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Gross morphometric relationships and growth in the Mediterranean gorgonian *Paramuricea clavata*

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ABSTRACT

Gross morphometric parameters in the Mediterranean gorgonian *Paramuricea clavata* have been considered with an aim to describe their intraspecific relationships. Bertalanffian growth curves have been calculated, as well as regression equations between parameters. Basal diameter proved to be the best parameter for describing growth of the species.

KEY WORDS: *Paramuricea clavata* - Celenterates - Morphometry - Ecology.

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INTRODUCTION

A key aspect of ecological studies on benthic organisms is the selection of the best morphological parameters for describing growth and architectural features. In some groups, e.g., bivalves, this choice is quite restricted, but in others the number of suitable morphological parameters is extremely wide. Gorgonian corals belong to the latter category.

Few studies, up to now, have dealt with the growth of these colonial organisms, and, in those, different parameters have been utilized: colony height and width (Grigg, 1974), branch length increments (Velimirov, 1975; Weinberg & Weinberg, 1979), total branch length (Velimirov & Weinbauer, 1992), skeleton rings diameter (Abbiati *et al.*, 1991; Mitchell *et al.*, 1993), and projection of most distant endbranch on the base of the colony (Mistri & Ceccherelli, 1993, 1994). Moreover, gorgonian architectural and structural features have been considered by using further morphological parameters, such as shape of spicules (Weinberg, 1976), colony rectangular area (Russo, 1985), bifurcation ratio (Brazeau & Lasker, 1988), colony effective area (Mistri, 1994), and colony fractal dimension (Mistri & Ceccherelli, 1993; Mistri, 1994). The measurement of some of these parameters is relatively approximate, although fast and easy to carry out in the field, while that of the others needs complex, time-consuming procedures often requiring the destruction of the whole organism.

A further problem arises when comparing results with those obtained by other researchers: the morphometric parameter chosen to describe the organism's growth or morphological feature is often different, and thus comparison is in no way possible.

This short note aims at describing the relationships between some morphological parameters of the Mediterranean gorgonian coral *Paramuricea clavata* (Risso, 1826), and to establish a trait that can represent the trade-off between the needs of accuracy and fast gathering of data in field studies.

MATERIALS AND METHODS

Paramuricea clavata colonies were manually collected at «La Montagna» (38°15'00 N, 15°43'18 E), a granitic shoal facing the rock of Scilla (Reggio Calabria). Detailed information about environmental characteristics, sampling dates and techniques are reported elsewhere (Mistri & Ceccherelli, 1994). The gorgonians collected (n = 36) were aged following Grigg (1974), that is by recognizing and counting annual growth increments (i.e., rings) in cross sections cut 1 cm from the base of each colony.

On the collected sea fans, a set of measurement was taken for each colony: fan height, i.e., the distance between the base and the furthest point of the endbranches of the colony; fan width, i.e., the largest dimension orthogonal to height; fan rectangular area, i.e., the area of the polygon which resulted from the product of fan height by width; fan effective area, i.e., the total area occupied by the outline of the colony traced on graph paper; total branch length, i.e., the linear development of colony branches; and, finally, colony basal cross-sectional diameter. Since the basal skeleton of *Paramuricea*

clavata is fairly elliptical in shape when viewed in cross section, the measurement of basal diameter was taken on the longer axis. All measurements are accurate to within 1 mm, except for basal diameter which is to within 0.05 mm.

The relationships between different morphometric traits were investigated by fitting several regression models (i.e., linear, curvilinear, logarithmic and exponential), and statistical significance was tested by means of regression ANOVA.

In modeling the growth of organisms, the most frequently used expressions are the Bertalanffy-like, the Gompertz and the logistic equations. Only the Bertalanffian has a physiological basis (Reiss, 1989), and for this reason it was selected for the present study. The relationships between age and the different morphometric traits were investigated by fitting a sigmoidal (Bertalanffy-like) model. Statistical significance was tested by means of regression ANOVA.

RESULTS AND DISCUSSION

In ecological studies, determination of the age of organisms is of considerable importance. Clearly recognizable growth marks are carried only by a minority of species, and, fortunately, gorgonian corals are among these (Grigg, 1974; Garcia-Rodriguez & Massò, 1986; Mistri & Ceccherelli, 1993). In gorgonians, alternating growth bands, light and dark when observed under a microscope, are laid down annually, and the count of these growth rings in cross sections taken from the base of the skeleton (i.e., the oldest part of the colony) is the most accurate method for age backcalculation. The only drawback is that while the method, on the one hand, allows precise estimate of the age of the colony, on the other it requires the destruction of the whole organism.

Table I reports, linear and curvilinear regression indices of determination for the considered morphometric traits (logarithmic and exponential model values are not given since they were significantly lower with respect to the values of linear and curvilinear models). Both regression models can be equally adopted to convert a field-measured parameter, which might be easier to obtain, into another which may be more useful for the aim of the study.

TABLE I - *Linear (a) and curvilinear (b) regression indices of determination for the considered morphometric traits of* Paramuricea clavata.

		H	EA	RA	TBL
(a)	H	–			
	EA	0.680	–		
	RA	0.763	0.907	–	
	TBL	0.742	0.980	0.882	–
	d	0.687	0.878	0.892	0.867
		H	EA	RA	TBL
(b)	H	–			
	EA	0.727	–		
	RA	0.819	0.925	–	
	TBL	0.771	0.981	0.884	–
	d	0.741	0.889	0.893	0.874

H, height; EA, effective area; RA, rectangular area; TBL, total branch length; d, basal diameter.

