GROWTH AND AGE DETERMINATION IN THE SPIRORBID POLYCHAETE ROMANCHELLA PUSTULATA KNIGHT-JONES, 1978.

Juan I. Cañete* and Rattcliff P. Ambler**

ABSTRACT.   Growth and age determination in the spirorbid poly-
chaete Romanchella pustulata Knight-Jones, 1978.

During Winter and Spring period of 1989 (July to September
and October to December, respectively), growth, first size at
female maturity and fecundity were determinated in the fouling
sprirorbid polychaete Romanchella pustulata on suspended glass
slides in Herradura Bay, Coquimbo (29° 58'S, 71° 22'W). During
both periods, maximal increments in tube (TD) and opercular
diameter (OD) were approx. 4 mm and 1 mm, respectively.   The
Logistic model allowed a better data fit (smaller residual sum
of squares) than Gompertz and Von Bertalanfy models. The growth
parameters of Logistic growth equation are: Winter: r = 0.0889;
K = 3,996; Y = 119.6; Spring: r = 0.0998; K = 3,827; Y = 160.3
Spring growth was statistically superior to winter growth.

Onset of female sexual maturity, defined as the presence of
embryos in the thoraxic brooder-sac, started at 40-50 days after
settlement at a TD of 2.5 and 3.2 mm for winter and spring,
respectively.   This event coincided with a decreasing in growth
rate.   Fecundity varied between 165 to 270 embryos per female.
Egg diameter ranged from 100 to 120 μm, body length of
hatchlings larvae varied from 150 to 210 μm and the smaller
recruits measured between 180 to 200 μm, indicate a possible
short stay in the plankton.

The finding of the present study are compared with literature
on growth of other benthic polychaetes and fouler invertebrate
species present in Coquimbo.

Key words: Demography, Reproduction, Chilean polychaete,
Mortality, Growth equations, Recruitment size.

* Departamento de Oceanología, Universidad de Concepción, Casilla 2407,
   Concepción, Chile.
** Facultad de Ciencias del Mar, Departamento de Biología Marina, Universidad Cató-
   lica del Norte. Casilla 117, Coquimbo, Chile.

RESUMEN. Crecimiento y determinación de edad en el poliqueto espirórbido **Romanchella pustulata** Kningt-Jones, 1978.

Se presentan antecedentes sobre crecimiento, edad, tamaño mínimo de actividad reproductiva y fecundidad en hembras del poliqueto espirórbido **Romanchella pustulata** Knight-Jones, 1978. El estudio se realizó en 2 períodos de 1989 (Invierno: julio-septiembre y Primavera: octubre-diciembre), utilizando porta-objetos mantenidos a 4 m de profundidad en un sector de bahía La Herradura, Coquimbo (29° 58'S, 71° 22'W), Chile. Las variables de crecimiento analizadas fueron el incremento del diámetro opercular (DO) y diámetro del tubo calcáreo (DTC).

En ambos períodos, se observó que el tamaño máximo aproximado alcanzado por DTC y DO fueron 4 mm y 1 mm, respectivamente. Los datos obtenidos se ajustaron a 3 modelos de crecimiento (Gompertz, Logístico y Von Bertalanffy), observándose un ajuste mejor (menor suma residual de cuadrados) con la ecuación de crecimiento logística. Los parámetros de crecimiento correspondientes a la ecuación logística son los siguientes: Invierno r = 0.0889; K = 3.996; Y = 119,6; Primavera: r = 0,0998; K = 3.827; Y = 160,3. El crecimiento primaveral fue estadísticamente superior al invernal.

A un tamaño de 2.5 mm y 3.2 mm (invierno y primavera, respectivamente) y a los 40-50 días posteriores al asentamiento, sobre el 50% de las hembras presentaban embriones en el saco incubatriz. Este evento coincidió con la reducción de la tasa de crecimiento. La fecundidad varió entre 165 y 270 embriones por hembra. El huevo mide entre 100 y 120 μm, la longitud de las larvas pre-eclosión miden entre 150 y 210 μm y el tamaño de reclutamiento fue de 180 a 200 μm. Esto sugiere que las larvas tienen una corta permanencia en el plancton.

