Belg. J. Zool., 130 (Supplement 1): 121-124 November 2000

Growth variation of *Eunicella singularis* (Esper, 1794) (Gorgonacea, anthozoa)

Georges Skoufas[1], **Mathieu Poulicek**[1] **and Chariton Charles Chintiroglou**[2]

[1] **University of Liege, Lab. of Animal Ecology and Ecotoxicology, Institute of Zoology, 22, quai VAN BENEDEN, B-4020 Liege, Belgium**
[2] **Aristotle University of Thessaloniki, Department of Zoology, Box 134, GR-54006 Thessaloniki, Greece**

ABSTRACT. Gorgonian colonies of *Eunicella singularis* were collected randomly from Arethoussa and Phidonissi at Kavala bay (North Aegean Sea, Greece) using SCUBA diving. The following biometric macro-features were measured after stabilisation of colony dry weight (DW): maximum height, maximum width, total branch length and rectangular surface area. The allometric or isometric relationships were examined using the equation: log(Y) = log(b)+a*log(X) or Y=b*Xa (Y: Dry Weight and X: the four macro-features) The investigation of the relationships between the dry weight and the other four macro-features demonstrates the presence of two groups of parameters. The first group, which includes the height and the rectangular surface area, exhibits a variation of growth depending on the sampling sites. The second one includes the width and the total branch length and does not exhibit significant variations depending on the hydrodynamical characteristics of the site. These results indicate that the most appropriate parameters for estimating the growth of the *Eunicella singularis* gorgonian colonies during a population dynamic survey were width and total branch length.

INTRODUCTION

While the number of studies concerning the growth and the secondary production of gorgonian colonies increases (Mistri & Ceccherelli, 1994) there are only a few studies on gorgonian biometry and morphology (Velimirov, 1976; Russo, 1985; Mistri, 1995). The choice of which macro-feature best describes the growth depends on the gorgonian species, and different authors use various macro-features. Thus, comparison of the results obtained by the use of too many different macro-features was not possible. *Eunicella* (*stricta*)*singularis* is a very common Mediterranean gorgonian but there are not many studies concerning the morphology and biometry of this species (Theodor, 1963; Weinberg & Weinberg, 1979; Skoufas et al., 1996). The aim of the present paper was to give, for the first time, the most appropriate macro-feature that best describes the growth of *E. singularis*. In addition, we examine the relationships between dry weight and four biometric parameters, and the hydrodynamical conditions in the sample sites. Macro-features were chosen as candidates for the estimation of Dry Weight on the basis of their ability to be measured using SCUBA diving and without destruction of the gorgonian colonies.

Corresponding author: G. Skoufas, e-mail: skoufas@bio.auth.gr

MATERIAL AND METHODS

Eunicella singularis colonies were collected randomly using SCUBA diving in Kavala bay (North Aegean sea, Greece) at Arethoussa and Phidonissi. The depth range of the samples was 5-8 m and 9-13 m at Arethoussa (AR 5-8 and AR 9-13) and 5-10 m and 11-13 m at Phidonissi site (PH 5-10 and PH 11-13). Evaluation of the effect of hydrodynamics according to KAANDORP (1986) was based on the corrosion of plaster in the water. Comparison of the two sampling sites indicated that the Arethoussa site is more exposed than the Phidonissi one. The number of collected colonies at each sampling site was: AR 5-8 m: 31 colonies, AR 9-13 m: 39 colonies, PH 5-10 m: 45 colonies, PH 11-13 m: 48 colonies. The following macro-features were measured after stabilisation of the colonies: Dry Weight: (DW, mg) Height (H, mm) defined as the greatest height of the colony from the base to the apex, Width (W, mm) defined as the greatest width of the colony perpendicular to the axis, Rectangular surface area (HxW, mm^2) and Total Branch Length (TBL, mm) defined as sum of the length of all the branches of the colony. Allometric growth was examined using the relationships between the dry weight and the four macro-features. The equation of the simple allometry applied was $y=b*x^a$ and the logarithmic transformation logy=logb+

a*logx (Gould, 1966). The isometric hypothesis (a=3 or a=3/2) was investigated using the t-test as suggested by DAGNELLIE (1975) and applied by GUILLAUME (1988). Comparison of the linear regression was examined using Bartlett's test as proposed by SNEDECOR & COCHRAN (1967).

