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Annual growth and age composition of the squat lobster *Cervimunida johni* off northern-central Chile (1996-97)*

HUGO ARANCIBIA[1], LUIS A. CUBILLOS[1,‡] and ENZO ACUÑA[2]

[1]Departamento de Oceanografía, Facultad de Ciencias Naturales y Oceanográficas, Casilla 160-C, Concepción, Chile.
E-mail: lucubillos@udec.cl
[2]Universidad Católica del Norte, Facultad de Ciencias del Mar, Departamento de Biología Marina, Casilla 117, Coquimbo, Chile.

SUMMARY: The MULTIFAN method was used to analyse a series of monthly length-frequency distributions of the squat lobster *Cervimunida johni* Porter (1903) (Galatheidae), for the estimation of growth and age composition in the fishing area off Coquimbo (29°59'S-71°22'W), in the northern-central area off Chile. Length frequency data (LFD) were collected from commercial catches made between 28°S and 32°10'S from September 1996 to September 1997. MULTIFAN distinguished 11 age classes in the LFD of males and 9 age classes in the LFD of females. This is an important result because usually only three to four age classes have been reported by analysing annual length-frequency data. Males and females were recruited to the fishery at 19.7 and 18.8 mm carapace length (CL) respectively. The von Bertalanffy growth parameters were estimated as K = 0.151 yr^{-1} and CL_∞= 52.8 mm for males, and K = 0.174 yr^{-1} and CL_∞ = 45.60 mm for females. Males reached larger sizes than females, which is in agreement with the growth of other Galatheids.

Key words: age structure, growth, von Bertalanffy model, squat lobster, northern-central Chile.

RESUMEN: CRECIMIENTO Y COMPOSICIÓN DE EDAD ANUAL DEL LANGOSTINO AMARILLO *CERVIMUNIDA JOHNI* DE LA ZONA NORTE-CENTRO DE CHILE (1996-97). – Se utilizó el método MULTIFAN para analizar una serie de tiempo mensual de distribuciones de frecuencia de tamaños del langostino amarillo *Cervimunida johni* Porter (1903) (Galatheidae), para estimar el crecimiento y la composición de edad en la zona de pesca del área frente a Coquimbo (29°59'S-71°22'W), Chile. Datos de frecuencia de tamaños (DFT) fueron obtenidos de las capturas comerciales realizadas entre 28°S y 32°10'S entre septiembre de 1996 y septiembre de 1997. Se distinguieron 11 clases de edad en los datos de machos y 9 clases de edad en el caso de las hembras. Se considera que este es un resultado importante debido a que usualmente sólo tres a cuatro clases de edad han sido reportadas analizando DFT anuales. Machos y hembras reclutaron a la pesquería a los 19,7 y 18,8 mm de longitud del caparazón (LC), respectivamente. Los parámetros de crecimiento del modelo de von Bertalanffy estimados fueron: K = 0,151 año^{-1} y LC_∞ = 52,8 mm para machos, y K = 0,174 año^{-1} y LC_∞ = 45,6 mm para hembras. Los machos alcanzaron un tamaño asintótico mayor que las hembras, lo que está de acuerdo con el crecimiento de otras especies de la familia Galatheidae.

Palabras clave: estructura de edad, crecimiento, modelo de von Bertalanffy, langostino amarillo, centro-norte de Chile.

INTRODUCTION

The galatheid squat lobster, *Cervimunida johni* Porter (1903), represents an important traditional resource for the Chilean benthic crustacean bottom-trawl fisheries, particularly for the fishery operating off northern-central Chile (28°S-32°S). *C. johni* is an endemic species distributed from Taltal (29°19'S) to Isla Mocha (38°20'S) at depths of 200-400 m (Bahamonde, 1965; Henríquez, 1979, Bahamondes *et al.*, 1986). Investigations into *C. johni*

‡ Corresponding author.

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have been conducted since 1950 by Chilean scientists, particularly on reproduction, taxonomy, population structure, exploitation and ecology, most of them with reference to the central zone of Chile (De Buen, 1957; Alegría *et al.*, 1963; Henriquez, 1979; Andrade and Baez, 1980; Arana and Pizarro, 1970; Bahamonde *et al.*, 1986). There have been few growth studies of squat lobster of northern-central Chile and estimates of the growth parameter needed for population analysis. The most recent contributions are from Wolff and Aroca (1995), and unpublished reports in which von Bertalanffy growth (VBG) parameters have been estimated by analysing annual length-frequency distributions (Pavez *et al.*, 1994; Pool *et al.*, 1996).

