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Asociación entre *Mulinia edulis* (Mollusca, Bivalvia) y *Edotea magellanica* (Crustacea, Isopoda) en el sur de Chile

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ABSTRACT

The association between the clam *Mulinia edulis* and the isopod *Edotea magellanica* was studied during the Spring-Summer period of 1987-1988 at the subtidal bottoms of sand bars located outside the outlets of Lingue and Queule estuaries (southern Chile), and at the subtidal muddy-sand sediments of the middle reaches of these estuaries. The percentage of bivalve occupation by isopods at those estuaries varied between 1.5-4.2%, while at the sand bars the ranges were 21.1-80.7%. Laboratory experiments suggested that the low frequency of isopod occupation in estuarine clams could be related to the low tolerance of *Edotea magellanica* to water salinities lower than 20 o/oo. The highest percentage of isopod occupation in the clams collected from the sand bars occured in bivalves with shell length ranging from 50 to 60 mm. Regression and covariance analyses for the relationship between shell length and dry-tissue weight of clams with and without isopods, showed that *Edotea magellanica* has no influence on the meat content of clams. Isopod females outnumbered males at both sand bars. Number of intramarsupial eggs and embryos was significantly correlated with sizes of ovigerous females, while no significant correlation was found between number of intramarsupial juveniles and sizes of ovigerous females. In general, no correlation was found between size of intramarsupial stages and sizes of ovigerous females. The mean size for eggs in the whole sample was 0.55 mm, 0.96 mm for embryos and 1.51 mm for intramarsupial juveniles. The life cycle of *Edotea magellanica* was schematically constructed using the available data. Clams would be first occupied by a female, then by a male. The new isopod generation develops in the marsupium of females and continues in the mantle cavity of clams until they reach an approximate body size of about 4 mm. The low number of juveniles found in the mantle cavity of clams suggests that these stages have a high mortality after released from the marsupium, or that they do not leave the clams at the same time. No isopods were ever seen outside the mantle cavity of clams.

Key words: Clam, isopod, sand bar, estuary.

RESUMEN

La asociación entre la almeja *Mulinia edulis* y el isópodo *Edotea magellanica* se estudió durante el período primavera-verano de 1987-1988 en el submareal de barras de arena ubicadas al exterior de las bocas de los estuarios Lingue y Queule (sur de Chile), y en los sedimentos submareales areno-fangosos del sector medio de ambos estuarios. El porcentaje de ocupación de bivalvos por isópodos en estos estuarios varió entre 1.5 y 4.2%, mientras que en las barras de arena los rangos fueron 21.1-80.7%. Experimentos de laboratorio sugieren que la baja frecuencia de ocupación por isópodos en las almejas estuariales, puede estar relacionada con la baja tolerancia de *Edotea magellanica* a salinidades del agua inferiores a 20 o/oo. Los porcentajes más altos de ocupación por isópodos en las almejas colectadas en las barras de arena se detectaron en bivalvos con longitudes de concha de 50-60 mm. Los análisis de regresión y covarianza para la relación entre longitud de la concha y peso seco de la carne de almejas con y sin isópodos, mostraron que *Edotea magellanica* no tiene influencia sobre el contenido de la carne de las almejas. El número de isópodos hembras sobrepasó al de machos en ambas barras de arena. El número de huevos y embriones intramarsupiales estuvo significativamente correlacionado con los tamaños de las hembras ovígeras, mientras que no se encontraron diferencias significativas entre el número de juveniles intramarsupiales y el tamaño de las hembras ovígeras. En general, no se encontró correlación entre tamaño de estados intramarsupiales y tamaño de hembras ovígeras. El tamaño medio de los huevos en la muestra total fue 0.55 mm, 0.96 mm el de los embriones y 1.51 mm el de los juveniles intramarsupiales. El ciclo de vida de *Edotea magellanica* se construyó esquemáticamente en base a los datos disponibles. Las almejas serían ocupadas primariamente por una hembra, luego, por un macho. La nueva generación de isópodos se desarrolla en el marsupio de las hembras y continúa en la cavidad del manto, hasta alcanzar un tamaño corporal de aproximadamente 4 mm. El bajo número de juveniles encontrado en la cavidad del manto de las almejas, sugiere que estos estados tienen una mortalidad alta después de ser liberados del marsupio, o que no abandonan las almejas al mismo tiempo. Nunca se observaron isópodos fuera de la cavidad del manto de las almejas.

Palabras claves: Almeja, isópodo, barra de arena, estuario.

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INTRODUCTION

Seven species of bivalves are commonly found in the marine and subtidal estuarine soft bottoms of the littoral of Mehuín and Lingue and Queule estuaries (*ca.* 39°S); these are the clams *Mulinia edulis* (King, 1831), *Mesodesma donacium* (Lamarck, 1818), *Gari solida* (Gray, 1828), *Protothaca thaca* (Molina, 1782), *Pholas chiloensis* (Molina, 1782), and the mussels *Mytilus chilensis* (Hupe 1854) and *Choromytilus chorus* (Molina 1782). Only one of these, *Mulinia edulis*, is occupied by the isopod *Edotea magellanica* Cunningham, 1871, which it has been found inhabiting the mantle cavity of this clam. *Edotea magellanica* has also been found in the mantle cavity of *Mytilus chilensis* in the Strait of Magellan (Jaramillo *et al.* 1981). These antecedents indicate how unusual such an association seems to be.

Mulinia edulis is a bivalve of wide distribution; it occurs along all the Chilean coast and part of Perú (Lorenzen *et al.*, 1979). In southern Chile, this species inhabits sandy sediments (e.g., subtidal bottoms of sand bars located nearby to estuarine outlets) or substrates with a high content of silt and clay particles (e.g., estuarine areas and sheltered bays) (Jaramillo *et al.* 1985, Tarifeño *et al.* 1981). Preliminary observations in the estuaries of Lingue and Queule and in the sand bars located nearby, showed that clam occupation by isopods is quite unfrequent in estuarine bottoms. A similar association of this isopod with the mussel *Mytilus chilensis* (Hupe 1854) has been studied by Jaramillo *et al.* (1978) in the Strait of Magellan. The authors concluded that *Edotea magellanica* should be considered a commensal of *Mytilus chilensis*, due to the fact that no detectable negative effect of isopod occupation in the meat content of this bivalve was observed. Wether that conclusion also aplies to the case of *Mulinia edulis* is unknown.

This paper describes the association *Mulinia edulis-Edotea magellanica*, based upon specimens collected in sand bars located at the outlets of Lingue and Queule estuaries and at the subtidal soft bottoms located in the middle reaches of these estuaries. The study was planned to find answers to the following questions: 1) is there different isopod occupation in the marine and estuarine populations of *Mulinia edulis*? If so, can differences in water salinity explain it?; 2) what is the effect of isopod occupation on the meat content of *Mulinia edulis*?; 3) what are the general characteristics of the life history of *Edotea magellanica*?

MATERIAL AND METHODS

Study area

The present study is based on samples collected in the subtidal of sand bars located outside the outlets of Lingue and Queule estuaries, and in muddy-sand bottoms of the same estuaries, southern Chile (*ca.* 39°S) (Fig. 1). Thus, stations a and b refer to the sand bars located outside the outlets of Lingue and Queule estuaries, while stations c and d refer to subtidal sites located in the middle reaches of both estuaries (Fig. 1). Stations c and d extended approximately 2000 m upstream the studied sand bars. Temporal fluctuations of salinity and temperature in the waters adjacent to Lingue sand bar (Mehuín) and to the estuarine sites are listed in Table 1 (mean and range values for the period 1985-1987; unpublished data from Instituto de Zoología, Universidad Austral de Chile). These data show that widest variation of both physical parameters ocurred in the estuarine stations.