RESULTS

The results from the measurements of dry weight and macro-features are given in Table 1. It was interesting to note that the colonies from the shallow water of the exposed site (AR 5-8) exhibited the higher values.

TABLE 1

Macro-feature values (mean ± standard error) of *Eunicella singularis colonies* at Arethoussa (AR 5-8 and AR 9-13) and Phidonissi (PH 5-10 and PH 11-13) sampling sites.

	Dry weight (mg)	**Height (mm)**	**Width (mm)**	**H x W (mm^2)**	**Total branches length (mm)**
AR 5-8 n=31	1373.744±181.107	162.161±6.758	96.355±7.027	16463.290±1656.301	1135.419±135.196
AR 9-13 n=39	1007.872±152.164	154.949±6.801	74.308±7.086	12727.179±1451.504	810.949±93.246
PH 5-10 n=45	802.711±77.733	129.822±4.550	68.467±5.107	9546.400±914.046	710.489±62.784
PH 11-13	1016.479±109.799	151.521±6.040	76.167±6.471	13068.729±1424.336	917.917±93.305

Relationships between DW and the four macro-features (H, W, HxW and TBL) were examined and two groups were distinguished. The first group included H and HxW, which exhibited a variability of relationships with DW that is related to sampling site. The second group included W and TBL; the relationships of these parameters with DW did not differ significantly in relation to the sampling sites.

DW=b*H^a

The linear regressions between log(DW) and log(H) at the four sampling (Fig. 1) sites show significantly different variances (Bartlett's test, d.f.=3, χ^2=33.752, p>0.05) and the four samples of gorgonians were considered as different populations. The investigation of those four relationships demonstrates that H was related to DW by a negative allometric relationship (a<3) (AR 5-8: t-test, d.f.=29, t=10.059, p>0.05; AR 9-13: t-test, d.f.=37, t=11.274, p>0.05; PH 5-10: t-test, d.f.=43, t=12.848, p>0.05; PH 11-13: t-test, d.f.=46, t=10.059, p>0.05). The ecological significance of this observation was that H increased more than DW.

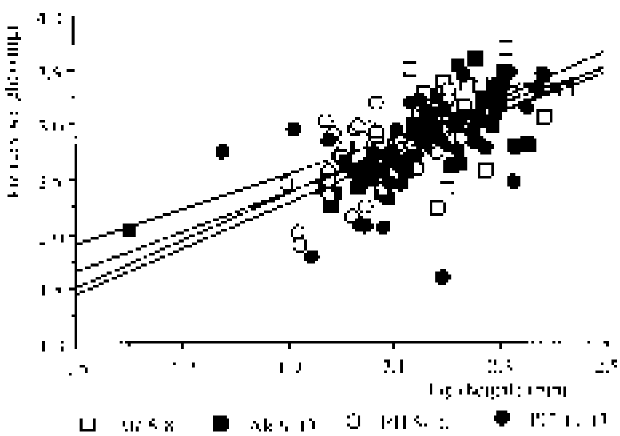

Fig. 1. – Linear regression between log(dry weight) and log(height) of *Eunicella singularis* colonies at Arethoussa (AR 5-8 and AR 9-13) and Phidonissi (PH 5-10 and PH 11-13) sampling sites. AR 5-8: DW=0.486*H$^{-1.595}$, n=31, r=0.441, p<0.05; AR 9-13: DW=1.690*H$^{-2.087}$, n=39, r=0.784, p<0.05; PH 5-10 DW=1.742*H$^{-2.162}$, n=45, r=0.671, p<0.05; PH 11-13: DW=1.071*H$^{-1.814}$, n=48, r=0.541, p<0.05.

