determine oceanographic characteristics and quantify primary productivity in the area studied.

Two research vessels were used: the *B/I Carlos Porter* of IFOP, length 25.2 m, and the *Tiberiades* of the Catholic University of Valparaiso, length 19.5 m.

Random samples, stratified by depth, were taken over the entire area in the above depth range (Table 2). Table 3 shows the geographic and bathymetric distribution of squat lobsters in Chile based on results of this survey. Only *C. johni* was found in the area between 31° and 36°S but both *C. johni* and *P. monodon* were found in the area between 36° and 37°S. Further south both species virtually disappeared. Further surveys were carried out in 1980–81 using the same methods in an area extending from 35°48"S to 37°05"S at depths of 60–350 m which is the lower depth limit of *P. monodon* fishing. Surveys were repeated in 1982, 1983, and 1984 in order to locate areas of greatest abundance, estimate density, and assess size frequency distribution and biomass.

Nine stations were sampled monthly for *P. monodon* over a 12-mo period from October 1980 to September 1981 in a transect perpendicular to the coast off Punta Achira (36°13"S) at depths from 70 to 300 m with 20 to 25 minute tows using semiballoon type trawl nets (Bustos et al. 1982).

Surveys in 1979, 1980 and 1981 indicated squat lobsters were located in discrete geographic areas which were separated by areas where there were none. Random stratified sampling was planned in 1982–83 in areas where squat lobsters were concentrated; three such areas were delimited (Fig. 5):

Zone A: Punta Achira
Zone B: Cajon del Bio-Bio
Zone C: External zone of the area.

A trawl net with a 30 m head rope and a 35.4 m foot rope was used for fishing squat lobsters. The height of the mouth ranged from 2.8 to 2.4 m and the wing tips, as estimated by the method of Koyama (1974), had a mean separation of 11.25 m. Biomass was estimated by the area swept method (Alverson et al. 1964; Domain 1972; Pereyra 1967; Edwards 1968; and Kaimer et al. 1975).

TABLE 2. Position and depth of sampling stations off Chile from October, 1980 to September 1981 (Bustos et al. 1982). (*) Over Itata Shelf.

Station No.	Latitude °S	Longitude °W	Depth (m)
1	36°14'40"	72°52'40"	70
2	36°10'40"	73°00'50"	100
3	36°10'00"	73°02'50"	150
4	36°09'00"	73°04'50"	200
5	36°09'40"	73°08'30"	250
6	36°09'40"	73°15'40"	300
7*	36°08'40"	73°19'00"	200
8*	36°08'45"	73°19'00"	180
9*	36°08'45"	73°19'00"	150

TABLE 3. Geographic distribution and depth range of squat lobsters off Chile. From IFOP (1979).

Depth (m)	Geographic range (latitude)	Hauls: N	Hauls: With *Cervimunida johni*	Hauls: With *Pleuroncodes monodon*	Catch (t)	Density (kg·km⁻¹)
	30 - 31°S	17	—	—	—	
51 - 150		10	—	—	—	
151 - 300		7	—	—	—	
	31 - 32°S	22	2	—	—	
51 - 150		6	—	—	—	
151 - 300		9	2	—	—	32.6
301 - 500		7	—	—	—	
	32 - 33°S	38	6	—	553	
51 - 150		17	—	—	—	
151 - 300		11	2	—	542.9	125
301 - 500		10	4	—	10.1	
	33 - 34°S	35	5	—	89.6	
51 - 150		24	2	—	—	
151 - 300		7	2	—	64.9	23.7
301 - 500		4	1	—	24.7	
	34 - 35°S	78	6	—	9.6	
51 - 150		15	—	—	—	
151 - 300		22	6	—	9.6	1.5
301 - 500		5	—	—	—	
	35 - 36°S	78	4	—	2.2	
51 - 150		39	2	—	0.4	
151 - 300		30	1	—	1.7	
301 - 500		9	1	—	0.1	
	36 - 37°S	96	4	40	62 125	
subzone 36°00' - 36°30'S		40	3	21	50 758	
51 - 150		18	—	11	36 793	1,509
151 - 300		16	2	9	13 965	60
301 - 500		6	1	1	—	
subzone 36°30' - 37°00'S		46	1	19	11 367	
51 - 150		31	—	17	11 236	663
151 - 300		12	1	2	131	65
301 - 500		3	—	—	—	
	37 - 38°S	22	1	—	—	
51 - 150		9	—	—	—	
151 - 300		8	1	—	—	61.1
301 - 500		5	—	—	—	

A 5 kg random sample was taken from the catch. Cephalothoracic length (CL) was measured from the back of the eye socket for each specimen in the sample with calipers to the nearest 0.1 mm. Animals in the samples were sorted by sex and the frequency of ovigerous females recorded. Hardness of the cephalothorax was examined to determine the time of molting. Squat lobsters were grouped into 1 mm intervals to provide a size frequency distribution of animals in 1979, 1982, and 1983. Kolmogorov-Smirnov's non-parametric test (Tate and Clelland 1957) was used to compare size distributions in these three years.

