# *ADAPTIVE MANAGEMENT PLAN FOR RED CORAL (Corallium rubrum) IN THE GFCM COMPETENCE AREA*

## FIRST PART – BACKGROUND INFORMATION

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# ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| **BH** | Beverton and Holt model |
| **CITES** | The Convention on International Trade in Endangered Species of Wild Fauna and Flora |
| **CoP** | Conference of Parties |
| **EAF** | Ecosystem Approach to Fishery |
| **FAO** | Food and Agriculture Organization of the United Nations |
| **GFCM** | General Fisheries Commission for the Mediterranean |
| **IUCN** | International Union for Conservation of Nature |
| **MPA** | Marine Protected Area |
| **MSY** | Maximum Sustainable Yield |
| **NGO** | Non-Governmental Organization |
| **NMP** | National Management Plan |
| **OY** | Optimum Yield |
| **RAC/SPA** | Regional Activity Centre for Specially Protected Areas |
| **RMP** | Regional Management Plan |
| **ROV** | Remotely Operated underwater Vehicle |
| **SAC** | Scientific Advisory Committee |
| **SAP BIO** | Strategic Action Programme for the Conservation of Biological Biodiversity in the Mediterranean Region |
| **SC** | Sub Committee |
| **SPA and BD** | Specially Protected Areas and Biological Diversity in the Mediterranean |
| **SPA** | Specially Protected Areas |
| **UNEP-MAP** | United Nations Environment Programme - Mediterranean Action Plan |

## SUMMARY

The present document has been prepared to gather together all the available information useful for the first preliminary draft of a regional management plan (RMP) for red coral (*Corallium rubrum*) in the GFCM competence area.

It is prepared according to the Recommendation GFCM/35/2011/2 on the exploitation of red coral in the GFCM Competence Area that states:

"Scientific and technical knowledge acquired through the actions stipulated under paragraphs 3 (c), 5, 7 and 9 above shall be taken into account by SAC with a view to develop an adaptive regional management plan" (Paragraph 10)

and the Recommendation GFCM/36/2012/1 on further measures for the exploitation of red coral in the GFCM area that states:

**"**In addition to substantiate the Terms of Reference provided in the 2012 Work Plan of its Sub-Committee for Marine Environment and Ecosystems, and pending the development of a regional management plan for red coral, as requested by the Recommendation GFCM/35/2011/2..." (Paragraph 6)

"The GFCM Secretariat is requested to take actions in support of the SAC with a view to put into operation, not later than 31 May 2013, the adaptive regional management plan." (Paragraph 7)

Three parts compose it:

'FIRST PART – BACKGROUND INFORMATION' contains data related to the distribution, biology, fishery, and legal instruments dealing with red coral

'SECOND PART – SOCIO-ECONOMIC ASPECTS' summarizes the main socio-economic data related to the red coral fishery

'THIRD PART – MANAGEMENT of red coral' contains the proposed the management for red coral

The first and second parts complement each other; only the combination of the two can give a complete picture of the past and present aspects concerning *C. rubrum*.

The first part is divided in five sections:

**BIOLOGY OF RED CORAL**
**FISHERY OF RED CORAL**
**NATIONAL LEGAL INSTRUMENTS FOR RED CORAL**
**INTERNATIONAL LEGAL INSTRUMENTS FOR RED CORAL**
**INTERNATIONAL LEGAL FRAMEWORK FOR MANAGEMENT OF RED CORAL**

The first section summarizes all the scientific information concerning the biology of the species including the main threats and environmental issues related to red coral and more in general gorgonian corals of the coralligenous biocoenosis. A brief discussion on the data available for management and how to improve them in terms of quantity and quality is provided.

The second section contains the description of the fishing methods, providing historical as well as current data on harvesting retrieved from the FAO and GFCM databases.

The third and fourth sections collect laws, both at the international and the national level, dealing with *C. rubrum* conservation and more in general management of fishery resources, and management of red coral at the national level.

Finally, the fifth section describes the international legal framework under which the red coral resource can be managed.

# BIOLOGY, ECOLOGY AND CONSERVATION OF RED CORAL

The biology of the red coral, *Corallium rubrum*, differs in many aspects from that of other commercially exploited marine organisms.

Many of its peculiar features, summarized in the following sections, can have important implications for the effectiveness of management plans.

## CLASSIFICATION AND TAXONOMIC ISSUES IN THE FAMILY CORALLIDAE

According to the information found in the WoRMS databases (van Ofwegen, 2012), the current accepted classification for the Mediterranean red coral (known also with the common name of Sardinia coral) is as follows:

| | |
|---|---|
| **Phylum** | Cnidaria Hatschek, 1888**;** |
| **Class** | Anthozoa Ehrenberg, 1834; |
| **Subclass** | Octocorallia Haeckel, 1866; |
| **Order** | Alcyonacea Lamouroux, 1816; |
| **Suborder** | Scleraxonia Studer, 1887; |
| **Family** | Coralliidae Lamouroux, 1812; |
| **Genus** | *Corallium* Cuvier, 1798; |
| **Species** | *Corallium rubrum* (Linnaeus, 1758) |

Along with *C. rubrum*, the family Coralliidae comprises some other 35 species distributed in two genera (in bold are shown the species of commercial interest):

1. Genus *Corallium* Cuvier, 1798 including the following species:
    - *Corallium abyssale* Bayer, 1956
    - *Corallium borneanse* Bayer
    - *Corallium boshuense* Kishinouye, 1903
    - *Corallium carusrubrum* Tu, Dai & Jeng, 2012
    - *Corallium ducale* Bayer
    - ***Corallium elatius* Ridley, 1882**
    - *Corallium gotoense* Nonaka, Muzik & Iwasaki, 2012
    - *Corallium halmaheirense* Hickson, 1907
    - *Corallium imperiale* Bayer
    - *Corallium johnsoni* Gray, 1860
    - *Corallium kishinouyei* Bayer, 1996
    - ***Corallium konojoi Kishinouye, 1903***
    - ***Corallium laauense Bayer, 1956***
    - *Corallium maderense* (Johnson, 1899)
    - *Corallium medea* Bayer, 1964
    - *Corallium niobe* Bayer, 1964
    - *Corallium niveum* Bayer, 1956
    - *Corallium porcellanum* Pasternak, 1981

- *Corallium pusillum* Kishinouye, 1903
- *Corallium reginae* Hickson, 1907
- ***Corallium regale* Bayer, 1956**
- ***Corallium rubrum* (Linnaeus, 1758)**
- ***Corallium secundum* Dana, 1846**
- *Corallium sp. nov*
- *Corallium sulcatum* Kishinouye, 1903
- *Corallium taiwanicum* Tu, Dai & Jeng, 2012
- *Corallium tricolor* (Johnson, 1899)
- *Corallium uchidai* Nonaka, Muzik & Iwasaki, 2012
- *Corallium vanderbilti* Boone, 1933
- *Corallium variabile* (Thomson & Henderson, 1906)

2. Genus *Paracorallium* Bayer & Cairns, 2003 including the following species:
    - *Paracorallium inutile* (Kishinouye, 1903)
    - ***Paracorallium japonicum* (Kishinouyi, 1903)**
    - *Paracorallium nix* (Bayer, 1996)
    - *Paracorallium salomonense* (Thomson & Mackinnon, 1910)
    - *Paracorallium stylasteroides* (Ridley, 1882)
    - *Paracorallium thrinax* (Bayer & Stefani in Bayer, 1996)
    - *Paracorallium tortuosum* (Bayer, 1956)

Several undescribed species are reported to exist within the Coralliidae, the taxonomy of the Midway coral listed as *Corallium sp. nov* has not yet been clarified and it may actually represent several species of the family Coralliidae (Grigg, 2002). Moreover, the basis for its inclusion in the genus *Corallium* or the family *Coralliidae* remains unpublished (IUCN/TRAFFIC, 2009).

*C. lauuense* and *C. regale* are listed as separate species even if sometimes they are considered to be synonymous (CITES, 2010).

Four species have been described and formally named only in 2012: *Corallium uchidai* and *Corallium gotoense* (Nokana *et al.,* 2012), *Corallium carusrubrum* and *Corallium taiwanicum* (Tu *et al.,* 2012). Nevertheless, the phylogenetic relationships within the precious coral family Coralliidae remain largely unexplored and their taxonomy somehow controversial. For instance, according to mitochondrial data of the recent paper of Ardila *et al.*, (2012), *Paracorallium* should not be a valid taxon, given that its species were all nested within *Corallium*. The only recognized genus should remain therefore *Corallium*, and *Paracorallium* as its junior synonym. However, some species (*C. johnsoni, C. abyssale, C. laauense, C. imperiale, C. niobe, C. sulcatum, C. ducale, C. halmaheirense, C. tricolor, C. maderense*), clustered together and they were proposed by Ardila *et al.*, (2012) to be included in the re-erect genus *Hemicorallium*.

## DISTRIBUTION

*Corallium rubrum* is a sciaphilous endemic species to the Mediterranean and the neighbouring Atlantic coasts that occurs primarily around the central and western basin (5-350 m, although more commonly at 30-200 m) with smaller populations in deeper water in the eastern basin (60-200 m) and off the coast of Africa around the Canary Islands, southern Portugal and around the Cape Verde Island (Chintiroglou *et al.,* 1989; Marchetti, 1965; Weinberg, 1976; Zibrowius *et al.,* 1984) (Figure 1). Recently, the bathymetric limits of red coral distribution have been greatly expanded: from 350 to 600-800 meter depth in the Central Mediterranean (Strait of Sicily) (Costantini *et al.,* 2010; Freiwald *et al.,* 2009; Taviani *et al.,* 2010).

In the Mediterranean, *C. rubrum* inhabits subtidal rocky substrates and is one of the dominant and important components of Mediterranean "coralligenous" species assemblages (Ballesteros, 2006), coexisting with other gorgonians, large sponges, and other benthic invertebrates.

The coralligenous biocoenosis, that hosts most of red coral populations, (Habitat identification code EUR27:1170; BARCON IV.3.1; EUNIS A4.26 and A4.32) is classified as a 'Priority habitat for conservation', that is a habitat whose conservation is mandatory because of its vulnerability, heritage value, rarity, aesthetic and economic values (Relini and Giaccone, 2009). More in general the coralligenous outcrops represent one of the hotspot for species diversity, and are considered a benthic habitat of high conservation interest (Ballesteros, 2006; UNEP/MAP, 2009), and also of special concern, as they are increasingly suffering impacts of a range of anthropogenic disturbances. In particular, the gorgonian corals play a very important role within the coralligenous biocoenosis as ecosystem engineers by providing structural complexity and biodiversity.

The precious red coral is found also outside the coralligenous, in the semi-dark caves (and upper enclaves) with the facies with *C. rubrum* (BARCON IV.3.2.2).

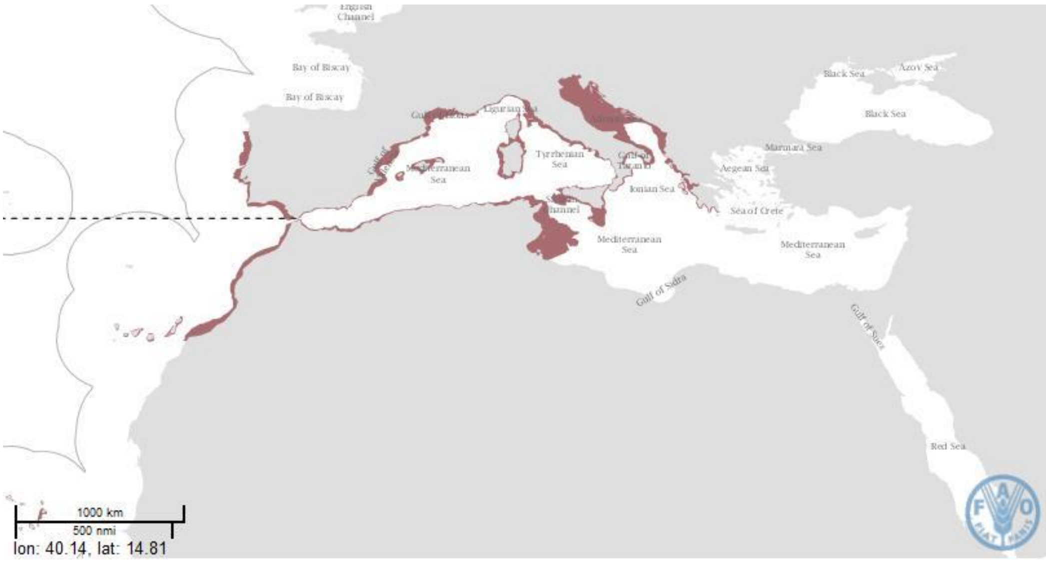


**Figure 1 – Map downloaded from FAO (2013); the square represent the maximum extension of the geographical distribution of red coral.**

Several studies (see the following sections) concordantly suggest the occurrence of different typologies of *C. rubrum* populations:

- **shallow-water populations** (depth range between 15 and about 50 m), dwelling on caves, crevices, overhangs and protected interstices. Many of them are reported to be over-exploited, in consequence of the heavy pressure exerted by SCUBA diving since the 1950s, able to picking of red coral in areas inaccessible to dredges. According to the Recommendation GFCM/35/2011/2 Paragraph 4, they are being fully protected from exploitation, to allow for their recovery.
- **deep-water populations** (depth range of between 50 and about 130 m), typically dwelling on open surfaces. The commercial harvesting was/is mainly focused on these populations. In the past, they were harvested by the use of dredging gears, nowadays, by divers down up to depths of 100-130 meters. They are the populations to be managed through the provisions of the Regional Management Plan (RMP) for red coral and the National Management Plans (NMPs).
- **deepest-water populations** (depth range 130 to about 800 m); poorly known. No legal harvesting is realized on those populations, but considering they are very sparse (very low densities) they are said of not commercial interest (not permitting any profitable exploitation). They should not be harvested in the future, as they could provide refugia for the species.

