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Pruning treatment: A possible method for improving the conservation status of a *Ellisella paraplexauroides* Stiasny, 1936 (Anthozoa, Alcyonacea) population in the Chafarinas Islands?

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Abstract

In the present paper, the results of a four-year conservation study on the giant gorgonian *Ellisella paraplexauroides* in the Chafarinas Islands are reported. This species, currently protected in Spain, is present as isolated colonies or as a low number of them, except in the Chafarinas Islands, where higher densities can be found below a depth of 20 m. Nevertheless, as revealed by a previous study, a great number of colonies are partially covered by epibionts or totally dead. As a first objective of the present work, seven transects were performed in 2013 and 2014 to evaluate the percentage of colonies affected in areas that had not been previously sampled. Approximately between 35% and 95% of the colonies had different degrees of epibiosis or were dead. In 2015, ten transects were performed to specifically locate young colonies smaller than 15 cm, which could be indicative of population regeneration by sexual reproduction. The high number of dead colonies as well as the colonies covered by epibionts, together with the inexistence of young colonies, indicated a progressive decline of the study population. The last aim of the study consisted of testing a restoration action by means of pruning the affected colonies between 2015 and 2016. The results of this restoration action showed a substantial improvement of the colonies (growth of branches, production of new branches and a general increase in the health status of the colonies). Our results recommend the employment of this technique for the future conservation of this species in the Chafarinas Islands. Nevertheless, this is a pilot study, and further experiments with a large number of samples should be performed to truly understand the significance of this technique.

Keywords: *Ellisella paraplexauroides*, West Mediterranean, conservation, pruning, recovery.

Introduction

In recent years, mass mortality events in infralittoral and circalittoral communities have become increasingly frequent (e.g., Cerrano *et al*., 2000; Cupido *et al*., 2009; Cebrian *et al*., 2011; Rubio-Portillo *et al*., 2016). Among the direct or indirect anthropogenic or natural drivers, increases in water temperatures have been noted as the main cause, while the regeneration of beaches, organic and inorganic spills, different types of professional and recreational fishing, etc., have also played a role in increasing such mortality, likely interacting synergistically (Gaino *et al*., 1992; Bianchi & Mori, 2000; Cerrano *et al*., 2001; Coma *et al*, 2004; Templado, 2014). These episodes have principally focussed on some vulnerable species of invertebrates, mainly cnidarians and sponges (Romano *et al*., 2000; Lejeusne *et al*., 2010). The repetition of these events, often linked to low recruitment of the affected species, has led to the diminution or disappearance of their populations in large areas (e.g., Webster, 2007; Templado, 2014).

Currently, this degradation and disappearance of coral reefs and other benthic colonial organisms is considered a serious global threat to the conservation of marine biodiversity. This fact calls for novel management and restoration approaches, including the recent concept of "gardening", in which a two-step restoration process is involved, nursery and transplantation, similar to that of silviculture (Rinkevich, 2015). In recent years, much effort has been spent improving transplantation techniques, including the transplantation of gorgonians (e.g., Kumagai *et al*., 2004; Linares *et al*., 2008), but no attention has been paid to the selective pruning of damaged parts.

One of the threatened species is the gorgonian *Ellisella paraplexauroides* Stiasny, 1936 (family Ellisellidae), which is a large species, up to 2 m in height, distributed in the Western Mediterranean Sea and the neighbouring Atlantic Ocean, reaching Angola, usually at depths of between 50 and 150 m (Arroyo *et al*., 2008; Angiolillo *et al*., 2012). The maximum depth recorded for this species is 690 m (Brito & Ocaña, 2004). It has been included in the Annex II of threatened species of the Protocol ZEP/BD (*Centro de Actividades Regionales para las Zonas Especialmente Protegidas*) (B.O.E., 2015) and, consequently, can be considered as a protected species in Spanish waters. In fact, this species has been recently listed as vulnerable in a recent assessment by the IUCN Red List (Maldonado *et al*., 2015). Across its entire distribution area, this giant gorgonian is present as isolated colonies or at low densities, except in the Chafarinas Islands, where below 20 m depth, densities of 0.59±0.99 living colonies per m^2 and a maximum of 5 gorgonians per m^2 occur (Maldonado *et al*., 2013). Nevertheless, despite its abundance, a great number of colonies are partially covered by epibionts (Fig. 1), 67.8% of the studied living colonies, and 22% of the total colonies are dead according to Maldonado *et al*. (2013). Additionally, the size distribution of *E. paraplexauroides* in the Chafarinas Islands suggests moderate to low recruitment (Maldonado *et al*., 2013). Together with this problem, *E. paraplexauroides* is also affected by the impacts of recreational and artisanal fishing and by its particular shallow distribution above its usual range of depth distribution. All of this suggests that some conservation efforts are needed to preserve the future of this species in the study area. Thus, it has been noted that despite the observation that coral reefs exhibit high resilience to even the greatest natural disasters, their current situation facing many damaging anthropogenic impacts prevents their natural recovery, and active intervention by man is needed for their subsistence (Rinkevich, 2006). In this sense, the aims of the present study are 1) to determine the conservation status of the *E. paraplexauroides* colonies around the Chafarinas Islands in different areas than those considered in a previous study (Maldonado *et al*., 2013), and 2) to evaluate the effectiveness of a restoration model using pruning in this area.