Sampling methods and treatment

During October 1987 - January 1988, specimens of *Mulinia edulis* were hand-collected in the shallow waters (0.5-1.0 m) of Lingue sand bar (station a, Fig. 1). Rough wave conditions precluded collection in other periods of the year. Queule sand bar (station b. Fig. 1) was also sampled but only during January 1988. During the same months as above, estuarine specimens were collected by diving from the subtidal bottoms (3.0-4.0 m) of the middle reaches of Lingue and Queule estuaries (stations c and d, Fig. 1). The sediments of these

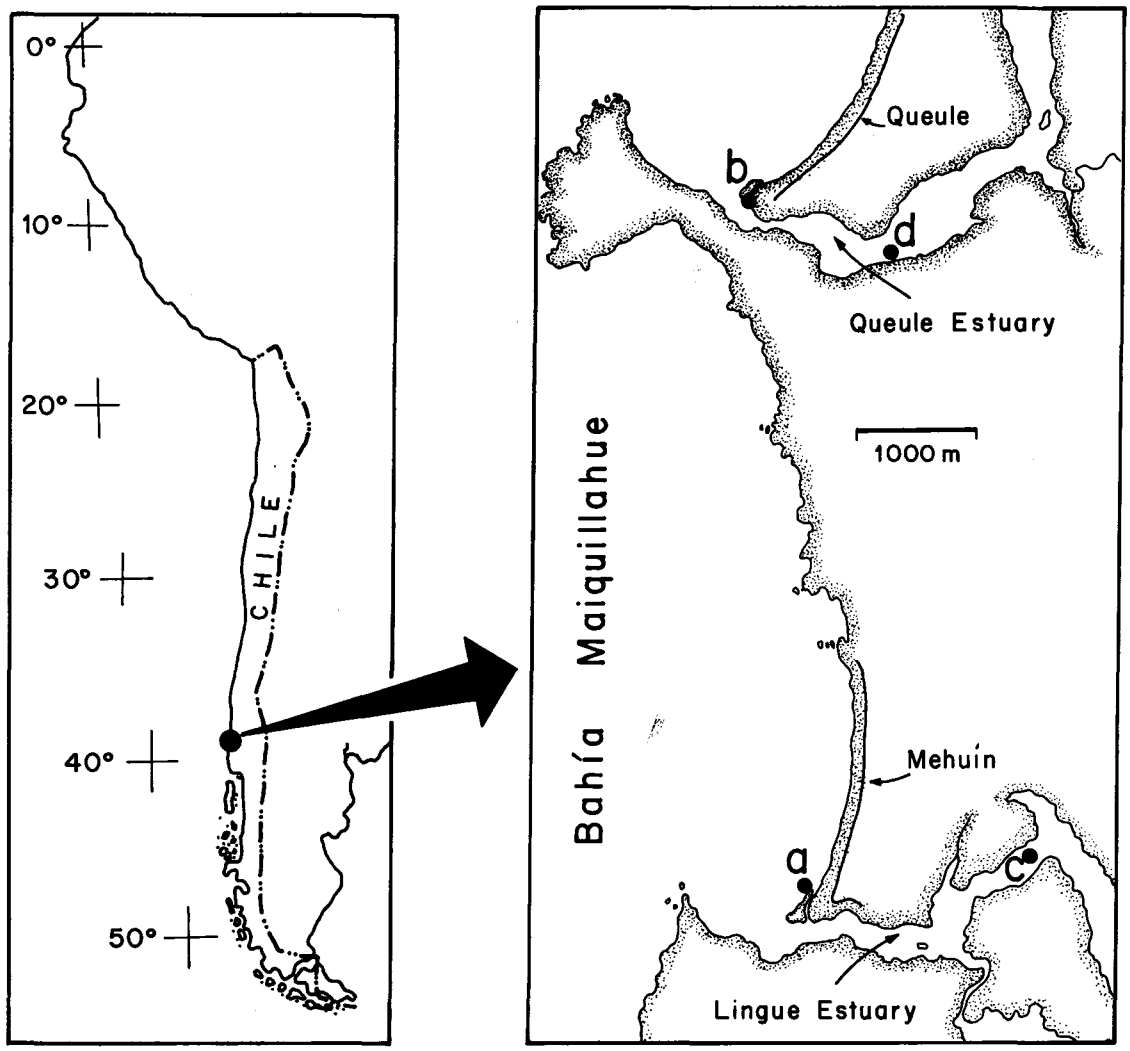

Fig. 1: Location of stations a (Lingue sand bar), b (Queule sand bar), c (Lingue estuary) and d (Queule estuary) in the south of Chile.

Ubicación de las estaciones a (barra Lingue), b (barra Queule), c (estuario Lingue) y d (estuario Queule) en el sur de Chile.

subtidal bottoms are mostly represented by muddy-sands with organic matter percentages ranging 1-5% (Jaramillo *et al.*, 1985). Clams were transported in separate plastic bags without water, and stored in a freezer to avoid loss of isopods from the mantle cavity. After shell length measurements, each clam was opened and the number of isopods recorded. Isopods from each clam were separated and kept in 70° alcohol for further analyses of length and sex.

Dry tissue weight of each clam (after 48 h at 80°C) was determined to calculate regression lines representing the relationship between shell length and dry tissue weight in clams with and without isopods. To find whether isopod occupation influences the meat content of *Mulinia edulis*, regression lines were compared through covariance analysis (Sokal and Rohlf 1969, Rohlf and Sokal 1981).

A salinity tolerance laboratory experiment was designed to elucidate the low occurrence of isopods found in the clams of Lingue and Queule estuaries. An experimental run was conducted (January 1988) with isolated isopods (i.e., extracted

TABLE 1

Mean and range values (in parenthesis) of salinity and temperature in the bottom waters of Lingue and Queule estuaries, and in the surf waters of Mehuín Beach during the period 1985-1987. Estuarine data were monthly collected during high and low tide. Salinity data for Mehuín (a site located nearby to Lingue sand bar) are based on weekly measurements during high tide, while temperature data for the same site are based on daily averages which resulted from temperature readings at 09:00, 14:00 and 18:00 h.

Valores promedios y rangos (en paréntesis) de salinidad y temperatura en las aguas del fondo de los estuarios Lingue y Queule, y en la zona de rompientes de la playa de Mehuín (un sitio localizado cerca de la barra del Lingue) durante el período 1985-1987. Los datos estuariales se colectaron mensualmente durante marea alta y marea baja. Los datos de salinidad para la playa de Mehuín están basados en mediciones semanales durante marea alta, mientras que los de temperatura están basados en promedios diarios resultantes de registros realizados a las 09:00, 14:00 y 18:00 h.

	Lingue Estuary	Queule Estuary	Mehuín
S °/oo at high tide	27.2 (1.9-34.3)	21.6 (1.4-35.2)	28.9 (13.9-35.3)
S °/oo at low tide	10.3 (0.2-25.4)	7.8 (0.0-18.6)	
°C at high tide	12.9 (10.0-17.5)	14.0 (9.0-22.0)	12.4 (10.3-15.2)
°C at low tide	14.0 (9.0-21.0)	14.7 (9.0-22.5)	

from clams) previously kept in the laboratory for 24 h. Experimental salinities were obtained by diluting natural sea water with distilled water. Salinity values were calculated through conductivity measurements obtained from a conductivity meter as well as from a list of formulas quoted by Bennett (1976). Four plastic containers (approximately 1,000 ml of capacity) holding 20 isopods each were prepared with waters of 29, 20, 12 and 6 o/oo. The control salinity was 29 o/oo, similar to the salinity in waters adjacent to areas with the highest frequencies of clam occupation by isopods. The containers were individually aerated and place on a fresh-water table with a temperature of 14 ± 1°C. The survival of isopods was observed daily (13.00 P.M.) over a 7 days period.

