Age and Growth of the Subantarctic Limpet Nacella (Patinigera) magellanica magellanica (Gmelin, 1791) from the Strait of Magellan, Chile

by

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Abstract. Age and growth rate of the subantarctic limpet Nacella (Patinigera) magellanica magellanica (Gmelin, 1791) from intertidal cobble-boulder fields of the Strait of Magellan were determined. Growth was defined using exterior shell growth lines and employing the Ford-Walford relationship and von Bertalanffy model. Males and females did not show significant differences in growth and, according to estimated growth parameters, which varied geographically along the Strait, the ten studied populations can be segregated into four distinct groups. A seasonal growth pattern, with higher growth rates during spring-summer and lower rates during autumn-winter, was present which correlates with seasonal fluctuations of physical and biological conditions of the Strait. Initiation of annulus formation might occur between the end of summer and the beginning of autumn. A low annual growth rate (K = 0.0263 - 0.1913), a low instantaneous rate of natural mortality (M = 0.026 - 0.191), and a long life (15.7-37.8 yr) were characteristics of the studied populations. Growth rate and longevity were inversely correlated. The western populations of the studied area had the highest growth rates and the lowest longevities, while the eastern populations showed the opposite trend. The observed growth pattern was inversely correlated with tidal range, but this single physical factor alone did not explain the trend.

INTRODUCTION

Comprehensive studies on growth and age have been undertaken for many marine gastropods at different latitudes (FRANK, 1969; BRANCH, 1974; BRETOS, 1980; COCKCROFT & FORBES, 1981), including the Antarctic region (PICKEN, 1979, 1980). However, comparatively little information exists for gastropods inhabiting the subantarctic zone (*e.g.*, BLANKLEY & BRANCH, 1985).

Among the subantarctic gastropods, the Nacella (Patinigera) complex is well represented within southern Patagonia and Tierra del Fuego of Chile and Argentina (*i.e.*, the Magellanic molluscan province; POWELL, 1973). Powell considers this complex to be constituted by cold water limpets with the greater part of their range being subantarctic. Nacella (Patinigera) magellanica magellanica (Gmelin, 1791) is one of the 14 species of the genus Nacella Schumaker, 1928, recognized in the subantarctic zone, and one of the most common inhabitants of the beaches of Tierra del Fuego, the Strait of Magellan, and the Falklands Islands (POWELL, 1973). Biological information for this species is scarce, although its geographical and bathymetric distributions (CARCELLES & WILLIAMSON, 1951), diagnostic features (DELL, 1971; POWELL, 1973; OTAEGUI, 1974), density, and spatial pattern of distribution (GUZMAN, 1978) have been studied. The aim of the present study was to determine age and growth for 10 intertidal populations of *Nacella (P.) magellanica* and to provide baseline data from which predictions and comparisons could be made.

MATERIALS AND METHODS

Samples of *Nacella* (*P.*) magellanica were obtained from 10 sites located in the Strait of Magellan, from the second narrow to its eastern entrance (Figure 1). Except for Punta Catalina, where the physical habitat is characterized by a hard clay terrace, the other sites are typical cobble-boulder beaches. The sites have a wide range of sediment sizes, exposures to wave action, slopes, and tidal amplitudes (see GUZMAN, 1978).

Fifty limpets at each site were randomly collected from



Location of the study area including sampling sites in the Strait of Magellan.

the mid-intertidal zone during spring 1977, winter 1978, and summer 1978 and 1979. Specimens from Punta Tandy were sampled in fall and spring 1980. In the laboratory the specimens were sexed by direct observation of the gonads, and the shell was used for growth measurements.

Growth was estimated by the growth ring method, which requires the establishment of rings as annual marks on the shell of the species under study (WILBUR & OWEN, 1964). This approach has been employed successfully in growth and age estimations in patellid (PICKEN, 1980), fissurellid (BRETOS, 1980, 1982), trochid (WILLIAMSON & KENDALL, 1981), and muricid (MIRANDA, 1975) species.