## THREATS AND ENVIRONMENTAL ISSUES

The red coral is considered one of the most vulnerable resources in the Mediterranean Sea because it is a long- lived species, with a slow growth, low fecundity and limited dispersal capabilities and consequently strong genetic differentiation of populations at spatial scales of 10s of meters (see following sections dealing with biology, ecology and genetics of red coral).

On account of its high economic value, the red coral has long been heavily exploited since ancient times (see the following sections on harvesting, both dealing with past and current aspects).

Fishing impacts are worsened by natural stressors and climate change, especially in shallow water where also mass mortality events have been documented since the late 1990s, attributed to a fungal and protozoan disease and linked to temperature anomalies (Bramanti *et al.,* 2005; Cerrano *et al.,* 1999; Garrabou *et al.,* 2009; Garrabou *et al.,* 2001; Perez *et al.,* 2000; Romano *et al.,* 2000). In particular, the Mediterranean red coral (*Corallium rubrum*) is expected to be particularly susceptible to acidification effects linked to climate change, due to the elevated solubility of its Mg-calcite skeleton. Recent experimental studies have shown, for the first time, evidence of detrimental ocean acidification effects on this valuable and endangered coral species (Bramanti *et al.,* 2013; Cerrano *et al.*, 2013).

Besides harvesting, other types of anthropogenic disturbances threat red coral populations: pollution, tourism, recreational diving, incidental takes, or habitat degradation (Coma *et al.,* 2004; Garrabou *et al.,* 1998; Linares *et al.,* 2003; Linares *et al.,* 2010b).

Currently, the most destructive impact affecting coralligenous communities is the action of trawling gear (Cinelli and Tunesi, 2009). In the past, special trawling used to collect the precious red coral by the so-called "Italian Bar" or "Saint Andrew Cross" proved to be highly destructive, causing degradation of large areas of coralligenous (RAC/SPA, 2008). Negative impacts on the coralligenous can be also caused by traditional artisanal fishing (long-lines, trammel nets, pots for catching lobsters), recreational fishing, diving activities and anchoring (RAC/SPA, 2008).

As most of the builder species (and red coral as well) are particularly long-lived, have low recruitment and complex demographic patterns, destruction of the coralligenous structure is critical as their recovery will probably take several decades or even centuries (Ballesteros, 2006; RAC/SPA 2008).

For instance, after 20 to 30 yr of protection within French and Spanish MPAs, red coral colony sizes did not reach the values of pristine populations (Garrabou and Harmelin 2002; Linares *et al.,* 2010a; Tsounis *et al.,* 2006b) suggesting that full recovery will require decades of effective protection (Linares *et al.,* 2010a; Torrents and Garrabou 2011; Tsounis *et al.,* 2006b).

Given the longevity of this species (more than 100 yr)(Garrabou and Harmelin 2002; Marschal *et al.,* 2004; Tsounis *et al.,* 2007), it seems reasonable to speculate that 20 yrs of protection are not sufficient to reach the size of pristine populations.

## REPRODUCTIVE BIOLOGY

Aspects of reproductive biology have been studied for the red coral *Corallium rubrum*, but they are still lacking. To date, except for the historical work of Lacaze-Duthiers (Lacaze-Duthiers, 1864), a few reports on red coral reproduction are published for shallow water colonies (Santangelo *et al.,* 2003; Torrents *et al.,* 2005; Tsounis 2005; Tsounis *et al.*, 2006a,b; Vighi, 1970, 1972; Weinberg, 1979). Since 2013, new knowledge on the fecundity of deep colonies is available for the Tyrrhenian Sea (Italy) (Priori *et al.,* 2013).

*C. rubrum* presents a limited capability for asexual reproduction. The sexual status of the population appears completely gonochoric at both the colony and the polyp level (Santangelo *et al.,* 2003; Tsounis *et al.,* 2006; Vighi 1970, 1972). Red coral is an iteroparous species, undergoes internal fertilization, and broods larvae internally (planulator). Gonadal development follows an annual cycle with a synchronized release in summer (Santangelo *et al.,* 2003; Tsounis *et al.,* 2006a; Vighi 1970). The embryonic period lasts about 30 days (Lacaze-Duthiers 1864; Vighi 1970). Colonies do not fuse together (in nature) and each adult colony therefore is likely to have originated from a singular planula (Stiller *et al.,* 1984; Weinberg, 1979). Larvae exist in the water column for a few hours to days before setting in close proximity to parent's colonies. It is therefore very likely that most populations are genetically isolated.

Data on fecundity is summarized in Table 1. Fertile female polyp of shallow water colonies produced from 1 to 4 mature oocytes per year, while each fertile male polyp produced 6±3.5 spermiaries on average (Santangelo *et al.,* 2003). Female fecundity and fertility are constant over time, but decrease after March, despite the fact that oocytes do not turn into planulae during this period (Santangelo *et al.,* 2003). Female's fecundity ranged between 0.05-3 mature oocytes per year has been found for the deep-water colonies (Priori *et al.,* 2013).

**Table 1 - Colonies fecundity in several Mediterranean shallow- and deep-water populations; fecundity is expressed as number of oocytes/ polyp /year.**

| COLONIES | Fecundity/sex | Substrate | Population examined | Reference |
|---|---|---|---|---|
| SHALLOW | 3-6/female | - | Italy (Liguria) | Vighi, 1970, 1972 |
| | 0.87/female | - | Italy (Calafuria) | Santangelo *et al.*, 2003 |
| | 0.9-1.6/female | - | Spain (Medes islands) | Tsounis *et al.*, 2006 a,b |
| | 1.0-3.2 / female | - | France (Provence) | Torrents and Garrabou, 2011 |
| | 2.1±1.5 / female | 39-42 m | France (Provence) | Torrents and Garrabou, 2011 |
| | 2.7±1.6 / female | 15-22 m | France (Provence) | Torrents and Garrabou, 2011 |
| | 2.7±1.6/ female | Cave entrance | France (Provence) | Torrents and Garrabou, 2011 |
| | 1-12/male | - | Italy (Liguria) | Vighi, 1970, 1972 |
| | 6/male | - | Italy (Calafuria) | Santangelo *et al.*, 2003 |
| | 1.9-3.9/male | - | Spain (Medes islands) | Tsounis *et al.*, 2006 a,b |
| | 5.0±1.7/ male | 39-42 m | France (Provence) | Torrents and Garrabou, 2011 |
| | 5.7±3.0/ male | 15-22 m | France (Provence) | Torrents and Garrabou, 2011 |
| | 5.7±3.0 / male | Cave entrance | France (Provence) | Torrents and Garrabou, 2011 |
| **DEEP** | 0.05-3/female | 50-130 m | Italy (Tyrrhenian sea) | Priori *et al.*, 2013 |

The size has positive effect on reproductive potential. The reproductive output increases exponentially with colony size. Generally, large colony contained more oocytes and sperm sacs and may produce a hundred or more of planulae than the small ones (some tens of planulae) (Santangelo *et al.*, 2003; Torrents *et al.*, 2005; Tsounis *et al.*, 2006a). The actual age of first reproduction is probably 7-10 years corresponding to colonies about 24.0 mm in eight, 3.6 mm in basal diameter and 0.6 g in wet weight (Torrents *et al.*, 2005). Female colonies reach fertility at a minimum age of approximately 10 years (corresponding to a diameter of 2 mm), although reproductive parameters (percentage of fertile colonies and fertility) are significantly lower in small size than in medium and large colonies (Torrents *et al.*, 2005). Male colonies, on the other hand, may develop gametes much earlier. The youngest fertile male colony of the sample with a basal diameter of 1.2 mm is supposed to be not older than six years (Gallmetzer *et al.*, 2010).

## RECRUITMENT

Recruitment is one of the main process determining both population structure and dynamics (Caley *et al.*, 1996). The rate of recruitment can greatly vary in space and time. It could be different if it occurs in natural or artificial substrates. There are few studies on the recruitment process in red coral populations (Table 2)

**Table 2 Recruitment rate measured in different time and areas of the Mediterranean**

| COLONIES | Recruitment rate | Substrate | Population examined | Reference |
|---|---|---|---|---|
| SHALLOW | 0-32 recruits/m2 | Shallow waters (40 m depth) | Spain (Medes Islands) | Linares *et al.*, 2000 |
| | 1.6±1.96 recruits/dm2 | Semi natural substrate on a vertical cliff | Spain (Medes Island) | Bramanti *et al.*, 2007 |
| | 0.4-0.6 recruits/dm2 | Semi natural substrate on a vertical cliff | France (Monaco) | Cerrano *et al.*, 1999 |
| | 0-12 recruits/m2 | Semi natural substrate on lateral wall | France (Marseille) | Garrabou and Harmelin, 2002 |
| | 1.3 recruits/dm2 | Semi natural substrate in a cave | France (Marseille) | Garrabou and Harmelin, 2002 |
| | 0.178 recruits/dm2 | Semi natural substrate in a cave | France (Marseille) | Garrabou and Harmelin, 2002 |
| | 6.24±4.26 recruits/dm2 | Semi natural substrate on a vertical cliff | Italy (Calafuria) | Bramanti *et al.*, 2005 |
| | 1.1±1.4 recruits/dm2 | Semi natural substrate on a vertical cliff | Italy (Elba Island) | Bramanti *et al.*, 2007 |
| | 3.88±0.68 recruits/dm2 | Semi natural substrate on marble tiles | mean (Medes I., Elba, Calafuria) | Santangelo *et al.*, 2012 |
| | 0.56±0.21 recruits/dm2 | Semi natural substrate on marble tiles | Spain (Medes Island) | Santangelo *et al.*, 2012 |
| | 6.06±1.75 recruits/dm2 | Semi natural substrate on marble tiles | Italy (Calafuria) | Santangelo *et al.*, 2012 |
| | 4.66±1.01 recruits/dm2 | Semi natural substrate on marble tiles | Italy (Elba Island) | Santangelo *et al.*, 2012 |

Saturation of space and interference competition appears to be a major controlling factor in red coral recruitment (Garrabou *et al.,* 2001; Santangelo *et al.,* 1988). This could explain why recruitment rates were higher after harvesting events (Linares *et al.,* 2000; Santangelo *et al.,* 1997).

## GROWTH RATE

*Corallium rubrum* is long-lived but how "long" its life span can be is still controversial and object of research. Some researches talk about >100 years (Garrabou *et al.,* 2002; Roark *et al.,* 2006) but this data has to be already confirmed. Up to now three different methods have been applied to determine the age of coral colonies:

- Petrographic method (Abbiati *et al.,* 1992; Garcia-Rodriguez and Massò, 1986a; Santangelo *et al.,* 1993);

- Organic matrix staining of thin sections from the base of colonies (Marshal *et al.,* 2004), which allows one to read annual growth rings.

Direct measurements of new settled colonies of known age, a not destructive approach to the study of colony growth rate, based on artificial or semi-natural substrates on which new settled colonies can be followed during their growth for a determined time interval (Bramanti *et al.,* 2005; Cerrano *et al.,* 1999; Garrabou and Harmelin, 2002).

Unfortunately, the dark bands highlighted with the first method (Petrographic method) were not annual, so colony age was underestimated. Only "organic matrix staining method" allowed reading growth rings that were checked to be annual by calcein labelling in vivo (Caley *et al.,* 1996). In general, colonies exhibit low growth rate that varies among location, depths, and habitats (Abbiati *et al.,* 1992; Bramanti *et al.,* 2005; Cerrano *et al.,* 1999; Garcia-Rodriguez and Massò 1986a; Garrabou and Harmelin, 2002) (Table 3).