DW=b*(HxW)^a

The relationships between log(DW) and the rectangular surface area log(HxW) (Fig. 2) were significantly different at the four sampling sites (Bartlett's tets, d.f.=3,

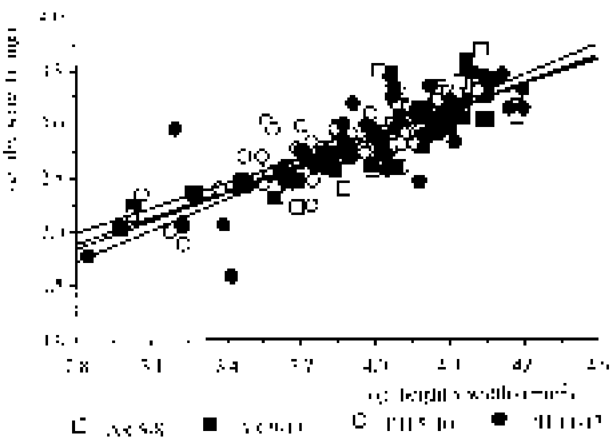

Fig. 2. – Linear regression between log(dry weight) and log(height x width) of *Eunicella singularis* colonies at Arethoussa (AR 5-8 and AR 9-13) and Phidonissi (PH 5-10 and PH 11-13) sampling sites. AR 5-8: DW=0.961*(HxW)$^{-0.961}$, n=31, r=0.755, p<0.05; AR 9-13: DW=0.394*(HxW)$^{-0.817}$, n=39, r=0.868, p<0.05; PH 5-10 DW=0.145*(HxW)$^{-0.762}$, n=45, r=0.814, p<0.05; PH 11-13: DW=0.564*(HxW)$^{-0.860}$, n=48, r=0.806, p<0.05.

χ^2=30.136, p>0.05) and the gorgonian colonies were considered as different populations. The isometric hypothesis (a=3/2) was also examined and accepted for the gorgonian samples from AR 9-13 and the two sites of Phidonissi (AR 9-13: t-test, d.f.=37, t=0.740, p<0.05; PH 5-10: t-test, d.f.=43, t=0.740, p<0.05; PH 11-13: t-test, d.f.=46, t=0.751, p<0.05). However, (HxW) was related to DW in the AR 5-8 gorgonian colonies, with a negative allometric relationship (a<3/2) (t-test, d.f.=29, t=2.003, p>0.05).

DW=b*(W)^a

Comparison of the linear regressions between log(DW) and log(W) (Fig. 3) did not exhibit significant differences (Bartlett's test, χ^2: 1.945, d.f.: 3, p<0.05) at the four sampling sites, and all the gorgonian samples were considered as one population. W was related to DW with a negative allometric relationship (t-test, d.f.=161, t=5.474, p>0.05).

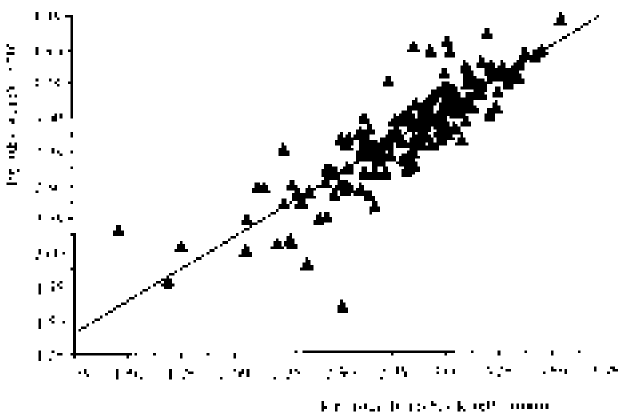

Fig. 3. – Linear regression between log(dry weight) and log(width) of *Eunicella singularis* colonies. The gorgonian colonies from the sampling sites of Arethoussa and Phidonissi were considered as one population. DW=0.984*W$^{1.039}$, n=163, r=0.808, p<0.05.

4DW=b*(TBL)^a

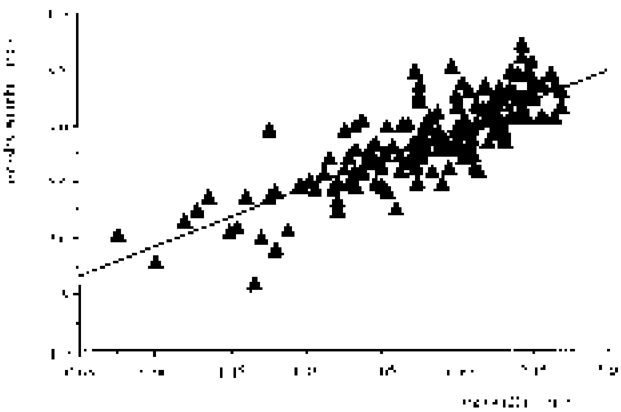

Fig. 4. – Linear regression between log(dry weight) and log(total branch length) of *Eunicella singularis* colonies. The gorgonian colonies from the sampling sites of Arethoussa and Phidonissi were considered as one population. DW=0.236*TBL$^{0.931}$, n=163, r=0.859, p<0.05.