On the exterior shell surface of Nacella (P.) magellanica growth marks are present. It was assumed that the marks correspond perfectly to true annuli and, consequently, they were used for aging purposes (see Discussion). The maximum length of each consecutive growth ring from the front of the ring to its posterior margin was measured to the nearest 0.1 mm with vernier calipers. Separate information for females, males, and sexually undetermined specimens was recorded.

Measurements of consecutive rings were not assigned to specific ages owing to difficulties in assessing the rings on the shell apex, which is usually eroded. Thus, growth was inferred by plotting the correspondent pairs of consecutive ring lengths measured in each specimen, grouped by sampling periods and by sexes, according to the Ford-Walford method (WALFORD, 1946). This method basically consists of the linear relation of size at t years against size at t + 1 years.

Age was inferred from VON BERTALANFFY's (1938) growth model. The parameters K (growth coefficient) and L_{∞} (asymptotic length) were derived from the regression coefficients of the Ford-Walford plots, while the theoretical age at length zero (t_{*}) was computed following GULLAND

(1965). The age at which 95% (p) of the asymptotic length or theoretical age limit (A_p) was reached, the instantaneous rate of natural mortality (M), and the fraction of an initial stock that would die during a year or conditional mortality rate (A) were derived from t_{ϕ} and K parameters following TAYLOR (1959). In this study, M is equivalent to the total instantaneous mortality rate (Z).

In order to evaluate both annual ring formation and seasonality in growth, the yearly marginal shell increment at six sites was evaluated. For this purpose, 10 shells from winter, spring, and summer samples were randomly chosen within an age range (7-9 yr) defined by the correspondent growth equation. Marginal increments were determined on the posterior edge of the shell, by measuring the distance from the last distinguishable growth ring to the edge of the shell using a stereomicroscope $(16 \times)$ with a precision of ± 0.02 mm.

RESULTS

The ranges of shell lengths of the specimens used in this study and those recorded during a 4-yr study program in the same sampling localities (unpublished data) are presented in Table 1.

Considering the residual variance, the best fit to the 10 Ford-Walford plots was given by an AM functional regression computed following Nair-Bartlett's procedure (BARTLETT, 1949). Taking into account the homogeneity of variances (Bartlett's test; P > 0.05), an analysis of covariance (ANCOVA) showed no significant difference in slopes and intercepts between sexes and sampling periods (P > 0.05). Consequently, the data were pooled and a global AM functional regression for each site was calculated.

In all cases the regressions of L_{t+1} on L_t were highly

Table 1

Range of shell lengths (mm) of Nacella (P.) magellanica collected during sampling periods in each study site (I: October-November 1977; II: January 1978; III: July-August 1978; IV: December 1978-February 1979). In parentheses are given the size ranges (mm) of limpets inhabiting the mid-intertidal zone. Locality codes are given in Figure 1.

Local-	I	II	III	IV	
ities	(Spring)	(Summer)	(Winter)	(Summer)	
G	10.9-46.7	10.2-46.5	12.4-43.5	14.2-46.5	
	(9-48)	(7-46)	(7-50)	(9-48)	
S	16.5-47.4	11.0-62.7	15.0-52.5	23.1-44.5	
	(11-48)	(7-62)	(13-52)	(9-46)	
D	17.5-45.0	8.3-54.8	13.8-50.0	15.0-51.0	
	(14-46)	(5-54)	(6-53)	(12-50)	
Р	20.5-47.4	11.7-36.2	10.3-43.2	11.3-50.8	
	(11-48)	(7-40)	(7-44)	(9-50)	
W	9.5-60.8	12.7–59.3	14.9-57.5	17.3–56.8	
	(7-68)	(5–64)	(3-57)	(9–64)	
С	19.0-41.2	20.4-48.9	14.8-56.9	22.6-42.5	
	(16-45)	(7-50)	(13-56)	(17-46)	
E	37.0-49.2	18.0-51.8	18.9-49.0	10.6-51.9	
	(33-52)	(9-52)	(6-50)	(7-52)	
R	37.0-48.8	16.6-48.8	20.1-49.1	43.5-48.8	
	(37-52)	(13-56)	(17-50)	(10-50)	
В	31.1-42.0	30.8-40.5	17.6-41.3	16.1-41.5	
	(29-43)	(21-42)	(13-43)	(9-50)	
T*	13.2-30.8 (12-41)		17.0-31.9 (12-32)		