External morphology was observed to determine the sex of both *P. monodon* and *C. johni*. The male genital pore is located on the coxa of the fifth pair of walking legs, and the first two swimmeret pleopods are developed into copulating organs. The female genital pore is on the coxa of the third pair of cephalothorac legs. The first pair of swimmeret pleopods is absent. Sexual maturity and time of spawning of females were estab-

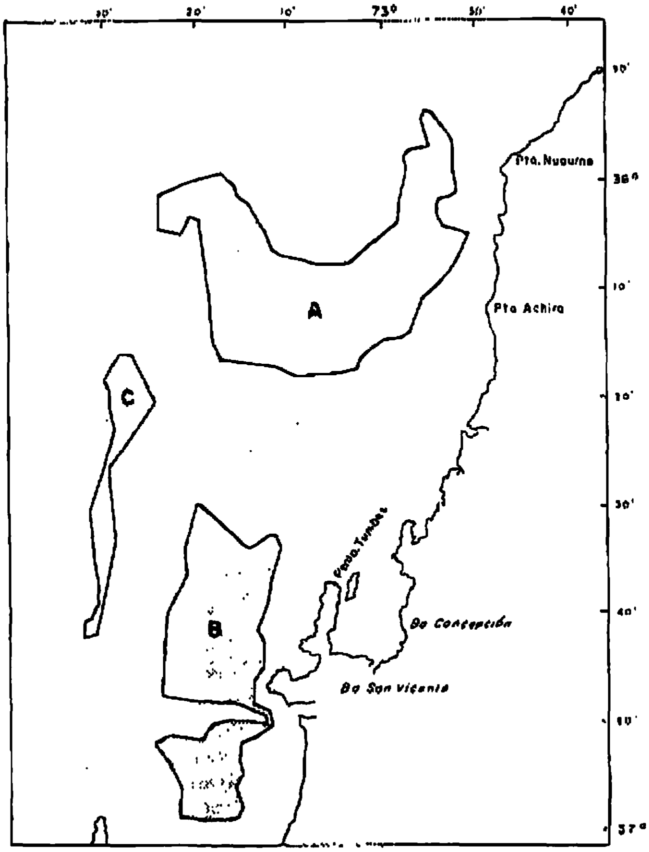

FIG. 5. Spatial boundaries of zones: A (Punta Achira), B (Cañon del Bio-Bio), and C (External).

lished from the frequency of ovigerous females in each sample.

Two methods were used to determine age and growth of *P. monodon*:

(a) Direct observations of size increases of animals kept in experimental aquaria under controlled light, temperature, salinity, oxygen and feeding conditions. Hiatt's (1948) method was used to estimate growth (Bustos et al. 1982).

(b) Statistical analysis of the length frequency distribution of CL measurements of squat lobsters using Cassie's (1954, 1963) method. The modes were determined by visual observations.

Two oceanographic cruises were carried out to determine temperature, salinity, and oxygen conditions (Fig. 6) in the fishing area, using research vessels IFOP-ECMA (Fishery Development Institute and School of Marine Science and Food), (IFOP 1979, Silva and Blanco 1980).

Results

Oceanography

From May 1 to June 1, 1980 the water temperature tended to be stable at depths between 100 and 200 m and ranged from 10 to 11°C except off Punta Nugurne where the temperature was over 12°C at 100 m (Fig. 6).

Salinities in the area ranged from 34.2 to 34.6‰ at the bottom, with highest salinities observed at depths of 200 m or more.

Oxygen concentrations ranged from 2 to 3 mL^{-1} in shallow water to a depth of 100 m, then decreased in deeper water to less than 1 mL^{-1} and reached a concentration of 0.5 mL^{-1} at a depth of 250 m.

The distribution of isotherms, isohalines and oxygen isolines at the bottom tended to follow the isobathic contour (Fig. 6) which according to Silva and Blanco (1980) is indicative of an absence of vertical mixing.

Subsurface equatorial water ranged from 80 to 470 m in depth on both cruises. A great part of the continental shelf and continental slope was covered by this water mass. Within this water mass, pockets of water occurred which had higher oxygen concentrations but whose volumes varied from year to year.

Intermediate antarctic water was detected below 470 m. In 1980 local upwelling was active in the vicinity of the fishing ground off Punta Nugurne (Brandhorst 1963, 1971; IFOP 1979; Silva and Blanco 1980). The absence of upwelling during the Langostino II cruise was attributed to a lack of southerly winds before and during the cruise.

Another important characteristic of the zone is that near the coast there is mixing of subantarctic water with rain and river water.

Abundance and Distribution

Table 4 shows estimates of squat lobster biomass for each zone from 1982 to 1983. During this period biomass increased by 5 500 t and the area occupied increased by 724 km^2. Zone A (Punta Achira) had the highest biomass in both years followed by Zones B (Cañon del Bio-Bio) and C.