Material and Methods

Four summer sampling campaigns (2013, 2014, 2015 and 2016) were carried out in the Chafarinas Islands (Alboran Sea, SW Mediterranean). This small Spanish archipelago is situated near the North African coast (two miles from Morocco, near the Argelian frontier) and is composed of three islands (Congreso, Isabel II and Rey Francisco) that together have a perimeter of approximately 7 km (Peña Cantero & García Carrascosa, 2002; Altamirano *et al*., 2013).

To complete the knowledge on the conservation status of the *E. paraplexauroides* colonies around the Chafarinas Islands, 7 transects (Fig. 2) were performed by scuba diving during 2013 and 2014. Transect depth ranged from 15 to 35 m, and immersion duration in each transect ranged from 10 to 30 minutes. In each transect, the number of healthy colonies, colonies with less than 25% damaged parts, colonies with 25% to 50% damaged parts, colonies with more than 50% damaged parts, and dead colonies were estimated by comprehensive observation and the counting of colonies. The total numbers of colonies detected in each transect are reported in Table 1.

As a pilot study, in 2015, ten colonies located in the north of Isabel II Island, (35°11´01.37´´N; 2º25´38.64´´W) (Fig. 2), between 23 and 26 m deep, with different degrees of epibiosis were photographed (with a

Fig. 1: Two colonies of *E. paraplexauroides*, one of them dead and completely covered by epibionts and the other alive and partially covered. In the photograph, a fishing line, which can often cause damage to the colonies, can be observed.

reference metric bar), and for nine of them, the damaged parts were removed by means of pruning (the remaining one was used as a control) (Figs. SD1-SD10). In some of those colonies, when the damaged areas were not very extensive, those areas were cleaned of epibionts instead of being pruned. In 2016, all ten colonies were again visited and photographed (again with a reference metric bar) to evaluate their status and possible growth. Moreover, in 2015, ten transects with a duration of 20 minutes for each one were performed with the specific aim of detecting colonies smaller than 15 cm that could be indicative of population regeneration by sexual reproduction.

Results

Regarding the conservation status of the *E. paraplexauroides* colonies around the Chafarinas Islands (Table 1), the high number of colonies with different degrees of epibiosis or that are dead is remarkable (Fig. 1). In 2013-2014, approximately 56% of the colonies were covered by epibionts or dead, with some transects particularly affected, such as transect C (91%) and transect G (95%). The transects carried out in 2015 were focussed on the searching for young colonies, but no colony smaller than 15 cm was detected.

The results of the restoration by pruning showed a substantial improvement of the colonies (Table 2; Fig. 3; Figs. SD1-SD10), with only nine branches with epibionts at their apexes from a total of 104 branches in the 9 pruned colonies (Table 2). However, some of the branches with epibionts had not been completely cleaned in the previous year (Fig. SD2). In cases in which growth could be clearly measured (N= 35 branches from 7 colonies), this growth oscillated between 3.80 and 58.00 mm/year. The mean ± SD growth for the studied colonies oscillated between 9.53 ± 9.08 to 34.14 ± 14.85 mm. Moreover,