Estimates of growth rates—and in particular estimates of VBG parameters and age composition—are important because they are necessary elements in the population dynamics models used in stock assessment (Hilborn and Walters, 1992). However, growth estimation is a difficult task in crustaceans as age marks are lost during moulting. Crustacean growth is composed of moulting frequency and size increment per moult and growth models should consider the discontinuities in the growth process (Saila *et al.*, 1979; Fogarty and Idoine, 1988; Dall *et al.*, 1990). Many authors find that a continuous asymptotic model, such as the VBG funcion, can be used to model crustacean growth, and length-frequency data (LFD) has been used to study growth and age-structure in animals that cannot be aged directly through annual marks in hard structures of their body. Modern computer programmes are currently available to decompose a time series of LFD into age classes and to estimate VBG parameters, such as MIX (MacDonald and Green, 1988), MULTIFAN (Fournier *et al.*,1990) and the FiSAT package (Gayanilo *et al.*, 1995).

The main objective of this paper is to describe the annual growth and age composition of *C. johni* by analysing a time series of LFD using the MULTIFAN method. The ultimate goal is to utilise these estimates to develop population dynamics models to be used for a rational exploitation of the resource.

Brief antecedents of the fishery

In addition to *C. johni*, two other decapod species, red squat lobster *Pleuroncodes monodon* (Milne Edwards 1837) and the shrimp *Heterocarpus reedi* (Bahamonde 1955), are the main benthic crustacea resources exploited by the same fleet of trawlers in the northern-central area off Chile. The squat lobster fishery began in 1953 on *C. johni*, with Coquimbo (29°59'S-71°22'W), Valparaíso (33º00'S-71º31'W) and San Antonio (33º35'S-71º38'W) as the main ports for landings. Catches of this species peaked at 14365 t in 1965, and then landings of *C. johni* declined gradually until 1973 in the area between Conquimbo and San Antonio. As the abundance and catch of *C. johni* decreased in northern Chile, the fishing fleet moved further south and important fishing zones for *P. monodon* were discovered. The latter species began to be dominant in total catches during the 1970s, but it was severely over-exploited and the fishery was closed in 1980-82. In that period, landings of *C. johni* were minimal because of low abundance (Bahamonde *et al.*, 1986). However, in the late 1980s the *C. johni* population reappeared again in the area off Coquimbo, and since 1988 a small number of fishing ships have been operating regularly on the three crustacea species *C. johni*, *P. monodon* and *H. reedi*. At present the fishing fleet is composed of 14 fishing vessels, with an average in length of 21.5 m (SD = 2.18), an average storage capacity of 115.9 m^3, and fishing gear consisting of a bottom trawl net with mesh size ranging between 35 and 40 mm at the cod-end (Acuña *et al.*, 1997). At present, the benthic crustacea fishery is regulated by setting annual catch quotas.

According to Arana *et al.* (1970) and Wolff and Aroca (1995), male *C. johni* are heavier than females above 30 mm carapace length (CL), due to their more developed chelae. Alegría *et al.* (1963) estimated 31 mm CL as the length at mean maturity, while recently Acuña *et al.* (2003) found a declining trend in the mean maturity size from 30.3 mm in year 1996 to 19 mm in year 2000. The average fecundity has been estimated as 7000 eggs by Acuña *et al.* (2003). In terms of the reproductive cycle of *C. johni*, the period of gravid females extends from May to December, peaking between July and October, and the period of egg eclosion starts between October and November (Alegría *et al.*, 1963; Wolff and Aroca, 1995). Wolff and Aroca (1995) found a high number of soft, recently moulted individuals of both sexes from December to April, when no reproductive activity was observed, and concluded that this period is the main moulting period of the population. According to the latter authors, relative growth for both sexes is well described by a linear growth increment of about 2.5 mm from one moult to the next .

MATERIALS AND METHODS

Data source

Length-frequency data were collected by observers from fishery catches between September 1996 and September 1997. All squat lobster measured were caught by trawl vessels on the most important fishing grounds, mainly within the area bounded by 28°-32°10' S (Acuña *et al*., 1998). Squat lobster were randomly selected and measured from the base of the eye socket to the posterior edge of the carapace, i.e. carapace length (CL). The CL measurements were with a precision of 0.1 millimetres and were recorded with the sampling date. The total numbers of individuals sampled per month are shown in Table 1, as well as the proportion of males and females in the samples. The *C. johni* fishery was closed from January to March 1997 and samples for that period were obtained from the by-catch of the shrimp *Heterocarpus reedi* fishery. The fishing gear used in the shrimp fishery is the same as in the *C. johni* fishery (35 to 40 mm mesh size), and these samples are considered here because smaller individuals were present in the samples. To avoid probable effects of small samples on growth results, we selected only size samples ≥ 1000 individuals per month. According to this criterion, samples for December 1996 and January and July 1997 were discarded from the analysis. Although in March 1997 the sample size consisted of only 1008 individuals (17.8 % for females), it was decided to accept this sample because it represented the lowest modal group, as required for growth analysis.