Length and sex analyses of isopods were carried out to study general characteristics of the reproductive biology of *Edotea magellanica*. Isopod length measurements, from anterior margin of cephalon to posterior end of telson, were made with a stereomicroscope fitted with an eye-piece micrometer. Male isopods were differentiated by the paired penes on the sternum of the 7th thoracic segment and the male appendices on the 2nd pleopod. Female isopods were recognized by the absence of the former characters, and by the presence of marsupial oostegites on the 2nd to the 4th thoracic segments. Counts of eggs, embryos and juveniles removed from the marsupium of each ovigerous female, were also made. Twenty randomly chosen individuals of each developmental stage were measured, Egg dimensions represented maximum diameter values, while embryo and juvenile dimensions represented the length from the anterior to the posterior ends of these developmental stages. Comparisons of brood sizes and size of marsupial stages were made by one-way analyses of variance (ANOVA) (Sokal and Rohlf 1969). If the analyses of variance indicated significant differences between means, all means were compared using the *a posteriori* TUKEY-KRAMER multiple comparison test (in Stoline, 1981). For that statistical tests, a significance level of $p < 0.05$ was used.

RESULTS

The association clam-isopod

The size class distribution of clams and frequency of isopod occupation in the dif-

ferent stations and sampling periods are shown in Fig. 2. The clams of Lingue and Queule estuaries presented very low percentages of isopod occupation (1.5-4.2%), a situation which was more evident at Lingue estuary where just one clam (57.8 mm) was occupied by *Edotea magellanica*. On the other hand, bivalves from Lingue and Queule sand bars showed higher percentages (21-81%) of isopod occupation. The highest frequency occurreds in that clams included in the size class 50-60 mm (Fig. 2). No influence of isopods on the meat content of clams, as revealed by regression lines and covariance analyses, was observed (Table 2).

The highest number of adult isopods per clam in samples from the Lingue and Queule sand bars was three; one and two individuals being the most frequent cases (Fig. 3). They varied between 1.20 and 23.72 mm in size without noticeable differences between both sand bars (Fig. 4). No significant correlations were found between, either number or size of isopods and size of *Mulinia edulis*. Figure 5 (based on the whole sample) shows the number and sexual stage of isopods found in the mantle cavity of the estudied clams. Of the 300 clams considered, 215 (71.7%) of the had only one isopod, being most of them ovigerous and non ovigerous adult females. Lone free juveniles (i.e., collected from the mantle cavity of clams) were found in 23 clams (7.7%). The most common cases for clams having two isopods were couples of ovigerous females and adult males (6.3%), ovigerous females and

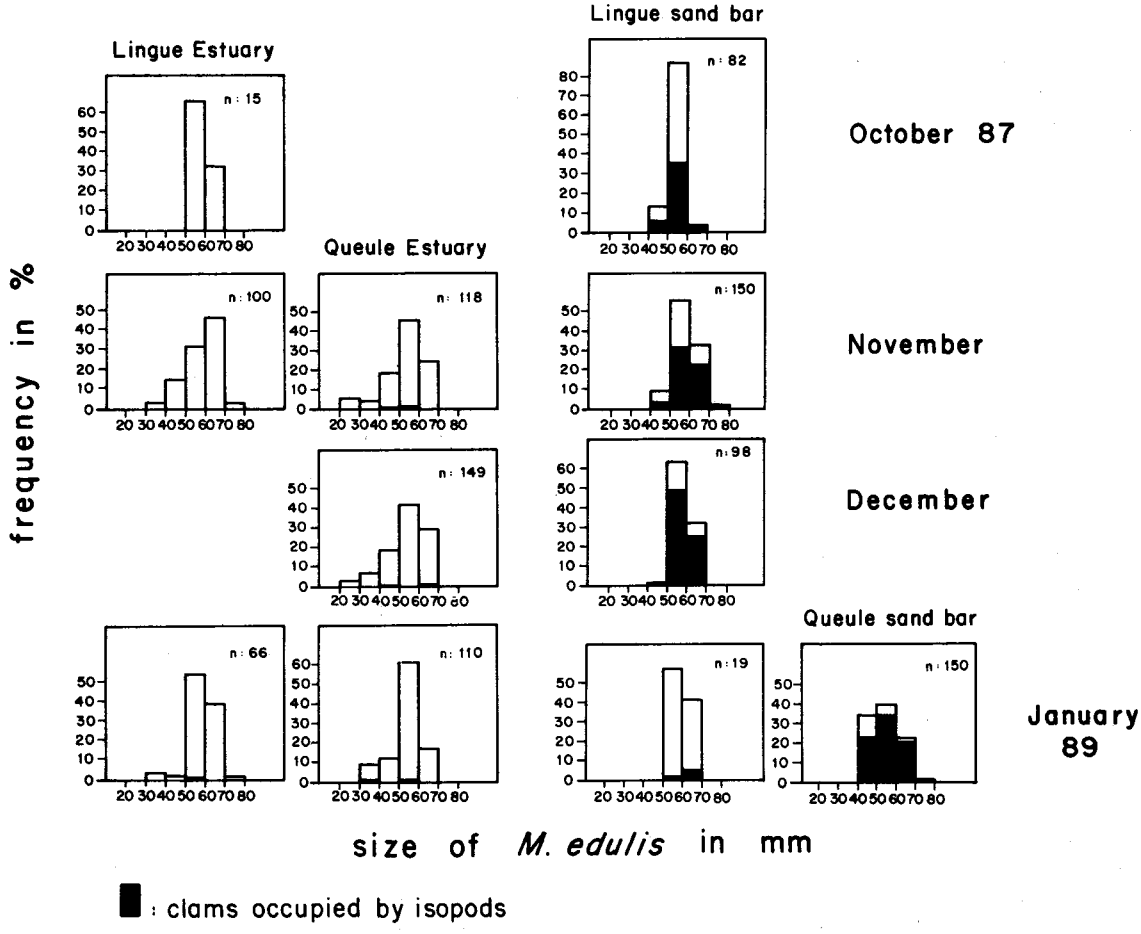

Fig. 2: Size class distribution of *Mulinia edulis* from the different stations, and frequency of clams occupied by isopods.

Distribución de clases de tallas de *Mulinia edulis* y frecuncia de bivalvos ocupados por isópodos.

TABLE 2

Summary of ANCOVA analysis with regression lines (length vs. weight) of clams with and without isopods.

Resumen de los análisis de covarianza con las líneas de regresión (longitud vs. peso) de almejas con y sin isópodos.

		ANCOVA				
Station	date	source of variation	degrees of freedom	F observed	F critical	
a	November 87	between slopes	1-148	2.338	6.63	> 0.01
		between adjusted slopes	1-148	2.882	6.63	> 0.01
b	December	between slopes	1-96	0.128	2.75	> 0.01
		between adjusted slopes	1-96	1.622	2.75	> 0.01
b	January 88	between slopes	1-143	0.302	6.63	> 0.01
		between adjusted slopes	1-143	0.437	6.63	> 0.01

free juveniles (3.7%) and non ovigerous adult females and free juveniles (3.0%). Three or more isopods were observed in 26 clams, being the most cammon case (in 11 clams) a group formed by an ovigerous females, an adult male and 1-5 free juveniles (Fig. 5).

Experimental results

Figure 6 shows the results of the salinity tolerance experiments. All the isopods died during the first day in the 6 o/oo salinity container. The survival of *Edotea magellanica* in the 12, 20 and 29 o/oo containers was quite similar until day 2; thereafer, survival in the 12 o/oo container sharply decreased until day 7 where no isopods were seen alive. At the end of the experiment, survival percentages in the 20 and 29 o/oo containers were 88.5 and 65.4%, respectively (Fig. 6).