Figures 7A–C show the spatial distribution of squat lobster densities in 1979, 1982, and 1983. Distribution in the last 2 years was similar. Spatial distribution by size is shown in Fig. 8.

TABLE 4. A. Total biomass (t) by zone of *Pleuroncodes monodon*.

Zone	Area (km^2)	Biomass (t)	95% confidence limits (t)
1982			
A	775 36	23 204	13 986–32 422
B	143 41	13 912	9 460–18 365
C	205 79	7 316	4 144–10 487
Total	1 124 56	44 432	33 859–55 005
1983			
A (Achira)	1 038 29	27 004	20 444–33 565
B (Bio-Bio)	639 57	21 233	14 623–27 843
C (Exterior)	170 79	1 746	947– 2 545
Total	1 848 65	49 983	40 723–59 243

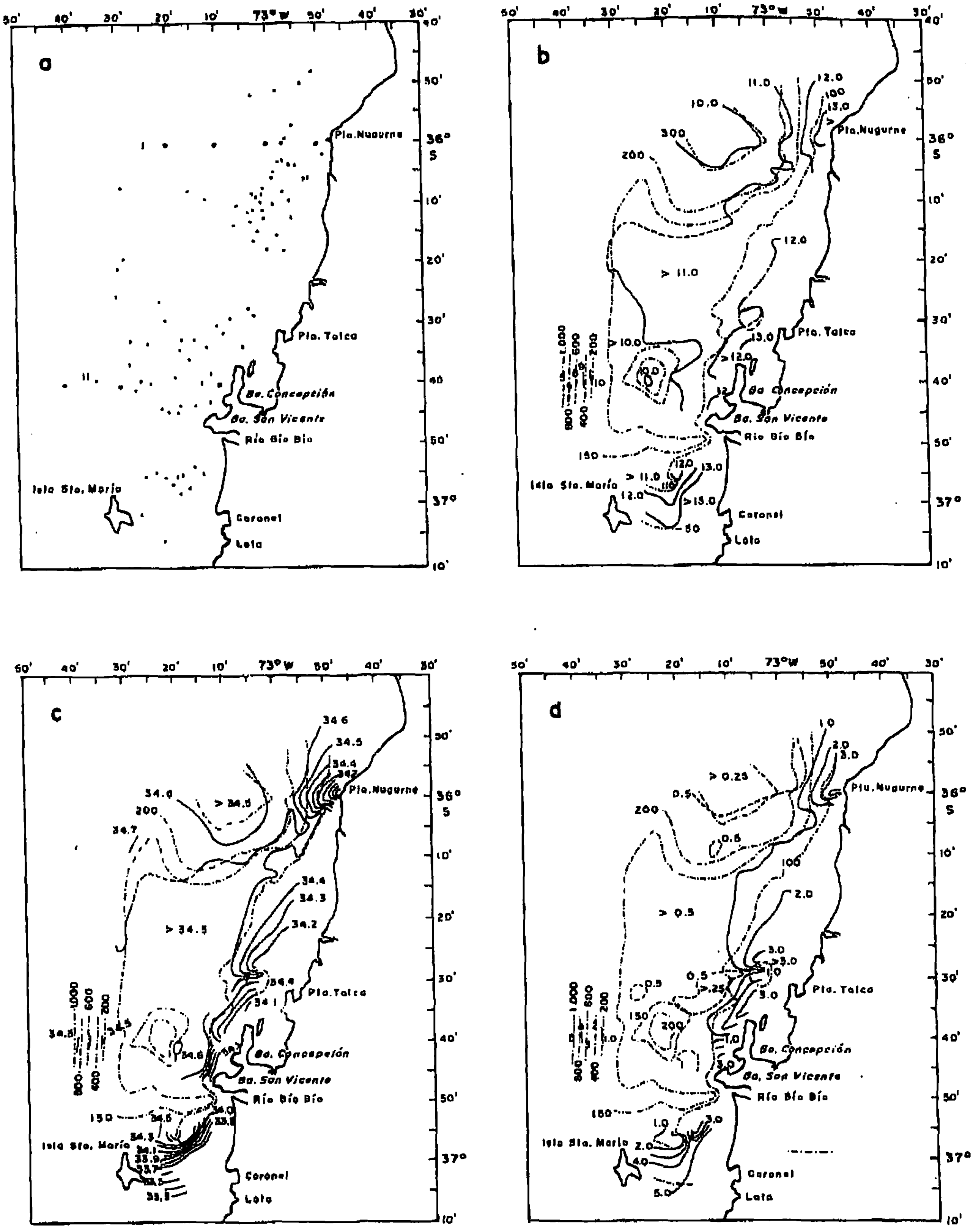

FIG. 6. Oceanographic conditions on squat lobster fishing grounds off Chile (Silva and Blanco, 1980). a. Oceanographic station (•); b. Depth (--) and bottom isotherms; c. Depth (--) and bottom isohalines; d. Depth (--) and bottom oxygen isolines.

