The state of red coral (*Corallium rubrum*) populations in the N.W. Sardinian fishing grounds

Lorenzo A. Chessa°, Michele Scardi*

°Department of Plant Protection -Ecology-
Sassari University– Italy
chessa@uniss.it

*Department of Biology
Tor Vergata University
Rome, Italy

Abstract
Some aspects concerning distribution and ecology of the red coral (*Corallium rubrum*) in N.W. Sardinian coast and in particular on fishing grounds are discussed. In particular the distribution of the shallow as well as deep population are considered. The main population parameters are exposed with a particular emphasis for those colonies of a commercial value for which a calculation of the structural complexity has been made.
The fishing techniques are also discussed keeping count of the recent technological advances that could allow a safe fishing with a high level of environmental protection and good management.

Key words: Corallium rubrum*, population structure, ROV, Sardinia*

Introduction
Sardinia Island has always been one of the most important place in the Mediterranean for the distribution of the precious red coral *Corallium rubrum*. This fact has been recognized since XII century. The fishing activities date back to the XII and XIII centuries. The deep coral (from 80m depth) is the only one which is permitted to fish.
This paper describes the distribution and some biometrical parameter and features of the populations of the red coral in the N.W. Sardinian coast. Moreover since the Sardinian and the Mediterranean legislations don't allow ROV coral fishing (it is restricted to professional divers with mattock) a preliminary approach that aims to minimize the impact of ROV if employed for red coral fishing, is described.

Materials and Methods
The study area is located in the coast of Alghero, the only, in NW Sardinia, where it is possible to find red coral in shallow as well as deep water. In shallow waters surveys were made by divers equipped with ARA while, in deep waters, by professional fishermen equipped with special helium-based gas mixtures. In this latter case the fishing grounds and coral shoals were also explored by ROV and a mini-submarine. Morphometric data were obtained by 200 ramifications measuring the basal diameter and the height with a calliper and a ruler and the wet weight with an electronic balance. The number of apices was counted and a number of pictures analysed as a preliminary approach to the study of the structural complessity of the ramifications.

Resultst
As it is generally found in other places of the Mediterranean, two red coral populations were identified: (1) dense shallow-water populations represented by small, slow-growing, short-lived colonies and (2) deep-dwelling populations, composed of large, sparse, long-lived colonies (Santangelo & Abbiati, 2001). The shallow water coral colonies mainly populated the obscure caves very abundant from Punta Giglio to Punta Ghiscera (Marine Protected Area of "Capo Caccia-

Isola Piana"), (Chessa *et al*., 1999), (Fig. 1), they ensure a reproductive stock for the species and are of great aesthetic value.

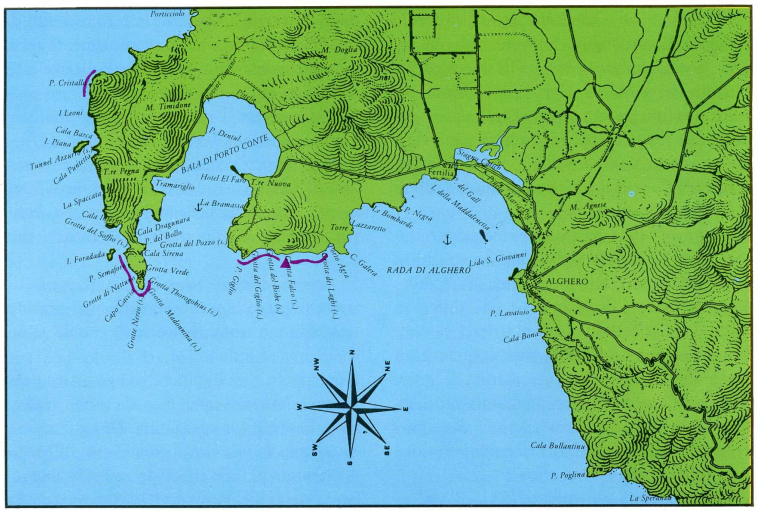

Fig. 1 -Distribution of shallow red coral (violet lines) along Alghero coast (Italy). (Russino, Chessa, 1989)