Los resultados obtenidos se comparan con datos de crecimiento de otros poliquetos y con otros invertebrados que componen la comunidad de incrustantes presentes en Coquimbo.

Palabras claves: Demografía, Reproducción, Poliquetos de Chile, Mortalidad, Ecuaciones de crecimiento, Tamaño de reclutamiento.

INTRODUCTION

A mayor problem arises during demographic studies in polychaete populations is the choice of parameters to measure. These parameters must present a minimum variability, for a given age. Generally, the first phase of a demographic study establish a set of size frecuency histograms. Growth parameters more often considered are dry weight, wet weight and linear body dimensions, such as length or cross section diameter. The number of segments is less used because segment number increases during the whole life; furthermore, the number of segment vary with species and may be fixed early or increase at different rates in distinct stages in the life cycle. Also, this parameter must be careful analized because of possible autotomy, regeneration or body contractions of preserved specimens (Duchene 1982).

Although the hard structures of errantia jaws have long been used for age determination (Kirkegaard 1970; Escourt 1975: Olive 1977 and 1980; Valderhaug 1985), they cannot be used in sedentary polychaetes because these ones do not posess such structures. However, the uncinal plates can also be used for determination of age in some families (Duchene & Bhaud 1988). Other structures to be used can be the tubes, diameter or length, because they increase of size during the life. Some sedentary polychaetes families that build tubes are Pectinariidae, Sabellariidae, Sabellidae, Serpulidae and Spirorbidae (Fauchald 1977). This last family builds coiled tubes of calcium carbonate and live always inside them. Only one work on Spirorbidae growth is mentioned in the literature (Gee 1967).

During an investigation on the demographic parameters of the fouling species present in the La Herradura Bay (Fig. 1), Coquimbo (29° 58'S, 71° 22' W), Chile, the growth in the spirorbid polychaete *Romanchella pustulata* Knight–Jones, 1978, was studied. Its geographical distribution is ranged from Coquimbo to Chiloé Island (42°S) (Rozbaczylo 1985) and is considered an early settler in this community, which is composed by 51 species with different taxonomical categories, life histories, body sizes, abundance and succesional stage (Dubois 1979; Viviani & DiSalvo 1980). *Romanchella* species brood the embryos in a tube-incubating attached to specialized thoraxic stalks (Knight–Jones et al. 1972).

The present work has three main aims: first, to know the growth of **Romanchella** pustulata and to analyse this in function of the actuals models of growth proposed for marine sessile invertebrates; second, to estimate the age of the first sexual maturation and the fecundity; and, third, to project these results in relation to the community. The study of growth in two periods of a year with different oceanographical variables was realized to know how could affect in a species with a short life cycle the seasonality and the recruitment size to the growth parameters.
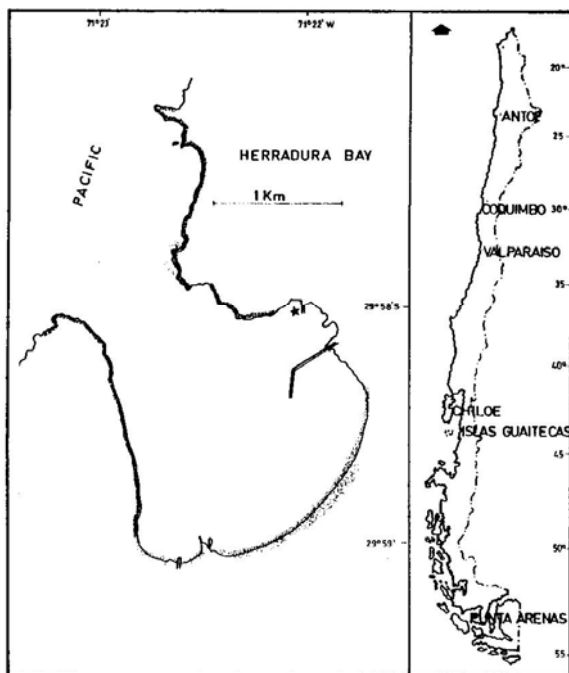
Fig. 1. **Romanchella pustulata**. Geographical location of the La Herradura Bay,
Coquimbo, Chile. Star: pier of Universidad Católica del Norte; Arrow:
signale the northern direction.