Reproductive biology of Edotea magellanica

During the study period, females of *Edotea magellanica* had a representation close to 80% or higher (Fig. 7a). In samples from Lingue sand bar, the sex ratio (males/females) was 0.09 in October, 0.21 in November and December, and 0.25 in January. The sex ratio for Queule sand bar was 0.11 (January). At the Lingue sand bar, ovigerous females were found from October to December but not in January, a month in which they were found on the contrary, at Queule sand bar. The number of ovigerous females carrying eggs, showed a gradual decrease from October to December at the Lingue sand bar, while a gradual increase in ovigerous females carrying embryos was also detected (Fig. 7b). Eggs and juveniles were the most frequent stages in the ovigerous females collected at the Queule sand bar. During January the percentages of free juveniles were similar at both sand bars. At Lingue sand bar, such life cycle stage showed a gradual increase peaking during November and December to decline in January (Fig. 7c).

Table 3 shows the results of regression analyses between brood size and size of ovigerous females of *Edotea magellanica.* Number of eggs and embryos were significantly correlated with sizes of ovigerous females; however, no correlation was found between number of juveniles and size of ovigerous females. The number of eggs per female in the whole sample (i.e., Lingue and Queule sand bars) ranged from 55 eggs carried by a female of 13.5 mm to 521 eggs carried by a female of 20.1 mm (whole mean: 230.8 eggs). The range for embryos was 72 (female size: 14.4 mm) to 417 (female size: 20.1 mm) (whole mean:

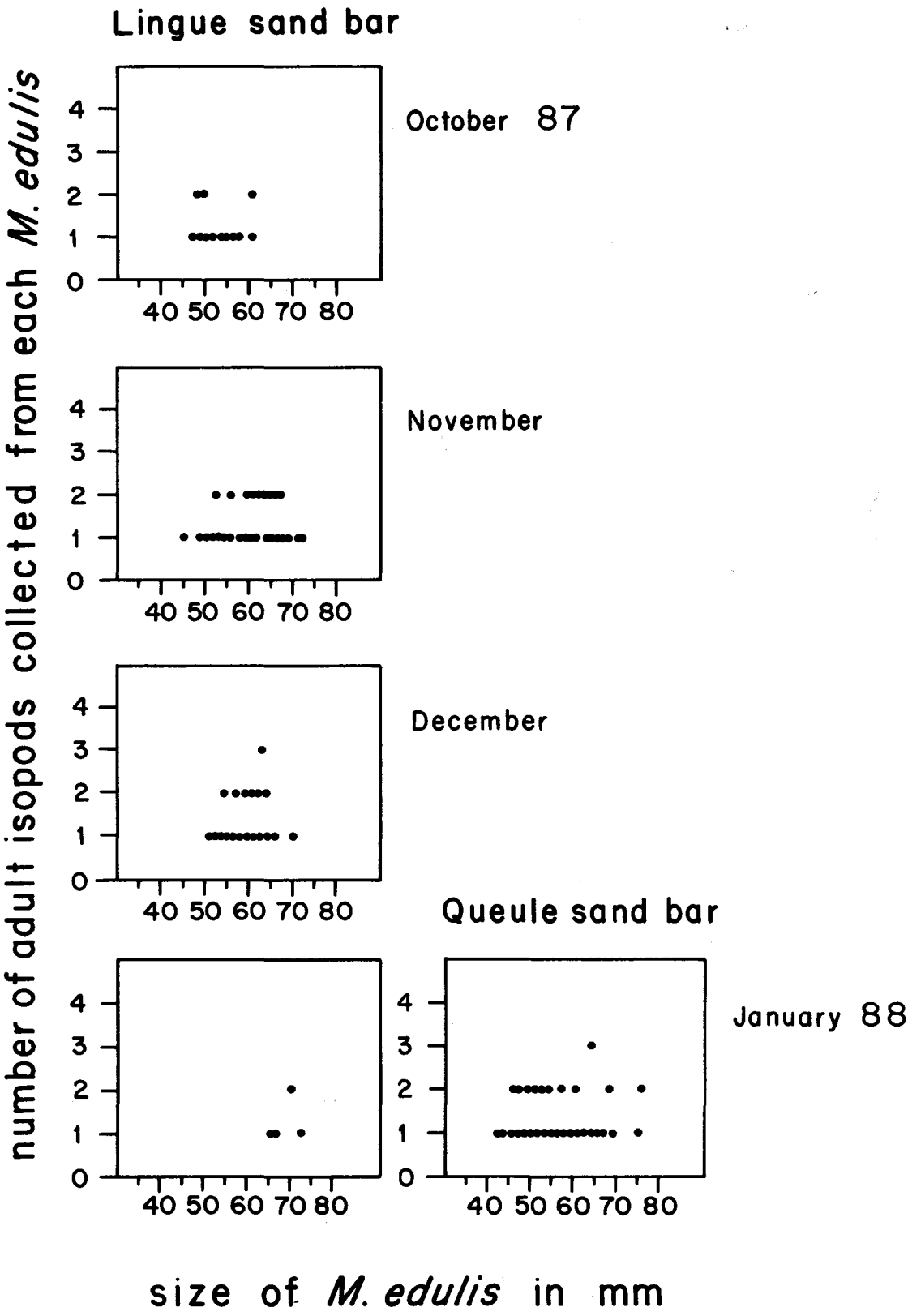

Fig. 3: Number of isopods versus size of *Mulinia edulis* in Lingue and Queule sand bars.

Número de isópodos versus tamaño de *Mulinia edulis* en las barras Lingue y Queule.