The density of shallow coral is 1345 ± 513 s colonies/m^2. The biomass is nearly 1106 g w.w./m^2. The height range of colonies is from 6 to 85 mm. Fifty percent of colonies has a height between 39 and 58.5 mm. Their weight is from 0.03 g to 6.4 g. The basal diameter is between 1.32 to 10.56 mm (Chessa *et al*., 1991). The average number of apices is 8.9.
The estimated maximum age based on literature data is 7 years (older colonies), (Harmelin, 1984; Garcia-Rodriguez e Massò, 1986b).
The deep settlements are located on coralligenous assemblages (Fig. 2) and shoals. This is one of the most important fishing area in Sardinia. The colonies settle mainly on vertical cliffs, at the edges and on the horizontal surface of the coralligenous reefs (Fig. 3).
The ramifications are of a good quality with low necrosis cases (<25% as number of colonies), moreover damages caused by parasites are negligible. The density of ramifications is equal to 2.5987 ± 0.0585 s g/cm^3.
The relationship of the wet weight (W) *vs*. basal diameter (D) is: $W = 0.4634\ D^{1.9125}$. The frequency distributions of the diameter (mm) and the wet weight are shown in Figg. 4-5. The average basal diameter is equal to 9.6 mm ± 2.2s wet weight is equal to 39.7 g ± 27.6s. The average height is 164 ± 44s.
Although until now no "in situ" density measures have been made, the ROV surveys showed no signs of depletion.
The colonies appeared rather branched, the average number of apices is 26 ± 13s but more then 100 of them had 30 to 40 apices (Fig. 6).

In 1990, 30 colonies in a shoal at 90 m depth W of Capo Caccia (Sardinia) were labelled "in situ" using plastic drilled labels (Fig. 7) . These colonies were accurately measured to determine the rate of growth, but unfortunately none one of them was still found due to the different positioning system currently in use.

Concerning the fishing techniques, as mentioned above, in Sardinia only professional divers can fish coral. They harvest red coral using a mattock and a net. The fishing ground are very deep, around 140 m with very high risk. For these reasons we started a research that aim to the

introduction of the ROV for coral fishing. The collection of coral by ROV or by manned submersibles are widely practiced in Pacific Ocean (Masanori & Muzik, 2009; Grigg R.W., 1993).

Fig. 2 – Main fishing grounds of red coral in N.W. Sardinian coasts (modified Google map)

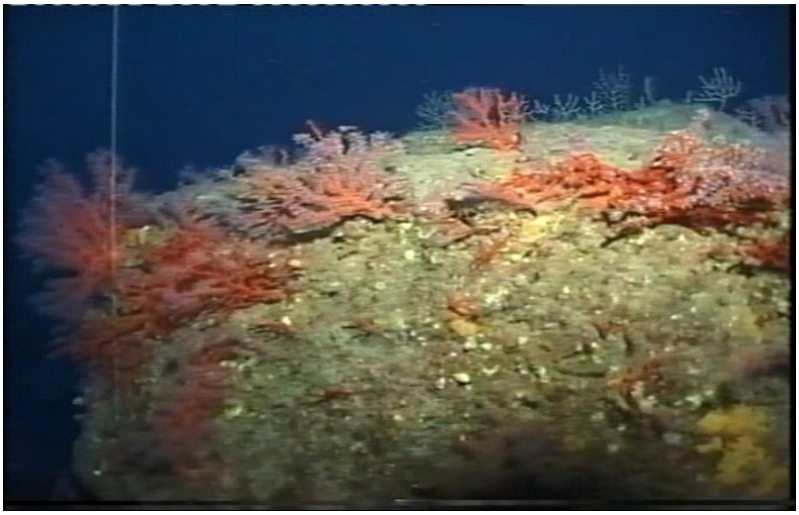

Fig. 3 – Horizontal settlement of deep red coral N.W. Sardinian coasts (From Gaymarine movie)