* Sampled on April (autumn) and December (spring) 1980, respectively.

significant and explained over 92% of the observed variances, reflecting a good predictive relationship. The variances about the regression lines were heteroscedastic (P >0.05), although three groups with homogeneous variances can be segregated; the population at Remo was heterogeneous with respect to all others. According to the AN-COVA applied within each homogeneous group, it is possible in some cases to calculate a common AM regression line, although the majority of the regression coefficients were significantly different (P > 0.05; Table 2).

A lower annual growth rate (slope) was estimated for the Gregorio and Remo populations, while higher values were obtained at Wreck-Catalina, reflecting an increasing tendency from west to east, *i.e.*, from the interior sites toward those near the eastern entrance of the Strait. The shell length at the first year of growth (intercept) follows an opposite tendency to the slope values, being larger in the inner sites. The value of the Gregorio population is almost three times larger than that of Wreck-Catalina.

The results obtained with the von Bertalanffy growth model reflect different growth rates of the studied populations. A greater growth rate was found at Gregorio,

Table 2

Single and common Ford-Walford regressions for Nacella (P.) magellanica. b = slope; a = intercept; $r^2 =$ determination coefficient; n = sample size. Locality codes are given in Figure 1.

Localities	Ь	а	r^2	n
G	0.826	9.368	0.941	362
R	0.863	7.481	0.974	601
S	0.881	7.964	0.949	432
E-D-B	0.896	6.332	0.964	300
T-P	0.924	4.636	0.963	412
W-C	0.974	3.127	0.991	200

Santiago, and Remo, and the opposite at Wreck-Catalina (Table 3; Figure 2). The largest specimen collected in each locality, the theoretical age limit, the instantaneous rate of natural mortality, and the conditional mortality rate are also included in Table 3.

Although Wreck-Catalina populations presented the highest asymptotic length (120 mm) and those at Gregorio the lowest (54 mm), this parameter did not show a geographic tendency. According to a two-tailed Spearman rank correlation test (SNEDECOR & COCHRAN, 1964) the asymptotic length and the actual maximum size registered at each sampling site are positively correlated (r = 0.652; P < 0.05). Von Bertalanffy growth coefficients (K) varied between 0.0263 and 0.1913, decreasing toward the sites located near the eastern entrance of the Strait. The higher K value was determined for Gregorio, and it is approximately nine times larger than the lowest value recorded at Wreck-Catalina. The estimated annual growth rate indicated that different ages reached the 95% asymptotic length (A_p) ; and that these ages ranged between 15 and 37 yr, excluding Wreck-Catalina where the value was extremely high (113 yr). Because as K increases asymptotic length decreases, the lowest theoretical age limit was estimated for Gregorio, while the highest was determined for Wreck-Catalina.

The mortality rates were low, varying between 0.026 at Wreck-Catalina (2.6%) and 0.191 at Gregorio (17.4%), and showing an inverse relationship with growth rate. Mortality at Gregorio (inner site) was almost seven times higher than that at Wreck-Catalina (outer sites).