TABLE II - *Sigmoidal regression relating age to growth parameters of* Paramuricea clavata.

			r^2	P
height				
L∞	149.1	(276.2)	0.830	***
k	0.023	(0.011)		
t0	−0.663	(0.814)		
effective area				
L∞	2755.3	(39454.1)	0.808	***
k	0.004	(0.054)		
t0	0.530	(0.682)		
rectangular area				
L∞	6600.3	(30903.6)	0.841	***
k	0.009	(0.050)		
t0	0.401	(0.610)		
branch length				
L∞	5815.5	(42090.2)	0.842	***
k	0.005	(0.041)		
t0	0.537	(0.602)		
diameter				
L∞	2.78	(3.08)	0.895	***
k	0.028	(0.039)		
t0	−1.053	(0.677)		

L∞, k, t0, coefficients of the Bertalanffy growth curve (SE in parentheses); r^2, indices of determination; ***, $P < 0.001$.

In this note, growth and architectural features of a gorgonian have been analyzed by considering different morphometric parameters, each of which can be more or less successfully utilized in studying the growth process and development of the fan of *P. clavata*. Height and basal diameter can be easily and quickly measured in the field, which is not of secondary importance when operating in troubled and often dangerous conditions; moreover, the collection, and thus the destruction, of the colony is not required. Effective area and total branch length, perhaps, give more information about the growth pattern of the colony, but cannot be measured in the field, and are time-consuming in the laboratory; furthermore, unless one adopts photographic techniques, the death of the whole colony ensues. Rectangular area, which is easy to measure, is a fuzzy parameter for defining growth: two of the sampled colonies, exhibiting more or less the same rectangular area (colony A: 363.8 cm^2 rectangular area, 38.1 cm^2 effective area; colony B: 384.4 cm^2 rectangular area, 75.9 cm^2 effective area), showed to be (by counting annual basal growth rings) in very different age classes (colony A: 4-5 yr; colony B: 10-11 yr). Rectangular area is a good index of the fan obstruction to water flow, but should not be used in studies dealing with growth processes, since it can lead to macroscopic errors on age backcalculation.

Equation parameters and indices of determination of

the sigmoidal model fitted to the matrices of age and morphometric measurements (height, effective area, rectangular area, total branch length and basal diameter) are reported in Table II. In the life span sampled (0-1/14-15 yr) and at yearly age intervals, the right end of all the calculated sigmoidal growth curves of the investigated population is poorly represented (graphs not shown), and fails to show its typical sigmoidal form, since sampled colonies are far from reaching the size plateau of each of the considered morphological parameters. This is not surprising in these colonial organisms: gorgonian growth pattern is ecologically limited (Sebens, 1987), and the organisms could tend towards a theoretically high size asymptote, but are generally prevented from approaching it under most habitat conditions. In fact, Mistri & Ceccherelli (in press) have reported recent mortality events and heavy tissue necrosis in the surviving colonies due to entangled mucus aggregates in the *P. clavata* population under study.

The choice of a morphometric parameter to describe growth, and thus life-history, of a gorgonian is not a simple matter: in fact, due to endogenous and external factors, gorgonian growth pattern can vary to a large extent (Grigg, 1974), and this is reflected in the overall morphology of the fan. It has been demonstrated (Velimirov, 1976) that variations in growth forms of the Mediterranean yellow gorgonian *Eunicella cavolinii* can be related to hydrodynamic forces. Moreover, polychaete and gastropod selective feeding and non-lethal predation are known to play quite a significant role in determining the gross shape of a fan (Harvell & Suchanek, 1987; Vreeland & Lasker, 1989). It has also been reported that partial consumers may have dramatic sublethal effects on morphology and patterns of allocation to growth and reproduction within attacked colonies (Wahle, 1983).

In defining growth pattern through parameters such as height, total branch length or effective area of the fan, one should take into account the possible biases that might be introduced if the measured colonies show heavy damage due to predation and/or abrasion. Any external factor leading to branch tip degeneration is likely to produce underestimates of gorgonian age. Basal diameter seems to be the best parameter for describing growth in *P. clavata*. First of all for the simple reason that it is directly related to the number of annual growth increments, then because the above-mentioned drawbacks of length measurements are avoided, and, finally, it is fast and simple to effect in the field, and avoids destructive methodologies. It must be stressed that annual rings growth in width, and thus, basal diameter, is affected by exogenous factors (water motion, food abundance etc.): nevertheless, oscillations of this parameter with respect to age are not so wide as those exhibited by the other growth parameters. Santangelo *et al.* (1993) came to a similar conclusion while studying the Mediterranean red coral *Corallium rubrum*.

In Table III, curvilinear regression parameters between basal diameter and the other morphological parameters of the Scilla population are given. These equations make it possible to convert basal diameter measurements into any other morphological parameter which may be more appropriate for a certain study.

TABLE III - *Curvilinear regression relating basal diameter to morphological parameters of* Paramuricea clavata.

						r^2
H	=	− 3.852	+ 71.808d	− 31.613d²		0.741
EA	=	− 10.993	+ 102.17d	+ 49.937d²		0.889
RA	=	− 86.691	+ 815.81d	+ 71.342d²		0.893
TBL	=	− 33.16	+ 326.02d	+ 110.71d²		0.874

H, height; EA, effective area; RA, rectangular area; TBL, total branch length; d, basal diameter; r^2, indices of determination.

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