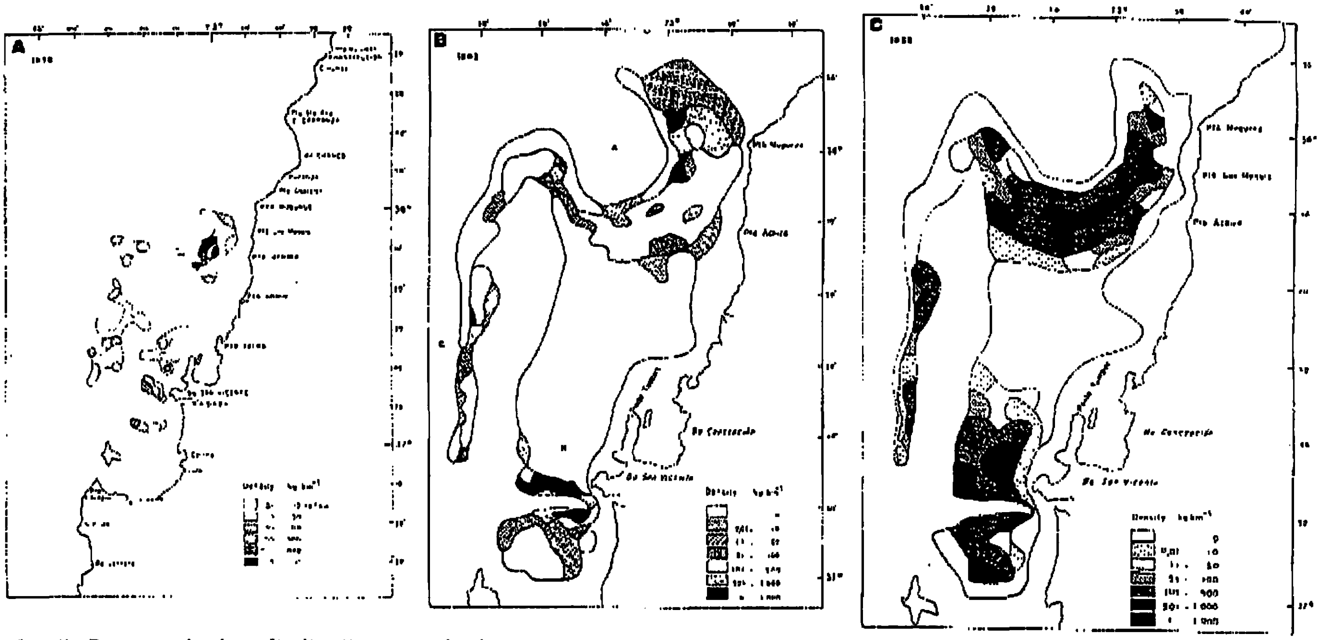

Fig. 7. Density (kg·km^{-1}) distribution of *Pleuroncodes monodon* from IFOP: A. May–August, 1979. B. April 4–30, 1982. C. April–May, 1983.

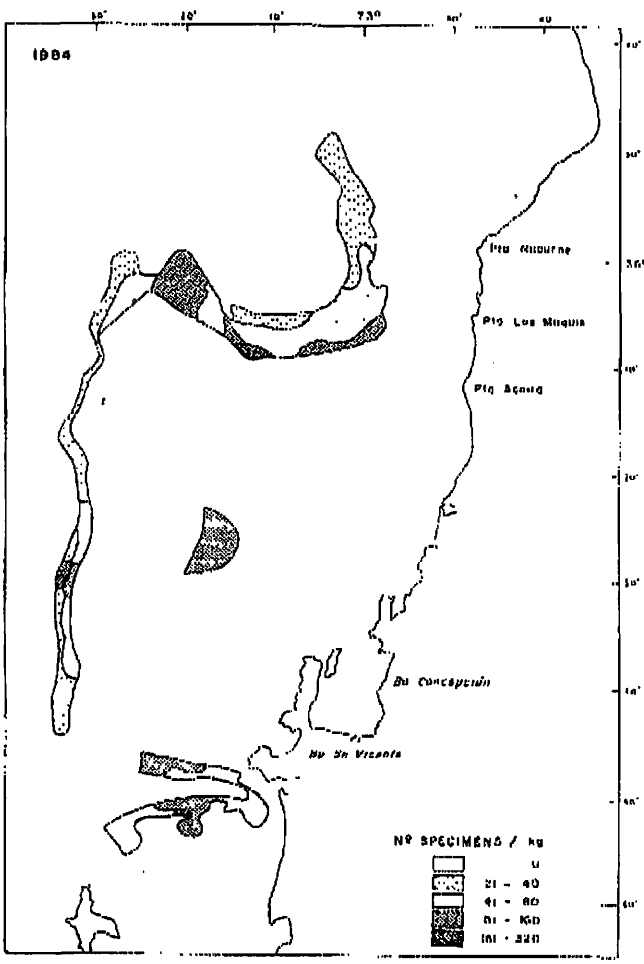

Fig. 8. Number of animals per kilogram in catches of *Pleuroncodes monodon* (March–April 1984), from IFOP.