Along the study areas, tidal range shows a clear gradient from the eastern entrance to the second narrow (approximately from 10 to 4 m during spring tides), and correlates with the limpet's annual growth rate, size at the first year of growth, longevity, and mortality. In contrast, an independent relationship between K, L_{∞} , relative height of sampling areas, and tidal range at each site (following Kendall's nonparametric concordance analysis W = 0.10; P > 0.05) was found. Annual growth rate, size at the first year of growth, mortality rate, and asymptotic length are not correlated with limpet population density (mean val-



Figure 2

Von Bertalanffy growth curves for six populations of Nacella (P.) magellanica in the Strait of Magellan.

ues, unpublished data) according to a two-tailed Spearman's rank correlation test (P > 0.05). These variables, excluding asymptotic length (P < 0.05), are also independent of the intensity of aggregation estimated according to the Morisita index (SOUTHWOOD, 1975) (P > 0.05; unpublished data).

According to an analysis of variance (ANOVA), the mean marginal growth for limpets collected during different seasons was significantly different (P < 0.05), being higher during summer in comparison to spring and winter seasons (ANOVA; P < 0.05) (Table 4). The largest differences were observed between summer and winter, while no difference was detected between summer periods (P < 0.05). A geographical gradient in marginal growth is also distinguishable and follows the trend described for the annual growth estimation, *i.e.*, a tendency to decrease from west to east.

The seasonality in mean marginal growth follows the same pattern observed in some physical and biological growth-related parameters of the Strait (Figure 3). Data on macroalgal abundance have demonstrated a clear seasonal pattern, with maximum coverage in spring-summer and minimum coverage in winter (unpublished data). Also, photoperiod length interpolated from FRANCIS (1972) for the 52°S latitude is characterized by 17 h in early summer (December) and 8 hr in winter (July). Meanwhile, the surface seawater temperatures (from National Petroleum Company records) show the highest values in February (11.9°C) and the lowest in August (2.4°C).

DISCUSSION

Several factors can affect age and growth estimates when they are based on the shell ring method. In our study it must be noted that (1) limits are imposed by the assumption that growth ring formation occurs only once a year, and (2) there are difficulties in assessing consecutive growth rings, especially at the shell apex.

The criteria adopted to assess consecutive rings seem to be appropriate according to the determination coefficient values and the non-significant differences in slopes and elevations of the Ford-Walford relationships when periods within each locality were compared. On the other hand, the difficulty in assessing the first three or four growth rings is reflected in a poor representation of the left part of the Ford-Walford plots. In this case, asymptotic length should be overestimated and growth rhythm could not be as low as that obtained. Nevertheless, excluding the Wreck-Catalina estimation, all other cases show the asymptotic length to be close to the actual maximum size recorded at each sampling site. The difference between predicted and actual size at Wreck-Catalina can be explained, as has been pointed by KNIGHT (1968), by the growth line curvature which mathematically leads to an extremely large asymptotic length and, consequently, has no biological meaning.

A seasonal growth pattern in *Nacella* (*P.*) magellanica has not been experimentally shown, but some results suggest that such a pattern might occur in this limpet species.

Table 3

Von Bertalanffy parameters for Nacella (P.) magellanica. t_{ϕ} = theoretical age at length zero; K = instantaneous growth rate; L_{∞} = asymptotic length; A_{ρ} = 95% theoretical limit age; M = instantaneous rate of natural mortality; A = conditional mortality rate; LT = maximum recorded length. Locality codes are given in Figure 1.

Localities	L_{∞} (mm)	К	t _ø	$\begin{array}{c} \mathbf{A}_{p} \\ (\mathbf{yr}) \end{array}$	М	A (%)	LT (mm)
G	54	0.1913	0.00910	15.7	0.191	17.4	55.1
R	55	0.1470	0.01153	20.4	0.147	13.7	55.2
S	67	0.1271	0.00910	23.6	0.127	11.9	61.0
E-D-B	61	0.1098	-0.00432	27.3	0.110	10.4	54.7-62.0-51.0
T-P	61	0.0792	-0.00289	37.8	0.079	7.6	41.8-52.0
W-C	120	0.0263	-0.00463	113.9	0.026	2.6	74.7-59.1