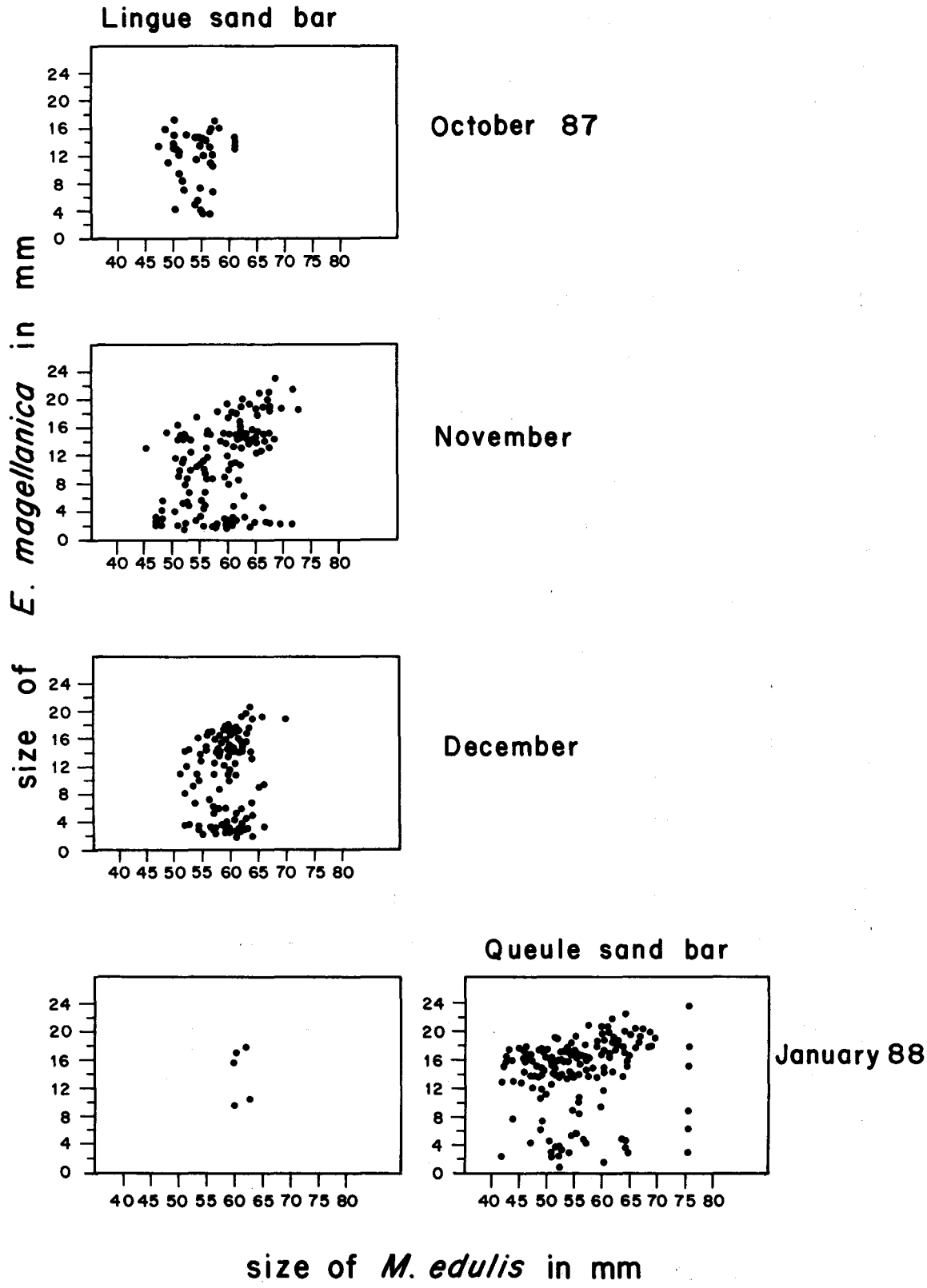

Fig. 4: Size of isopods versus size of *Mulinia edulis* in Lingue and Queule sand bars.

Tamaño de isópodos versus tamaño de *Mulinia edulis* en las barras Lingue y Queule.

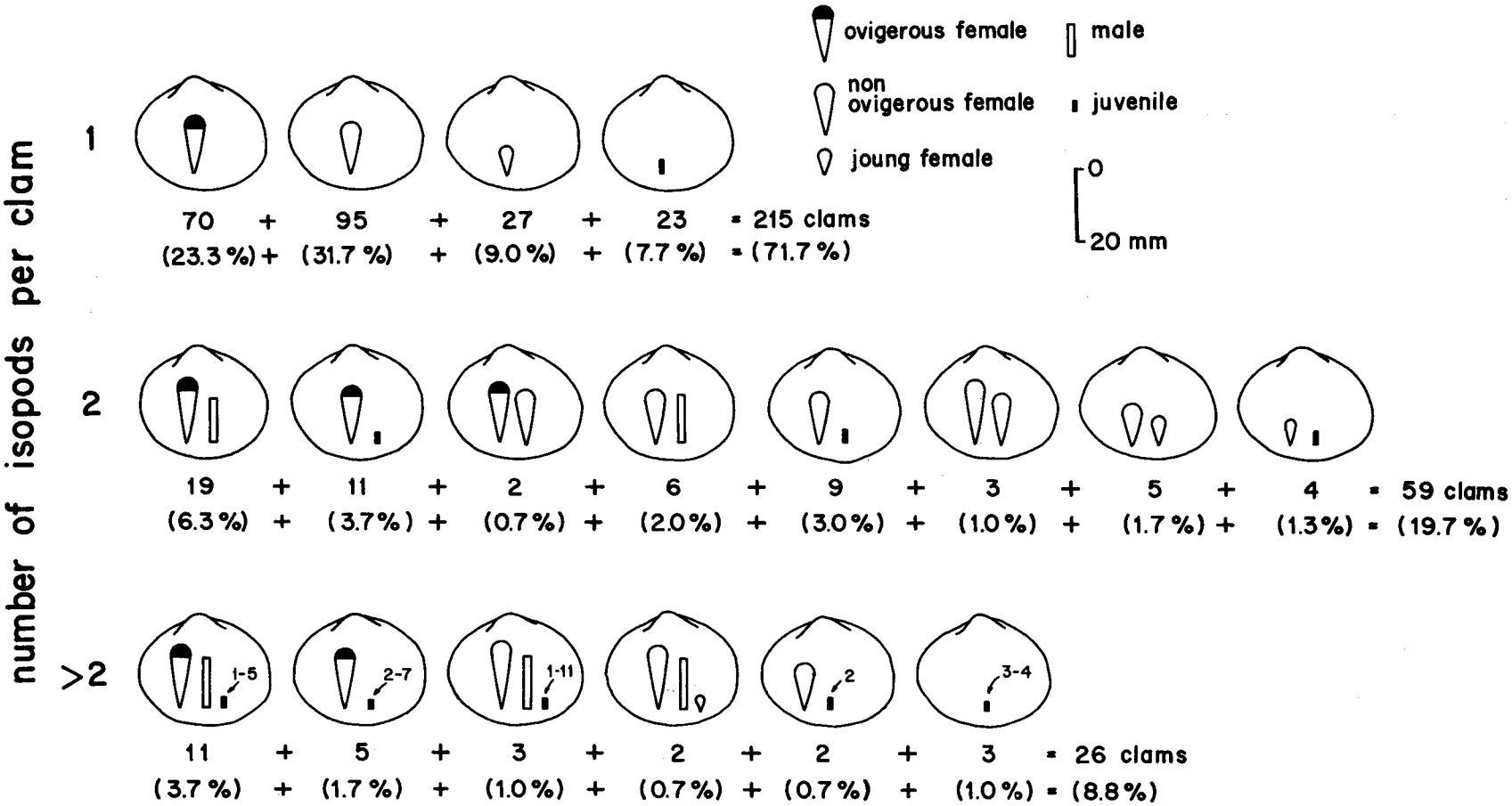

Fig. 5: Number, percentage and sexual stages of isopods found in the mantle cavity of *Mulinia edulis* in Lingue and Queule sand bars. Only sizes of isopods are scale represented.

Número, porcentaje y estadio sexual de los isópodos encontrados en la cavidad del manto de *Mulinia edulis* en las barras Lingue y Queule. Sólo el tamaño de los isópodos se ha representado a escala.

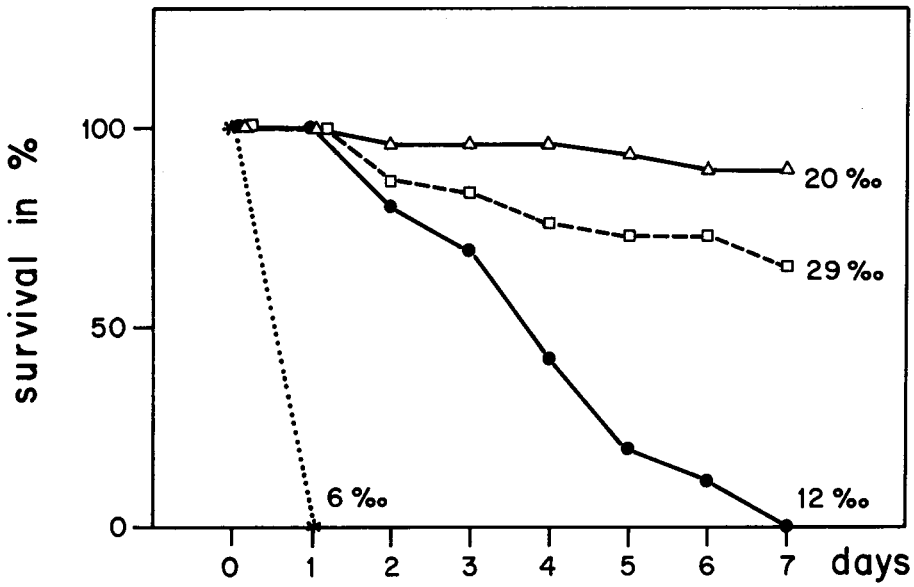

Fig. 6: Survival of isopods at different water salinity concentrations.

Sobrevivencia de isópodos en diferentes concentraciones de salinidad del agua.

