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CONNECTIVITY AND MANAGEMENT OF *CORALLIUM RUBRUM* COMMERCIAL BANKS

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Understanding patterns of population genetic structuring provides an invaluable contribution for a scientifically sound management and conservation of exploited marine species. When tracking of larvae in the field is not possible, genetic data allow quantifying gene flow and larval connectivity among populations. Little is known about larval ecology of the exploited species of the genus *Corallium*, such as the Mediterranean red coral (*C. rubrum*), and the Pacific and Atlantic species (e.g. *C. secundum*, *C. lauuense*). Population genetic studies, done mainly on Mediterranean red coral, investigated connectivity patterns at different geographical and bathymetrical distances. Mediterranean shallow water red coral populations showed chaotic genetic structuring. Surprisingly strong divergence among populations was observed at very short distances, down to 1m. Reduction of genetic variability along a depth gradient was reported, with a major drop across 40 m in depth. These information, together with those gathered on population structure, supported the recommendation by the FAO-GFCM Committee to ban red coral harvesting above 50 meters depth. Recent studies on commercial banks (50-120m depth) provided a different picture on genetic structuring, compare to shallow populations. A major barrier to gene flow was found between the northern and southern Tyrrhenian Sea. These results suggest that criteria used in management of deep red coral banks, which are exploited nowadays, require a careful evaluation and can not be inferred from patterns observed in shallow water populations. Off shore marine protected areas for the conservation of red coral and deep sea biodiversity need to be established in the Mediterranean sea.

DEMOGRAPHIC PARAMETERS OF TWO POPULATIONS OF RED CORAL (*CORALLIUM RUBRUM* L. 1758) IN THE NORTH WESTERN MEDITERRANEAN

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The demographic and reproductive structure of populations represents the main data set needed for conservation and management plans. Mediterranean red coral *Corallium rubrum* has been exploited for 2000 years but only recently management plans have been solicited by the international community. We examined the demographic features of two red coral shallow populations located in distinct geographic locations: Portofino (Italy) and Cap de Creus (Spain). Adults and recruits density, growth rates, population size and age structure, fecundity and fertility were examined. Recruitment was the dominant class (33%) in both populations. The analysis of the gamete content of 653 colonies revealed that the populations have balanced sex ratios and similar fertility and polyp fecundity. The average annual growth rate, determined on 119 colonies by annual growth rings count, was similar in both populations (0.24 mm y^{-1}), decreasing with colony age. Maximum life span of 99% of the colonies was 60 and 40 years at Portofino and Cap de Creus, respectively. Minimum harvestable size (7 mm basal diameter) was reached in 30-35 years and the percentage of colonies above it was 6.7% at Portofino and 2.1 % at Cap de Creus, where recruitment and adult colony densities were significantly lower and the percentage of commercial-sized colonies reduced by 25% in just a few years. Notwithstanding similar growth and fecundity, the two populations showed different densities and size/age structures suggesting local factors, together with different fishing pressures, have to be taken into account in the management plans for this species.

MONITORING OF THE RED CORAL HARVESTING IN SARDINIA BY ON-BOARD SCIENTIFIC OBSERVERS

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Since 1979 the Sardinian Government has implemented a management plan for *Corallium rubrum*; this has allowed maintaining the exploitation sustainable.

During the 2012 and 2013 red coral harvesting seasons, a new management tool has been tested: the monitoring on-board, based on scientific observers. This experience allowed to monitoring several aspects of the exploitation: i) the actual ban on the use of ROV for the harvesting, in accordance with the Recommendation GFCM/35/2011/2, ii) the respect of regulations for the exploitation enacted in the annual Regional Decrees and iii) the gathering of data for the assessment of the state of the resource and how it is exploited.

Two areas (in the North and Central Western coast of Sardinia) were surveyed, for a total of 424 days-at-sea, 375 dives and about 16800 colonies measured. All these data has allowed the identification of where the harvesting effort is concentrated (location and depth range) as well as to estimate of the daily catches and the percentage of under legal sized colonies (< 8 mm basal diameter) in the different areas and bathymetric ranges.

In general, the comparison of data between the two years points out an alarming trend: divers catch more coral, of smaller size and to this they need go deeper and deeper, suggesting the need for new management actions, stricter controls, and additional scientific surveys on the actual status of exploited banks.

Considering the bulk of data collected and the effectiveness in enforcing the regulations, the observers' program has proved to be a useful management tool and should be confirmed also for the incoming harvesting seasons.