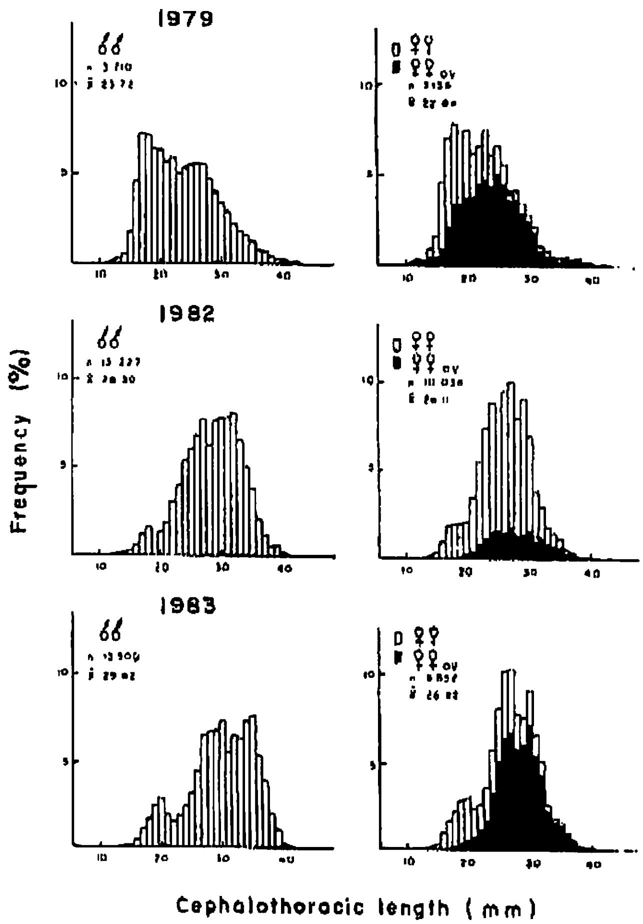

Fig. 9. Size distribution of males, females and ovigerous females of *Pleuroncodes monodon*. IFOP cruises: 1979, 1982, 1983. Table 1.

Figure 9 shows the size frequency distribution of the total *P. monodon* population on the fishing ground in 1979, 1982, and 1983. In 1979, which was the last year of non-restricted fishing, the mean size of the population was relatively low: 23.3 mm. It increased to 27.3 mm in 1982 and to 28.5 mm in 1983. A multimodal frequency distribution became more evident in 1983 along with a considerable increase in the frequency of specimens of > 30 mm CL. Size frequency distribution differed significantly ($P < 0.05$) between 1979 and 1983.

BYCATCH SPECIES

Several other species of animals were caught incidental to *P. monodon* and *C. johni* (Tables 5 and 6); these are detailed more fully in IFOP documents (Trujillo 1972; Pantoja et al. 1973; Yañez 1978; Bahamonde 1977, 1978; Labra and Lederman 1979). Table 5 estimates the amount of bycatch taken incidentally in hauls for *P. monodon* in an area from 36° to 37°S (Labra and Lederman 1979). Table 6 shows the percent distribution of the different bycatch species by zones in the Talcahuano Basin fishing area in two successive years. The most important bycatch species was *Merluccius gayi*.

Pleuroncodes and *Cervimunida* are preyed on by several species of fish (Table 7). In 1964 Henriquez and Bahamonde studied the feeding habits of *Genypterus maculatus* between San Antonio and Constitución in central Chile and reported it as an important predator on *Pleurocondes*. Of specimens of this species examined, 75% contained *Pleuroncodes*; this predator was able to consume any size of *Pleuroncodes* present. The main predators of squat lobsters appear to be *Genypterus maculatus*, *Paralichthys microps* and *Merluccius gayi*.

To determine whether the feeding habits of *G. maculatus* may have changed when squat lobster populations declined (Henriquez and Bahamonde 1964), further sampling was undertaken in May 1981 and results were reported by Bahamonde and Zavala (1981). It was noted that *Genypterus* was feeding mainly on *Pterygosquilla armata*. There were no squat lobsters in the stomach contents. Although both species were caught in trawl nets, they may have been spatially separated on the bottom because of different habitat preferences.

According to available information, *P. monodon* and *C. johni* are demersal, at least in the adult stage. *Pleuroncodes* is found mostly in areas of green mud that have a high organic content which according to Gallardo (1963) is probably due to the sinking of surface diatoms. These phytoplankton bloom areas may be associated with areas of upwelling that are characteristic of the central and northeast coast of Chile. Gallardo et al. (1980) found *Ampelisca araucana* zoeas and crustacean eggs in the stomachs of *P. monodon*. Diatoms (*Chaetoceros, Biddulphi, Synedra, Coscinodiscus* and *Thalassiosira*), foraminifera, bacteria filaments, organic detritus and fish scales were also found.