In fact, marginal summer growth increments were consistently higher than those estimated for winter and also, but to a lesser extent, than those of spring. We assumed that the beginning of ring formation occurs between the end of summer and early autumn, i.e., between March and April. Initiation of annulus formation cannot occur during mid winter, because this would require a very short lapse of time to explain the relatively high marginal growth increment of spring samples. Breeding of N. (P.) magellanica in the Strait occurs annually between December and January (unpublished data), and the formation of a reproductive growth ring must be discarded because the marginal growth increment in summer samples is relatively too high. This seasonality in growth is in concordance with the annual fluctuation of physical and biological environmental conditions registered in the eastern part of the Strait of Magellan. Strong seasonal constraints by these factors (e.g., incident light, temperature, and algal coverage) could result in restrictions in molluscan shell growth during these critically limiting months. A seasonal growth pattern has been observed in a number of marine gastropods (e.g., SEAPY, 1966; BRETOS, 1978; MCQUAID, 1981; PHILLIPS, 1981; RACE, 1981; COCKCROFT & FORBES, 1981; MC-LACHLAN & LOMBARD, 1981); but growth rate seasonality reported for several Antarctic invertebrates as a response to the marked seasonal fluctuations of physical parameters is especially enlightening. Among these, the Antarctic littorinid Laevilacunaria antarctica (Martens, 1885) (PICKEN, 1979) and the Antarctic limpet N. (P.) concinna (Strebel, 1908) (PICKEN, 1980) have been reported.

The growth parameters obtained here fall well within the reported range for several species of marine gastropods, although Nacella (P.) magellanica can be considered among those species with a low growth rate. This feature is in accordance with estimates for N. (P.) concinna (PICKEN, 1980) but differs from N. delesserti (BLANKLEY & BRANCH, 1985), which shows a much higher growth rate. The first year of growth of N. delesserti is almost four times greater than the highest estimation obtained for N. (P.) magellanica.

An inverse relationship between growth rate and longevity is evident for *Nacella* (*P.*) magellanica. This relation is in agreement with FISHER-PIETTE's (1941) conclusion on growth of several European marine species (*i.e.*, the faster growth, the shorter longevity). A similar inference was reached by BRANCH (1974) working with five South African Patella species, demonstrating that this relationship occurs at an intraspecific and interspecific level.

The longevities we report are among the highest recorded for marine gastropods (see review by POWELL & CUMMINS, 1985). It is interesting to point out that, in a littoral population of the Antarctic limpet *Nacella* (*P.*) *concinna*, longevity is approximately 21 yrs (PICKEN, 1980), while in a sublittoral population of the same species, it

Table 4

Mean marginal growth (mm) \pm SE for Nacella (P.) magellanica at selected sites of the study area. Locality codes are given in Figure 1.

Localities	Oct. '77 (Spring)	Jan. '78 (Summer)	JulAug. '78 (Winter)	Dec. '78-Feb. '79 (Summer)
G S D	$\begin{array}{c} 0.58 \pm 0.054 \\ 0.88 \pm 0.122 \\ 0.68 \pm 0.107 \\ 0.58 \pm 0.120 \end{array}$	$\begin{array}{r} 1.14 \pm 0.155 \\ 0.96 \pm 0.098 \\ 1.18 \pm 0.156 \\ 0.65 \pm 0.070 \end{array}$	$\begin{array}{c} 0.62 \pm 0.094 \\ 0.51 \pm 0.051 \\ 0.34 \pm 0.104 \\ 0.144 + 0.048 \end{array}$	$\begin{array}{c} 1.28 \pm 0.172 \\ 1.46 \pm 0.144 \\ 1.00 \pm 0.084 \\ 0.78 \pm 0.028 \end{array}$
P R	$\begin{array}{c} 0.59 \pm 0.120 \\ 0.83 \pm 0.124 \\ 0.68 \pm 0.097 \end{array}$	$\begin{array}{c} 0.65 \pm 0.070 \\ 1.13 \pm 0.104 \\ 0.89 \pm 0.097 \end{array}$	$\begin{array}{c} 0.14 \pm 0.048 \\ 0.53 \pm 0.095 \\ 0.34 \pm 0.075 \end{array}$	$\begin{array}{c} 0.78 \pm 0.028 \\ 0.85 \pm 0.114 \\ 0.86 \pm 0.107 \end{array}$