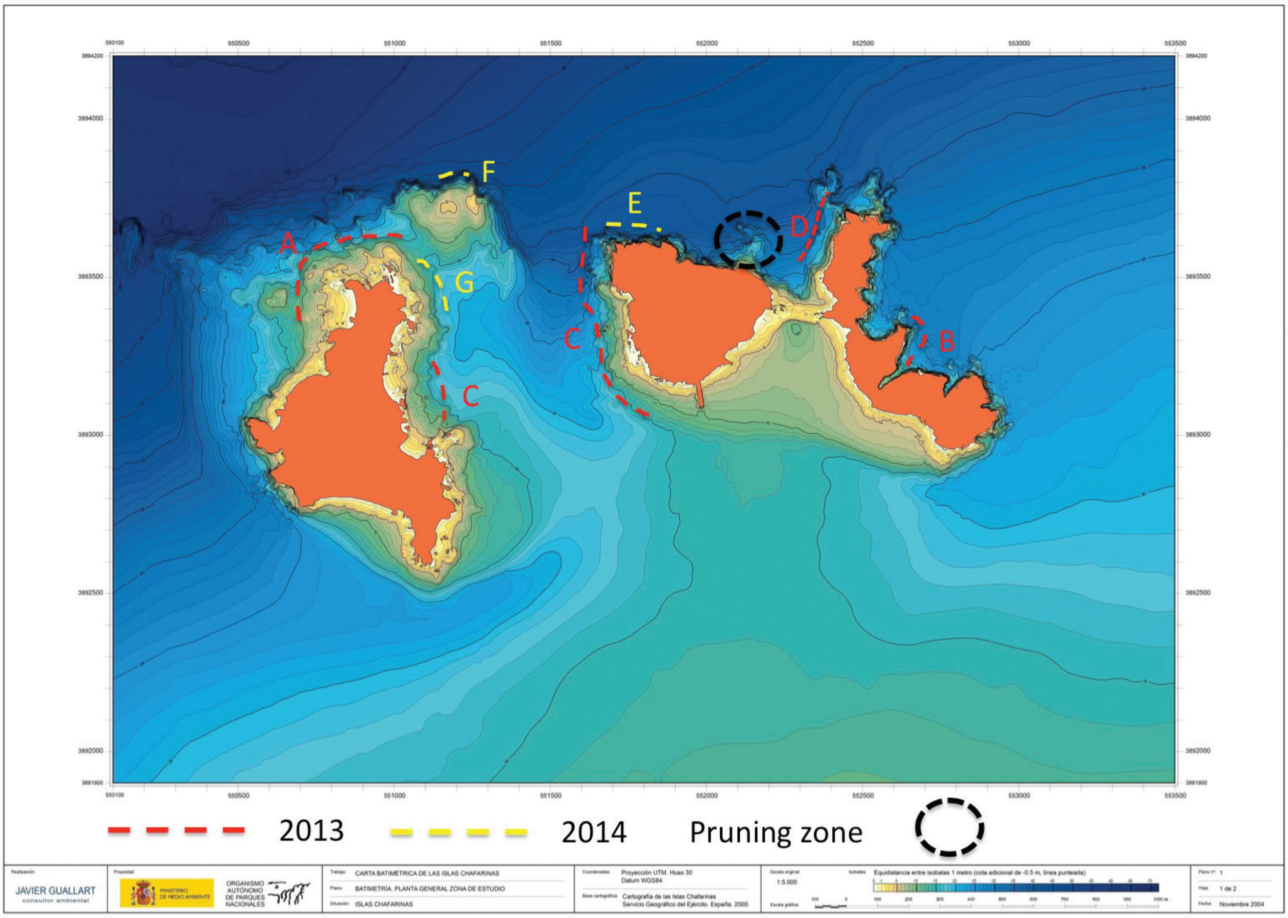

Fig. 2: Transects performed in 2013 and 2014 for evaluating the conservation status of the *E. paraplexauroides* colonies around the Chafarinas Islands and the area where the pruning treatment (2015) and monitoring and control (2016) were conducted.

Table 1. Data on transects (depth, time and coordinates at the beginning of the transect) performed in 2013-2014. Healthy: number of healthy *Ellisella paraplexauroides* colonies; <25%: number of colonies with less than 25% damaged parts; 25-50%: number of colonies with 25% to 50% damaged parts; >50%: number of colonies with more than 50% damaged parts; and Dead: number of dead colonies.