MATERIALS AND METHODS

La Herradura Bay is located to the
south of the Coquimbo city, Chile (Fig.
1). Information on oceanographic con-
dition of this bay has been published
by Moraga & Olivares (1987) and Oli-
vares (1988).

To estimate the growth in Romanche-
lla pustulata, glass slides as artifi-
cial panels (7.5 × 2.5 cm) were used
and were inmersed at a depht of 4 m in
two periods of 1989: July-September
(Winter) and October-December (Spring).

In each period, 60 panels were placed in sections of PVC tube (5" of diameter and 25 cm of long) cut up in two half; in each half, 20 groves were made and there each glass slides were placed. Each PVC half and its glass slide was put within a pearl-net and it was lashed to a raft fixed to a pier belonging to Universidad Católica del Norte, Coquimbo. In each opportunity (1 or 2 weeks) were selected randomly 10 to 20 panels and the larger individuals were measured with a Profile Proyector NIKON type 210. Two growth parameter were considered: diameter of calcareous tube and opercular plate diameter (Fig. 2a).

The age and minimal size of female reproduction were analyzed seing the reverse of some glass slides and it was observed if the individuals could have brooder-sac with embryos or larvae. This variable was determinated when near of 50% of the individuals on 2.0 mm of diameter of tube presented brooder-sac with embryos or larvae. The age and the size of first male reproduction were not considered because the small size of the individuals and because there are not evident parameters indicating the male phase. The spirorbid are protandricous (DeSilva 1967). The fecundity were estimated counting the number of embryos or larvae pre-hatching in each brooder-sac; this variables was studied only in the period July-September.

The program FISHPARM was used to fit the Gompertz, Logistic and Von Bertalanffy growth equations. These are the following:

Gompertz: $Lt = L_0 \, e^{G(1 - e^{-gt})}$, where L_0 = is the length at time t measured from a conventional 0 at the time in which the polychaete have length L_0; G = is the instaneous growth rate when t = 0 and $L_t = L$; and g = is the instantaneous rate of decrease of the instantaneous rate of growth, and also the instantaneous rate of growth itself at the inflexion point of the curve (Riklefs 1967; Ricker 1975).

The Logistic equation is: $LT = Loo / 1 + (Loo - Y_0 / Y_0) (e^{-rt})$, where Loo is the asymptotic length, Y_0 is the initial length and r is the growth constant (Yamaguchi 1975).

The Von Bertalanffy growth equation is: $LT = Loo (1 - e^{K(t - t_0)})$, where Loo is the asymptotic length, K is the instantaneous growth rate and t_0 is the theorical age where the length is 0 (Ricker 1975).

The sigmoid curve was aligned through methods described by Neter & Wasserman (1974) to allow the comparison between slopes.

During both periods, the only oceanographical parameter recorded was the surface temperature.

The statistical methods were used according to Sokal & Rohlf (1969).

RESULTS

During this study some information not considered initially were obtained and will be mention here.

RECRUITMENT

The smallest individuals of **Romanchella pustulata** settled on glass slides have a length between 180 to 200 μm of tube length. First, the tube is rectangular in shape with an open anterior end (Fig. 2b). The R. pustulata postlarvae have a orange body with two red eyes placed in the basal end of the central radioles; The thorax is composed by three segments and the abdomen present between 5-7 segments. In total, 4-6 radioles were observed in the postlarvae. After, the individuals secreted a coiled tube nearly circular in shape and their aperture was sinistral (Fig. 2c). Initially, the dorsal side of they show two notorious dorsal ridges (Fig. 2d). The first ridge is presented when the tubes have 1000 to 1200 μm and the second ridge when the tubes have between 1500 to 2000 μm. Some uncommon postlarval tubes of great length and not coiled were observed (Fig. 2e).