THE OPPORTUNITY OF USING THE ROV FOR BETTER MANAGEMENT OF *CORALLIUM RUBRUM* AND FOR THE SAFETY OF WORKERS

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In the early '60s the professional underwater fishing of the red coral started; initially from 30 m to -70 m depth. Today free divers between 100 m and 140 m depth are common. These are made without any contact with the vessel, with no possibility of recovery in case of accident or illness, without any specific professional title and with the help of a crew not qualified. In short, the work is performed at the limit of the human possibilities.

The new European safety rules impose, to all professional divers operating over 50 m depth, the use of hyperbaric plants in closed bell, cables and umbilical cords. Besides a constant audio-visual monitoring, medical assistance as well as adequate naval support means are required.

The coral harvesting is to be considered, without any doubt, a diving professional activity, and as such, it needs to ensure compliance with all safety regulations. The international safety rules mentioned are applicable on industrial scale, but not on artisanal scale for economical reasons. A code of conduct for a responsible fishing must of course take into account these issues, already apparent at important international conferences such as the GFCM of Ajaccio - 2011 and the GFCM of Alghero - 2010. During those Meetings, the extreme difficulties of the means of fishing of coral divers were discussed and a scientific contribution to prove the validity of ROV for a conservative red coral fishing was also given. In the General Conclusions of those Meetings it was recognized that the ROV is an effective tool for research surveys on red coral populations and that it can harvest the red coral in a healthier way (for the environment) that a diver can do. Not surprisingly, the GFCM recommend the Member States to initiate appropriate experimental campaigns in different sites and areas of the Mediterranean. with the direct involvement of the operators, in order to test and evaluate the proper functioning of the ROV for harvesting in good conditions of profitability, safety for the fisherman and sustainable for the environment.

This paper discusses the opportunities offered by the new ROV technologies for coral fishing comparing critically some scientific emergencies and some practical aspects as well as the reflections of these approach in the safety for the operators.

THE SCHAEFFER PRODUCTION MODEL FOR THE SETTING OF OPERATIONAL OBJECTIVES: AN EXEMPLE FROM SARDINIA

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Using the fishing effort and red coral catch data recorded in logbooks, between 1990 and 2012 by Sardinian fishermen, the Schaeffer production model was applied. The results derived from the model were used for the setting of operational objectives to be used in the red coral management plan. The model showed that the B_{2012} (biomass present at sea in 2012) appeared lower than the biomass values registered in the 1990s and than the carrying capacity (limit value where the red coral biomass should stabilize without harvesting). Although, the B_{2012} value is far from the B_{target} (value of target reference point), it must be considered a sign of suffering of the Sardinian red coral. Even if, for a more complete and real assessment of the condition of the stock, the production model results must be considered together with those derived from analytical models, these preliminary results can confirm that in Sardinian seas the fishing effort on red coral should not be increased during the next years of management.

CONSERVATION AND MANAGEMENT OF THE HIGH VALUABLE MEDITERRANEAN RED CORAL: THE DEEP-DWELLING COMMERCIAL POPULATIONS

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Demography supplies basic tools for conservation and management of overharvested, long-lived species. The high valuable, endemic, temperate gorgonian *Corallium rubrum* has been harvested in the Mediterranean since 2,000 years and several populations have been depleted. Recently, some efforts have been addressed towards conservation and management of the populations living in the shallower portion (within 50 meter depth) of the wide bathymetric distribution range of this species. Notwithstanding, the deep dwelling, commercial populations, have only been scarcely studied by a demographic point of view. This lack of knowledge is mainly due to the difficulty to carry out quantitative studies on populations living below 50-60 m depth. To fill this lack of knowledge two research projects were promoted by the Italian Environmental and Agriculture Ministries and a PhD thesis at Pisa University was carried out (C. Priori, Demography of “deep-dwelling “red coral populations). These researches were conducted by means of the Astrea research vessel offshore the Liguria, Tuscany, Campania and Sicily coasts. The rocky sea bottom between 50 and 200 meters depth was firstly mapped by Multibeam Echo sound and coral patches were recorded inside 60 ROV transects. Red coral colony samples were also collected by technical diving. On the basis of these researches the population reproductive output and annual colony growth rates have been assessed. Our findings allowed us to estimate an annual average growth rate of 0.26 mm in basal diameter. A colony with an age of 30-35 years reaches a basal diameter of 7 mm (the minimum legal size proposed by FAO-GFCM in 2011), population sex ratio was balanced and the reproductive output of female colonies ranged between 400 and 6.500 planulae. Based on these findings and on those obtained by ROV recordings, it will be possible to set out harvesting and management plans based on population size/age structure and population growth rates.