The linear regression between log(DW) and log(TBL) (Fig. 4) did not exhibit significant differences (Bartlett's test, χ^2: 2.854, d.f.: 3, p<0.05) among the colonies from the four sampling sites. Therefore, for this relationship these colonies could be considered as one population. In this case the relationship between dry weight and TBL was a negative allometric one (isometry: a=3) (t-test, d.f.=161, t=1.988, p>0.05).

DISCUSSION

Gorgonian growth is a compromise between current intensity and feeding ability. Some species of gorgonian colonies, as for example *Eunicella cavolinii* (Velimirov, 1976), have reduced surface area which enables them to resist the water intensity. However, other authors (Jeyasuria & Lewis, 1987; Lowenstam & Weiner, 1989; Lewis et al., 1992) have demonstrated the ability of some gorgonians to increase their flexibility in order to increase their resistance to the water intensity. Our investigation proved that the *Eunicella singularis* colonies belong to the second group, and we have observed that the significantly higher colonies were located in the exposed site (Tab. 1). The question that arose when we observed the previous results was whether growth and the relationships between DW and the macro-features were affected by the hydrodynamic properties of the site. The present investigation demonstrates the presence of two groups of macro-features related to DW: the first group (H and HxW) exhibits a variability depending on the sampling site, and in the second one (W and TBL) the relationships between the DW and the biometric parameters are independent from the sampling site and are still constants.

The height of colonies is an easy parameter to measure, but is not the most appropriate parameter to describe the gorgonian growth. The linear regression growth curve exhibits significant differences among the colonies from the four sampling sites. Moreover, the observations of Weinberg & Weinberg (1979), also in *Eunicella singularis*, prove that the use of colony height is not appropriate because this biometric parameter could be affected by predation on the colony from other animals.

The growth curve obtained by the use of rectangular surface area as suggested by Russo (1985) also exhibits significant differences that depend on the hydrodynamic properties of the sampling sites. In addition to our observations, application of the same biometric parameter in the growth study of *Paramuricea clavata* gorgonians (Mistri, 1995) did not give satisfactory results. Interesting were also the results in the present study obtained by allometric investigation. The isometry hypothesis relating DW to HxW was accepted in all the three sampling sites, except in the gorgonian samples from the shallow water of the exposed site (AR 5-8), which exhibit a negative allometric relationship. That difference between the colonies from AR 5- 8 and the other three sites could be explained by two hypotheses. The first one concerns circulation of the more important nutrients at the AR 5-8 site and a consequently higher feeding capacity of the gorgonian colonies. The second, and preferable, hypothesis suggests that this growth mode of the shallow water colonies at the exposed site is an adaptation to the strong spatial competition between gorgonians and the sponges *Aplysina aerophoba*. In situ observations indicate a high density of this sponge species within the hard substratum area covered by the gorgonian colonies.

The second, and more interesting, group of biometric parameters includes width and total branch length of the colonies. The linear regression between those macro-features and the DW did not exhibit significant differences that depended on the hydrodynamic characteristics of the environment. Thus, concerning those relationships, all the *Eunicella singularis* colonies can be considered as one population. According to the fractal growth process proposed by several authors (MANDELBROT, 1982; BURLANDO et al., 1991 ; KAANDORP & DE KLUIJVER, 1992; MISTRI & CECCHERELLI, 1993), the gorgonian width increases more regularly than the other biometric parameters. In addition, the use of the total branch length was also proposed by other authors (VELIMIROV, 1976; WEINBERG & WEINBERG, 1979) as a very interesting biometric parameter for the growth study.

In conclusion, in the present study we have indicated that the growth of *Eunicella singularis* followed a negative allometric relationship ($a<3$ and $a<3/2$) as has also been demonstrated in other cnidarian colonies (MIGNE & DAVOULT, 1993). The measurements of all the four macro-features that have been investigated did not involve the destruction of colonies, and they could be used for monitoring of the gorgonian population. However, the most appropriate biometric parameters applied to the gorgonian growth study seems to be W and TBL. The relationships between those parameters and the dry weight did not exhibit significant differences that depended on the hydrodynamic characteristics of the sampling areas.