The recruitment was a continuous event during both periods of study and it was observed as a constant increment of abundance. In both cases, the initial greatest abundance of recruits was near to 12 indiv./cm2 and the process of settling began within the first ten days of inmersion (Table 1).

GROWTH

The growth of the tube and the body is presented both in length and diameter (Fig. 2f). The external edge of the basal section of the tube presents empty cavities with different sizes being observed when the individuals have a size near to 1000 μm; the proximal cavities to the postlarval tube are smaller then those more distals (Fig. 2g). The maximal size observed in both periods was not superior to 4 mm of tube diameter and 1 mm of opercular diameter and need 60 to 70 days to become the curve asymptote.

Winter and spring data growth of Romanchella pustulata are showed in Table 1 and were fitted to three equations: Gompertz, Logistic and Von Bertalanffy. The curves, their equations and the residuals sum of squares are showed in the Fig. 3. The growth of R. pustulata in this locality is best described by using the Logistic equation because presents minimal values of residual sum of squares (Fig. 3b). It is observed that growth rate between the three equation are very different, but within each equation there are not much difference between winter and spring growth rate (Fig. 3).

To aligne the curves of the logistic growth equation is observed that the slope of the line of Spring is higher to the one observed in winter (Fig. 4). There are significative differences betwwen both lines when the slopes are compared (F = 21.12; p < 0.05). The methodology used to obtain the aligned curves is showed in the Table 2.

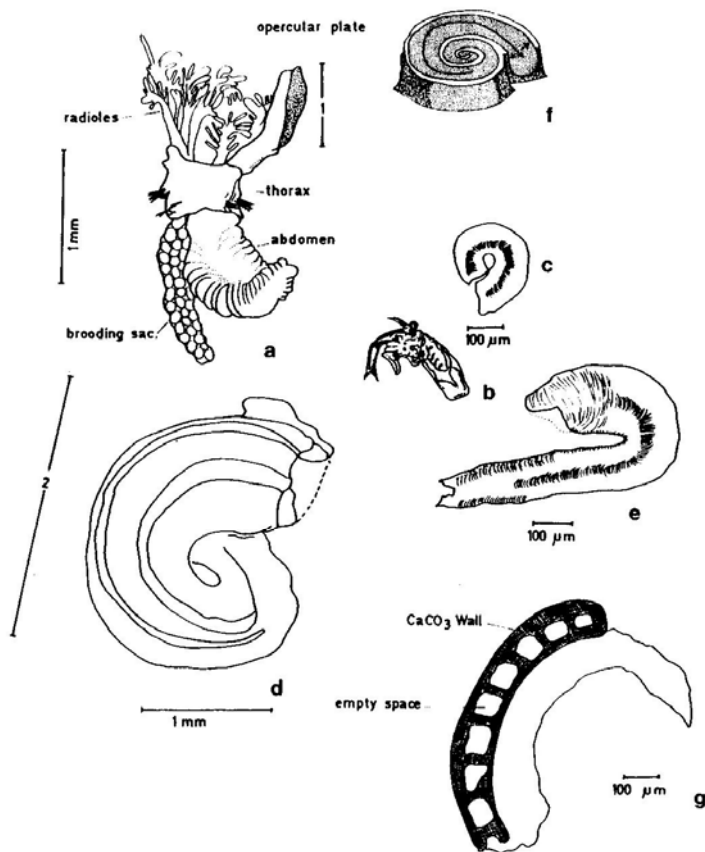In both periods, there is a positive significative correlation between tube

Fig. 2. Romanchella pustulata. a) Ventral view of a whole female removed from the tube; 1 = opercular diameter. b) Lateral view of early postlarvae; c) Dorsal view of old postlarvae tube; d) Dorsal view of the tube of a female individual; 2 = tube diameter; e) Dorsal view of a uncommon old postlarval tube; f) Shematic section of a tube as if cut parallel to the substratum, with the top removed; the arrows indicated the pattern of growth of the tube and the animal body; g) Section of a tube if cut parallel to the substratum showing the internal morphology.

and opercular diameter. The regression functions that show these relationships are the following:

July – September : $Y = 0.217 X + 33.14$
($r= 0.98; p < 0.05; N =395$)

October –December : $Y = 0.298 X + 25.17$
($r= 0.96; p< 0.05; N =278$),

where Y is opercular diameter and X is the tube diameter.