**Table 3 - Growth rates (mm yr-1) in several Mediterranean shallow- and deep-water populations of *C. rubrum***

| COLONIES | Growth rate (mm yr-1) | Method used* | Population examined | Reference |
|---|---|---|---|---|
| SHALLOW | 1.32 | P | Spain (Gerona) | (Garcia-Rodriguez and Massò 1986a) |
| | 0.24±0.06 | OMS | Spain (Cape de Creus) | (Vielmini *et al.*, 2010) |
| | 0.35±0.15 | OMS | France (Marseille) | (Marschal *et al.*, 2004) |
| | 0.24±0.05 | D (semi natural substrate in a cave) | France (Marseillle) | (Garrabou and Harmelin 2002) |
| | 0.91 | P | Italy (Calafuria, Livorno) | (Abbiati *et al.*, 1992) |
| | 0.62±0.19 | D (semi natural substrate in vertical cliff) | Italy (Calafuria, Livorno) | (Bramanti *et al.*, 2005) |
| | 0.62 | D (natural substrate in a cave) | Italy (Portofino) | (Cerrano *et al.*, 1999) |
| | 0.22±0.04 | OMS | Italy (Portofino) | (Vielmini *et al.*, 2010) |
| | 0.2 | OMS | Italy (Ligurian Sea) | (Gallmetzer *et al.*, 2010) |
| | 0.68±0.02** | D (marble tiles) | Italy (Calafuria, Livorno) | (Santangelo *et al.*, 2012) |
| | 0.59±0.02** | D (marble tiles) | Italy (Elba, Tuscany) | (Santangelo *et al.*, 2012) |
| **DEEP** | 0.26 | OMS | Italy (Tyrrhenian Sea) | (Priori *et al.*, 2013) |

* OMS = Organic matrix staining; D = Direct measure; P = Petrographic; ** first year of life

After settlement, the growth rate of shallow water colonies is about 1 mm year$^{-1}$ for the base diameter, and 10 mm year$^{-1}$ for the height (Cattaneo-Vietti and Bavestrello, 1994) but after 4-5 years, the growth virtually stops and become negligible (Bavestrello *et al.*, 2010). The growth rate of deep-water colonies seems to be narrower (0.26 mm) (Priori *et al.*, 2013)

## POPULATION STRUCTURE AND DENSITY

Red coral population density varies from place to place, according to depth and exploitation (Rossi *et al.*, 2008; Tsounis *et al.*, 2006b). Schematically, we can distinguish two different spatial situations: 1) coastal populations, occurring up to 50 m depth, characterized by high density (up to 1000 colony/m$^2$) and small colony size (until 5 cm of height); 2) deeper populations, extending up to 200 m depth and more, characterized by low density and high colony size. At this depth range, colonies are characterized by more extensive branching patterns (Santangelo *et al.*, 2007) forming small aggregates on individual banks and hard ground areas, where colonies are concentrated on the exposed surface facing into high-current areas (Cannas *et al.*, 2010; Rossi *et al.*, 2008) (Table 4).

**Table 4 - Adult colonies densities (colonies m$^{-2}$) at different depths in several Mediterranean areas.**

| POPULATIONS | Country | Density (colonies m$^{-2}$) | Depth (m) | Reference |
|---|---|---|---|---|
| SHALLOW | France (Scandola) | 70 | 19-22 | Linares *et al.*, 2010a |
| | France (Banylus) | 137 | 23-25 | Linares *et al.*, 2010a |
| | France (Carry) | 47 | 24-25 | Linares *et al.*, 2010a |
| | France (NW Mediterranean) | 228-606 | 25 | Garrabou *et al.*, 2001 |
| | Spain (Costa Brava) | 3.42±4.39 | 20-50 | Tsounis *et al.*, 2006b |
| | Spain (Palma de Mallorca) | 55 | 40 | GFCM, 1984 |
| | Spain ( Costa Brava) | 20 | 60 | GFCM, 1984 |
| | Italy (Calafuria) | 4322±3358 | 20-45 | Santangelo *et al.*, 1993 |
| | Italy (Ligurian Sea) | 1050 ± 7.39; 212.5±10.38 | 22-40 | Santangelo *et al.*, 1988 |
| | Italy (Eastern Ligurian Sea) | 2493±1299.5 | 30-50 | Santangelo and Abbiati 1989 |
| DEEP | Spain ( Cap de Creus) | 43±53 | 45-85 | Rossi *et al.*, 2008 |
| | Italy (Calabrian coast, South) | 18.04±23.6 | 50-105 | Angiolillo *et al.*, 2009 |
| | Italy (Calabrian coast, South) | 6.42±4.6 | 70-130 | Angiolillo *et al.*, 2009 |
| | Italy (Calabrian coast, South) | 96.57±7.5 | 50-200 | Angiolillo *et al.*, 2009 |
| | Italy (Tyrrhenian Sea) | 12.9±7.9 | 50-130 | Priori *et al.*, 2013 |

## GENETICS AND GENETIC STOCK IDENTIFICATION

The main bulk of available genetic knowledge refers to the more accessible shallow-water populations (from -15 to -60 m of depth) (Abbiati *et al.*, 1992, 1993, 1997; Aurelle *et al.*, 2011; Calderon *et al.*, 2006; Casu *et al.*, 2008; Costantini *et al.*, 2003, 2007a,b,2011; Del Gaudio *et al.*, 2004; Ledoux *et al.*, 2010a,b). These studies found evidence of breeding isolation and population sub-structuring suggesting that larval dispersal could not be able to ensure sufficient gene flow to preserve genetic homogeneity of the species. Several studies confirmed the occurrence of genetic differentiation at spatial scales of 10s of meters (that is the effective larval dispersal range may be restricted to < 10 m). The strong genetic differentiation between nearby samples implies that the recovery of over-exploited populations should be mainly due to self-recruitment.

Moreover, a pattern of Isolation by Distance was described in Ledoux *et al.*, (2010b), that is the more distant the more different populations are. All studies revealed, through the use of differentially powerful markers, significant deviations from Hardy-Weinberg equilibrium due to elevated heterozygote deficiencies, consistent with the occurrence of inbreeding (mating between consanguineous).

As regards deep-water populations, the number of genetic studies dealing with them is very limited.

Costantini *et al.,* (2011) analysed colonies along a depth gradient (from -20 to -70 m) and showed strong patterns of genetic structuring among the samples both within and between two study sites (Catalan and Ligurian Sea), with a pattern of reduction in genetic variability with depth. A threshold in connectivity was observed among the samples collected across 40–50 m depth, supporting the hypothesis that discrete shallow- and deep-water red coral populations occur. This finding could have major implications for management strategies and the conservation of commercially exploited deep red coral populations (Costantini *et al.,* 2011)

In Sardinian populations (range from -80 m to –120 m of depth) high level of genetic differentiation was measured, over different spatial scales from hundreds to less than 1 km (Cannas *et al.,* 2010, 2011). First preliminary results seems indicate the existence of a strong genetic differentiation among populations over the different depths (banks from -30/-60 meters vs. banks from -80/-120 m), further underlying possible restrictions to gene flow along the depth gradient and hence possible local adaptations to the two different environments, the deep- and shallow-waters (Cau *et al.,* in preparation).

The genetic spatial structuring of deep-water *C. rubrum* colonies found between -58/-118 m of depth within the Tyrrhenian Sea confirmed the occurrence of significant genetic differentiation at both small and large spatial scales (Costantini *et al.,* 2013)

As concerns the deepest red coral populations, a few colonies (a total of 12 fragments from 5 sites from Malta and Linosa shelves) from the lower limit of red coral depth range in the Mediterranean Sea (up to 819 m of depth) were genetically characterized by Costantini *et al.* (2010). The authors found differences between shallow and deep-water samples, but the small sample size of the deep-water collections does not allow the authors to make final considerations on their degree of isolation (Costantini *et al.,* 2010).

Finally, an interesting experiment was recently performed combining transplant and genetic analyses (Ledoux *et al.,* 2010c). Two populations dwelling in contrasted temperature regimes and depths (-20 m and -40 m) were reciprocally transplanted. The population from -20 m showed a significant decrease in growth rate when transplanted at -40 m. Since previous genetic analysed indicated significant differentiation among the studied populations, the authors concluded that different genotype*environment interactions could exist and hence local adaptation in these populations of *C. rubrum*.

On the overall the genetic studies performed so far highlight a strong genetic heterogeneity even at very small spatial scales, and suggest that management of red coral has to be planned on a local base. Individual harvesting plans for each bank should also to be considered, that is each commercial stock should be previously characterized from the genetic point of view to identify population boundaries and define Management Units.

## MORTALITY

The high commercial value of red coral involves that this vulnerable species is subject not only to natural mortality but also to harvesting mortality.

Natural mortality of red coral includes completion of space with sponges and other sessile biota, dislodgement from the substrate due to the action of boring species (Harmelin *et al.,* 1984) or seismic movement (Di Geronimo *et al.,* 1994), predation by the small gastropod *Pseudosimnia carnea* and the crustacean *Balssia gasti* (Abbiati *et al.,* 1992), sedimentation increase and widespread mortality due to epidemics.

In fact, phenomena of mass mortality events have been observed in shallow waters populations since the late 1990s, including several mass-mortality events linked to elevated temperature anomalies (Bramanti *et al.,* 2005). A mass mortality event occurred in the NW Mediterranean, from Tuscany (Italy) to Marseille (France), in summer 1999. The phenomena, in which about 80% of the colonies were affected, was attributed to a fungal and protozoan disease, and linked to temperature anomalies (Cerrano *et al.,* 2000; Garrabou *et al.,* 2001; Perez *et al.,* 2000; Romano *et al.,* 2000). In the same year (late summer 1999) some shallow water red coral populations have been affected by mass mortality associated to anomalous temperature increase in the Eastern Ligurian Sea (Calafuria, Italy; Bramanti *et al.,* 2005), as well as western Ligurian Sea.

Mortality in *C. rubrum* had a different impact, depending on the colony size. Large colonies are more resilient to natural stressors. On the contrary, small colonies prevalently suffer of higher virulence, showing higher whole-colony mortality rates. However, further studies are urgently required to provide basic information regarding red coral population dynamics as a basis for the hypothesis on the actual recovery capability of affected populations.

A large number of species (mainly sponges, crustaceans, brachiopods, molluscs and echinoderms) have been documented living on/in or in strict association with red coral colonies (Calcinai *et al.,* 2010; Crocetta and Spanu, 2008 and references therein). Some of these species, especially the parasitic ones, may increase the red coral mortality rate and therefore profoundly affect its population structure (Corriero *et al.,* 1997). Apart from being the main causes of natural mortality, sponges have the ability to damage colonies and thus reduce the commercial value of red coral (Calcinai *et al.,* 2010).

## CONSIDERATIONS ON THE DATA AVAILABLE FOR RED CORAL

Huge differences exist in the availability of data from the different areas, reflecting the different efforts (and economic availability) in studying and monitoring red coral populations.

The aim of these paragraphs is to give an overlook (summary) on the main sources that have been utilized in the past to gather data on red coral populations, as well as indications on which are the sources to be used in the future and how to implement them. The priority actions and future efforts to be made in improving the management and the conservation of this important species are given. Furthermore, a discussion on pros and cons of the main type of data is presented.

### FISHERY-DEPENDENT AND INDEPENDENT DATA

The following Table 5 shows the main type of Fishery-dependent data and gives indication priorities in using and collecting them for management or scientific purposes.

Table 6 shows the main type of Fishery-independent data and gives indication priorities in using and collecting them for management or scientific purposes.

**Table 5 - Fishery-dependent data (task C = completed; H = high priority; M = medium priority; L = low priority; na = not applicable)**

| Information source | Data on | | Notes* |
|---|---|---|---|
| Fisheries agencies | Landings | H | There is the very urgent need to improve the quality of data collected by countries and provided to GFCM |
| | Fishing effort | H | As above |
| | Size/branching patterns | H | Through scientific surveys + observer at sea + improvement of fishermen logbooks |
| Museum / private collections | Size/branching patterns | L | Data on a few individuals cannot give relevant information for the management of the species |
| | Population dynamics and biological data (ancient DNA, isotopic analyses) | L | Scientifically relevant, but low priority for management |
| Fishermen (logbooks + ad hoc interviews) | Landings | H | There is the very urgent need to improve the quality of collected data (Logbook) e.g. not only gross weight but also number of colonies, if possible also individual weights and sizes (basal diameter) |
| | Fishing effort (length of dive/harvested coral) | H | |
| | Position of banks | H | |
| | Size/branching pattern | M | Better if collected through scientific surveys + observer at sea |
| | Trade (amount and prices) | H | |
| Manufacturers/traders | Trade (amount and prices) | H | Market is the major driver of harvesting |
| | Stockpiles (amounts) | M | As above |
| | Stockpiles (biological data, DNA, isotopic analyses) | L | Scientifically relevant, but low utility for management |
| Independent observers (Random e/o systematic assessment of fishing activities) | Biometric data (diameter, height, weight, branches, etc.) | H | There is the very urgent need to improve the quality/quantity of data, especially in some areas and depths |
| | Fishing effort (length of dive/harvested coral) | H | |
| | %dead, %broken corals, %infested by sponges | M | Scientifically relevant, but low priority for management |
| | Samples collection (reproduction, genetics, physiology etc.) | H | Scientifically relevant, relevant for management |
| | Monitoring of habitat and environment | M | Scientifically relevant, especially for conservation issues |

* Priority (**H** = high priority; **M** = medium priority; **L** = low priority)

**Table 6 - Fishery-independent data (e.g. through observer programs / scientific surveys)**

| Data on | priority | Notes* |
|---|---|---|
| Size/branching pattern | H (De) | Comparison **Ha/Pr** pops and over time monitoring give indications of the effects of fishing on the studied populations; for **Sh** populations data are available (some areas only) |
| Density, abundance, biomass | M/L (De) | Difficulties in measuring, comparing and interpreting the data; for **Sh** populations data are available (some areas only) |
| Recruitment, growth | H (De) | To measure recovery time that is responses to disturbances (fishing but also climate changes etc.); for **Sh** populations data are partially available (some areas only) |
| Reproduction, genetics, physiology etc. | H (De) | To measure reproductive output, connectivity, resilience to disturbances (fishing but also climate changes, etc.); for **Sh** populations data are partially available (some areas only) |
| Environmental parameters (temperature, currents, pH etc) | H | Monitoring effects of emerging threats (e.g. global warming) in **Sh** pops; data on **De** are completely lacking |
| Habitat and biodiversity surveys (associated species) | M/L | Scientifically very relevant (conservation purposes), but not strictly linked to the acquisition of data for management purposes |

* Priority (**H** = high priority; **M** = medium priority; **L** = low priority); banks (Deep= **De**; Shallow= **Sh**); populations (Harvested= **Ha**; Protected= **Pr**)

## COMPARISON AMONG INFORMATION OBTAINED THROUGH DIFFERENT TYPES OF DATA

### SIZE

**Size** of the colony is a major determinant of first reproduction, reproductive output, and colony survival. The size of colonies is principally measured through**: height of the colony, basal diameter, and branching pattern**.

