# RELATIVE HABITAT SUITABILITY AND STABILITY OF THE MEDITERRANEAN GORGONIAN CORAL EUNICELLA CAVOLINI (COELENTERATA: OCTOCORALLIA)

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### ABSTRACT

Habitat suitability and stability of the Mediterranean gorgonian *Eunicella cavolini* were investigated at three study sites in the Bay of Calvi (Corsica, France): a channel (25 m), a wall (16–28 m) and a boulder field (10–15 m). Relative differences between habitats were analysed by using the age structure at the three study sites. Population density and recruitment rates were highest in the channel, intermediate at the wall, and lowest at the boulders. The study sites could be ranked in terms of both habitat suitability and stability (from highest to lowest) as follows: channel, wall and boulders. The channel was about 1.9 times more stable than the wall and about 2.5 times more stable than the boulders. The observed differences between habitats were related to light intensity, overgrowth of colonies, substratum occupation, and the intensity of water movement.

The population dynamics of octocorals has been investigated in several seas (Grigg, 1977; Benayahu and Loya, 1984a, 1984b; Farrant, 1987; Gotelli, 1988; Lasker, 1990) and there is also some information on the secondary production of gorgonian corals (Mitchell et al., 1992; Mistri and Ceccherelli, 1994). Demographic models were established for Caribbean gorgonians (Gotelli, 1991; Yoshioka, 1994). Lasker (1991) presented models on equilibrium and non-equilibrium sensitivity of gorgonian life history for testing elasticity and stability of populations. This method is very powerful, but has the disadvantage that time-consuming intra- and inter-annual measurements have to be performed. Based on the analysis of the age structure of a gorgonian, Grigg (1975) presented a simple method to study relative differences of habitat suitability and stability between study sites of sessile, longevous species. That author suggested that the environmental suitability between habitats of gorgonians can be evaluated by the relative differences in age structure and longvity, i.e., habitats suitable for a species are characterized by a high abundance of young colonies and/or low mortality. Habitat stability is defined as variability between age classes. A stable environment would be characterized by populations with low numerical variability between successive age classes due to relatively constant recruitment and age-specific mortality rates. In the present study we investigated populations of the gorgonian Eunicella cavolini from three different habitats. We used the age structure and data on recruitment and mortality to evaluate the habitat suitability and stability of the three study sites investigated.

#### METHODS

Colonies were counted and measured at three sites on the west coast of Corsica (France) near Calvi at Stareso: 1) a slightly overhanging wall in a large underwater channel at about 25 m depth; 2) a steep wall from 16 to 28 m depth; and 3) a group a large boulders between 10 and 15 m depth. A more detailed description of the study sites is given in Weinbauer and Velimirov (submitted). In the following, these sites are termed channel, wall and boulders. In the channel and at the wall two transects 25 cm wide and between 3.5 and 10 m long were set up on each rock face. At the boulders we surveyed several areas of about 0.5 m<sup>2</sup> each. Measurements were made in August 1989, August 1990 and August 1991. Colonies with algal or animal epibionts were recorded.

The determination of colony age was performed as described previously (Weinbauer and Velimi-

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Table 1. Population density and overgrowth of E. cavolini, and relative light intensity at the various
study sites. Population density and overgrowth are given as average from three years' investigation.
Overgrowth is defined as the percentage of colonies with algal or animal epibionts. Relative light
intensity is given as proportion of the light intensity of the least illuminated study site (Weinbauer
and Velimirov, submitted). ±SD.