SPAWNING AND SPAWNING SEASON

Analysis of samples showed variation existed in the percentage of ovigerous females caught on the fishing grounds between April 6–20, 1982 and April 15–May 8, 1983; 8.1% in 1982 and 24.6% in 1983. The percentage of males was higher than females and ranged from 56 to 60%. The spawning season of *P. monodon* in the Talcahuano Basin extends from April to November. The highest frequencies of ovigerous females were recorded between June and October (Fig. 10) with percentages exceeding 25% of the total number of females. The highest percentage of females in an advanced stage of incubation was recorded in July and November. The smallest ovigerous female size observed was 9 mm CL and by 40 mm CL, most females were ovigerous (Fig. 11).

When spawning begins in April, ovigerous females are at depths between 200 and 300 m but seem to migrate to shallow waters (100–150 m) in July–August (Fig. 10) and 1979 (Fig. 11).

The spawning season of *Cervimunida* begins one month later than that of *P. monodon*, and occurs from

TABLE 5. Estimates of biomass (t) of fauna caught incidentally in *Pleuroncodes monodon* fisheries Lat. 36°–37°S, 30-min trawling, mean velocity: 2.2 knots.

	Number of tows				
	18	29	15	10	8
A. Species	51–100(m)	101–150(m)	151–200(m)	201–300(m)	301–400(m)
Merluccius gayi	714	16 167	2 562	2 264	288
Genypterus blacodes	—	—	—	43	8
Genypterus maculatus	—	82	675	47	83
Cancroids crabs	82	2 105	49	139	—
Grenadiers	—	167	1 957	24 640	4 677
Spider crab	207	—	110	1 084	1 953
Rays	—	—	113	513	1 291
Total biomass	1 003	18 532	5 468	18 730	8 300
B. Bycatch CPUE (kg km^{-1})					
Average	13	89	116	298	—
Main bycatch species	9 (*M. gayi*)	78 (*M. gayi*)	55 (*M gayi*)	233 (Grenadiers)	

TABLE 6. Distribution of species caught in survey cruises for squat lobsters in 1982 and 1983 off Chile expressed as a percentage of the catch by zone and total catch.

Specie	Zone A (Achira) 1982	Zone A (Achira) 1983	Zone B (Bio-Bio) 1982	Zone B (Bio-Bio) 1983	Zone C (Exterior) 1982	Zone C (Exterior) 1983	Total 1982	Total 1983
Pleuroncodes monodon (langostino colorado)	67.99	76.13	93.94	84.95	78.86	59.18	79.46	78.64
Cervimunida johni (langostino amarillo)	1.38	0.20	—[b]	—[b]	6.15	13.30	1.61	0.8
Merluccius gayi (merluza común)	23.33	18.74	5.33	14.32	4.89	5.96	13.66	16.38
Hippoglossina macrops and *Paralichthys microps* (flatfishes)	0.68	1.76	0.01	0.25	0.43	2.37	0.39	1.21
Coelorhynchus patagoniae (grenadiers)	1.15	0.15	—[b]	—[b]	4.36	7.73	1.22	0.48
Genypterus maculatus (congrio negro)	1.48	0.64	0.18	—[a]	—[b]	—[b]	0.76	0.37
Trachurus murphyi (jurel)	3.11	1.01	0.19	0.29	5.06	5.09	2.32	0.95
Prolatilus jugularis (blanquillo)	0.01	0.44	0.05	—[a]	—[b]	—[b]	0.02	0.25
Brachyura (crabs)	0.55	0.42	0.20	0.11	0.03	—[a]	0.34	0.28
Elasmobranchii (rays and sharks)	0.16	0.34	0.02	0.04	0.22	0.32	0.12	0.22
Others	0.16	0.17	0.08	0.04	—[b]	6.05	0.10	0.42
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[a]Incidental catch
[b]No catch.

TABLE 7. Main predators of *Pleuroncodes monodon*, between 35 and 37°S (according Melendez 1981).

Species	Predator frequency (%)	CL (mm) of squat lobsters found inside stomachs
Genypterus maculatus	25.0	2.0 - 14.0
Paralichthys microps	24.5	5.0 - 14.0
Merluccius gayi	17.4	18 - 33
Prolatilus yugularis	7.1	4 - 23
Trachurus murphyi	1.7	7.5
Coelorhynchus patagonia	0.8	7.3

May to December with >50% of observed females ovigerous from June to November. The smallest size of spawning *Cervimunida* was 25 mm CL. In 1959 the average size of ovigerous females was 35 mm, larger than that found for *Pleuroncodes* in 1980–81.

The number of eggs produced by individual *Pleuroncodes* females ranged from 3 000 to 6 000 depending on the size of the specimen. Figure 10 shows an estimated fecundity curve for this species but no attempt was made to determine whether this relationship varied over time. The fecundity of *Cervimunida* is somewhat higher, ranging from 3 400 to 6 900 eggs, again depending on the size of the animal (Alegría et al. 1963).