In general, as the height increases with age, the diameter also increases. However, the growth pattern could vary among different areas and according to environmental parameters. For a given height, in different areas, colonies could have very diverse basal diameter values and ages. Therefore, to a more accurate description of populations, **local estimates** should be preferable.

### BRANCHING PATTERN

The size (and branching pattern) are related to the number of polyps in the colony and hence to its reproductive output.

Small colonies have not developed a branching morphology and consist in relatively few reproduction polyps, which produce only low numbers of gamete once per year.

The increase in polyps is partially related to size (larger colonies have more polyps overall), polyp number also increases in proportion to the degree of branching, which is much more extensive in large colonies. However, large colonies lack polyps at the basal portions and polyps may be more dense but smaller at the branch tips.

## DENSITY

Numbers of colonies per unit area are unlikely to provide an indication of the population status or trends. This is because these measures differ depending on how they are assessed (colony density measured over the entire suitable habitat is much less than the density of small patches occupied by the coral within this habitat), and the life stage of the population. In fact, higher values are found in populations composed of smaller colonies: they tend to occur in large aggregates because they settle relatively close to their parent; these smaller-sized colonies lack a branching morphology. As they increase in size, and in branching pattern, they require more space. When they reach a large size, populations will ultimately become less dense, with a lower overall abundance throughout a bed.

In general in red coral, high abundance and density values, such as those present in Mediterranean shallow waters, are an indication of frequent continuing perturbations responsible for rapid turnover of populations and a persistent state of early-stage recovery.

However, it should be considered that for sessile colonial organism, such as *C. rubrum*, successful reproduction is critically dependent on the density (a minimum density is required for successful reproduction). Therefore, very low levels of density, associated with the selective removal of the largest colonies on a coral bed, should be avoided since they may alter the reproductive potential due to the well-known Allee effect.

## ABUNDANCE AND BIOMASS

Abundance data must be combined with knowledge on the entire size of the bed suitable for colonization, and abundance must be normalized over the entire bed.

Abundance data are associated with high standard deviations due to patchy distribution of corals. Abundance data cannot be directly compared among populations or within individual beds over time, due to their patchy occurrence within these beds, differences in the available habitat within an area occupied by this coral, and highly variable features such as crevices and outcrops that are not uniformly distributed throughout the habitat.

Furthermore, identifying population biomass decline requires a time series of comparison or comparison with unharvested populations, and this kind of data is lacking for red coral. In the case of red corals a precise estimate of decline will probably never be possible because the lack of natural baseline. In any case analysing polyp numbers, not colony numbers, can identify population decline in colonial animals because polyps are the reproductive modules. For colonial organisms, change in population structure (size frequency distribution) is a more suitable measure of decline than changes in the absolute numbers of colonies.

## POPULATION STRUCTURE

Data on the population structure are the most useful data in identifying monitoring population status, in identifying changing proportion of mature/immature colonies, which is more functional as a basis for management decisions that need to ensure minimum recruitment, especially for sessile animals that require a certain density to ensure fertilization success (Bruckner and Hill, 2009)

Furthermore, shifts in the size structure of populations due to fishing pressure can be directly compared, while density and abundance cannot.

A recent study (Linares *et al.,* 2010a) documented as the demographic structure of red coral populations from 3 of the oldest Mediterranean MPAs (all in France: Scandola Nature Reserve, Cèrbere-Banyuls Nature Reserve and Carry-le Rouet Marine Protected Zone) has changed with time and it is now significant different from unprotected populations (Linares *et al.,* 2010a). Within the MPAs the size values are higher than those reported for most of the shallow populations and deep-dwelling populations. Differences in the observed size distributions are more closely related to the structure at the beginning of the reserve than to the number of years of protection. Despite these positive effects, colony sizes did not reach characteristic values of pristine populations estimated from museum specimens (Garrabou and Harmelin, 2002), most likely as a result of other impacts such as poaching and diving, which do not allow their total recovery (Linares *et al.,* 2003). The percentages of colonies with basal diameter greater than 7 mm or colony height greater than 100 mm has been proposed as useful descriptors for evaluating the conservation status of each population.

## USING DATA IN MODELS

Developing a quantitative model for an exploited population, which reflects its main demographic features, is a standard precondition for drawing up a management plan for the resource (Caddy, 1993).

According to Caddy (1993) four aspects of modelling a red coral population emerge from the biology of this species in which it differs significantly from, for example, the more commonly modelled finfish populations, namely:

1) Populations are sedentary, and their density varies from place to place.

2) Because they are sedentary, the effects of past local harvesting remain local, at least until the population regenerates itself. In other words, the dynamic pool assumption must be rejected (Caddy, 1975).

3) Like other high-value sedentary or semi-sedentary organisms, harvesting (especially by scuba) tends to be in a 'pulse' fishing mode, in which local patches are cleaned out selectively, leaving only inaccessible or non-commercial individuals, before another patch is located and harvested in turn.

4) Growth of corals, and hence regeneration of exploited populations, is very slow, and as such, harvested areas are effectively removed from production for a significant period. Periods of up to 50 years have been mentioned as recovery times in Pacific fisheries (Grigg, 1984).

Furthermore, developing a population model for precious coral resources has to take into account the fact that population parameters are often not precisely known and are likely to show wide variation from place to place; nor is usually the size of the population, the rates of recruitment and growth, or the death rates due to natural causes and fishing (Caddy, 1993).

The question of modelling red coral resources has been discussed and examined the first time during the first GFCM Technical Consultation on red coral resources of the western Mediterranean (GFCM, 1984): three types of models have been compared, as proposed by Garcia (GFCM, 1984): 1) Models that assume a 'mining' strategy (curve of exhaustion models), 2) global or production models, and 3) analytical, structural or yield-per-recruit models.

According to Garcia (in GFCM, 1984) the deposit exhaustion model can be used to analyse the reaction to exploitation of a small, isolated coral bed, as in this case the growth rate and natural mortality are insignificant with respect to the fishing mortality (the only actually affecting the biomass). It allows calculate the theoretical time needed to reduce the bed to certain percentage of its initial biomass for different extraction rates (Table 7).

**Table 7 - 'life span' of the coral bed in years for different exploitation rates (form 1% to 75% biomass/year) and final abundances (5, 10, 50% of the initial biomass) (from Garcia in GFCM, 1984).**

| | **extraction rate / year** | | | | | |
|---|---|---|---|---|---|---|
| | 1% | 5% | 10% | 25% | 50% | 75% |
| **fishing mortality F** | 0,01 | 0,051 | 0,105 | 0,287 | 0,699 | 1,386 |
| **t50% (years)** | 69 | 14 | 6,6 | 2,4 | 1 | 0,5 |
| **t10%(years)** | nc | nc | nc | 8 | 3 | 1,5 |
| **t5% (years)** | nc | nc | nc | 10 | 4 | 2 |

The global production models are applicable only on a large geographical scale if the concepts of average exploitation pattern, average size of colonies, average abundances, etc. is to have a minimum sense (Garcia in GFCM, 1984). These models, despite their limitations, make it possible to perceive the economic problems.

The analytical model underlines the importance of the size of the coral colonies, when first exploited.

In order to simulate population growth and exploitation, two different kind of models have been applied to red coral: Beverton and Holt model (or "yield per recruit model" Beverton and Holt, 1957) and life history table and Leslie-Lewis matrix model (Caswell, 2001).

The Beverton-Holt (BH) model provides a useful estimator of the age/size at which colonies should be harvested, and provides a conservative estimate of harvest yields.

Data requirement for using this model are: i) natural mortality rate; ii) age/size at recruitment to fishery - selectivity of gear for different age/size classes; mean size at sexual maturity.

Main assumptions of the model are: i) it assumes knife edge selectivity and constant fishing mortality and natural mortality for all ages; ii) it assumes the stock is in equilibrium i.e. that the biomass and age –structure are constant from year to year; iii) it assumes that recruitment is constant from year to year, which is likely to be false at high fishing mortalities when low spawning biomass may reduce recruitment.

One the main advantages are that data can be collected only once (in a single survey) (Santangelo *et al.,* 2010).

However, the assumption that red coral recruitment is constant in time cannot be taken for granted, because it has been demonstrated that, depending on the studied area and habitat, red coral recruitment may be discontinuous over time (Garrabou and Harmelin, 2002; Bramanti *et al.,* 2005). Furthermore, a precise estimate for natural mortality, the most critical parameter in the BH model, by using the population structure of natural populations is not possible in red corals as no untouched populations are known or accessible. Moreover, the size classes (colony diameter) conversion to age classes, as well as the correlation growth and age, are not easily done. Other limitations to the original model are that it assumes that all the colonies above a determined (age) size will be completely removed and it does not take into account the effects of reproduction and density-dependence on biomass growth (Santangelo *et al.,* 2010).

The BH model has been applied to *C. rubrum* by Garcia (in GFMC, 1984), Garcia-Rodriquez and Massò (1986b) and Tsounis *et al.,* (2007) and to other coral species in Hawaii (Grigg 1976, 2002, 2004).

Based on these models a range of estimates has been made for continuous harvesting in a sustainable way (i.e., without depleting the resource). According to Garcia-Rodriquez and Massò (1986b) it would necessitate very low levels of annual harvest (1.3%) with respect to the stock size, if populations were not to be depleted. Figures of the order of 5% are in Garcia (1984) while Grigg (1984) mentions values of 3.5% of the stock size harvested annually as corresponding to the Maximum Sustainable Yield (MSY).

The age at MSY calculated for red coral using the Beverton and Holt 'yield per recruit' ranged from 80 years (Garcia-Rodriguez and Massò 1986b) and 98 years (Tsounis *et al.,* 2007). Different ages at MSY can be found according to the different growth and mortality rates applied that can vary for different geographical areas and environments. According to Tsounis *et al.,* (2007), the current practise of harvesting red coral with a basal diameter of 7 mm (about 11 year old) results in a yield of only 6% of what would be reached by harvesting coral colonies of 98 years.

Estimates of maximum sustainable yield (MSY) and OY (optimum yield) are used in the fishery management plan for precious corals in the Hawaii Archipelago for the definition of harvest quotas (WPRFMC, 2009).

MSY has been estimated using a Beverton and Holt model for *Corallium secundum*, for a single bank for which biological data were available (Grigg, 1976). For the Makapu'u Bed the age at MSY has been estimated at 34 years and the harvest quota at MSY has been identified to be 1185 kg/year (Grigg, 1976).

The same author using the BH model estimated black coral MSYs of 6,174 kg/yr for the Auau Channel and 1480 kg/year for the area around Kauai (Grigg, 1976). More recently, Grigg discovered a greater impact to the black coral resource from an invasive soft coral, Carijoa riisei, and based on that, coupled with harvesting impacts, estimated a reduced MSY of 3,750 kg/yr for the Auau Channel (Grigg, 2004).

In the Hawawii archipelago, to estimate MSY for gold (*Gerardia* spp.) and bamboo (*Lepidisis olapa*) corals the Gulland Model (Gulland, 1970) is used, because information on population dynamics was lacking (Grigg, 2002; WPRFMC, 2009).

Actually, the harvest quotas are based on extrapolations from "rounded down MSY values" for the ecological and economic reasons (OY). All the beds for which OY has been determined are called 'Established Beds'. For all the other bed known to contain precious but in which biological data are not available ('Conditional Bed'), the OY is prorated based on the area of the Conditional Bed relative to the area of established beds.

In particular, the dynamic pool yield-per-recruit models have been considered not particularly well adapted to a sedentary species, unless the spatial nature of the resource is taken into account (e.g. Caddy, 1975; Gales and Caddy, 1975; Sluczanowsky, 1983). They may be useful, however, for a first treatment of an open-access resource in which we wish to know the effects of a minimum size limit and a particular level of fishing effort on the resource (Caddy, 1993).

Finally, the compilation of life-history tables (describing the demography of a population, gathering data for density, fertility, fecundity, sex ratio, recruitment, population structure, mortality), and the inclusion of those data in Leslie–Lewis transition matrix were used to simulate the trends of red coral populations over time (Bramanti *et al.,* 2009; Santangelo *et al.,* 2007).

They link reproduction, growth, mortality, and demographic structure into one model and can take density dependence into account as well. Furthermore, the contribution of each cohort to population growth rate by reproduction and survival is included.

These models allow predictions of harvest effects based on every possible variation in fishing effort, and selective harvesting affecting the different age classes in a different way (Santangelo *et al.,* 2010).

However, they are highly-demand model in terms of data requirement.

## A SPECIAL CASE: THE ROTATING HARVEST REGIME

According to Caddy (1993) for sedentary species an alternative 'ideal' management scheme is the Rotating harvest regime: the stock is divided into subareas, whose harvesting is staggered over a period of years, thus allowing depleted stocks to recover before restart harvesting.

Arab fishermen apparently also practiced a 9-year rotating closure period in the 10th Century (Grigg, 1988). Several countries and regions already had closures of coral fisheries in their fisheries legislation; notably, a 5-year closure established for coral fisheries in Sardinia in the 1970s (GFCM, 1984,

1989) and a 25-year closure provided for in Spanish legislation (GFCM, 1984, 1989). Nowadays, harvesting based on rotating areas is in place in Morocco and Greece.