Study site	Relative light intensity	Overgrowth (%)	Density (colonies·m <sup>2</sup> )
Channel	1.0	$30.8 \pm 17.05$	$162.7 \pm 15.82$
Wall	3.7	$51.3 \pm 23.15$	$61.0 \pm 6.25$
Boulders	4.9	$68.9 \pm 21.73$	$17.3 \pm 2.08$

rov<sup>1</sup>). Briefly, after determinating total branch length *in situ*, total branch length was converted to age by using a hypothetical growth formula developed for *E. cavolini* (Velimirov, 1975). We have shown that this growth formula can be used to determine age in colonies from all investigated sites (Velimirov and Weinbauer, 1992; Weinbauer and Velimirov<sup>1</sup>). Although the age structure at each study site did not vary strongly between subsequent years, we followed the recommendation of Deevey (1947) to average age structure from the investigated years, to obtain a more representative age frequency distribution at the various study sites.

### RESULTS

The various habitats showed strong differences in population density, overgrowth, and light availability (Table 1). Population density and overgrowth varied significantly between study sites (Friedman;  $x_r$  squared > 6; P < 0.05). The channel was the study site with the highest population density and the lowest overgrowth of colonies, the boulders the site with the lowest population density and highest overgrowth; the wall was intermediate. Differences of the light intensity between habitats -low in the channel, intermediate at the wall and high at the boulders-, are reflected in space occupation of substratum (mainly by algae) which was lowest in the channel and highest at the boulders (Weinbauer and Velimirov, unpublished data).

Grigg (1975) defined habitat suitability by the longvity of a population. A suitable habitat is characterized by a high number of young colonies and/or low mortality. The age frequency distribution showed that there were more old colonies ( $\geq 10$  yr) in the channel than at the wall; the boulders lack old colonies (Fig. 1). Moreover, mortality of *E. cavolini* was similar at all study sites, whereas recruitment rates were highest in the channel, intermediate at the wall and lowest at the boulders (Table 2). In addition, population density was highest in the channel, intermediate at the wall and lowest at the boulders (Table 1). For these reasons, the study sites can be ranked (from most to least) in terms of habitat suitability as follows: channel, wall and boulders.

Substratum occupation was related inversely to habitat suitability. The boulders, e.g., were the site with the highest substratum occupation and the lowest habitat suitability. Moreover, the boulders were the habitat with the lowest recruitment of young colonies (Table 2). This indicates low larval settlement at this study site. Thus we suspected availability of substratum for larval settlement being an important cause for the observed population density and recruitment rates at the different localities.

Since overgrowth was also inversely related to habitat suitability, overgrowth of recruits could have influenced the differences of suitability between habitats.

<sup>&</sup>lt;sup>1</sup> Weinbauer, M. G. and B. Velimirov. submitted. Population dynamics and overgrowth of the sea fan *Eunicella cavolini* (Coelenterata: Octocorallia). Estuar. Coast. Shelf Sci.



Figure 1. Age structure of *E. cavolini* from the various study sites. Values are averaged from the 3 years' investigation. N = mean colony number.

Study site	Recruitment (%)	Mortality (%)
Channel	15.9 ± 5.94	20.2 ± 17.04
Wall	$9.7 \pm 3.25$	$19.1 \pm 7.00$
Boulders	$7.5 \pm 1.13$	$21.7 \pm 16.48$

Table 2. Recruitment and mortality of *E. cavolini* at the various study sites. (Data are calculated as mean of 2 years.  $\pm$ SD)

Moreover, since reproduction is probably a function of age (or size) (Wahle, 1983), the low number of large colonies and the low population density at the boulders might result in low reproduction. Since fertilization is less probable at high turbulences according to Denny and Shibata (1989), the shallow colonies at the boulders may have lower reproductive success compared to populations at greater depths (channel and wall). This could also explain the differences of recruitment between study sites.

The boulders were characterized by a lack of colonies older than 9 years. One possibility for this observation could be that older, i.e., larger colonies were torn off by storms, since this habitat is the shallowest of all investigated study sites and thus subjected to strong hydrodynamical forces.