Growth analysis

The numbers of measurements per month were compiled into length-frequency histograms (regular length classes of 1 mm) , from which von Bertalanffy growth (VBG) parameters were estimated using the MULTIFAN computer program (Fournier *et al*., 1990) under the assumption that the modes in the data represent year classes. MULTIFAN can incorporate specific structural hypotheses into models being fitted to the length-frequency data (LFD). The simplest structural hypothesis assumes that the mean lengths-at-age lie on the VBG curve and that the standard deviations of length-at-age are identical for all cohorts. The more complex hypotheses tested assume that the following processes can occur in the population sampled: (i) sampling bias for the first year class, (ii) age-dependent standard deviation, and (iii) seasonally oscillating growth.

In this paper, we systematically fitted models incorporating all possible combinations of the above structural hypotheses, except seasonally oscillating growth (see discussion below), and used likelihood ratio tests to identify the most parsimonious model structure. The composition of these models is summarised in Table 2, where the parameter λ_2 determines the age-dependent trend in the standard deviation and b_1 is a parameter determining the amount of size selectivity bias for the first age-class. If $\lambda_2 = 0$ and $b_1 = 0$, the standard deviations are age-independent and there is no sampling bias for the first year-class respectively. Testing procedures were done automatically by MULTIFAN using a χ^2 test to determine what constitutes a significant increase in the maximum value of log-likelihood function. As recommended by Fournier *et al*. (1990), we employed the 0.90 point of the χ^2 random variable to accept an extra age-class into the model description. To test the significance of the inclusion of other parameters such as the parameter for age-dependent standard deviation into the models, we used the 0.95 level. Estimates of the VBG parameters K and CL_∞ were obtained along with parameters for sampling bias and age-specific standard deviations. In the absence of information on the age of the first age-class, MULTIFAN assumes that the the VBG curve passes through the origin (i.e. $t_0 = 0$).

Age composition

Monthly catch data in weight were obtained for the study period. The data were collected by the National Fisheries Service (Servicio Nacional de Pesca de Chile) at the main ports of landings in the Third (Caldera, 27°S) and Fourth (Coquimbo, 29°S) administrative Regions of Chile. Catch at age in number was obtained for males and females by using monthly global sex proportion in weight to separate the monthly total yield of *C. johni*. Subsequently, catch at age in number per month *i* (C_{ij}) was obtained from catch in number of month *i* (C_i) multiplied by the proportion of each proportion of each age class (p_{ij}) estimated by MULTIFAN, i.e.

$$C_{ij} = C_i \times p_{ij} = \frac{Y_i}{W_i} \times p_{ij} \quad , \tag{1}$$

where Y_i is the yield (catch in weight) of *C. johni* in month i and W_i is the mean weight of *C. johni* in month *i*, i.e.

$$W_i = \frac{\sum_{l=1}^{L} w_i f_{li}}{\sum_{l=1}^{L} f_{li}} \qquad (2)$$

where f_{li} is the number of individuals in the length class l in the sample of month i and w_l is the mean weight in the length class l, which was obtained by using the equation proposed by Beyer (1987), i.e.

$$w_l = a\left[L_{l+1} - L_t\right]^{-1}\left[b+1\right]^{-1}\left[\left(L_{l+1}\right)^{(b+1)} - \left(L_t\right)^{(b+1)}\right], (3)$$

where a and b are the parameters of the length-weight relationship and L_l is the lower length of length class l. Parameters for the length-weight relationship were obtained from Acuña *et al*. (1998), i.e. a = 1.833×10^{-4} and b = 3.349 for males, and a = 2.847×10^{-4} and b = 3.233 for females.

TABLE 1. – *Cervimunida johni*. Size sample (n), percentage of males and females in total sample, and size range (CL, mm) in length frequency data. (*) Size sample discarded from the analysis (n < 1000).