Mean marginal growth of *Nacella (P.) magellanica* at different sites of the Strait of Magellan. The seasonal pattern of some physical and biological growth-related parameters in the study area are included. A \oplus , algal coverage in ln%; B \oplus , solar radiation in Langley/h; C \blacktriangle , photoperiod in hours with an intensity >10 foot candles (107.6 lux); D×, surface seawater temperature (°C).

exceeds 60 yr (Shabica, 1976, in PICKEN, 1980). This last estimate is similar to the longevity of an intertidal population of N. (P.) magellanica from Wollaston Island (62 yr, unpublished data). The studied populations from inner sites, which presented the lowest longevities, showed a clearly higher longevity than that reported by BLANKLEY & BRANCH (1985) for Nacella delesserti (8–10 yr) from Marion Island.

Although mortality rate estimates have a predictive value, mortality agents probably exert a relatively low pressure on the studied populations. At least three mortality sources can be mentioned in our case: predation, parasitism, and physical disturbance. Along the studied areas it has been observed that *Anasterias antarctica* (Lutkan, 1856) preys on *Nacella* (*P.*) *magellanica*, but the low density and relatively small size of this seastar in the sampling area (personal observations) suggest that predation by this species is unimportant as a regulating factor. Other characteristic limpet predators, the sea gull Larus dominicanus (Lichtenstein) and the oystercatchers Haematopus spp., have been observed in low density, and restricted to a few sites within the study area (personal observations). A low predation pressure has also been suggested by WALKER (1972) for the Antarctic limpet Patinigera polaris (Hombron & Jacquinot) (=Nacella [P.] concinna) at the South Orkney Islands, although L. dominicanus has been mentioned as the main predator for this species (WALKER, 1972; CASTILLA & ROZBACZYLO, 1985). On the other hand, BRANCH (1985) indicates an important role of L. dominicanus preying on a subantarctic limpet, N. delesserti, with the predator accounting for about 50% of the known annual mortality of the largest limpets. Parasitism may also contribute to mortality. Limpets at Remo, Baxa, and Tandy showed a variable but unquantified infestation by trematodes of the family Gymnophallidae (M. O. de Nunez, personal communication). As many as 1500 metacercaria have been

found in a single individual (unpublished data). The third major source of mortality is represented by the rolling of cobbles and boulders. Although this aspect has not been evaluated, it likely has a greater influence on the limpet population dynamics, especially during severe storms.

A number of unknown factors induce an ecological gradient along the study area. For example, the population density of the mussel *Mytilus chilensis* (Hupe, 1840) increases substantially from the second narrow toward the eastern entrance of the Strait (LANGLEY *et al.*, 1980), as does the species richness of the infauna and epibenthos (WENDT, 1982; unpublished data). Now we have added the growth trend of *Nacella* (*P.*) magellanica, which is correlated with tidal range. However, several physical and biological factors may induce changes in the growth of gastropods (*e.g.*, BRANCH, 1974; LEWIS & BOWMAN, 1975; BLACK, 1977; BRETOS, 1978; MCQUAID, 1981), suggesting that the single tidal range-growth relationship we encountered may not explain all the geographical growth trend reported.