Observations of both periods show that the principal cause of natural mortality in R. pustulata in September was provocated by the settlement and overgrowth of the barnacle Balanus laevis and the polychaete Polydora cf rickettsi. The barnacle occupied all the space and the polychaete bored the calcareous tube. During December, the tubes were attacked only by Polydora. This polychaete is considered an important borer in the northern chileans bivalves marine culture (Cañete 1988).

In both periods, when the larvae hatch, all the adults individual died. This fact suggests that R. pustulata could be a semelparous species. The mortality before of the larvae hatch is low because a great proportion of those individuals settled during the first week (those of bigger size) are present.

MINIMAL SIZE OF REPRODUCTION IN FEMALES
The minimal sizes of the R. pustulata female reproductive were different in both periods. In winter, the average size was smaller than in Spring (2539 and 3068 μm; SD = 116 and 152 μm; N = 41 and 53, respectively), and there are significative differences between them ($t= 18.48$; $p < 0.01$). The age at this size, in both periods, varied between 40 to 50 days postsettlement. This

event coincided almost simultaneously with a growth decreasing.

FECUNDITY
The fecundity of R. pustulata was expressed as the number of embryos or postlarvae present in the brood-sac per female. The range varied between 165 to 270 individual with a average abundance of 212.0 (SD = 26.76). The eggs have a diameter of 100 to 120 μm, are orange in color and spherical in shape; pre-hatchling larvae have a length between 120 to 210 μm. If we realized comparison between old pre-hatchling larvae settled it could suggest a short stay in the plankton and the larvae could be lecitotrophic. There is a positive lineal relationship between fecundity and female size, but is not significative ($r= 0.39$; $p > 0.01$; N = 20). The equation that relates both parameters is:

$Y = 0.019X + 154.15$, where Y is the number larvae per famale and X is the female size.

OCEANOGRAPHICAL DATA
It is found there are notorious difference between the surface temperature of Winter and Spring, being higher in this last season. It is observed also during Spring that the temperature shows a high range of variations near to ^{4}ºC (Fig. 5).

$$TD = 47.01\,e^{(4.519(1-e^{-0.0556\,t}))}$$
$$RSS = 503.62$$

$$TD = 33.78\,e^{(4.950(1-e^{-0.095\,t}))}$$
$$RSS = 519.25$$

a)

$$TD = \frac{3827}{1 + 22.87\,e^{-0.099\,t}}$$
$$RSS = 453.10$$

$$TD = \frac{3996}{1 + 32.41\,e^{-0.0889\,t}}$$
$$RSS = 302.77$$

b)

$$TD = 18170\,(1 - e^{-0.0041(t-3.88)})$$
$$RSS = 1187.62$$

$$TD = 24740\,(1 - e^{-0.0027(t-8.04)})$$
$$RSS = 1201.68$$
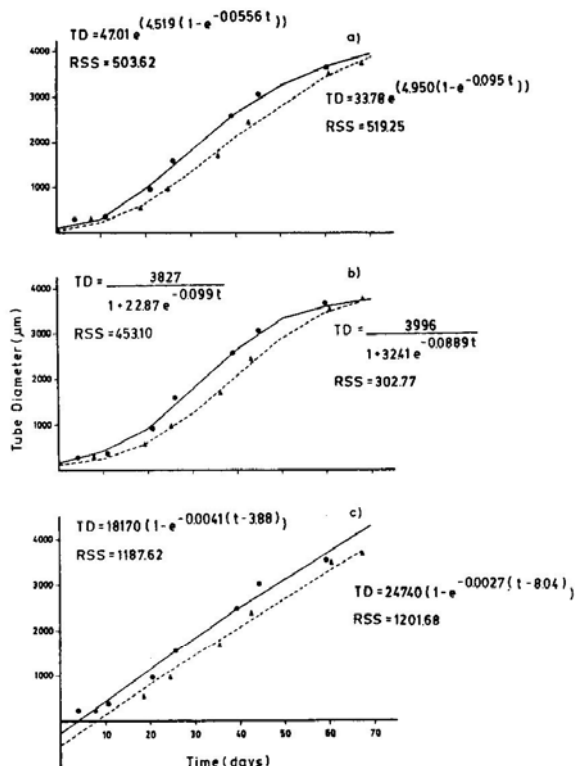
c)