Transect	Year	Depth (m)	Time (minutes)	Coordinates at the transect beginning	Healthy	<25%	25-50%	>50%	Dead	Total
A *El Pedregal-Norte del Congreso*	2013	18-15	30	35°10´51.06´´N 2°26’33.94´´W	67	16	5	1	14	103
B *La Sartén-Tajo del Halcón*	2013	24-18	30	35°10´54.84´´N 2°25’18.33´´W	182	39	11	4	50	286
C *Este del Congreso*	2013	14-20	30	35°10´50.53´´N 2°26’22.19´´W	3	4	3	3	22	35
D *Noroeste Isla del Rey*	2013	23-30	20	35°10´58.80´´N 2°25’31.15´´W	104	64	21	18	76	283
E *Faro-Punta España*	2014	33-23	15	35°11´03.94´´N 2°25’50.98´´W	64	63	8	5	5	145
F *La Laja*	2014	35-34	10	35°11´08.55´´N 2°26’13.74´´W	42	38	1	1	5	87
G *Norte del Congreso-Canal*	2014	17-16	20	35°11´00.21´´N 2°26’21.04´´W	6	23	10	23	72	134
Total					468	247	59	55	244	1073

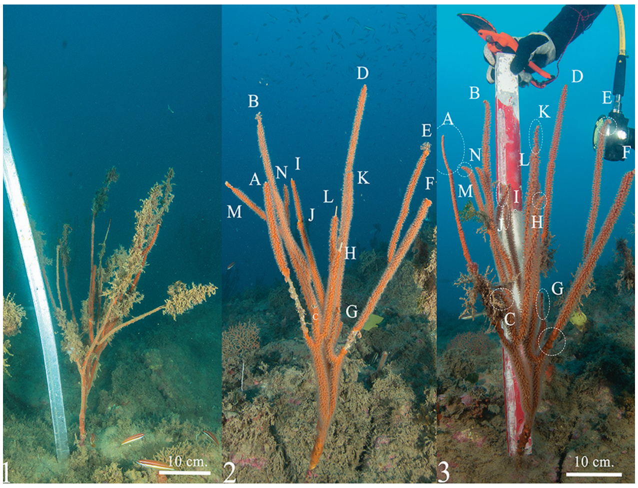

Fig. 3: An example of one of the colonies in which the pruning treatment was performed. 1) Before pruning, 2015; 2) just after pruning, 2015; and 3) colony status a year later, 2016. A general improvement and the growth of branches can be observed.

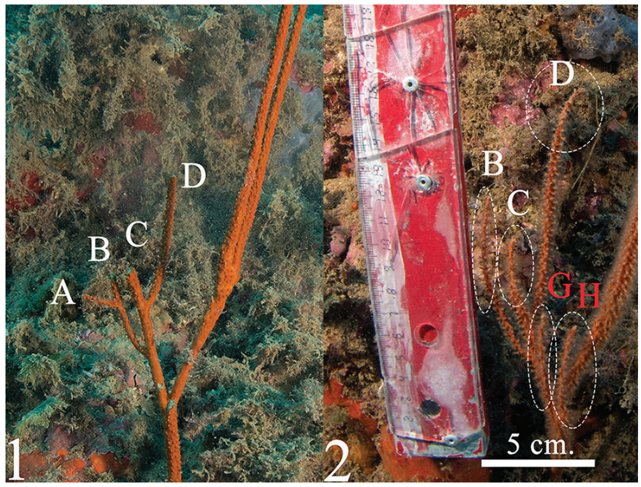

Fig. 4: Colony of *E. paraplexauroides* just after pruning (1) and a year later (2) showing the growth of some branches (B, C and D) and the production of new branches (G and H).

Table 2. Results of the restoration by pruning shown by the studied *Ellisella paraplexauroides* colonies between 2015 and 2016 in cases in which they could be evaluated.

Colony	N branches in 2015-2016	Branches with epibionts at the apex in 2016	N of branches in which growth could be measured	Mean growth (mm)	S.D	Min-Max growth (mm)
2	23-23	2	7	25.86	9.75	15.00-39.00
3	14-14	-	7	33.29	15.68	17.00-58.00
4	9-9	-	-	-	-	-
5	12-12	1	7	34.14	14.85	15.00-57.00
6	15-15	1	4	27.50	6.14	23.00-36.00
7	1-3	1	-	-	-	-
8	9-9	-	2	15.50	4.95	12.00-19.00
9	11-11	3	3	9.53	9.08	3.80-20.00
10	6-8	1	5	29.80	9.73	19.00-40.00

new branches could be detected in some colonies, particularly in colony 7 (1 and 3 branches in 2015 and 2016, respectively) and colony 10 (6 and 8 branches in 2015 and 2016, respectively) (Fig. 4; Fig. SD7). In the control colony, no significant changes could be detected in terms of epibiont coverture or colony growth (Fig. SD1).

The regeneration of the damaged areas by cleaning was less effective when those areas had not been completely cleaned and some epibiont remains, mainly cirriped shells, had not been removed. In this sense, the length of the damaged area and the degree of cleanliness influenced the subsequent regeneration of tissues (Fig. 5).