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LITERATURE CITED

- BARTLETT, M. S. 1949. Fitting a straight line when both variables are subject to error. Biometric 5:207-211.
- BLACK, R. 1977. Population regulation in the intertidal limpet Patelloidea alticostata (Angas, 1865). Oecologia 30:1-22.
- BLANKLEY, W. O. & G. M. BRANCH. 1985. Ecology of the limpet Nacella delesserti (Philippi) at Marion Island in the sub-Antarctic southern ocean. Jour. Exp. Mar. Biol. Ecol. 92:259-281.
- BRANCH, G. M. 1974. The ecology of *Patella* Linnaeus from the Cape Peninsula, South Africa. 3. Growth rate. Trans. Roy. Soc. S. Africa 41:161-193.
- BRANCH, G. M. 1985. The impact of predation by kelp gulls Larus dominicanus on the sub-antarctic limpet Nacella delesserti. Polar Biol. 4:171-177.
- BRETOS, M. 1978. Growth in the keyhole limpet *Fissurella* crassa Lamarck (Mollusca: Archaeogastropoda) in northern Chile. Veliger 21:268-273.
- BRETOS, M. 1980. Age determination in the keyhole limpet Fissurella crassa Lamarck (Archaeogastropoda: Fissurellidae), based on shell growth rings. Biol. Bull. 159:606-612.
- BRETOS, M. 1982. Biologia de Fissurella maxima (Mollusca: Archaeogastropoda) en el norte de Chile. I. Caracteres generales, edad y crecimiento. Cahiers Biol. Mar. 23:159–170.
- CARCELLES, A. R. & S. WILLIAMSON. 1951. Catalogo de los moluscos marinos de la Provincia Magallanica. Mus. Arg. Cs. Nat. Bernardino Rivadavia, Ciencias Zoologicas 2:225– 383.
- CASTILLA, J. C. & N. ROZBACZYLO. 1985. Rocky intertidal assemblages and predation on the gastropod Nacella (Pati-

nigera) concinna at Robert Island, South Shetland, Antarctica. Ser. Cient. INACH 32:65-73.

- COCKCROFT, V. G. & A. T. FORBES. 1981. Growth, mortality and longevity of *Cerithidea decollata* Linnaeus (Gastropoda: Prosobranchia) from Bayhead Mangroves, Durban Bay, South Africa. Veliger 23:300-308.
- DELL, R. K. 1971. The marine Mollusca of the Royal Society Expedition to southern Chile, 1958–59. Rec. Dom. Museum 7:155–233.
- FISHER-PIETTE, E. 1941. Croissance, taille maxima et longevite possible de quelques animaux intercotidaux en fonction du millieu. Annls. Inst. Oceanog., Monaco 21:1–28.
- FRANCIS, C. A. 1972. Duracion del dia para la reaccion fotoperiodica en plantas. Folleto Tecnico No. 2. Centro Internacional de Agricultura Tropical, Cali, Colombia. 32 pp.
- FRANK, P. W. 1969. Growth rates and longevity of some gastropod mollusks on the coral reef at Heron Island. Oecologia 2:232-250.
- GULLAND, J. A. 1965. Manual of methods for fish stock assessment. Part 1. Fish population analysis. FAO Fish. Tech. Pap. 40, Rev 1. 68 pp.
- GUZMAN, L. 1978. Patron de distribucion espacial y densidad de Nacella magellanica (Gmelin, 1791) en el intermareal del sector oriental del Estrecho de Magallanes (Mollusca: Gastropoda). Ans. Inst. Pat., Punta Arenas (Chile) 9:205-219.
- KNIGHT, W. 1968. Asymptotic growth: an example of nonsense disguised as mathematics. Jour. Fish. Res. Bd. Canada 25: 1303–1307.
- LANGLEY, S., L. GUZMAN & C. RIOS. 1980. Aspectos dinamicos de Mytilus chilensis (Hupe, 1840) en el Estrecho de Magallanes. I. Distribucion, densidad y disposicion espacial en el intermareal. Ans. Inst. Pat., Punta Arenas (Chile) 11:319– 332.
- LEWIS, J. R. & R. S. BOWMAN. 1975. Local habitat induced variations in the population dynamics of *Patella vulgata* L. Jour. Exp. Mar. Biol. Ecol. 17:165–203.
- McLachlan, A. & H. W. LOMBARD. 1981. Growth and production in exploited and unexploited populations of a rocky shore gastropod, *Turbo sarmaticus*. Veliger 23:221-229.
- MCQUAID, C. 1981. Population dynamics of Littorina africana knysnaensis (Philippi) on an exposed rocky shore. Jour. Exp. Mar. Biol. Ecol. 54:65-75.
- MIRANDA, O. 1975. Crecimiento y estructura poblacional de *Thais (Stromanita) chocolata* (Duclos, 1823) en la Bahia de Mejillones del Sur, Chile (Mollusca, Gastropoda, Thaididae). Rev. Biol. Mar. Dep. Oceanol. Univ. Chile 15:263– 286.
- OTAEGUI, A. V. 1974. Las especies del genero *Patinigera* Dall 1905 en la Provincia Magallanica (Mollusca, Gastropoda, Prosobranchiata). Physis B. Aires 33:173-184.
- PHILLIPS, D. W. 1981. Life-history features of the marine intertidal limpet *Notoacmea scutum* (Gastropoda) in central California. Mar. Biol. 64:95–103.
- PICKEN, G. B. 1979. Growth, reproduction and biomass of the Antarctic gastropod *Laevilacunaria antarctica* Martens 1885. Jour. Exp. Mar. Biol. Ecol. 40:71–79.
- PICKEN, G. B. 1980. The distribution, growth, and reproduction of the Antarctic limpet *Nacella* (*Patinigera*) concinna (Strebel, 1908). Jour. Exp. Mar. Biol. Ecol. 4:71-85.
- POWELL, A. W. B. 1973. The patellid limpets of the world (Patellidae). Indo-Pacific Mollusca 3:75-206.
- POWELL, E. N. & H. CUMMINS. 1985. Are molluscan maximum life spans determined by long-term cycles in benthic communities? Oecologia 67:177-182.
- RACE, M. S. 1981. Field ecology and natural history of Cer-