Rotating harvest regimes for sedentary organisms can be represented using yield-per-recruit *(Y/R)* models with spatial components (Caddy, 1975, 1993). Based on these models estimates can be made for continuous harvesting in a sustainable way (i.e., without depleting the resource (Caddy, 1993). It has been proposed also by the same author that some fraction (B') of the total biomass (B) could be excluded from the rotation scheme, or two or more unit areas could be opened simultaneously to harvesting. For instance, areas of fringe population can be excluded from the rotation scheme and left open to harvesting full time. Alternatively, some areas where reproduction occurs more regularly (Caddy, 1988) could be closed indefinitely as "mother lodes" or stock conservation areas (Caddy, 1993).

Advantages and disadvantages of this approach, when compared to the principal alternative management approach, namely a quota scheme, are described in the paper by Caddy (1993).

In summary, firstly considerable information on population parameters are required for the application of these models, which are not yet available for red coral populations in many areas.

Moreover, this management scheme, providing for the closure of a coral fishery for a long time (several decades can be necessary for juveniles to grow to adequate size), imposes very high surveillance costs and leads to an increasing incentive for illegal fishing (Garcia, 1984). There is the need for control of fishing operations at sea, to ensure that fishing is not occurring in unauthorized areas; and also, a precise control of the location of fishing will be needed (today technically feasible using VMS systems). Fisheries surveillance, which is supposed to increase progressively as the biomass on the grounds builds up.

Furthermore, this practice could disrupt the gene flow through coral populations itself, and also potentially interrupt migrations of other species that take refuge in coral populations, or benefit otherwise from its presence (Tsounis *et al.,* 2009).

## STANDARDIZED DATA COLLECTION PROGRAM WITHIN THE GFCM AREA FOR RED CORAL

Considering that valid scientific information is essential to develop meaningful management measures, a standardized data-collection program for red coral in the GFCM area should be urgently implemented.

A long-term monitoring program is important both to understand the fishery and to facilitate adaptive management.

Information should be collected in different ways through:

- Simple, regular and standardized record from logbook or landings (catch data),
- Sampling at landing sites and/or on board (size data),
- Scientific surveys or focused studies as part of in-depth scientific research programmes (biological data for stock assessment, ecological data in view of the EAF 'Ecosystem Approach to Fishery')

To obtain valid data it should be stressed that:

- Methods of data collection should be standardized and kept consistent over time to allow comparisons across years.
- Funding for monitoring should be adequate
- Staff personnel should be well trained and motivated

# FISHERY OF RED CORAL

## FISHING METHODS

### FREE DIVING

Thousands of years ago red coral was collected as fragments or branches, washed up on shores by wave action after heavy storms. Afterwards, about 5000 years ago, Greek fishermen began to look for it by breath-held diving. Harvested was performed by free diving by using iron hooks (called 'kouraliò') and Japanese goggles to harvest red coral (Bruckner, 2009; Tsounis *et al.,* 2009).

### DRAGGING GEARS

Gears that can be employed from boats dated to the fourth to third centuries BC (Tsounis *et al.,* 2010b). These gears changed very little with time, just modifying the materials or dimensions. The dredge mainly used in Mediterranean was the "St. Andrew Cross." It was made up by two beams in a cross shape with some weight to the junction. Some hooks and pieces of nets were put at the tip of the cross. During the Industrial Age, the Saint Andrews cross was abandoned in favour of a modified metal version called "ingegno" ("barra italiana"): a wooden or iron bar with pieces of nets and chains on it.

These gears were used to dredge the bottom of the sea; while moving, they broke the coral branches that remained entangled in the net and could be collected (Cicogna, 2000; Bruckner, 2009; Liverino, 1998; Tescione, 1973). They are known to have caused extensive habitat impacts to the coralligenous in Mediterranean (Chessa and Cudoni, 1989). Dredges exclusively accessed exposed banks and removed the vast majority of coral on the rocks, down to the limit of 100/200 m of depth (Tsounis *et al.,* 2010a). Coral dredge are also extremely inefficient, as only about 40% of the detached colonies are entangled and retrieved (Grigg, 1984; WP COUNCIL 2007).

Since the mid-1980s coral dredging was banned in many countries (e.g. 1977 in Algeria, 1985 in the former-Yugoslavia and Tunisia, in 1989 in Sardinia [Italy], and in 1994 in European Union waters); scuba diving using advanced technology remains the unique legal exploitation method today.

### SCUBA DIVING

At the end of the 1950s SCUBA diving became a common tool for surveying hard bottom communities and the way of harvesting the red coral has completely changed toward a less destructive and more selective way of harvesting (Harmelin, 2010). Scuba divers were so able to access colonies hidden in caves, overhangs and crevices that dredges cannot reach (Rossi *et al.,* 2008; Tsounis *et al.,* 2010a)

From the first use of the SCUBA diving for harvesting red coral, divers have been moving to deeper and deeper depths; in 1956 divers worked at 30–35 m, in 1958 at 40–45 m, by 1964 an at depths of 72 m (Liverino, 1983). Inevitably a growing number of accidents were recorded as the result of the spreading 'coral fever' among the divers (Liverino, 1983). Others similarly documented that by the late 1950s divers in France and Italy already had to descend to depths of 80 m, and at times to even more than 100 m, to find coral (Galasso, 2000). In 1974, helium-based mixed-gas diving techniques started to spread among coral divers, permitting them to work at 120 m for 20 min without the dangers of nitrogen narcosis (Liverino, 1983).

They use a pick to break the chosen branches, leaving untouched the rest. Scuba harvesting inflicts little direct damage to non-target species in the same habitat. Responsible divers cut the red coral base instead of extracting the whole colony; leaving the base in place leaves a chance that this colony might re-growth as sporadically observed (Rossi *et al.,* 2008). Studies on catches confiscated to poachers confirmed that up to 60-70% were entire colonies with the substratum still attached to their base (Hereu *et al.,* 2002; Linares *et al.,* 2003; Tsounis *et al.,* 2010b). However, as regards the selectivity of this fishing method, it is absolute only theoretically. In the '80s divers have been reported to make a "clean sweep" of an entire precious coral population at one site, and recently poachers have been harvesting young corals in shallow waters (GFCM, 1989).

The dive at high depths is a very dangerous activity and it needs a very long decompression, after which the divers usually go into a hyperbaric chamber for 6-9 hours (Cicogna, 2000). Furthermore, the considerable time, pressure and difficulty in working underwater and at those depth is quite incapacitating, so that red coral divers may not be able to consistently perform a precise size selection or partial harvest of corals (Tsounis *et al.,* 2010b).

## SUBMARINES

To our best knowledge until 1997 the Isla de Alboran was the only area, off the Spanish coast, where submarines were used to collect the red coral (Paracuellos *et al.,* 2006). A total of two submarines were authorized: the Neree 201 and the 66 Tours DGK 300. These type of submarine were transported to the area of work by support vessels, Cote de Nacre and Boreal. The first one began operating in the Alboran Island in 1989, and had an uninterrupted harvesting license until 1997. It could dive as deep as 180 m and had a great manoeuvrability thanks to its five engines. The submersibles were equipped with manipulator arms or baskets of recovery and could work for long periods in the extraction of coral at great depth, bound by ropes to the support vessels on the surface.

These devices were permitted only at depths exceeding 120 m, with a fixed quota of a maximum of 1500 kg of coral per year and engine. However, the average catches of the submarine Neree 201 were 503.6 kg/year during the period 1990-1995. As regards the other submergible, the 66 Tours, no harvesting data are known and there are doubts about that it never became operationally active. The sum of divers and submarine, 677.8 kg, was very close to the 700 kg/year that were obtained using the barra Italiana.

## ROVS

Nowadays robotic extraction is not practical and not permitted in many fisheries. ROV (Remote Operating Vehicles) are increasingly employed to scout a potential bed, improving the yield per dive. Basic ROV consist of motorized real-time video camera that is controlled from the boat via a cable that also transmits the video signal to a topside monitor and recorder.

ROV can also be equipped with a robotic arm that permits remote-controlled harvesting, although this option raises the acquisition cost considerably.

Remote harvesting is still considered impractical compared with manual methods. Currents, nets, and the topography of coral habitats make it difficult to handle the tethered machines, and without a dedicated technician a minor malfunction may easily render an ROV unusable for an entire expedition (Tsounis *et al.,* 2010b). Furthermore, according to the experimental uses in the Pacific, ROV tether may damage precious corals if not carefully used (WP COUNCIL 2007).

In recent years in the Mediterranean ROVs have proven to be very useful for habitat mapping, studying biocoenosis and quantifying the distribution, structure, abundance, status of benthic biocoenosis, especially in areas that could not be sampled using traditional methods (scuba, trawl) due to the depth or the roughness of the terrain. ROV surveys have also been applied to red coral studies, to describe the occurrence, spatial distribution, and population structure (Angiolillo *et al.,* 2009; Bo *et al.,* 2011; Rossi *et al.,* 2008; Taviani *et al.,* 2010). Similarly, ROV videos permitted to obtained data on spatial distribution and structure of commercial banks (from -80 to -130 m) around Sardinia seas (Cannas *et al.,* 2010; Cannas *et al.,* 2011, Follesa *et al.*, 2013).

However, as pointed out in the two transversal Workshops on red coral organized by the GFCM in 2010 and 2011, many different problems can arise from the use of ROV for harvesting red coral.

Considering the peculiarities of this machines (not limited by the physical constraints of divers, and hence capable of diving deeper and longer than humans) the number of ROV licenses, its operational time/day, the season length, the depth limits etc. should be attentively defined before the gear is massively employed to avoid the risk that its unregulated (mis)use will lead to a sudden and unsustainable increase in the amount of coral harvested (Cau in GFCM, 2010). Last but not least, according to the experimental uses in the Pacific, ROV may damage precious corals if not carefully used because currents, nets and the topography of coral habitats make difficult to handle these tethered machines (WP COUNCIL 2007); consequently long lasting damages to the ecosystems (the coralligenous communities) are also to be considered (Cau, in GFCM 2010).

Considering the high risk to legalise a new harvesting methodology (robotic harvesting) without comprehensive knowledge of the fishing effort and the sustainability of the gear, since 2011 according to Recommendation GFCM/35/2011/2the use of the Remotely Operated underwater Vehicles (ROVs) in the GFCM Competence Area for the exploitation of red coral; ROV is authorized only for reasons of observation and prospection and provided that ROV models cannot be equipped with manipulator arms or any other device allowing the cutting and harvesting of red coral. The use of ROV is allowed for scientific experimental campaigns both for observation and harvesting during a limited period not extending beyond 2015, to evaluate impact and the advisability of using ROV for direct harvesting of red coral.

In this context, in Italy the Government has financed two important projects using ROVs.

- Prospection
    - An interdisciplinary research project on red coral deep-dwelling populations was promoted by the Italian Environmental Ministry (GFCM, 2011). This project involved researchers of several institutions working on red coral, cooperating within the "Italian Red Coral Research Group". A first survey cruise was carried out during early Summer 2010 in the Tyrrhenian Sea between 60 and 130 meter depth to investigate the following topics: 1) the demographic structure (in terms of size/age, spatial and sexual structure); 2) the population genetic structure; 3) the associated community with particular interest in epi and endobionts (which greatly affect colony economic value); 4) the microbial community associated to red coral colonies. A second survey cruise was carried out during summer 2011 to complete the project.
- Harvesting
    - A second project was promoted by the Ministry of Agricultural, Food and Forestry Policies (Italian - Ministero delle Politiche

Agricole, Alimentari e Forestali, or MiPAAF) in the framework of a national three-year program on fishery and aquaculture: "Use of ROV (Remotely Operated Vehicle) in the applicative definition of management plans for red coral (*Corallium rubrum*). Management Strategies for the conservation of the species and assessment of the compatibility of the resource with a potential commercial exploitation along the north-central Tyrrhenian Sea Italian coasts." The project is on-going.

At the time of writing, it was no possible to gather additional information on other projects using ROV within the GFCM competence area.

## HISTORICAL FISHING DATA

Red coral has been a precious good since Prehistoric times. It has been found among archaeological finds of prehistoric graves of both Mediterranean marine people and European inland ones (Marini and Ferru, 1989; Tescione 1965). Antique vestiges found at Marseilles, the oldest port in France, state that red coral was already collected there 26 centuries ago (Harmelin, 2010).

In XII and XIII century the most exploited areas were located in Tunisia and Algeria. Here Catalan, Genoese and Marseillaise were used to compete for coral banks. At about 1400, Marseillaise moved also along the coasts of Naples (Italy) and Alghero (North-Western Sardinia, Italy).

In 1451 a company was founded by Genoese people was authorized to collect red coral in the western coasts of the Reign of Tunis, for 20 years (Berti, 2003). At the beginning of 1500, Genoese people moved to Tabarka and in 1542 they obtained there the exclusive right of fishing coral. Here they caught an average of about 105.7 quintals (225 canthari).

With time, a lot of companies were created to exploit red coral banks. One of the most important was established in 1553 by Marseillaise, the "Grande Compagnie du Corail des mers de Bône", having the monopoly of fishing along 250 km of Northern African coasts ("Barberia"), but also used to collect coral in Corsica, Sardinia, Tunisia and the isle of Scarpanto (Aegean Sea). They were very capable and organized, it is reported that they caught high amount of red coral: 40000 quintals in 15 years (from 1575 to 1591) (Berti, 2003).