Year	Month	n	males (%)	males size range CL (mm)	females (%)	females size range CL (mm)
1996	Sep	6349	28.8	(16 - 46)	71.2	(17 - 38)
	Oct	2039	34.2	(20 - 42)	65.8	(22 - 37)
	Nov	3335	47.9	(21 - 46)	52.1	(23 - 43)
	Dec (*)	810	46.2	(24 - 42)	53.8	(23 - 36)
1997	Jan (*)	103	62.1	(12 - 41)	37.9	(14 - 36)
	Feb	1585	49.1	(17 - 47)	50.9	(17 - 39)
	Mar	1008	82.2	(10 - 51)	17.8	(14 - 43)
	Apr	3884	54.2	(10 - 50)	45.8	(12 - 43)
	May	2002	51.5	(20 - 50)	48.5	(20 - 46)
	Jun	3740	31.1	(17 - 51)	68.9	(18 - 44)
	Jul (*)	377	43.0	(26 - 49)	57.0	(23 - 39)
	Aug	3192	44.6	(18 - 50)	55.4	(17 - 44)
	Sep	2271	42.6	(24 - 44)	57.4	(23 - 36)
	Total	30695	42.4	(10 - 51)	57.6	(12 - 46)

RESULTS

Growth

Squat lobster females are small compared to the males, the maximum length observed being 51 mm for males and 46 mm for females, while the smallest sizes occurred between March and April (Table 1). The LFD sets for the 10 selected months are shown in Figures 1 and 2 for males and females respectively. In the time series of LFD sets, the smallest modal group was observed in March for males (15 mm CL) and females (17-18 mm CL). Although this sample was obtained from the by-catch of the shrimp fishery (with identical mesh net), it was considered in the growth analysis with MULTIFAN and selected as Month 1 sample.

The hypotheses tested for four different models for males and females are summarised in Table 3, that is, the results of four different models are compared which systematically test combinations of two hypotheses involving a linear trend in standard deviations of the length at age and first age-class size selectivity. There are 10 length frequency samples in each data set and the addition of one age class to the models requires the estimation of one additional proportion at age for each sample in the data set. Therefore, the number of parameters in the model increases by 10 for each age-class added. In males, the candidates for best fit are the 9 age-class models, but the 11 age-class models generated a significant increase in the log-likelihood for all cases when they were compared with the 9 age-classes (P > 0.9). Therefore, the candidates for the best fit are the 11 age-class models and 9 age-class models for males and females respectively (Table 3). Considering the effect of the combination of the two structural hypotheses, the candidate for the best fit was Model 1 for males and females (Table 3). Model 1 assumes that the standard deviations of length-at-age are identical for all cohorts, and $b_1 = 0$ (see Table 2).

The predictive length-frequency distributions fitted the observed distributions very well over the entire range of sizes, and the predicted modes closely matched the actual modes in most months. Parameter estimates produced by the best fits are presented in Table 4 and estimates of the means and

TABLE 2. – Combination of parameters determining different structural models. A + or - indicates whether or not the corresponding parameter is estimated in the model.

PARAMETER Definition	Symbol	MODEL (1)	(2)	(3)	(4)
VBG coefficient	K	+	+	+	+
Parameter determining the SD	λ_2	-	-	+	+
Parameter determining the size selectivity for 1st age class.	b_1	-	+	-	+