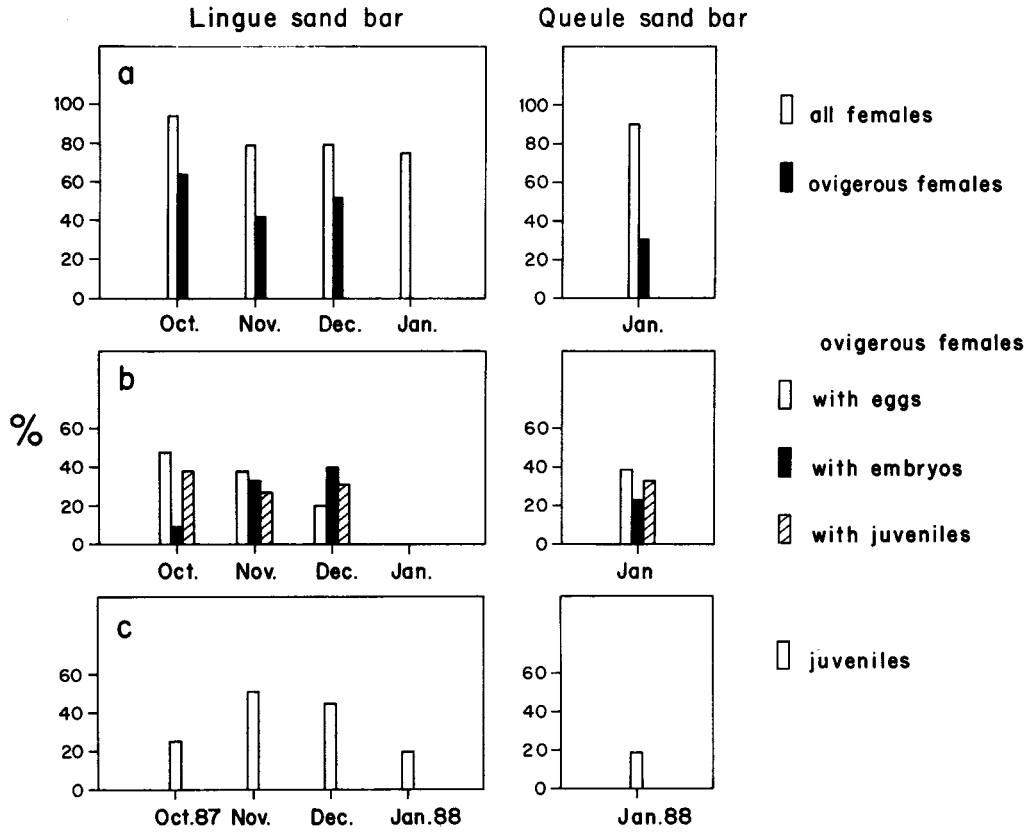

Fig. 7: Percentage number of a) females and ovigerous females, b) ovigerous females carrying eggs, embryos and juveniles, and c) free living juveniles (i.e., found in the mantle cavity of clams) in the Lingue and Queule sand bars.

Porcentaje de a) hembras y hembras ovígeras, b) hembras ovígeras con huevos, embriones y juveniles, y c) juveniles libres (i.e., encontrados en la cavidad del manto de las almejas) en las barras Lingue y Queule.

218.1 embryos), while figures for marsupial juveniles were 10 to 346 per brood (female sizes: 16.4 and 20.9 mm, respectively) (whole mean: 139.3 juveniles). These values and Fig. 8, show that mean number of marsupial stages per brood drop as their stage of development progress. However, significant differences were found only between mean number of eggs and juveniles in October (Lingue sand bar)

TABLE 3

Summary results of regression analyses between number of eggs, embryos and marsupial juveniles versus size of ovigerous females of *Edotea magellanica*. Underlined values of r are significant at the 0.05 probability level.

Resultados resumidos de los análisis de regresión entre el número de huevos, embriones y juveniles marsupiales versus el tamaño de hembras ovígeras de *Edotea magellanica*. Los valores subrayados de r son significativos a un nivel 0.05 de probabilidad.

Site	Month	Number of ovigerous females	r	R^2
Lingue sand bar	October 87	10 females with eggs	0.70	0.49
		8 females with juveniles	−0.44	0.19
	November 87	13 females with eggs	0.82	0.67
		11 females with embryos	0.61	0.37
		9 females with juveniles	−0.02	0.00
	December 87	7 females with eggs	0.62	0.39
		14 females with embryos	0.66	0.44
		9 females with juveniles	0.18	0.03
Queule sand bar	January 88	15 females with eggs	0.82	0.67
		9 females with embryos	0.82	0.67
		13 females with juveniles	0.32	0.10

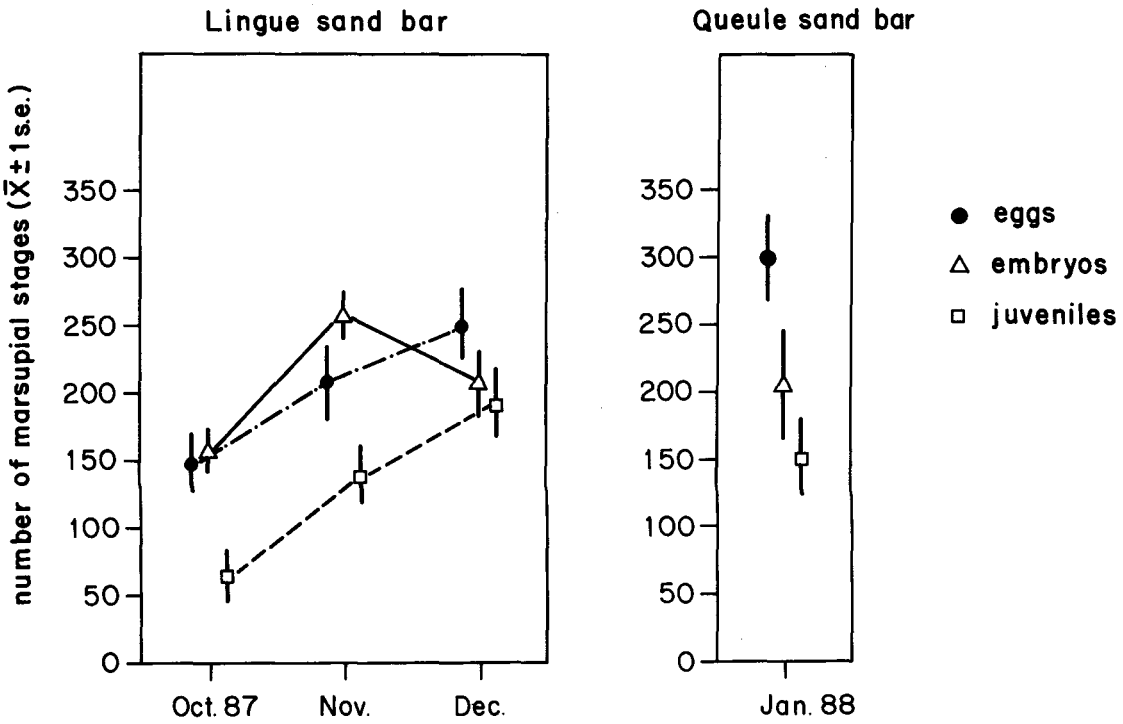

Fig. 8: Temporal variation in the mean number of marsupial stages in Lingue and Queule sand bars.

Variación temporal en el número promedio de estadios marsupiales en las barras Lingue y Queule.

and January (Queule sand bar), and between mean number of embryos and juveniles in November (Lingue sand bar). Figure 8 also shows an apparent increase in brood size from spring to summer. But, results of ANOVA and TUKEY-KRAMER tests carried out with the samples collected from Lingue sand bar, showed that significant differences in number of marsupial stages, occurred only between the mean number of juveniles collected in October and December.