In 1500 fishermen from Torre del Greco (Italy) moved towards Corsica and Sardinia to collect red coral, and in 1688 they had more than 400 boats to fish it. They reached the African coasts in 1780, becoming the more expert coral harvester in the Mediterranean Sea.

The coral fisheries in XIX and XX century underwent fluctuating periods of prosperity and decline (Tsounis *et al.,* 2007). For instance in Algeria, in 1876 almost 250 vessels were fishing by the cross; landings during this period were some 250-300 t/vessel/y for the eastern coast (El Kala) (GFCM, 1989). After a period of stasis, following the independence from France (1962) fishing was resumed (1975-1977) totalling some 10 t. In Tunisia from 1885 to 1895, the production was about 7000 kg/year, while from 1920 to 1925, despite the technical improvement, it did not reached 1200 kg /year.

In Italy, in the 1880s the discovery of the Sciacca banks, off Sicily (wide banks of dead fossilized coral) led to a ‘coral rush’ of 2000 vessels into the small area and quickly depleted those grounds, while lowering prices and reducing fishing in other areas (Tsounis *et al.,* 2010). Coral fishing stopped completely during the WWI in 1914–1918. At about the same time, imports of Japanese coral started to reduce demand, and thus fishing, dramatically. Demand for Mediterranean coral increased again, and apart from another pause during WWII (in 1941, there were only 5 boats active, which increased to 31 in 1947), larger-scale coral fishing was resumed. A major event it has been the spread of Scuba diving in coral harvesting, soon after its invention in the early 1940s’, because it allowed divers to pick corals in protected crevices that were inaccessible to dredging. Since the 1954, many Italian sport divers became professional scuba coral harvesters working on banks in Southern Italy (Palinuro), Sardinia, Elba, and Corsica (Liverino, 1983). The 14-mile long Scherchi Channel from Sicily to Tunisia was regarded as a coral ‘el Dorado’, with 80 divers from Italy, France, and Spain harvesting 70–120 t in 1978. In 1979, there were 366 boats at work (283 of them were registered in Italy) and 150 divers (Liverino, 1983).

## PRESENT DATA: FAO DATABASE

FAO (FAO FIGIS) started compiling continuous yield statistics in the 1970s. Differently from the other catch statistics included in the database, which are usually submitted by national official sources, data on red coral are consistently provided since mid-1980s by a major red coral import-export and production of jewellery wholesaler (Garibaldi in GFCM 2010, 2011). Although the data available in the FAO database present some shortcomings (i.e. possible conflict of interest for an industry data provider, data may refer in some cases to trade information rather than to actual annual harvest), the constant provision by the same source ensure consistent information for trend analysis (Garibaldi in GFCM 2010, 2011).

The FAO data certainly underestimate the overall Mediterranean yield since illegal fishing and black-market trade are said to be common (Santangelo *et al.,* 2009). Poaching has been confirmed at the Costa Brava (Spain), Italy and Greece, and is probably common throughout the Mediterranean. In some cases it seems that poachers sell their harvest through licensed divers (Tsounis *et al.,* 2009).

Today's main stocks are located at the Costa Brava (Spain), Corsica (France), Sardinia (Italy), Morocco, and Algeria, although harvesting occurs as well in Sicily (Italy), Mallorca (Spain) and to a lesser extent in some other locations (Croatia, Albania, Greece) (Tsounis *et al.,* 2009).

FAO data since 1978 (Figure 2) show a sharp decline in landings over 20 years. The last major peak recorded lists 98 t of *C. rubrum* in 1978. Coral landings decreased in the period 1978-2010: from 98 t in 1978 to the minimum of 18.9 (1998). Later, the reported yields slightly increased again but in general remained below 40 t (Figure 2, 3).

The global production reaches nowadays the value of 54.11 t (2010). The countries with the largest catches in 2010 are Italy (10.3 t), Tunisia (10.1 t) and France (9.3 t).

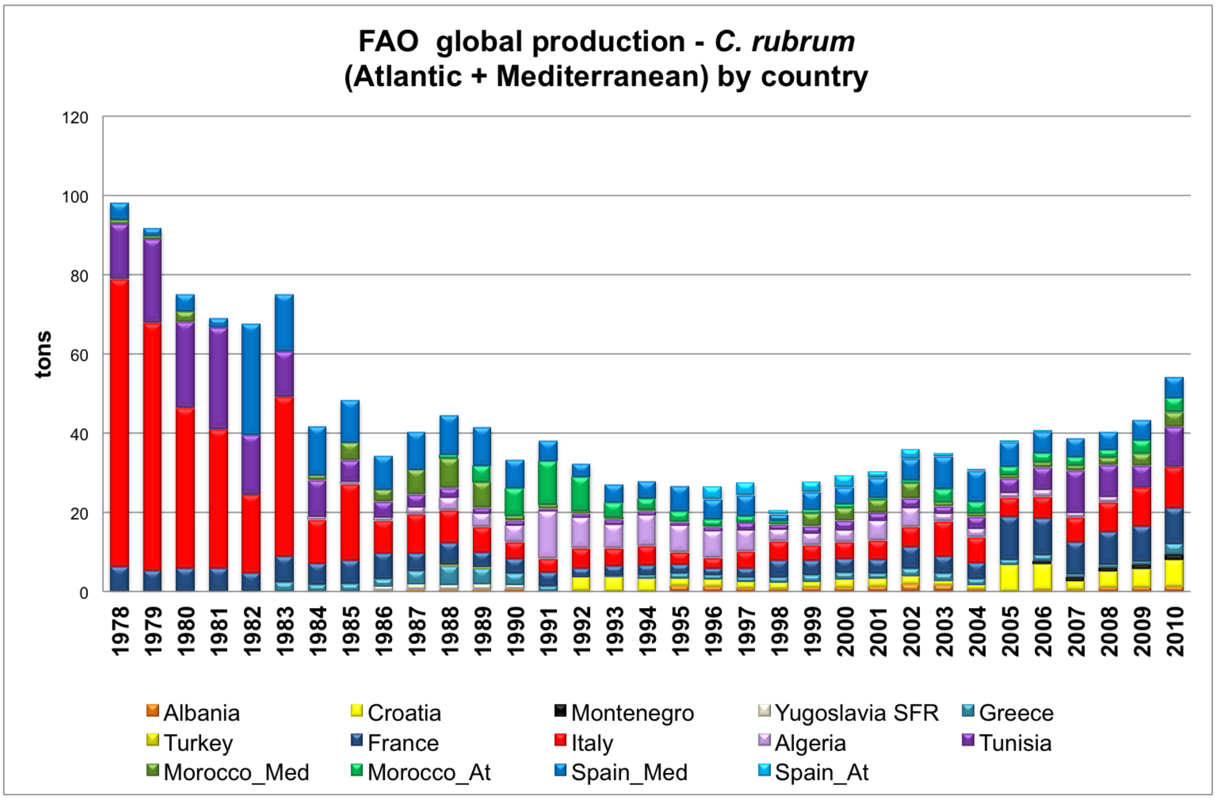


**Figure 2 - FAO FIGIS data for *Corallium rubrum*.**

Apart from minor amounts from the Atlantic coast off Morocco and Spain, all red corals were harvested in the Mediterranean Sea (Figure 2).

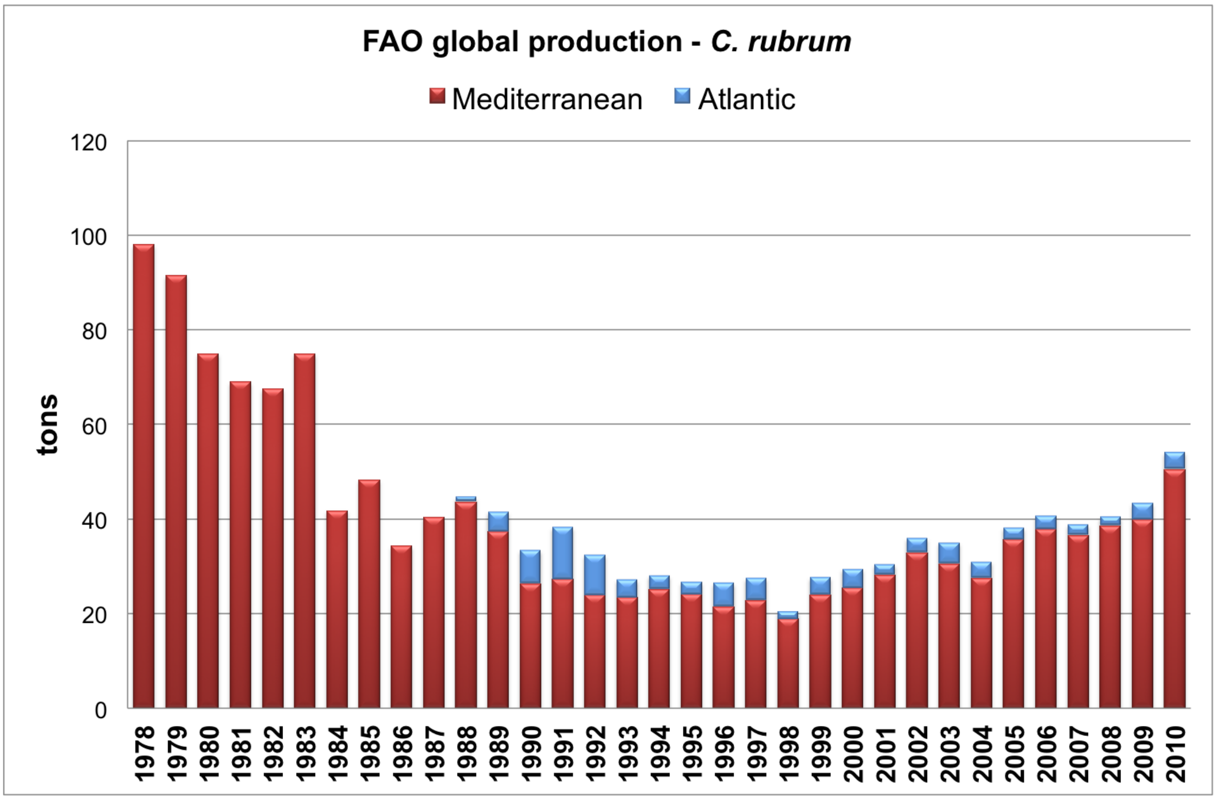


**Figure 3 - FAO FIGIS data for *Corallium rubrum*.**

The decrease in landings is mainly due to the change in harvesting techniques (from the destructive dredging to the selective diving) that has greatly reduced the fishing effort exerted on the species.

In fact, in the light of the immense ecological damage that dredging inflicts on coral habitats (Thrush & Dayton, 2002), coral dredging in European Union waters was banned in 1994. Actually, dredging was phased out even earlier in some countries (see section on gears and countries profiles for further details).

Since inception of SCUBA fishing, landings reported by individual countries have continued to show sharp peaks and declines, which are suggestive of the discovery of large aggregations of coral in a particular area, followed by rapid overexploitation of these populations. Individual peaks in landings during a single year reflect the pulse fishing mode associated with SCUBA harvest, where individual beds are selectively cleared of large colonies, then a new area is targeted. SCUBA fishing was originally concentrated in shallow water, extracting corals from areas that were largely inaccessible to dredges. Over the last two decades, SCUBA fishing has been progressively moving into deeper areas, in response to a depletion of corals in shallow water.

According to a recent publication (Tsounis *et al.,* 2013) in the last decade the yield has been able to remain stable or even increase thanks to 1) the harvesting of ever-smaller corals after depleting larger size classes; 2) the harvesting in ever-deeper waters, and 3) the use of ROV technology for scouting (legal) and harvesting (illegal). Furthermore, the fear to the listing in CITES and the incoming GFCM Fishery Management Plan (FMP) seems to have pushed coral divers to collect as much as possible, before the possible stricter regulations on trade and harvesting become implemented (Tsounis *et al.,* 2013). In fact, the possibility of introducing elements of bureaucratization in trade has been negatively perceived by both Mediterranean divers and manufacturers as having an high probability of leading to significant reductions of red coral in selling and processing (Stampacchia, 2010).

## COUNTRY PROFILES ON PRODUCTION

Hereinafter, Figures 4-13 report FAO data by countries.