ithidea californica (Gastropoda: Prosobranchia) in San Francisco Bay. Veliger 24:18-27.

- SEAPY, R. R. 1966. Reproduction and growth in the file limpet, Acmaea limatula Carpenter, 1864 (Mollusca: Gastropoda). Veliger 8:300-310.
- SNEDECOR, G. & W. COCHRAN. 1964. Metodos estadisticos aplicados a la investigacion agricola y biologica. Compania Editorial Continental S. A., Mexico. 626 pp.
- SOUTHWOOD, T. R. E. 1975. Ecological methods. Chapman and Hall: London. 391 pp.
- TAYLOR, C. C. 1959. Cod growth and temperature. Cons. Int. Explor. Mar. 23:366-370.
- VON BERTALANFFY, L. 1938. A quantitative theory of organic growth (Inquiries on growth laws). II. Human Biology 10: 181-213.
- WALFORD, L. 1946. A new graphic method of describing the growth of animals. Biol. Bull. 90:141-147.

- WALKER, A. J. M. 1972. Introduction to the ecology of the Antarctic limpet *Patinigera polaris* (Hombron & Jacquinot) at Signy Island, South Orkney Islands. Brit. Antarct. Surv. Bull. 28:49-69.
- WENDT, A. 1982. Descripcion de comunidades faunisticas intermareales de la costa oriental del Estrecho de Magallanes. Mar. Biol. Tesis, Universidad de Concepcion. 126 pp.
- WILBUR, K. M. & G. OWEN. 1964. Growth. Pp. 211-242. In:
 K. M. Wilbur & C. M. Yonge (eds.), Physiology of Mollusca, Vol. I. Academic Press, Inc.
- WILLIAMSON, P. & M. A. KENDALL. 1981. Population age structure and growth of the trochid *Monodonta lineata* determined from shell rings. Jour. Mar. Biol. Assoc. U.K. 61: 1011-1026.



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