Table 4 shows the results of regression analyses between mean sizes of marsupial stages and size of ovigerous females of *Edotea magellanica*. In general, no significant correlations were found between size of these stages and isopod size. The mean size of eggs/females in the whole sample ranged from 0.40 to 0.61 mm (whole mean: 0.55 mm). The range for embryos was 0.74 to 1.14 mm (whole mean: 0.96 mm), while figures for juveniles were 1.33 and 1.70 mm (whole mean: 1.51 mm). Thus, and based upon the whole means, the size increment between eggs and embryos was 0.41 mm, while the difference between mean size of embryos and juveniles was 0.55 mm. Mean sizes of marsupial stages were quite constant through the study period (Fig. 9). As a matter of fact, no significant differences (ANOVA and TUKEY-KRAMER tests) were detected between the mean sizes estimated for different moths.

DISCUSSION

Edotea magellanica was found only in the mantle cavity of *Mulinia edulis*. Frequent samplings of sandy sediments from Lingue and Queule sand bars did not result in the collection of free living isopods. This contrasts with the situation observed in the Strait of Magellan where *Edotea magellanica* has also been found as a free-living isopod, burrowing in shell gravel and coarse sand under stones in the intertidal area (Jaramillo *et al.* 1981), a situation similar to earlier mentions of the species (e.g., Nordenstam 1933). Perhaps, these differences are related to the higher mobility of the substrate in which clams live at Lingue and Queule sand bars (i.e., soft substrate), as compared to those in which mussels are settled in the Strait of Magellan (i.e., a harder bottom). Thus, the

TABLE 4

Summary results of regression analysis between size of eggs, embryos and marsupial juveniles versus size of ovigerous females of *Edotea magellanica*. Underlined values of r are significant at the 0.05 probability level.

Resultados resumidos de los análisis de regresión entre el tamaño de huevos, embriones y juveniles marsupiales versus el tamaño de hembras ovígeras de *Edotea magellanica*. Los valores subrayados de r son significativos a un nivel 0.05 de probabilidad.

Site	Month	Number of ovigerous females	r	R^2
Lingue sand bar	October 87	10 females with eggs	–0.17	0.03
		8 females with juveniles	0.71	0.50
	November 87	13 females with eggs	0.03	0.00
		11 females with embryos	0.08	0.01
		9 females with juveniles	0.49	0.24
	December 87	7 females		
	December 87	7 females with eggs	–0.81	0.65
		14 females with embryos	0.05	0.00
		9 females with juveniles	0.28	0.08
Queule sand bar	January 88	15 females with eggs	–0.23	0.05
		9 females with embryos	0.11	0.01
		13 females with juveniles	0.10	0.01

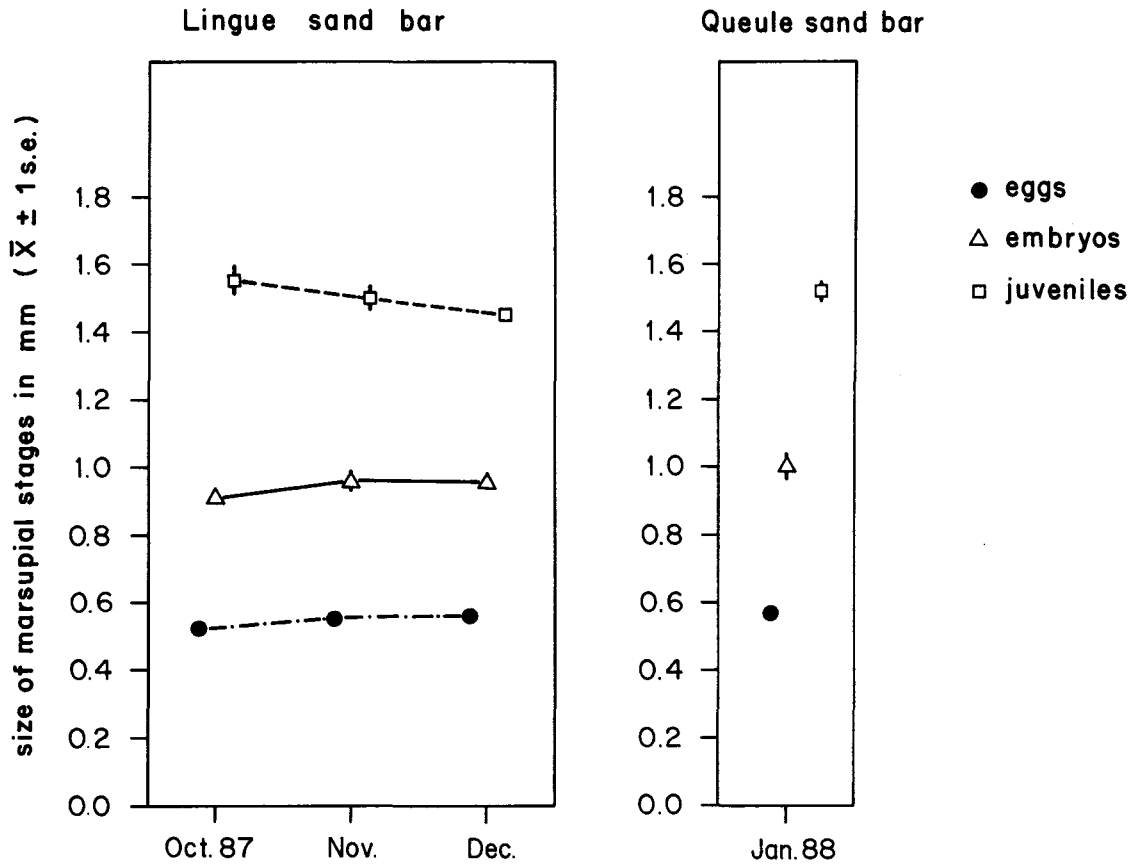

Fig. 9: Temporal variation in the mean size of marsupial stages in Lingue and Queule sand bars.

Variación temporal en el tamaño promedio de los estadios marsupiales en las barras Lingue y Queule.

free-living stages of *Edotea magellanica* could be easily washed far away from the clam beds located in the Lingue and Queule sand bars. This speculation may be well worth further investigation.

Occupation by *Edotea magellanica* had no detectable negative effect on the meat content of *Mulinia edulis*. Hence, it can be hypothesized that the isopods may not be feeding on clam food particles. The isopods may be feeding on the pseudofeces, which are accumulated in the mantle cavity and which contain, entangled in mucus, energy-rich food particles. It could also be that during the reproductive periods, ovigerous females do not feed as mentioned for other marine isopods, e.g., *Arcturella sawayae* Moreira 1973 (Moreira 1973). Thus, *Edotea magellanica* should be considered a commensal of *Mulinia edulis*, as it has been suggested for other crustaceans of the Chilean coast; i.e., crabs of the family Pinnotheridae found in the internal cavity of echinoids, holothuroids, bivalves, and in burrows of polychaetes (Garth 1957). Similarly to these cases, *Edotea magellanica* would get a refuge in the mantle cavity of its host. But, even though no negative effect of isopod occupation was detected on *Mulinia edulis*, the idea that isopods could cause another kind of negative effects can not be rejected, e.g., damages on gills or pedal zone. Truly parasitic isopods as those of the family *Cymothoidae*, produce negative effects on their host fishes (e.g., morphological changes in the skull bones and gill rakers), which do not necessarily affect the size-weight relationship in those fishes (Romestand 1978, Trilles, 1964). No attempt to search for negative effects other than the meat content was carried out in this study.

Edotea magellanica did show a very low survival in experimental water salinities with range similar to those found in the

estuarine waters. Thus, it can be suggested that water salinity is a key factor in explaining the low percentages of clam occupation by isopods in the soft bottoms of Lingue and Queule estuaries. On the other hand, the differences in substrate characteristics between the estuarine and marine soft bottoms (e.g., higher percentages of clay and silt in the estuarine bottoms) could also be important as an explanatory factor for the observed differences in isopod occupation, but we do not have evidence to support this point.