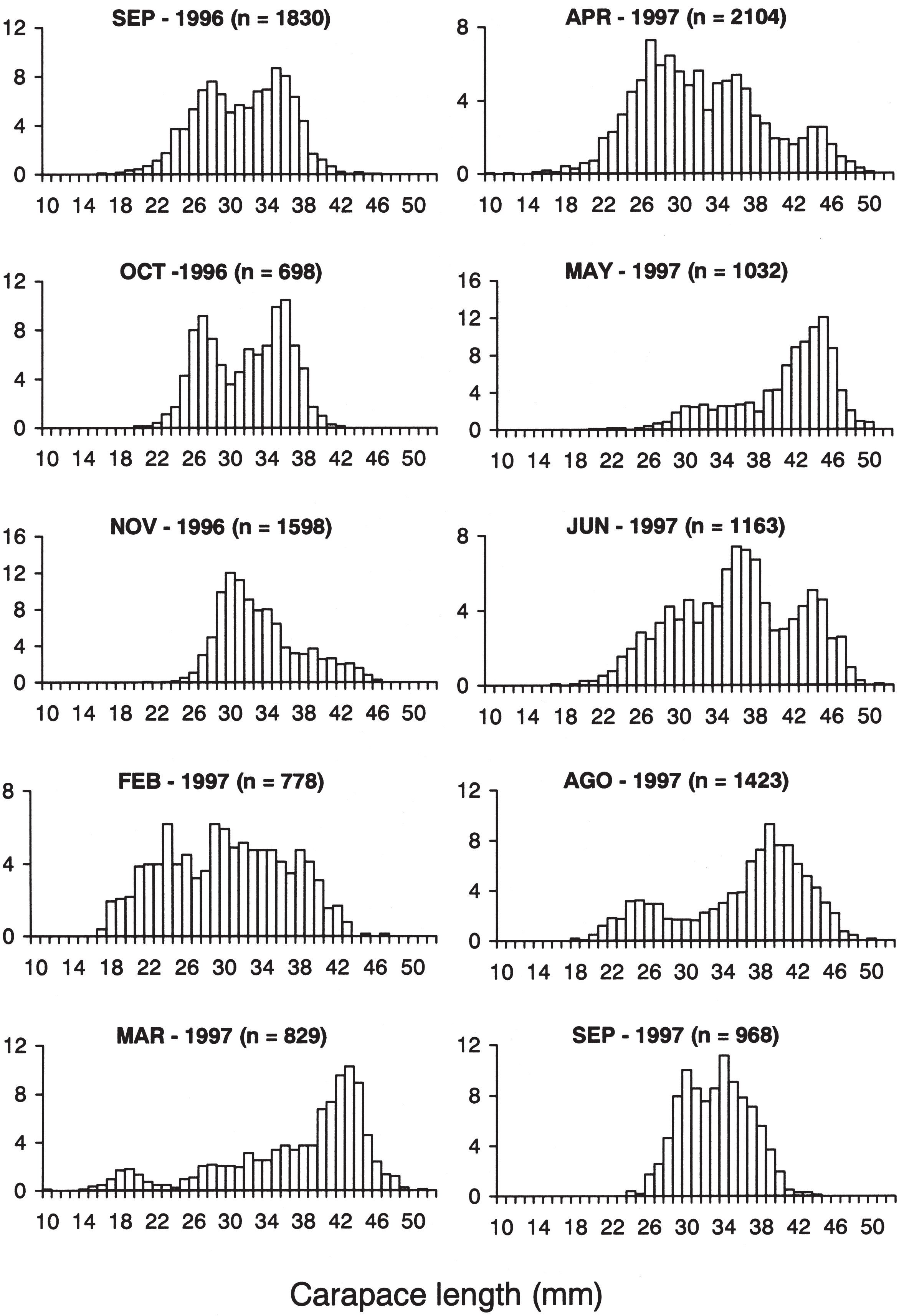

FIG. 1. – Monthly observed length frequency distributions of males of *C. johni* during 1996-97. The vertical axis represents relative frequency in percentage.