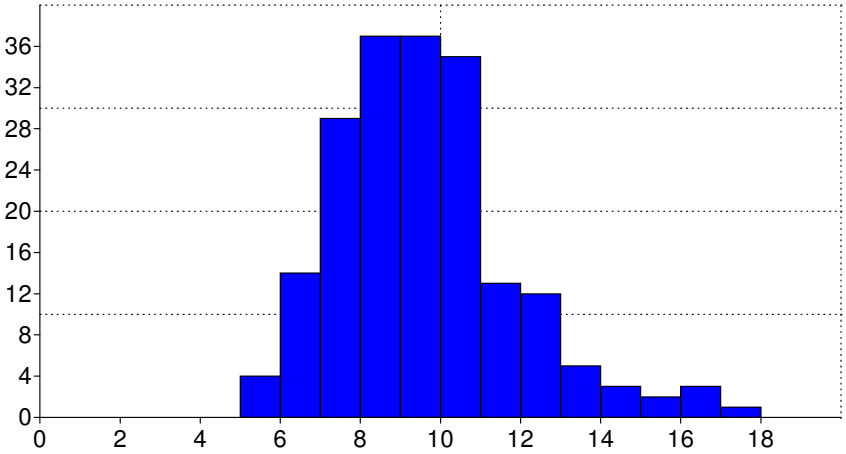

Fig. 4 - Frequency distribution on the basal diameter (mm)

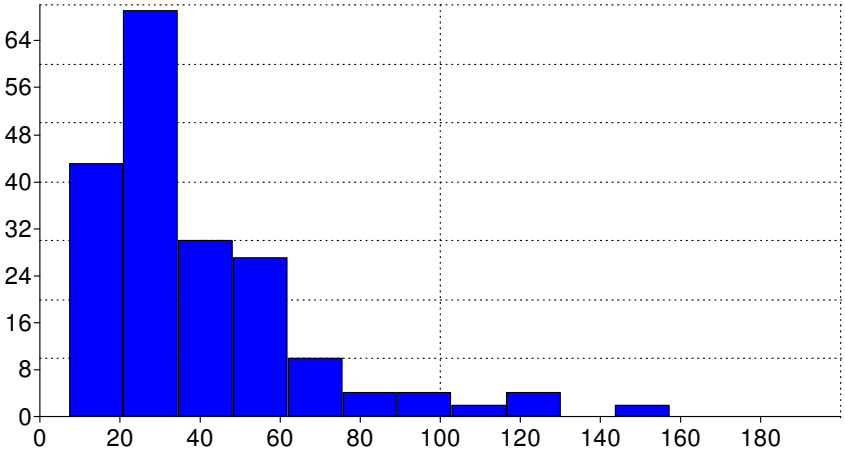

Fig. 5 – Frequency distribution of the wet weight (g)

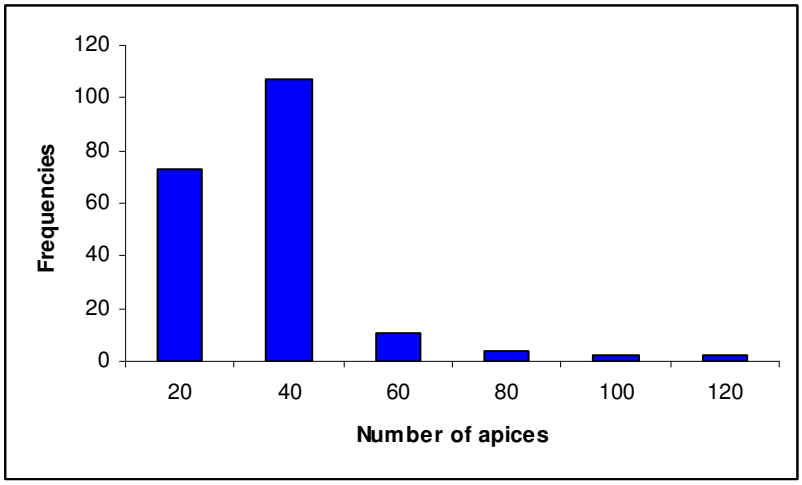

Fig.6 – Distribution of the frequencies of the number of apices

Fig. 7 – The tags used to label the deep red coral colonies (90 m depth)

Our approach has already been exposed in other scientific meetings (Chessa & Scardi, 2010). It is based on the application of machine learning techniques that allow a good estimation of the basal diameter of a red coral colony starting from the wet weight and number of apices. These could be counted by ROV images and image analysis (Fig. 10).