POPULATION DYNAMICS

Analysis of data collected during 1980–81 enabled us to describe the depth distribution of squat lobsters throughout the year. In October the entire population was at a depth of 100 m and there were three distinct age groups with modes at 8, 25, and 32 mm CL. Ovigerous females of all sizes were present (Fig. 10).

During the first 2 weeks of November the population was at a depth between 70 and 100 m; at 70 m the mode was at 12 mm CL whereas at 100 m the mode was 25 mm CL, the same as observed for spawning females. The number of spawning females at 100 m was less than at 70 m, but that they were larger. There were no ovigerous females with a CI > 27 mm, but there were non-spawning females at 31–34 mm CL.

The situation was slightly different during the second fortnight of November when the population was distributed between 100–150 m depth. There were two distinct size groups at 100 m; one with a mode at 14 mm CL and another with a 25 mm CL mode. The second modal group contained the greatest number of ovigerous females. At 150 m, the dominant modal group was at 26 mm CL coinciding with the greatest number of ovigerous females.

In December the population had a greater bathymetric distribution (100–250 m); spawning had ended.

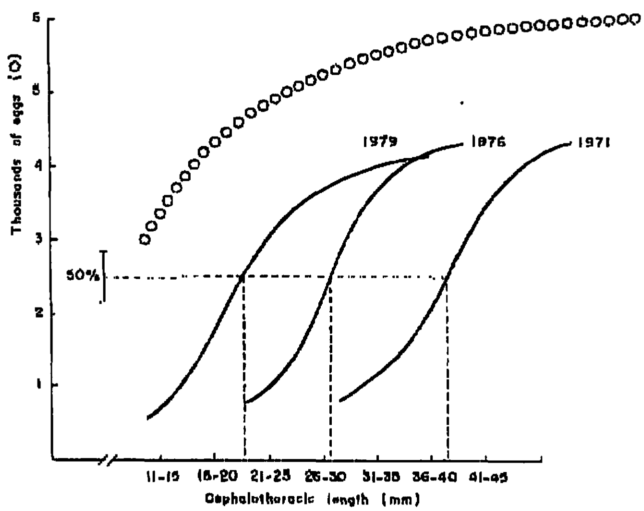

FIG. 11. Fecundity of *Pleuroncodes monodon* (O) and percentage of size distribution of ovigerous females: 1971, 1976, 1979, (IFOP), 1979.