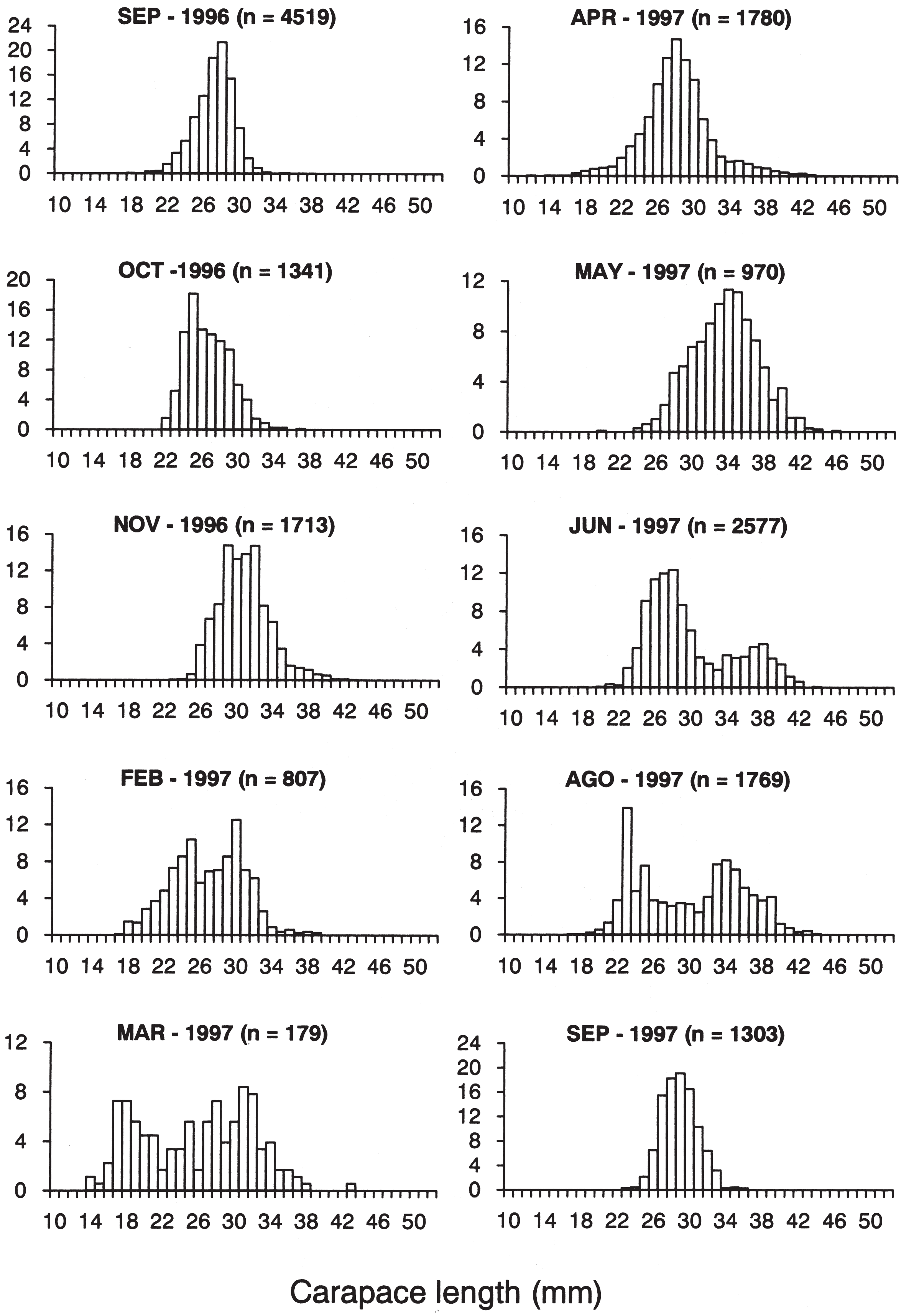

FIG. 2. – Monthly length frequency distributions of females of *C. johni* during 1996-97. The vertical axis represents relative frequency in percentage.

TABLE 3. – Summary of hypothesis testing for fits for four models to males and females *Cervimunida johni*. Two times the log-likelihood values are shown for each model with the number of estimated parameters shown below in parentheses. Log-likelihood function values with a single underline are the best fits for each model. The overall are best fit is in boldface.

	Model tested							
	Males				Females			
age-classes	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
5	6168.84	6192.11	6250.01	6261.19	5378.42	5376.73	5417.50	5417.65
	(44)	(45)	(45)	(46)	(44)	(45)	(45)	(46)
6	6727.73	6731.83	6745.24	6745.46	5534.98	5536.44	5546.08	5541.96
	(54)	(55)	(55)	(56)	(54)	(55)	(55)	(56)
7	6856.16	6857.67	6851.44	6862.16	5634.17	5633.26	5626.50	5629.16
	(64)	(65)	(65)	(66)	(64)	(65)	(65)	(66)
8	6908.24	6922.47	6911.68	6912.80	5685.68	5691.11	5669.64	5686.04
	(74)	(75)	(75)	(76)	(74)	(75)	(75)	(76)
9	7045.59	6973.82	7045.18	6974.29	**5715.79**	5715.79	5714.68	5714.68
	(84)	(85)	(85)	(86)	(84)	(85)	(85)	(86)
10	7042.37	7073.93	7045.14	7045.10	5720.67	5722.87	5720.66	5720.66
	(94)	(95)	(95)	(96)	(94)	(95)	(95)	(96)
11	**7082.71**	7084.29	7082.51	7074.17	5720.59	5723.38	5721.72	5721.72
	(104)	(105)	(105)	(106)	(104)	(105)	(105)	(106)
12	7080.78	7080.78	7081.09	7083.21	5717.96	5719.67	5715.20	5728.07
	(114)	(115)	(115)	(116)	(114)	(115)	(115)	(116)

TABLE 4. – Estimated parameters from the MULTIFAN analysis, with standard error in parentheses.

Parameter		Units	Males	Females
Asymptotic length	CL_∞	mm	52.8 (0.184)	45.6 (0.249)
Growth coefficient	K	yr^{-1}	0.151 (0.003)	0.174 (0.003)
Mean length of the first age-class on VBG curve at month 1	l_1	mm	19.27 (0.101)	18.79 (0.0313)
Mean length of the last age-class on VBG curve at month 1	l_m	mm	45.39 (0.029)	38.95 (0.047)
Age estimated of the first age class	t_1	yr	3.01 (0.012)	3.06 (0.012)
Mean SD		mm	1.74 (0.025)	1.49 (0.029)
Number of age-classes present in the data sets			11	9
MODEL			(1)	(1)
Two times the log-likelihood			7082.71	5715.79
Number of non-empty length classes			300	228
Number of parameter estimated			104	84
Degree of freedom			196	144

TABLE 5. – Predicted carapace lengths (CL) at Month 1 (January) for males and females of *Cervimunida johni* and standard deviations (SD) of lengths-at-age.