Working with deep coral colonies we found that the correlation between W and the number of apex (A) was quite good (r = 0.77**), while the one found between D and A was somewhat weaker (r = 0.50**). This could be due to the fact that the W *vs*. A correlation depends on colony shape, which in turn depends on D. This means that the relation that links A to the other parameters is not a simple one. The log-log linear correlation between W and D ($W=0.4634 \cdot D^{1.9125}$, MSE=369.2), is a rather good one. According to it, the ramifications that can be fished on the basis of Sardinian

regulations are those with a minimum weight of 37.9 g (10 mm diameter). Colonies of 24,7 g (8 mm diameter) can be fished with some limitations (20% of tolerance). The correlation between predicted and observed wet weight, based on a validation set of 63 colonies, was r=0.76**, thus showing that using A to assess W was a viable solution for red coral colonies. Using the Classification Tree (Breiman *et al.,* 1984). (see a sample branch in Fig 8) not only provided slightly better weight estimates (MSE=355.7) tha regression, but it also allows obtaining those estimates with no calculations, using a simple table. For instance, the expected weight of a colony with 23 apices is 31 g (see Fig. 8) and therefore its expected basal diameter is larger than 8 mm. This way an operator can easily decide whether a colony can be harvested or not.

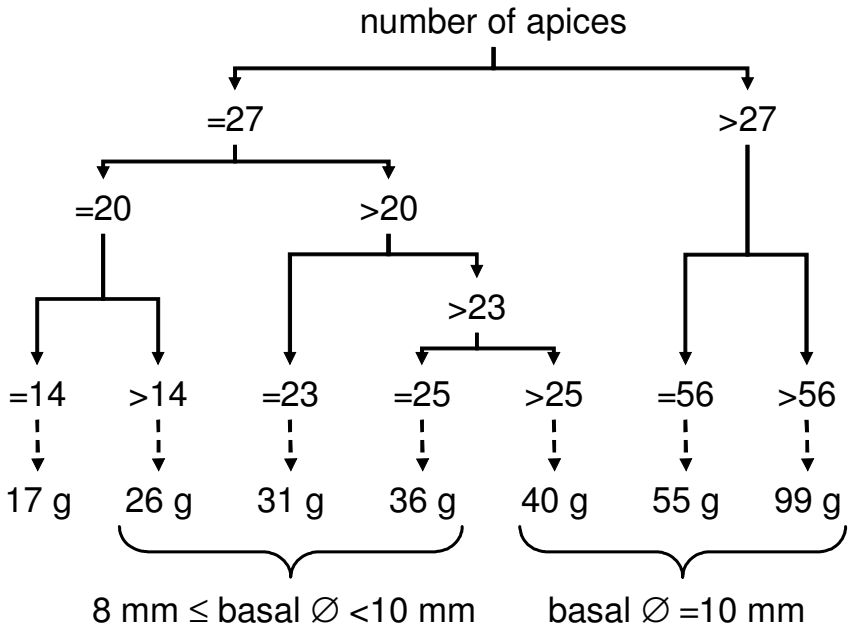

Fig. 8 – A sample branch of the Classification Tree: it predicts the weight of colonies with 20 or less apices (this is only a small part of the whole tree, which has 6 leaves).

A second approach that is still in progress is based on the application of the "box counting" dimension which is loosely related to the Hausdorff dimension (Duvall *et al*., 2000) and that can give estimation of the structural complexity of a colony. By means of one of the several filters or pre-processing techniques we separated the coral ramification shape from its background. Growing the pixel size we obtained an estimation of structural complexity based on "box counting" dimension (Fig. 9). If it is $\propto$ to shape complexity and shape complexity is $\propto$ to colony size than "box counting" dimension is $\propto$ to colony size. A tool like this implemented by a software can "tell" the ROV operator if a colony can be harvested or not, thus allowing a conscious fishing.

Discussion

The shallow red coral populations of N.W. Sardinia that in the sixties ran the risk to disappear, because of the heavy harvest by divers, are now well protected because the coast has become a Marine Protected Area ("Riserva Marina di Capo Caccia-Isola Piana").

The exposed data concerning some population descriptors of deep red coral together with ROV surveys show no signs of over exploitation. The average basal diameter and height, are well above the harvested populations described by Garrabou & Harmelin (2002) for several Mediterannean locations. This means that the number of licences that the Sardinia Government issued for this district are fully compatible with red coral protection. However today the fishermen must dive deeper and deeper to collect coral of a commercial value with consequent high risk. The use of