From the large number of clams occupied only by one female (Lingue and Queule sand bars), and the fact that lone male isopods were observed in just one clam, we conclude that the clams are first occupied by a female, a similar conclusion to that reached for *Edotea magellanica* occupying *Mytilus chilensis* in the Strait of Magellan (Jaramillo *et al.*, 1981). Occupation of one clam by more than one adult female seems to be rare, since in only 1.7% of the clams investigated we found two such females would be joined by a males, which would either stay in the mantle cavity of clams just for mating, or stay for a while during the brooding period of reproductive females. The new isopod generation develops in the marsupium of ovigerous females and continues in the mantle cavity of clams until they reach an approximate body size of 4.0 mm. Thus, *Mulinia edulis* could provide food (pseudofeces) and refuge to brooding females and new released juveniles. Release of juveniles might not necessarily be a synchronic process, since different marsupial stages were observed in some brooding females (14.3%). The presence of one adult female and one juvenile in some clams suggests that juveniles may occupy a clam, and then reach sexual maturity as males. The presence of adult female isopods (either ovigerous or non ovigerous) and free juveniles suggests that females reproduce at least twice. Finally, the fact that a very low number of juveniles are found in the mantle cavity of clams (as compared with the number of marsupial juveniles) suggests that these stages have a high mortality after released from the brood chamber of incubating females, or that they do not leave the clams at the same time. The last situation could be an adaptative strategy in order to ensure, that enough number of free young isopods and clams available to be occupied occur at the same time.

The adult population of *Edotea magellanica* was characterized by a sex ratio (males/females) ranging 0.09-0.25. The preponderance of females in that populations could be explained by several factors; e.g., differential growth of the sexes resulting in a changing sex ratio throughout the life cycle as discussed by Carefoot (1973) for the supralittoral isopod *Ligia pallasii*, artifacts due to sampling procedures which failed to detect the presence of free-living stages in which males would have a higher representation, and / or great mortality of males (e.g., predation by surf fishes) during the period seeking out a new host. Marked differences in sex ratios of marine isopods have been attributed to other causes as e.g., artifacts due to differences in swimming activity of the sexes in *Sphaeroma rugicauda* (Heath and Khazaeli, 1985), and asynchrony in the settlement to the breeding habitat of final stage male and female larvae and significant differences in adult life span in the harem-forming isopod *Paragnathia formica* (Upton 1987).

Brood size of *Edora magellanica* was linearly related to body size of incubating females, a feature common to many aquatic and terrestrial isopods, e.g., *Dynamene bidentata* (Holdich 1968), *Cyathura carinata* (Olafsson and Persson, 1986), *Eurydice pulchra* and *Eurydice affinis* (Jones 1970). *Excirolana braziliensis* (Dexter 1977) and *Philoscia muscorum* (Sunderland *et al.* 1976). However, that relationship did not hold true for the number of marsupial juveniles carried by brooding females of *Edotea magellanica*, probably because loss of tht stages during sampling and analytical procedures. The mean brood size of *Edotea magellanica* (range: 139.3-230.8, considering eggs, embryos and juveniles) was larger than that reported for some free living isopods; e.g., up to 70 eggs in *Sphaeroma rugicauda* (Heath and Khazaeli 1985), ca. 30 and 40 eggs in *Eurydice affinis* and *Eurydice*

pulchra, respectively (Jones 1970), up to 17 in tropical populations of *Excirolana braziliensis* (Dexter 1977), and near 60 in *Cyathura carinata* (Olafsson y Persson, 1986). The brood size figures for *Edotea magellanica* are rather similar to those reported for some parasitic isopods (e.g., Trilles, 1968). Thus, more studies are needed to fully understand the way the life cycle and population dynamics of *Mulinia edulis* ensure its local persistence, and to answer the many questions brought up by this study.

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LITERATURE CITED

BENNETT AS (1976) Conversion of *in situ* measurements of conductivity to salinity. Deep Sea Res. 23: 157-165.

CAREFOOT TH (1973) Studies on the growth, reproduction, and life cycle of the supralittoral isopod *Ligia pallasii*. Mar. Biol. 18: 302-311.

DEXTER DM (1977) Natural history of the Pan-American sand beach isopod *Excirolana braziliensis* (Crustacea: Malacostraca). J. Zool., Lond. 183: 103-109.

GARTH JS (1957) The crustacea decapoda brachyura of Chile. Reports of the Lund University Chile Expedition 1948-49. N° 29. Acta Univ. Lund, N.F. Avd. 2, 53: 1-130.

HEATH DJ & AA KHAZAELI (1985) Propulation dynamics of the esturiane isopod *Sphaeroma rugicauda*. Estuarine, Coastal Shelf Sci. 20: 105-116.

HOLDICH DM (1968) Reproduction, growth and bionomics of *Dynamene bidentata* (Crustacea: Isopoda). J. Zool., Lond. 156: 137-153.

JARAMILLO E, J NAVARRO & J WINTER (1981) The association between *Mytilus chilensis* Hupe (Bivalvia, Mytilidae) and *Edotea magellanica* Cunningham (Isopoda, Valvifera) in southern Chile. Biol. Bull., 160: 107-113.

JARAMILLO E, S MULSON & R NAVARRO (1985) Intertidal and subtidal macroinfauna in the Queule River Estuary, south of Chile. Revista Chilena de Historia Natural 58: 127-137.

JONES DA (1970) Population densities and breeding in *Eurydice pulchra* and *Eurydice affinis* in Britain. J. mar. biol. Ass. U.K. 50: 635-655.

LORENZEN S, C GALLARDO, C JARA, E CLASSING, G PEQUENO & C MORENO (1979) Mariscos y peces de importancia comercial en el sur de Chile. Publicación ocasional Universidad Austral de Chile: 131 pp.

MOREIRA PS (1973) Food and feeding behaviour of *Arcturella sawayae* Moreira, 1973 (Crustacea, Isopoda, Valvifera). Bol. Zool. e Biol. Mar., n.s., Sao Paulo 30: 217-232.

DENSTAM A (1933) Marine Isopoda. Further Zoological Results of the Swedish Antarctic Expedition 1901-1903: 3-284.

OLAFSSON EB & LE PERSSON (1986) Distribution, life cycle and demography in a brackish water population of the isopod *Cyathura carinata* (Kroyer) (Crustacea). Estuarine, Coastal Shelf Sci. 23: 673-687.

ROHLF FJ & RR SOKAL (1981) Statistical Tables. W.H. Freeman and Co., San Francisco.

ROMESTAND B (1978) Etude ecophysiologique des parasitoses a Cymothoidae. Thèse, Université des Sciences et Techniques du Languedoc, France: 315 pp.

SOKAL RR & FJ ROHLF (1969) Biometria. H. Blume Ediciones, Madrid.

SUNDERLAND KD, M Hassall & SL SUTTON (1976) The population dynamics of *Philoscia muscorum* (Crustacea Oniscoidea) in a dune grassland ecosystem. J. Anim. Ecol. 45: 487-506.

STOLINE, M.R. (1981) The status of multiple comparisons: simultaneous estimation of all pairwise comparisons in one way anova designs. The American Statistician 35: 134-141.

TARIFEÑO E, G TRONCOSO & M ROJAS (1981) Fisiología ecológica de la almeja amarilla *Mulinia edulis* (Bivalvia, Mactracidae). Resumen Primeras Jornadas de Ciencias del Mar (Montemar, Chile): 76.

TRILLES JP (1964) Variations morphologiques du crane chez les téleostéens Sparidae et Centracanthidae en raport avec l'existence sur ces poissons de certains Cymothoidae parasites. Annls. Parasit. Hum. Comp. (Paris) 39: 627-630.

TRILLES JP (1968) Recherches sur les Isopodes Cymothoidae des côtes françaises. Thèse, Université de Montpellier, France: 793 pp.

UPTON NPD (1987) Asynchronous male and female cycles in the sexually dimorphic, harem-forming isopod *Paragnathia formica* (Crustacea: Isopoda). J. Zool., Lond. 212: 677-690.