	Males			Females	
Relative age class	CL (mm)	SD	Relative age class	CL (mm)	SD
3.01	19.27	1.74	3.06	18.79	1.49
4.01	23.97	1.74	4.06	23.07	1.49
5.01	27.28	1.74	5.06	26.67	1.49
6.01	31.48	1.74	6.06	29.70	1.49
7.01	34.46	1.74	7.06	32.24	1.49
8.01	37.03	1.74	8.06	34.38	1.49
9.01	39.24	1.74	9.06	36.17	1.49
10.01	41.14	1.74	10.06	36.68	1.49
11.01	42.77	1.74	11.06	38.95	1.49
12.01	44.18	1.74			
13.01	45.39	1.74			

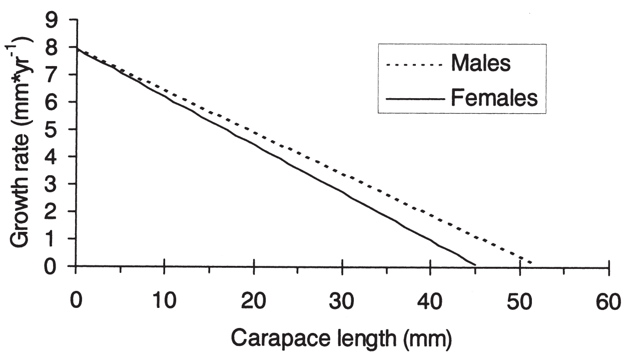

FIG. 3. – Von Bertalanffy growth rate of females and males of *C. johni* as a function of carapace length.

standard deviations of length-at-age are given in Table 5. There is a clear difference between the sexes in terms of parameterisation of their VBG function (Fig. 3).

Catch-at-age composition

Monthly proportions at relative age classes, as obtained from MULTIFAN, were used to compute

TABLE 6. – Monthly yield and catch in numbers of *Cervimunida johni*, by sex.

Year	Month	Catch (t) Males	Catch (t) Females	Captura (n° x 10^3) Males	Captura (n° x 10^3) Females	Both sexes
1996	Sep.	310.3	776.7	23488.0	58001.2	81489.2
	Oct.	133.8	242.2	9910.5	19040.0	28950.5
	Nov.	359.3	498.7	22825.3	24810.8	47636.1
	Dec.(*)	154.0	138.0	9929.8	11575.9	21505.6
1997	Jan.(*)	Closure				
	Feb.	Closure				
	Mar.	Closure				
	Apr.	298.2	251.6	19051.9	16118.0	35169.9
	May.	709.8	602.2	23851.1	22418.2	46269.2
	Jun.	280.1	577.2	13298.4	29467.0	42765.4
	Jul.(*)	197.8	207.5	6294.4	8353.7	14648.0
	Aug.	201.8	240.8	9441.7	11737.5	21179.2
	Sep.	176.8	254.5	11635.9	15662.9	27298.8

(*) Total size sample < 1000, and discarded from the growth analysis.

the annual age composition of the catch. We use the term "relative age class" to denote that estimates of absolute age are based on the assumptions that length modes represent annual cohorts and $t_0 = 0$, i.e. the third VBG parameter is zero. Monthly yield and catch in number by sex of *C. johni* are shown in Table 6, and the annual catch composition reveals that the contribution of the youngest age class is the lowest for both sexes. In males, there are five age-classes which contribute with annual catches greater than 10%, while for females only three age-classes sustain catches greater than 10% (Fig. 4).

DISCUSSION

The LFD analysis using MULTIFAN suggests that annual growth in both sexes of *C. johni* follows a VBG function. Despite their exoskeleton and the discontinuities in the growth process (Cobb and Caddy, 1989; Dall *et al.*, 1990), continuous asymptotic models are considered a common result for decapod crustaceans (Campbell, 1983; Fogarty and Idoine, 1988; Roa, 1993; Roa and Ernst, 1996; Ragonese *et al.*, 1994; Ragonese and Biachini, 1996, Gramitto and Froglia, 1998). Male *C. johni* grow larger than females in size at age. Usually females are found to be smaller in length due to the need to allocate energy to reproduction and the results of this paper are consistent with results for other crustaceans (Fogarty and Idoine, 1988; Anderson, 1991; Plaut and Fishelson, 1991; Roa, 1993).