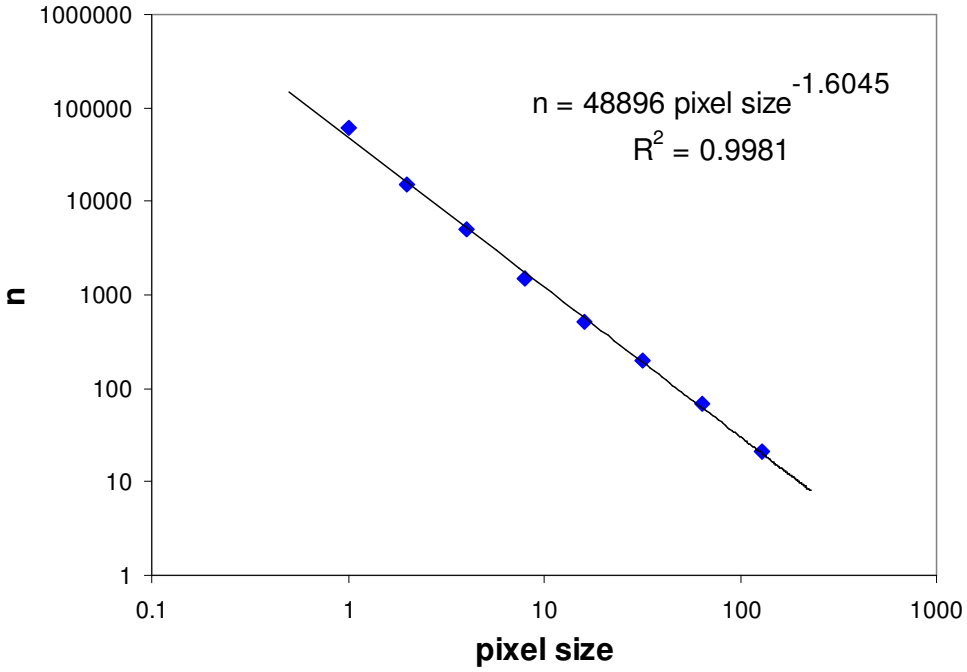

Fig. 9 - Representation of the "box counting" dimension of a deep red coral colony

ROV specifically designed for this purpose can solve this problem and the machine learning and the "box counting" dimension approaches though not the only possible represent a valid tool for a responsible fishing.