Discussion

Both previous data from Maldonado *et al.* (2013) and the present data support the critical status of the *E. paraplexauroides* colonies in the Chafarinas Islands. The number of dead colonies is high, and the colonies covered by epibionts are very abundant (Table 1), particularly in the shallower parts of its distribution. The colonization of the colony surface by epibionts can be favoured by predation actions, such as that of the polychaete *Hermodice carunculata* (Pallas, 1966) (Fig. 6), although this predation causes damage exclusively to the apices of the branches, which, under normal conditions, regenerate without difficulty (Maldonado *et al.*, 2013). Nevertheless, mechanical damage caused by fishing gear (Fig. 1) is more aggressive (Sánchez-Tocino *et al.*, 2009; Maldonado *et al.*, 2013), as also reported for *Paramuricea clavata* (Risso, 1826) in the Ligurian Sea (Bavestrello *et al.*, 1997). After being colonized by epibionts, apart from the increased stress, the colony suffers from a gain in weight in its upper parts, and, due to the additional volume represented by the epibionts, a decrease in its hydrodynamism occurs, favouring its breakage (Weinberg & Weinberg, 1979) (Fig. 7).

The absence of information on the growth rate of *E. paraplexauroides* colonies prevents the estimation of the age of the observed colonies. Nevertheless, based on studies conducted on 21 gorgonian species (Weinberg & Weinberg, 1979; Coma *et al*., 1998 and references therein; Skoufas *et al*., 2000; Sartoretto & Francour, 2012; Munari *et al*. 2013), we can conclude that the studied population is not composed of colonies younger than a few years old. In fact, Coma *et al*. (1998), from their own data plus those recompiled from other authors, showed that the mean annual growth for 11 gorgonian species was 2.2 cm and that the maximum growth for a total of 14 gorgonian species was 8.3 cm/year. These authors (Coma et al., 1998) found growth of 8-30 mm during the first year in *Eunicella singularis* (Esper, 1794) and that the largest colonies (55 cm) in a population of *P. clavata* in the Medes Islands were approximately 31 years old. Munari *et al*. (2013) reported a growth rate of 3.55 to 4.52 cm/year for two populations of *E. singularis* in the Tyrrhenian Sea. It is also known that growth varies between and within years for a particular species and especially in relation with the colony age. Thus, Sartoretto & Francour (2012) noted a variable growth rate with age for *Eunicella verrucosa* (Pallas, 1766) populations along the Marseilles coast (France), shifting from 3.33 cm/year in colonies with a height less than 15 cm to 0.62 cm/year for populations with a height greater than 40 cm. All this reveals that the absence of colonies smaller than 15 cm in our study is the result of a low rate of population regeneration by sexual reproduction (low recruitment), and this is also supported by our results on growth after pruning (Table 1), where the maximum growth detected for a colony branch was 5.8 cm/year.

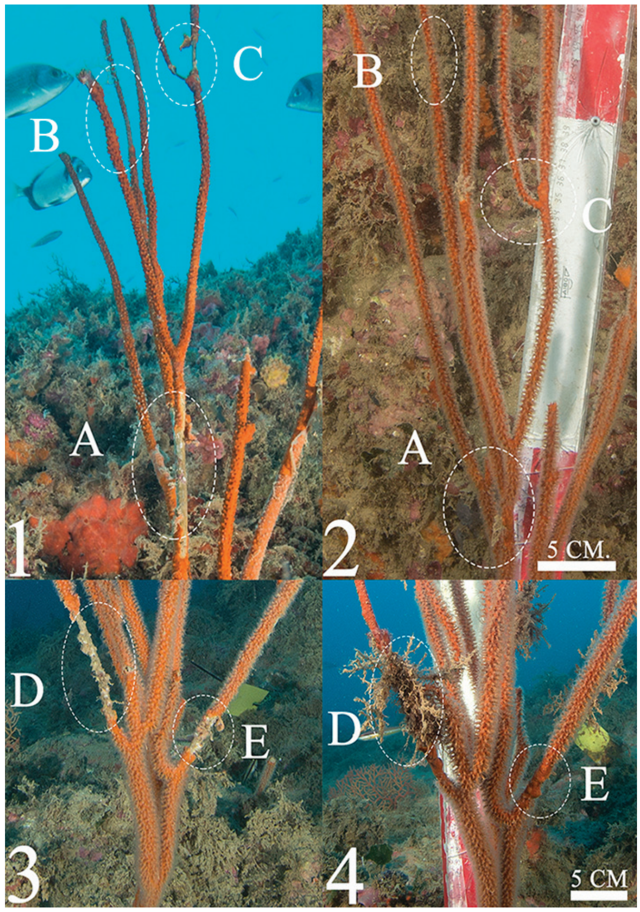

Fig. 5: Two colonies of *E. paraplexauroides* just after pruning (1 and 3) and a year later (2 and 4) showing the regeneration of tissues (inside ovals).