Time (days)

Tube Diameter (μm)

Fig. 3. **Romanchella pustulata.** Data of tube diameter and fitted lines through growth equations; dotted line: winter fitted line; complete line: spring fitted line; triangles: winter data; circles: spring data. a) Gompertz growth equation; b) Logistic growth equation and c) von Bartalanffy growth equation.
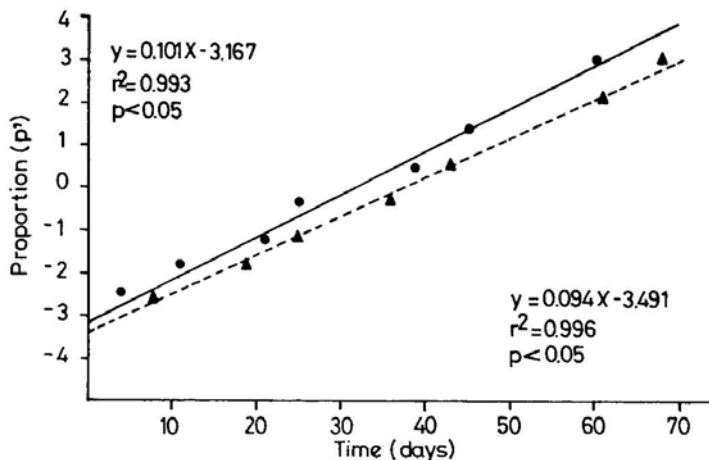
Fig. 4. **Romanchella pustulata.** Logistic growth curves linearized by Neter and Wasserman (1974) method. Dotted line: winter fitted line; complete line: spring fitted line; triangles: winter data; circles: spring data. See Table 2 for explanations.
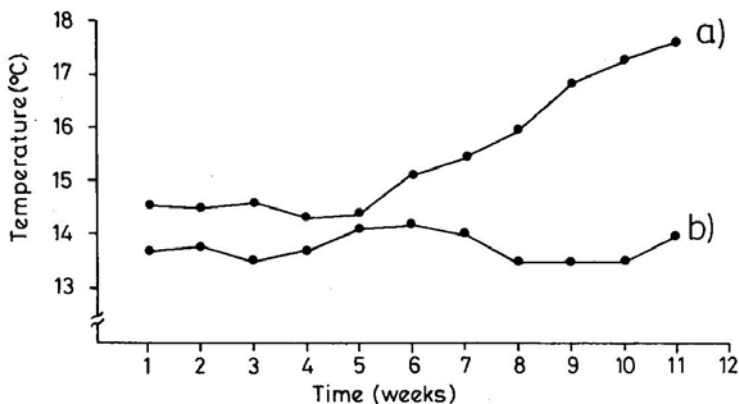

Fig. 5. **Romanchella pustulata.** Weekly data of mean surface temperature of the La Herradura Bay, Coquimbo, Chile, during Spring (A) and Winter (B) of 1989.

DISCUSSION

Growth parameters estimation constitutes one of the most important methods in analyzing population dynamics of marine sedentary invertebrates, principally in those organisms of fouling communities, where the macrobenthos tend to grow quickly. Other methods such as the study of size-frecuency distribution often do not give any conclusive results because of continuous recruitment and fast growth. This characteristic is similar to the observed in coral communities (Yamaguchi 1975).