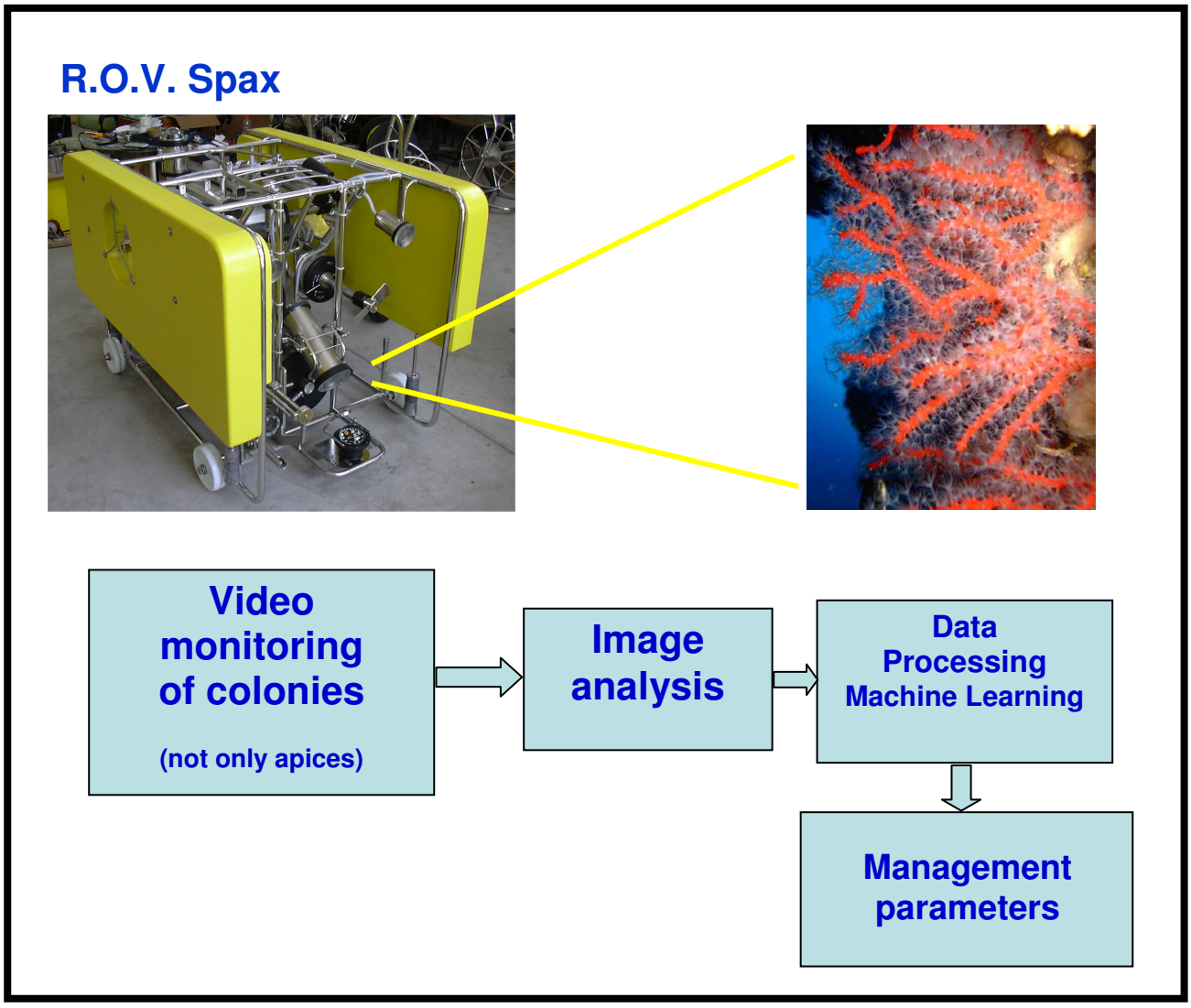

Fig. 10 – Conceptual diagram of Machine Learning application to ROV red coral surveys

Bibliography

Breiman L.F.J, Olshen R., Stone C. (1984). *Classification and regression trees*. Chapman and Hall, New York.

Chessa L.A., Vitale L., Scardi M. (1999). Descrizione dell'ambiente sommerso con censimento e studio delle grotte sottomarine: In *Protezione dell'ambiente e gestione delle risorse naturali*: *Quaderni dell'Istituto di studi Politico-Giuridici dell'Università di Pavia*. Collana Diritto e Ambiente, a cura di M. Gutierrez. Cedam: 167-198.

Chessa L.A., Pais A., Cudoni S. (1992). Indagine su *Corallium rubrum* (L) nel promontorio di Punta Giglio (Sardegna Nord-Occidentale). *Oebalia*, Suppl. **17**: 485-493.

Chessa L.A., Scardi M (2010). Biometrical analysis and observations on deep red coral *Corallium rubrum* in N.W. Sardinia shoals (Italy). In Bussoletti, E., D. Cottingham, A. Bruckner, G. Roberts, and R. Sandulli (editors). 2010. Proceedingsof the International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean. NOAA Technical Memorandum CRCP-13, Silver Spring, MD 233 pp.

Duvall P., Keesling J., and Vince A. (2000). "The Hausdorff Dimension of the Boundary of a Self-Similar Tile. *J. London Math. Soc*.: **61**: 649-760.

Garcia-Rodriguez M, Masso C. (1986). Algunas bases para la determinacion directa de la edad del coral rojo (*Corallium rubrum* L). *Bol Inst Esp Oceanogr* **3(4)**:6 5–74.

Grigg R.W. (1993). Precious coral fisheries of Hawaii and theU.S. Pacific Islands: fisheries of Hawaii and U.S.-associated Pacific Islands. *Mar Fish Rev* : **55**: 50–60.

Harmelin, J.G (1984). Biologie du corail rouge. Parametres de populations, croissance et mortalite naturelle. Etat des connaissance en France. FAO Fisheries Report, **306**: 99-103.

Masanori N., Muzik K. (2009). Recent harvest of commercially valuable precious corals in the Ryukyu Archipelago. *Mar.Ecol. Prog. Ser*.: **397**: 269-278.

Russino G.A., Chessa L.A. (1989). Vita sotto il mare di Alghero, Vo. I, Vegetali e Invertebrati. La Celere Editrice, 180 pp.

Santangelo, G. and Abbiati, M. (2001). Red coral**:** conservation and management of an over-exploited Mediterranean species. *Aquatic Conservation: Mar. Freshw. Ecosyst*., **11**: 253-259.