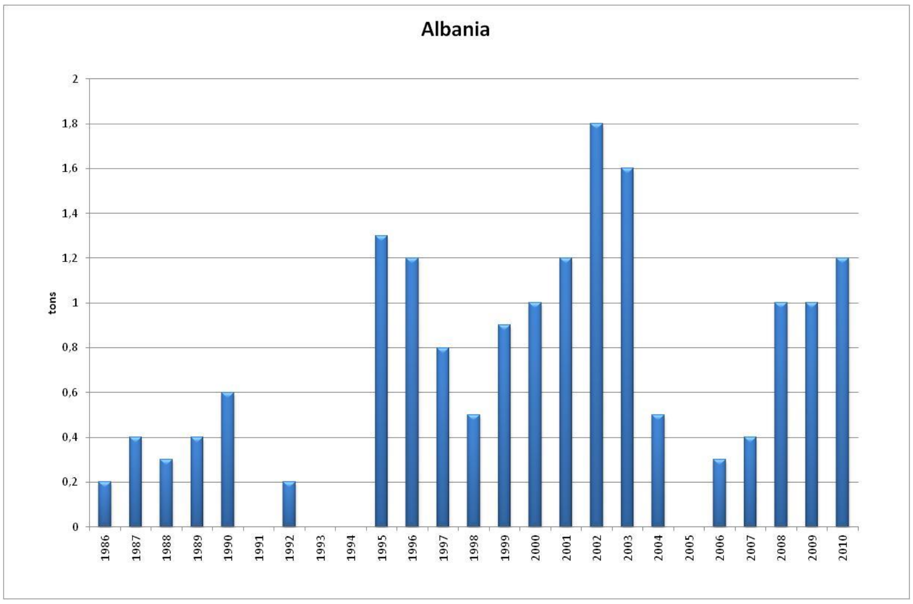


**Figure 4 - FAO FIGIS data for *Corallium rubrum* in Albania.**

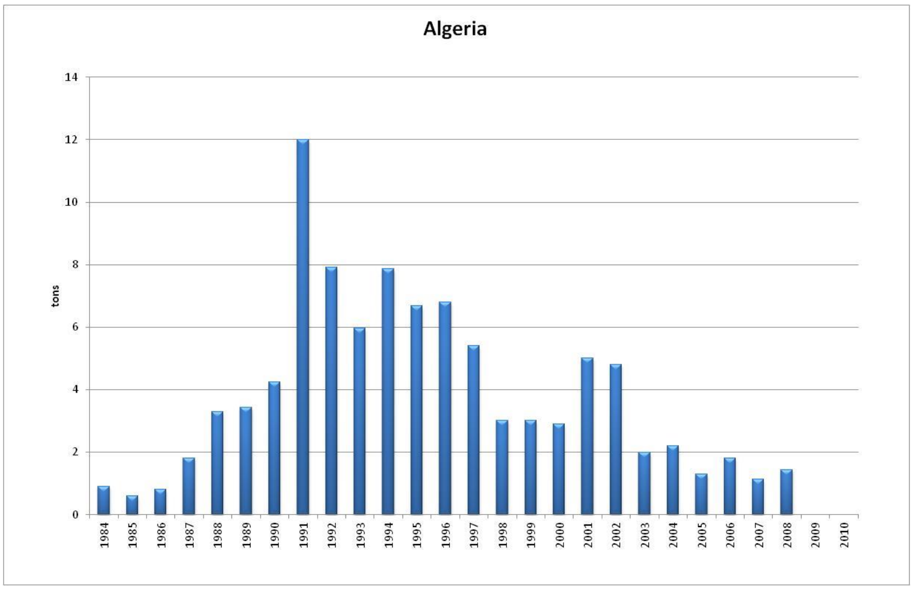


**Figure 5 - FAO FIGIS data for *Corallium rubrum* in Algeria.**

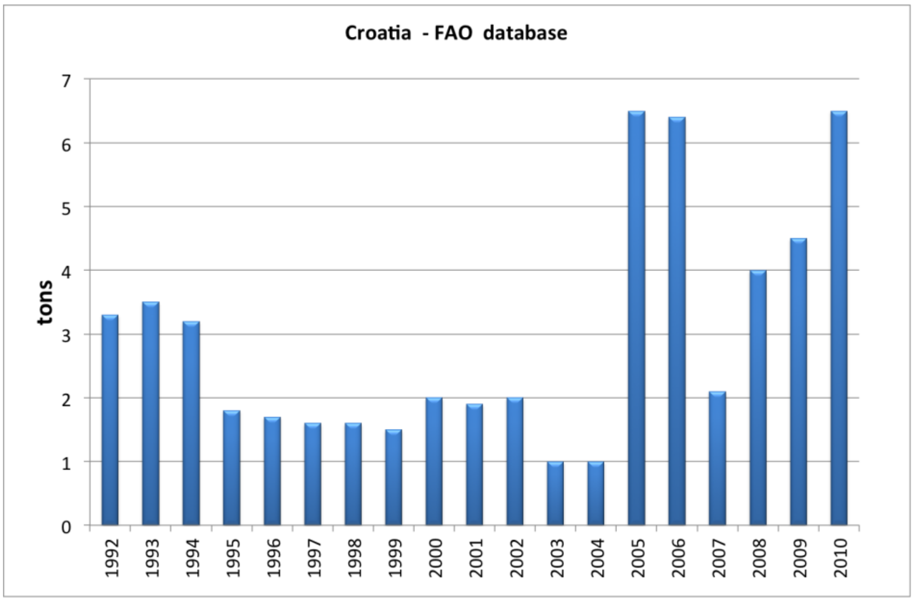


**Figure 6 - FAO FIGIS data for *Corallium rubrum* in Croatia**

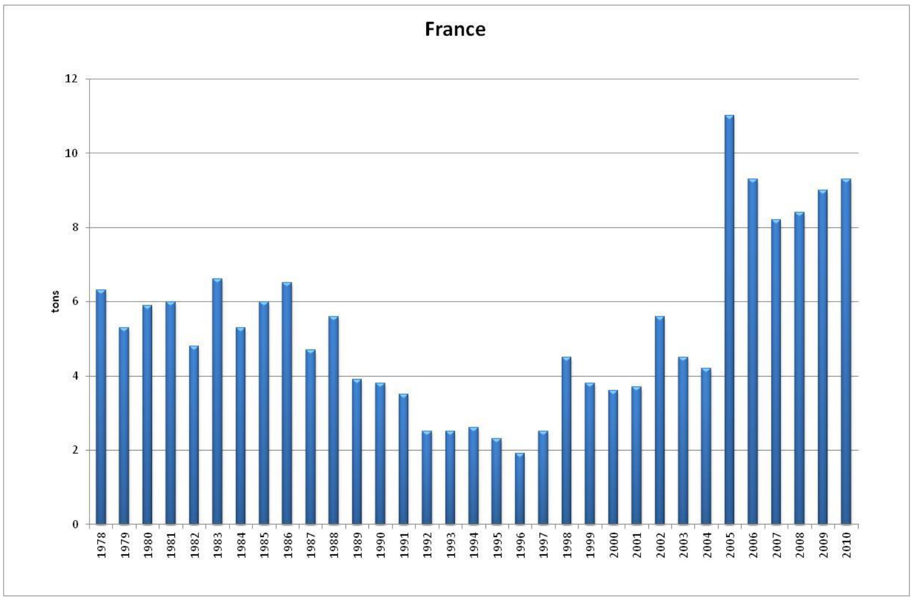


**Figure 7 - FAO FIGIS data for *Corallium rubrum* in France.**

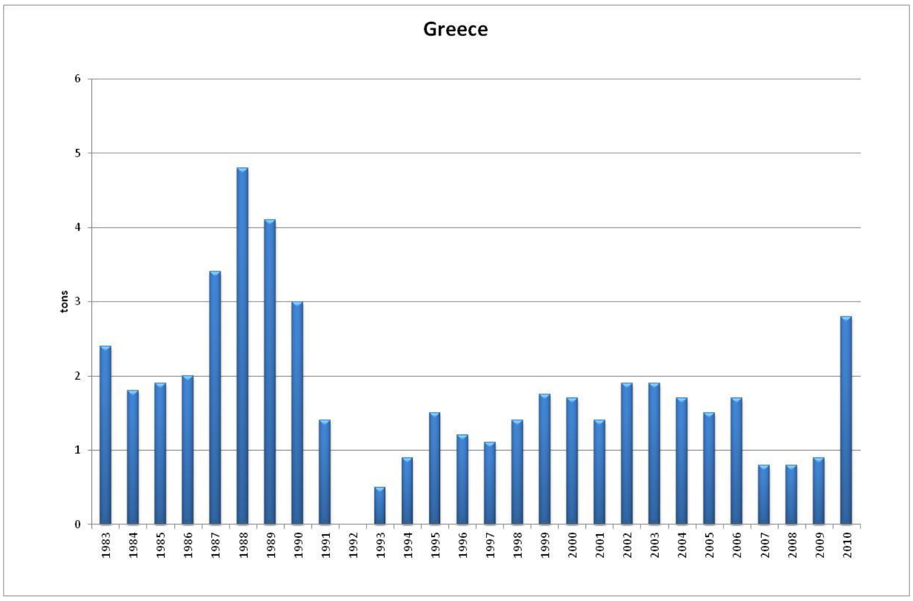


**Figure 8 - FAO FIGIS data for *Corallium rubrum* in Greece.**

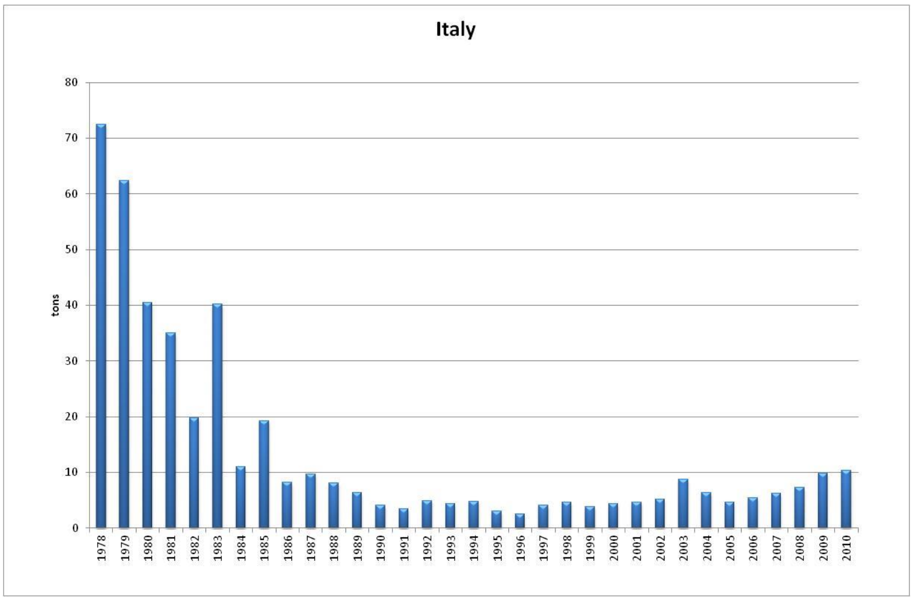


**Figure 9 - FAO FIGIS data for *Corallium rubrum* in Italy.**

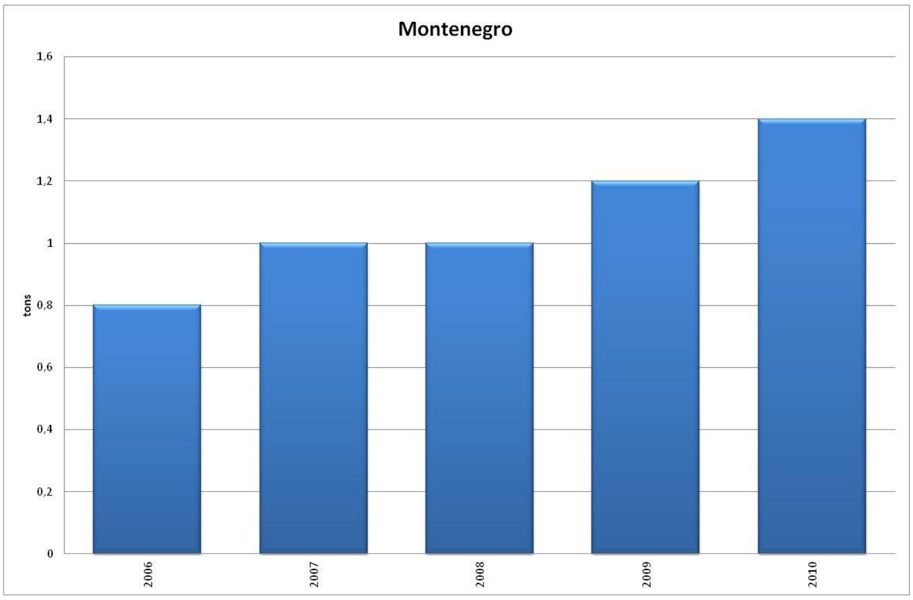


**Figure 10 - FAO FIGIS data for *Corallium rubrum* in Montenegro.**

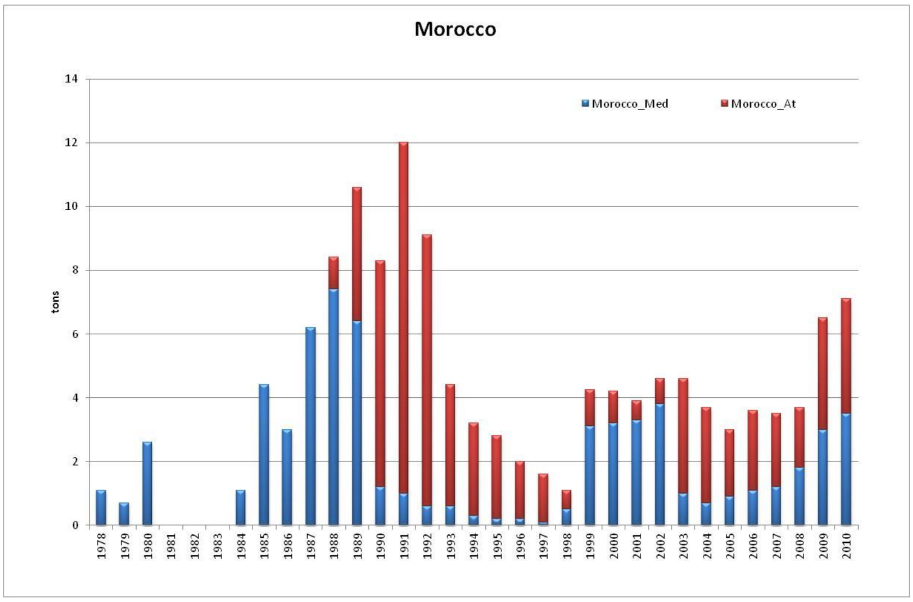


**Figure 11 - FAO FIGIS data for *Corallium rubrum* in Morocco.**

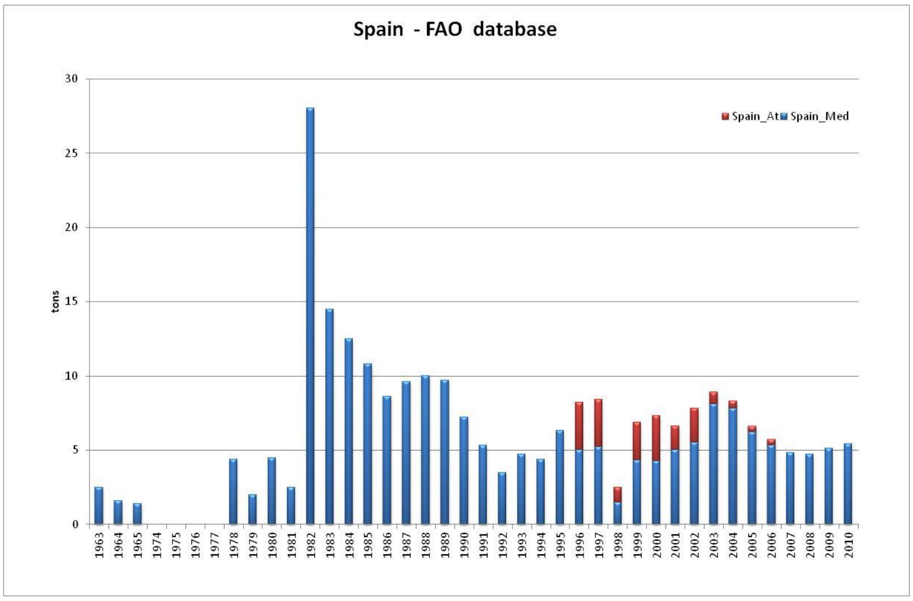


**Figure 12 - FAO FIGIS data for *Corallium rubrum* in Spain.**

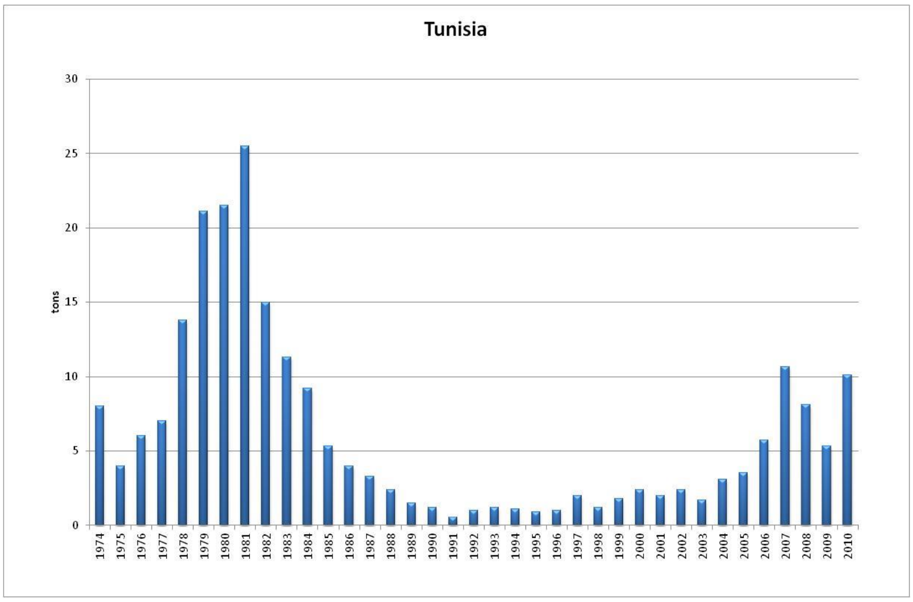


**Figure 13 - FAO FIGIS data for *Corallium rubrum* in Tunisia**

# NATIONAL LEGAL INSTRUMENTS FOR RED CORAL

Apart from being part of the international convention (see International legal instruments on this document), several country have enacted specific laws related to *C. rubrum*.

Actually, only the banks of *C. rubrum* within the limit of the 12 nautical miles from the coast (territorial waters) can be regulated by national laws. The following paragraphs are not to be regarded as containing all the existing information on the subject; the exhaustive lists of all laws, decrees or decisions made by the different countries on red coral is out of the scope of this document.

The information was collected by non-experts and it is reported here for documentation purpose only, with the idea of giving a picture of the different approaches adopted by the different countries.

All the 'best possible and updated' legislative instruments, that were accessible through the FAO-lex database and the Webpages of Governments, Ministries and agencies, are summarized. However, the difficulties in retrieving the documents (especially at the local level) and the involvement of so many different countries and so many different languages could have led to incompleteness and errors due to misunderstandings during the translation.

Further information on management of red coral can be retrieved from the answers of the technical questionnaires (Appendix C) and the document by Cannas *et al.,* (Appendix D) included in the Report of the Transversal workshop on red coral held in Alghero (Sardinia, Italy) in 2010 (Document GFCM: SAC13/2011/Inf.12).

## COUNTRY PROFILES – NATIONAL LEGAL INSTRUMENTS

### ALBANIA

Despite the fact that the taking of corals and sponges is prohibited at any time throughout Albanian waters (except for scientific research purposes (Article 22 of Law No. 7908 of 1995) the FAO global production database record data from 1986 to 2010.

### ALGERIA

Coral fishing was banned from 1977 to at least 1982 considering the opportunity of regulating the fishery (Akrour, 1989). Then, in 1982 the State Secretariat allowed the exploitation of this resource by the Entreprise Nationale des pêches (ENAPECHES); from 1982 to 1987 only two vessels equipped for scuba-diving were active in this fishery in the El Kala area but their number seems to have increased later on (Akrour, 1989). Since 1995

(Décret exécutif n° 95-323 du 21 Octobre 1995 réglementant l'exploitation des ressources corallifères), red coral harvesting was allowed only if in possession of a personal permit, strictly linked to a specific area. Eight areas are identified for exploitation with an annual maximum quota and number of licenses per area, defined as follows:

| area | From to | Maximum quota per area (Kg/year) | N° licenses |
|---|---|---|---|
| **A** | Ras Roux - Ras Rosa | 850 | 20 |
| **B** | Ras Rosa - Ras EI-Hadid | 850 | 20 |
| **C** | Ras EI-Hadid - Ras Bougarouni | 1200 | 10 |
| **D** | Ras Bougarouni - Ras Corbelin | 1200 | 10 |
| **E** | Ras Corbelin - Ras Cascine | 1200 | 10 |
| **F** | Ras Cascine - Ras Ténès | 1200 | 10 |
| **G** | Ras Ténès à Ras Falcon | 1200 | 10 |
| **H** | Ras Falcon à la frontière Algéro-Marocaine | 1200 | 10 |
| **Total** | | 8900 | 100 |

Each area was allowed to be harvested for not more than five (5) consecutive years, and closed for a minimum period of fifteen (15) years following harvesting, to allow for the natural regeneration of beds.

The size limit for the harvesting was fixed at 8 mm of basal diameter. The cut should have been realized at a minimum of 3 cm from the base. To allow for the emission of gametes, the colonies should have been kept submerged for at least two hours from the time if the cut. At the harbour the colonies were checked and weighted in presence of officers (coast guard, customs etc).

Since 1998 the harvest of red coral was again completely interdict, this ban is formally implemented by a later executive decree (Décret exécutif N° 01-56 15 February 2001) that provides for the suspension of the red coral fishery until studies on the evaluation of resource had been finished. Despite the interdiction, the FAO global production database records data also for the period from 1998 to 2008.

## CROATIA

The harvesting is permitted and regulated by the Ministry of Agriculture, Fisheries, and Rural Development.

The Ministry of Agriculture, Fisheries and Rural Development regulates *C. rubrum* fishery imposing a license (around 15 license have been released for 2010), a seasonal closure (the collection of corals is prohibited from 1 December to 31st March), a quota (maximum of 200 kg per year per license*),* the collection can be done by hand with or without diving gear and other tools only powered by human strength and a maximum 2 axes for the detachment of the coral; fishing zones open to license holder have to be indicated in the license. No new licenses will be issued for commercial fishing (including coral extraction) until scientifically based indicators of their status are available. *(Regulation on commercial fishing on the sea (Official Gazette 6/06, 46/06, 66/07, 121/08, 146/08) Regulation on fishing gear* (*Official Gazette 6/06, 46/06, 93/06*) *Regulation on licenses for commercial fishing on the sea and license register (OG 155/05, 135/06, 133/07) Regulation on commercial fishing on the sea (Official Gazette 6/06, 46/06, 66/07, 121/08, 146/08).*