In sedentary polychaetes, with exception of uncinal plates and tubes, there are not other morphological structures present as to estimate growth parameters. So, a good method to know the growth is to maintain observations on the individuals early settled. According to the present study, the methodology used have some problems. The Romanchella pustulata individuals do not use all the internal cavity of the tube and the tube size do not have a good association with the body size. The best way could be use the opercular diameter, but this structure suffers moulting (Thorp & Segrove 1975) and could show similar problems to those observed in works on growth crustaceans. Other problems associated with this methodology is not to be able estimate secondary production because other age-classes information are lost (Grant et al. 1987). Working with the tube diameter could produce problems relationed with the changes in the tube morphology provocated by high density and the gregariousness. We observed that in high density, the anterior end of R. pustulata tube is elevated from of the surface and placed in vertical position. As this spirorbid does not have other detectable growth records then other option avaible is to estimate the population parameters directly from the population, but the Herradura Bay population is not size-structured and seem be reproductive during the whole year, not producing discrete-peaks of recruits. In spite of these problems we considered that to estimate the growth in the Spirorbidae could be best to use the increase of diameter of the tube.

Several growth functions used commonly in the literature were used to fit the growth in R. pustulata (Fig. 3). The familiar Von Bertalanffy equation did not provide a reasonable fit to adult size producing high values of Loo; however, if are aliminated the two initial values, the Von Bertalanffy equation show a best fit with a Loo near to 7.0 and 4.7 mm and a residual sum of squares of 453.9 and 205.6 for Winter and Spring, respectively. The sigmoidal functions such as Gompertz and Logistic may be more appropiate. Von Bertalanffy functions show greatest residual sum of squares; however, the lowest residual sum of squares does not always indicate the best choice of model (Gallucci & Quinn 1979). The logistic curve differs from Gompertz by being symmetrical on both either sides of the inflection point. The R. pustulata growth could be best fit by the Logistic or autocatalytic equation.

In the literature at least three me-
thods have been used to discriminate
and choose the best model between some
growth models. Orensanz & Gallucci
(1988) use an "F" statistical test for
the comparison of growth models using
the residual sume of squares (RSS) as
basic elements for the comparison.
Somerton (1980) makes a comparison of
the fits obtained by the straight-line
and hyperbolic models usign the Wil-
coxon signed rank statistic test to
discrimate them. Cellario & Fenaux
(1990) used the Lockwood diagrams to
choose between growth equations of Von
Bertalanffy and Gompertz. In the study
only was considered the RSS to choose
the Logistic model as the best model
adjusted to the data obtained.

In spite of having significative
difference between logistic curves of
Winter and Spring (Table 2 and Fig. 4),
the seasonallity or temperature do not
effect the Loo neither the growth rate,
but there are notorious differences in
the constant (Loo - Lo/Lo). This di-
fferences could be explained by the
differentes recruitment sizes observed
(Table 1 and Fig. 3). Yamaguchi (1975)
show that the time intervals over which
growth is measured modify the growth
parameters and growth rate in non-
linear growth curves and this could
explain in part the variations observed
in the Fig. 3b.

The differences observed in the
Winter and Spring growth could be ex-
plained in relation to the temperature
fluctuation range of each season.
There are a lot of bibliography about
the importance of the temperature in
the life cycle of the marine species.
But there is not much information about

temperated seas species that develop
all life cycle within a only range of
temperature as seem to be in R.
pustula. The genus Romanchella has
principally species restricted to sub-
antarctic waters (Knight-Jones 1984)
and R. pustulata is one of the member
distributed more to the northern and
could be estimated that high tempera-
tures could produce a low growth to be
distributed in the peripherical zone of
latitudinal distribution. However, the
results are different to the previously
hypotetized. It is also important to
consider the larval adaptations to
survive to different thermics condi-
tions from one season to other. In the
La Herradura Bay, during the Winter
there are a thermic amplitude near to
0.78ºC and during Spring this ampli-
tude is increasing to 3.45ºC (Fig. 5).