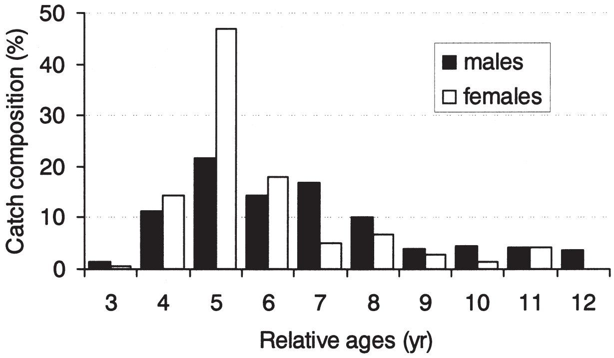

FIG. 4. – Annual age composition of males and females of *C. johni*.

The asymptotic length for males and females was estimated at 52.8 and 45.6 mm respectively. This is in agreement with the maximum recorded length in the catches, i.e. 51 mm (males) and 46 mm (females). The growth coefficient (*K*) was estimated as 0.151 yr^{-1} for males and 0.174 yr^{-1} for females, which result in differences in absolute growth between the sexes. However, the growth performance index of Pauly and Munro (1984) ($\phi' = \log_{10}K + 2\log_{10}L_\infty$) was similar between sexes, ϕ' = 2.62 for males and ϕ' = 2.56 for females, suggesting that both sexes are growing in a similar fashion, but growth parameters are different.

MULTIFAN provides useful information on age composition. The selected models suggested 9 and 11 age-classes in the female and male LFD sets respectively. These results are important because in previous studies only 3 to 4 year classes have been estimated from annual length frequency distributions similar in size range to those used in this paper (Pavez *et al.*, 1994; Pool *et al.*, 1996). In these previous studies, age composition was identified by analysing a single annual LFD set, using the MIX algorithm of MacDonald and Green (1988). However, it has long been recognised that the reliability of parameter estimates derived from a single data set is limited, and better parameter estimates can be obtained by simultaneously analysing several LFD sets obtained at several different times from a population (Sparre, 1987; Fournier *et al*., 1990).

In this paper, March was assigned as the month in which the youngest age-class entered the fishery (late austral summer). MULTIFAN relies on the detection of modes in the length frequency data which correspond to age classes. In the present application only one recruitment period should occur to accept the annual growth analysis in this paper. The presence of one cohort per year in the LFD is in agreement with only a single reproductive season. In Talcahuano (37°S-73°W), the spawning season of *C. johni* extends from May to December and more than 50% of ovigerous females have been observed from June to December (Alegría *et al*., 1963). In Coquimbo, Wolff and Aroca (1995) pointed out that egg eclosion starts in October and terminates in November (austral spring), which is consistent with only a single reproductive season.

Our results on the growth function and age composition of *C. johni* are the first in which a formal statistical technique has been applied in order to test possible combinations of structural hypotheses affecting the LFD. In fact, Wolff and Aroca (1995) used the ELEFAN method (Gayanilo *et al*., 1988, 1995) to obtain growth parameters, including seasonal growth. The seasonally oscillating VBG parameters obtained by Wolff and Aroca (1995) were CL_∞ = 46 mm, K = 0.315 yr^{-1}, C = 0.25 and WP = 0.6 for both sexes, representing a fast growing species. However, Pool *et al*. (1996) used MIX to analyse annual LFD for the years 1965, 1966, 1968, 1970, 1979, 1981 and 1995-96. The growth was described by CL_∞ = 62.1 mm, K = 0.165 yr^{-1} for males and CL_∞ = 54.6 mm, K = 0.177 yr^{-1} for females by combining all the age classes identified. Pavez *et al*. (1994) estimated CL_∞ = 58.1 mm, K = 0.165 yr^{-1} for males, and CL_∞ = 51.8 mm, K = 0.194 yr^{-1} for females using MIX. In this way, the VBG parameters obtained by Pavez *et al*. (1994), Pool *et al*. (1996) and the present study suggest that *C. johni* is a slow-growing species rather than a fast-growing species as suggested by the study of Wolff and Aroca (1995). The results obtained from the ELEFAN method are limited because they cannot be used to confront hypothesis tests, so the VBG parameters estimated by Pavez *et al*. (1994) and Pool *et al*. (1996) are more comparable with the parameters estimated here.

In this study, we do not attempt to include a seasonally oscillating growth curve in our analysis with MULTIFAN because to test that hypothesis a different sampling scheme would be required. The commercial fleet operates at different depths throughout the year and the length and age composition of *C. johni* could be depth-dependent (Bahamonde *et al*., 1986; Acuña *et al*., 2003). Length-frequency data could be biased due to the operation of the fleet at different depths through the year, and it would affect the seasonal growth analysis. We are not sure whether these aspects could bias our growth analysis, and further research will be required to investigate this important aspect. In the meantime, our results of annual growth can be considered reasonable for *C. johni* and hence used to perform population dynamics and stock assessment analysis.

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