Fig. 6: Colony of *E. paraplexauroides* being predated by the polychaete *Hermodice carunculata.*

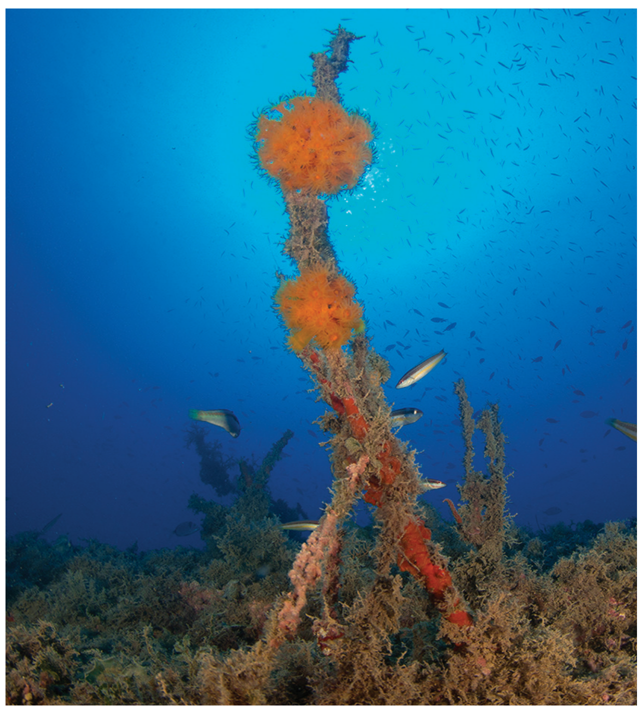

Fig. 7: Dead colony of *E. paraplexauroides* covered by epibionts, particularly two colonies of *Astroides calycularis* (Pallas, 1766), and with fishing gear in its lower-left portion.

Moreover, all these negative effects on the Chafarinas Islands *E. paraplexauroides* population can be magnified as a consequence of mortality episodes due to rising temperature events, such as those in 1999 and 2003 (Cerrano *et al*., 2000; Cupido *et al*., 2009; Cebrian *et al*., 2011), which affected other species of gorgonians in other locations in the Mediterranean. Additionally, in the Chafarinas Islands, in summer 2015, mass mortality of *E. singularis* and increased epibiosis in *P. clavata* were detected (unpublished data). Because the dead colonies of *E. singularis* were heavily covered by epibionts, the mortality should have occurred at the end of summer 2014 after our sampling. These episodes of high temperature could also have important consequences for populations of *E. paraplexauroides* with a usually deeper distribution.

The previously reported problems for *E. paraplexauroides* in the Chafarinas Islands lead us to consider the difficult recovery of the population by itself under natural conditions and, consequently, the need to assist with some management measures based on the "gardening" concept (Rinkevich, 2015). As can be deduced from our results, the application of pruning and cleaning entails very positive effects on the colonies: growth of branches (Fig. 3; Table 2), production of new branches (Fig. 4; Fig. SD7) and regeneration of tissues (Fig. 5) as well as the general improvement of the colonies (Figs. SD1-SD10). From the obtained results, two conclusions should be drawn: 1) tissue regeneration is much more effective when the gorgonian axis is completely cleaned and the fragment to recover is not too long, and 2) pruning is only applicable to colonies with a healthy base.

The results obtained are encouraging, and investigations should be continued with the long-term monitoring of both the studied colonies and some new ones, as well as with further experiments with a large number of samples to truly understand the significance of this technique. Moreover, it is necessary to perform studies on the biology of this species to fulfil the current scarce knowledge. In particular, topics such as growth rate, recruitment, and regeneration of damaged tissues together with new experience in "gardening", including sowing (previously applied to other gorgonian species), should be addressed. Pruning should also be applied to other threatened gorgonian species with epibiotic processes. Nevertheless, management and surveillance measures are needed to prevent artisanal and sport fishing from continuing to cause damage to the colonies.

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