The growth of R. pustulata is nearly
similar to other tubicolous poly-
chaetes. Miura & Kajihara (1984)
show that Hydroides ezoensis and Poma-
toleios krausii, both serpulid poly-
chaetes, take 5 months to get the
asymptote size. Gee (1967) shows that
Spirorbis rupestis a spirorbid poly-
chaete, get the asymptote size in 4
months. Oyenekan (1967) mention that
Caulleriella caputesocis, a cirratulid
polychaete, obtains their asymptote
size in aprox. 6 months. Other poly-
chaetes require larger periods of time
to obtain the asymptote size and pre-
sent larger life span. Rainer (1984)
shows that the life span of Pactinaria
koreni is near to 3 years. Creaser
(1973) mentions that Glycera dibran-
chiata has a life span near to 3-4
years and Olive (1978) cites that
Nephtys hombergii and N. caeca have a
life span aprox. to 2-3 years. Capite-

lla capitata has a life span less than 2 years (Warren 1976). A common way to all these studies is that they do not present the data in functions of growth equations and the present study seems to be the first one to do it.

The growth of R. pustulata is one of the fastest within the fouler marine invertebrates present in the Herradura Bay. This Growth is nearly similar to the one showed by the small barnacle Balanus laevis (maximum base diameter of 10 mm obtained during 85 days; personal observations). However, are these comparisons important?. The different morphology and the different structures to be measured could not indicate good correspondence. The only common way within the last mentioned species is the use of an external protection that increase in size while the individual grow up. The fouler invertebrates present a great variability in the body morphology and do not permit to establish comparison between the data of this study and those obtained for Bugula neritina (ramificated bryozoan), Umbonula alvareziana (Incrustants bryozoan), Ciona intestinalis and Pyura chilensis (Both solitary ascidians), because the mechanism of space occupation is different. It is possible that the size range can be expressed in the terms of the common logarithm of the ratio of the maximal size against the recruitment size, so that the increase of linear dimension for each species could be showed as number of orders of magnitude (Yamaguchi 1975).

At the community level, it has been suggested for some subtidal systems, species arriving first may be able to resist late invasor species, so that the abundance of sessile species in such communities can be explained by measuring the colonising ability of components species (Sutherland & Karlson 1977). In relation to R. pustulata. this is an early invader, but it is covered by the other species of bigger size or by ones of fastest growth rate. Also, this spirorbid seem be a semelparous species, which implies a short life and could not present problems to the arrivals of recruits of later species.

If R. pustulata is semelparous, then the brooding development could take near 10 to 20 days from the beginning of the female reproductive activity to the hatchling larvae stage. This estimation seems similar to the data reported by Rothlisberg (1974), which indicates that in Spirorbis marioni the brooding time is 15 days. R. pustulata seems to have lecitotrophic larvae because the old pre-hatchling larvae have a size similar to postlarvae ealier settled. Furthermore, some works show thats spirorbids polychaetes have a planktonic life shorter than 24 hours (Knight-Jones 1953).

There are few growth data on fouling species present in the Herradura Bay and the chilean coast. The present work is the first of several studies in advances that will permit to know the biology of the species of this community.

Table 1. **Romanchella pustulata**. Mean growth of the calcareous tube in two periods de 1989: July-September (A) and October-December (B). Sampling developed in the La Herradura Bay, Coquimbo, Chile. Artificial plates placed at 4 m depth.

Time (Days)		Tube Diameter (µm)		Standard Desviation (µm)		N	
A	B	A	B	A	B	A	B
8	4	290	280	40	30	40	68
19	11	530	350	120	80	52	76
25	21	960	930	140	120	56	50
36	26	1670	1560	290	230	95	75
43	39	2440	2550	340	330	121	62
61	45	3520	3040	400	300	69	49
68	60	3720	3640	310	360	67	67

Table 2. **Romanchella pustulata**. Winter Growth data of calcareous tube to show how the values of the Fig. 4 were obtained.

Time (Days)	Tube Diameter (µm)	Proportion of the asymptotic size (p)	transformed proportion (P')
8	286.50	0.073	-2.535
19	533.84	0.136	-1.841
25	958.04	0.245	-1.121
36	1672.52	0.427	-0.286
43	2437.92	0.623	0.511
61	3519.56	0.899	2.220
68	3720.14	0.950	3.032

L_∞ = 3915 µm; where L_∞ = L max / 0.95.
p = Tube Diameter / L_∞.
$p' = \ln(p / 1 - p)$.

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