A stable age structure is the result of balanced recruitment and death in time, and is characterized by a high number of young colonies and by progressively fewer colonies in older size classes (Grigg, 1975). Several monotonically decreasing functions (Table 3) were fitted to the age frequency, to test habitat suitability (Grigg, 1975). Monotonically decreasing functions should generate a curve which is close to a best fit of a population, if recruitment and age-specific mortality are constant. The standard deviations of the curve fits are a measure of departures from steady-state recruitment and mortality rates and, thus, a measure of habitat stability (Grigg, 1975). Note that this method is not concerned with the shape of the curve, but rather with the variability of the data around the curve. The use of only one equation could introduce a small bias by making those distributions for which the fit is best appear to be more stable. For example, the equation y = a- bx would make the population at the boulders slightly more stable and the habitat in the channel slightly more unstable (Table 3). Although it is obvious that there are differences of the age structure and stability between study sites (Fig. 1), the extent of these differences cannot be simply derived from this figure. However, the method outline above can be used to quantify the relative differences of stability between various habitats.

Age structure of E. cavolini showed the lowest standard deviation in the channel, an intermediate one at the wall and the highest at the boulders (Table 3). Of

Table 3. Standard deviation of curve fits to age frequencies of *E. cavolini* from Figure 1. (Data are given as coefficient of variation, x = age in yr and y = age frequency in percent)

····	Study site		
Equation	Channel	Wall	Boulders
y = a - bx	0.53	0.84	1.05
$y = ae^{-bx}$	0.45	0.86	0.99
$y = ax^{-b}$	0.39	0.90	1.23
y = 1/(a + bx)	0.50	0.83	1.56
$y = a - b \ln x$	0.36	0.82	1.18
Mean	0.45	0.85	1.20

all study sites, the age composition of the population in the channel fitted best the assumption of a stable age structure (Fig. 1). The age structure at the wall is quite similar; however, young colonies (age class 1 and 2) are generally less numerous than 3-4 year-old colonies. The smallest colonies observed during our survey were 2-3 mm in length. While it is possible that we have underestimated recruitment and therefore the numbers of colonies in the first age classes, this cannot explain the low colony numbers in age class 3 and 4 years (corresponding to a total branch length between 3.9-12.7 cm per colony) at the boulders (Fig. 1). All colonies at the boulders were less than 10 years old. Although there are some uncertainties regarding the quantitative representation of colonies in the single age classes, habitats can be ranked in terms of stability (from most to least) as follows: channel, wall and boulders. Using the mean values of the standard deviations, the population in the channel is 1.9 times more stable than at the wall, and 2.5 times more stable than at the boulders (Table 3).

Production of larvae or survival of recruits might differ strongly between subsequent years. In *Briareum asbestinum* it was shown that reproductive success was low in a year in which colonies showed a low growth rate (Brazeau and Lasker, 1992). Grigg (1975) suggested that small changes in larval mortality of *Muricea californica* would cause large changes in recruitment, because the intrinsic rate of natural increase is very high in this species. Changes in fitness between years could thus cause differences of recruitment and survival for larvae and consequently a non-stable age structure as e.g., observed at the boulders (Fig. 1).

In the present study habitat suitability of *E. cavolini* matches with stability. Contrary, in the gorgonian *M. californica* the least suitable habitat was not the least stable (Grigg, 1975). Grigg (1975) showed that the most stable of these populations was 2.7 times more stable than the least stable. This is very similar to our finding of a maximum 2.5 fold difference in the habitat stability of *E. cavolini*. In *M. californica*, both habitat suitability and stability were related to features of the habitat, such as water quality, sediment load, and composition and availability of substratum. In *E. cavolini* habitat suitability and stability are inversely related to light intensity, and the amount of overgrowth and substratum occupation (mainly by algae). Thus, by influencing algal growth, light can affect the competition of *E. cavolini* for space and the mortality of colonies by algal overgrowth. The varying intensity of water movement between habitats might be important as well by affecting the reproductive success (Denny and Shibata, 1989) and by causing mortality due to detachment of colonies.

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