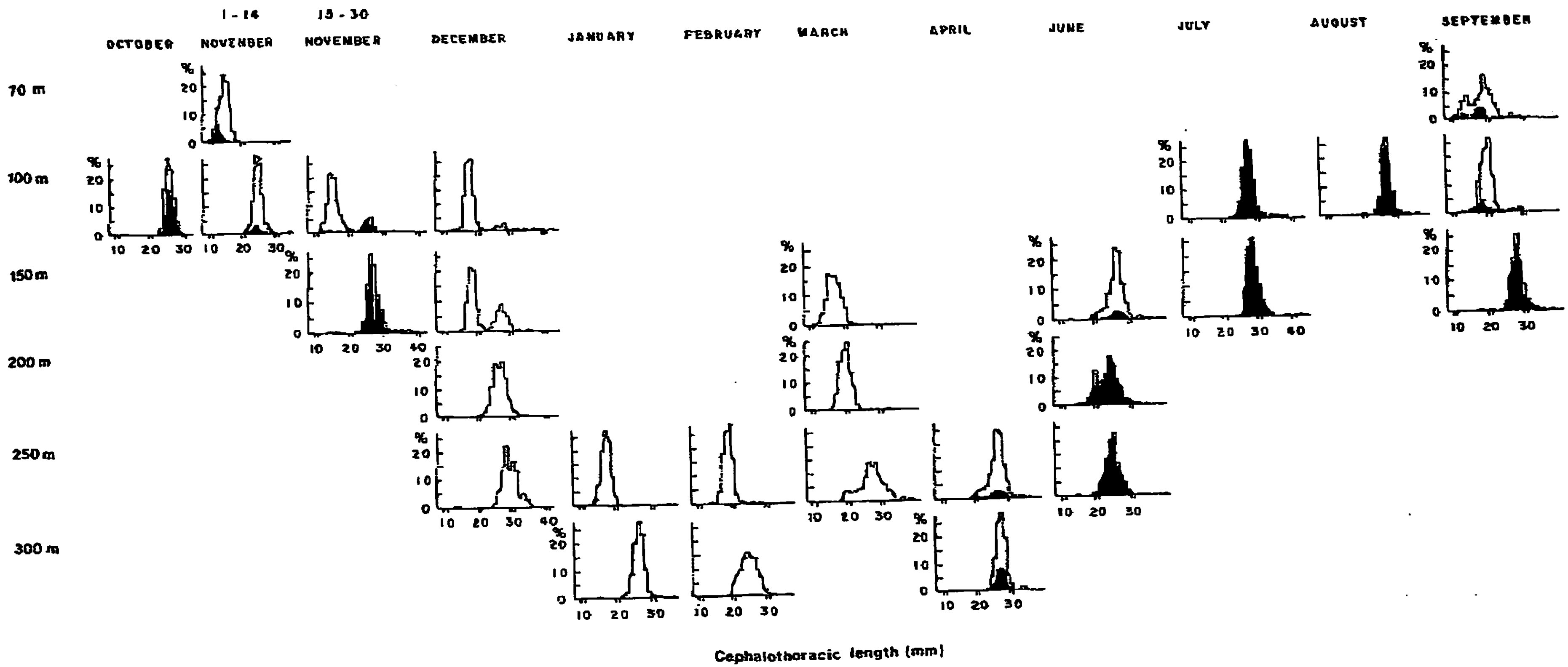

FIG. 10. *Pleuroncodes monodon:* Monthly percentage and size distribution of ovigerous females off Punta Achira (Table 2). Solid bars are ovigerous females.

There was a small mode between 13-14 mm at 250 m probably from the spawning the previous year. In January and February, the population was clearly stratified by depth between 250 and 300 m. The smallest animals were located at 250 m.

In March the population was located between 150 and 250 m. Stratification by size was obvious and the average size increased with increasing depth. In April the population was between 200 and 300 m and egg extrusion spawning had begun, the highest percentage of ovigerous females was found at 300 m.

No samples were obtained in May. In June stratification was the reverse to that noted in April. Most of the ovigerous females were between 200 and 250 m. In July and August, the population had moved upwards to depths between 100 and 150 m and showed little stratification by size.

In September the population had begun to stratify by size; the largest animals were found at 150 m, also the location of most of the ovigerous females.

Results of analysis of polymodal frequency curves of cephalothoracic lengths using Cassie's method (1954, 1963) are shown in Table 8. Estimates of the modes which were considered to be equivalent to annual year classes were made on the basis of annual surveys and these results are also included in Table 8. There were no significant differences between males and females.

As a result of experimentally raising *P. monodon* larvae it was possible to distinguish 10 stages of zoea and one stage of megalops (Bustos et al. 1982). The young measured 6 mm CL at 6 mo and 11 mm at 12 mo.

Discussion and Conclusion

Between Coquimbo (30°S) and Isla Mocha (38°20"S), *C. johni* is endemic and is distributed practically over the entire area on stoney-mud bottom. *P. monodon* has a wider but apparently more sporadic distribution and occurs at least as far north as the Peruvian coast, inhabitating muddy bottom in areas of reduced current.

The life cycle of both species is similar and they seem to have alternating periods of abundance. Publications in the first half of the 19th century refer only to *P. monodon*, and the first specimens of *C. johni* were found at the beginning of the present century. Towards 1950, *C. johni* was the only species of squat lobster exploited in the fishery, but it has gradually been replaced by *P. monodon* in recent years. In the last 7 yr the fishery for this species has moved southward and is now in a well defined fishing area in the Talcahuano Basin (Fig. 3).

Both species *C. johni* and *P. monodon* feed on detritus and the remains of marine organisms. They are preyed upon by several species of fish, some of which are commercially important.

Populations of both species seem to be regulated by both environmental factors and commercial fisheries. In recent years population decreases have been attributed to fishing but there is evidence that natural phenomena may also be important. A large part of the detritus on which squat lobsters feed is produced in the photic zone of subantarctic water (Gallardo et al. 1980). Accumulation of detritus depends on upwelling which occurs in the vicinity of the present fishing grounds off Punta Nugurne (Brandhorst 1963; Kelly and Blanco 1984). Also, in recent years clupeid fisheries have increased in both the north and central southern area, including Talcahuano. Clupeids are large consumers of plankton, especially phytoplankton, and this may affect the food supply for bentho-demersal detritus eating animals.

There are other factors related to detritus production that merit investigation: variation in the transport of detritus by rivers and the dynamics of the subsurface equatorial water mass that is dragged southward by the Gunther Current. This water mass has a high salinity and low oxygen content (Brandhorst 1963; and Robles et al. 1976) and expands over the upper slope of the continental shelf. This may explain the absence of demersal fisheries in the northern zone (Robles et al. 1976). Squat lobsters may live at the boundary of these water masses and movement of *Pleuroncodes* populations may be due to the dynamic interaction between them.

At present, there is insufficient oceanographic data to explain many of the biological phenomenon observed with squat lobsters. Collection of oceanographic data in conjunction with squat lobster abundance and distribution should have a high priority.

TABLE 8. Average size (CL) by age class of *Pleuroncodes monodon* calculated according to Cassie's method for samples of Punta Achira (1980-81).

Age (y)	Average CL size (Cassie) Males	Females	Average size estimated from survey data modes
0	11.00	11.3	
1	15.10	15.0	16.60
2	20.20	19.1	24.70
3	27.40	24.0	29.80
4	32.20	37.6	36.40
5	35.20	36.2	41.00
6	38.80	39.2	

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