REFERENCES

BURLANDO, B.B., R. CATTANEO-VIETTI, R. PARODI & M. SCARDI (1991). Emerging fractal properties in Gorgonian Growth forms (Cnidaria: Octocorallia). *Growth, Development & Ageing*, 55: 161-168.

DAGNELLIE, P. (1975). *Théorie et méthodes statistiques (2)*. Les presses agronomiques de Gembloux: 1-463.

GOULD, S.J. (1966). Allometry and size in ontogeny and phylogeny. *Biol. Rev.*, 41, 587-640.

GUILLAUME, M. (1988). *La croissance du squelette de* Porites lutea *scléractiniaire hermatypique sur le récif frangeant de la Saline, île de la Réunion, Océan Indien*. Thèse de doctorat: 1-254.

JEYASURIA, P. & J.C. LEWIS (1987). Mechanical properties of the axial skeleton in gorgonians. *Coral reefs*, 7: 147-153.

KAANDORP, J. (1986). Rocky substrate communities of the infralittoral fringe of the Boulonnais coast, NW France: a quantitative survey. *Mar. Biol.*, 92: 255-265.

KAANDORP, J. & M.J. DE KLUIJVER (1992). Verification of fractal growth models of the sponge *Haliclona oculata* (Porifera, class Demospongiae) with transplantation experiments. *Mar Biol.*, 113: 133-143.

LEWIS, J.C., T.F. BARNOWSKI & G.J. TELESNICKI (1992). Characteristics of Carbonates of Gorgonian Axes (Coelenterata, Octocorallia). *Biol. Bull.*, 183: 278-296.

LOWENSTAM, H. & S. WEINER (1989). *On biomineralization.* Oxford University Press, New York, 1-324.

MANDELBROT, B.B. (1982). *Fractal geometry of nature*. Freeman & Co Ed. (San Francisco): 1-468.

MIGNE, A. & D. DAVOULT (1993). Relations “taille-poids” chez quelques Cnidaires coloniaux. *Cah. Biol. Mar.*, 34: 103-110.

MISTRI, M. & V.U. CECCHERELLI (1993). Growth of the Mediterranean Gorgonian *Lophogorgia ceratophyta* (L., 1758). *P.S.Z.N.I.: Mar. Ecol.*, 14 (4): 329-340.

MISTRI, M. & V.U. CECCHERELLI (1994). Growth and secondary production of the Mediterranean gorgonian *Paramuricea clavata*. *Mar. Ecol. Progr. Ser.*, 103: 291-296.

MISTRI, M. (1995) Gross morphometric relationships and growth in the Mediterranean gorgonian *Paramuricea clavata*. *Bull. Zool.*, 62: 5-8.

RUSSO, A.R. (1985) Ecological observations on the gorgonian sea fan *Eunicella cavolinii* in the bay of Naples. *Mar. Ecol. Prog, Ser.*, 24: 155-159.

SKOUFAS, G., M. POULICEK & C.C. CHINTIROGLOU (1996). Étude préliminaire de la biométrie d’*Eunicella singularis* (Esper, 1794) (Gorgonacea, Anthozoa) à la Mer Egée. *Belg. J. Zool.*, 126 (2): 85-92.

SNEDECOR, G.W. & W.G. COCHRAN (1967). Statistical methods. The Iowa State University Press, Ames, Iowa, U.S.A.: 1-593.

THEODOR, J. (1963). Contribution à l’étude des gorgones III. Trois formes adaptatives d’ *Eunicella stricta* en fonction de la turbulence et du courant. *Vie et Milieu.*, 14 (4): 815-818.

VELIMIROV, B. (1976). Variations in growth forms of *Eunicella cavolinii* Koch (Octocorallia) related to intensity of water movement. J. *Exp. Mar. Biol. Ecol.*, 21: 109-117.

WEINBERG, S. & F. WEINBERG (1979). The life cycle of a gorgonian: *Eunicella singularis* (ESPER, 1794). *Bijdr. Dierk.*, vol. 48: 127-140.