Recently, pursuant the Nature Protection Act (NPA) (Official Gazette Official Gazette NN 70/05, 139/08) and Ordinance on the proclamation of protected and strictly protected wild taxa (Official Gazette NN 06/07and99/09 Annex III 'protected native species' corresponding to the Annex V of the EU Habitats Directive) *Corallium rubrum* has been declared a protected wild taxa in Croatia. It is listed as a critically endangered species on the Red list of corals of Croatia (CITES, 2010).

## FRANCE

The practice of fishing for coral requires the immersion of a diver and ranks in the activity "pêche sous-marine." However, fishing using a breathing apparatus without rising to the surface is prohibited in the France. Therefore, permission to coral harvesting requires derogation from the provisions of Ministerial Decree of 01.12.1960. To this is added the Administrative Decree (DAM) No 85 of 11.4.1980 laying down the conditions for granting authorizations to collect coral diving underwater with breathing apparatus. Fishermen should be in possession of medical and professional documented skills (certificat d'aptitude à l'hyperbarie classe II ou III mention B option pêche au corail). Their license is subject to annual renewal. Furthermore, they must fill a harvest logbook and should be assisted on board by a fisherman with the same hyperbaric certification.

In France, specific regulations for the harvesting of red coral are in place in of the Provence-Alpes-Côte d'Azur (PACA) and Corsica.

The issuance of permits and the conditions governing the exercise in the waters of the French Mediterranean continental (thus excluding Corsica) is regulated each year of a decision of the Prefect of the Provence-Alpes-Côte d'Azur. By delegation, the Regional Director of Maritime Affairs in PACA can take such a decision (Decree No. 90-95 of 25.01.1990 as amended). The last decision that was possible to find date back to 09.01.2003; it grants permits for one year to 17 fishermen. This decision does not mention any restriction in relation to sampling (colony size, quantity) and do not excludes any area of the coast. However, according to the Arrêté n °2012157-0001 du 05 Juin 2012, as a precaution for a period of one year from the publication of the decree the harvesting of red coral in the waters bordering the 'départment des Pyrénée Orientales' is authorized from the 1St of May to the 30th of September each year except in the Reserve of Cerbère-Banyuls where it is interdicted. The harvesting of red coral is interdicted from 0 to 50 m as well as the use of ROV for prospection. The minimum size for collecting colonies is fixed at 8 mm basal diameter. Each authorized fishermen each season can harvest a maximum of 50 kg of red coral (net weight cleaned) and he is obliged to record all the catches in a logbook (with the coordinate, GPS position, date and hour, weight and basal diameter for each colony).

According to the information provided by CRPMEM PACA in 2011, 21 permits were granted for harvesting red coral. This number has changed little during the last ten years, and the idea is to fix this number to a maximum of fisherman licensed to practice this activity of between 22 and 25. However, only 14 of these divers are allowed in the Mediterranean continental French to work beyond 60 meters depth (possessing the Certificat d'Aptitude à l'Hyperbarie (C.A.H.) Class III). It should be noted these figures refers to the fishermen that have a "right" to access to the resource coral not necessarily to those actively harvesting the species. Some of them could exercise another activity (fisherman / sea urchin divers in particular) but renewed still their debit authorization.

Today, red coral fishery in **Corsica** is regulated according to several laws (JORF n°162 du 14 juillet 2006 Texte n°61 and the administrative decrees Decree No. 67-2002, Arrêté N° 06-0358 and 06-0359 du 13 July 2006). The regional administration of Corsica is responsible for determining the number of permits that could be issued, taking particular account of biological capabilities of the areas, market trends and socio-economic issues. Since 2006, in Corsica the number of licenses has been fixed to 10 (art 2 Arrêté N° 06-0358). In case of infraction the license can be retreated and the renewal refused. This decision does not mention any restriction in relation to sampling (colony size, quantity) and excludes no area of the coast. Recently, the Corsican fishermen have agreed to work below 50 m to allow the stocks in shallower waters to recuperate (Arrêté No. 67 / 2002/DRAM; Harmelin, 2007).

## GREECE

The Ministry of Agriculture established the first time relevant legislation in 1987 (Greek Law 1740/1987). According to this legislation, harvesting, processing, and trade of the red coral were to be allowed only after the purchase of a special license. Five years later, after scientific data confirmed its presence in large populations in certain areas of the Greek Seas and at depths ranging from 50 to 110 m (Chintiroglou, 1989), two additional laws were enacted in order to further manage the exploitation of *C. rubrum* (Presidential Decree 174/1994; Ministry Decision 240102/1995). A national rotating harvesting system covering five large fishing geographical zones is applied in Greek waters since the legislative framework was in place in 1994 (Figure 14). According to this scheme, each area may be harvested on a maximum 5-year rotational basis, which is then followed by a 20-year closure period. The harvesting period in each zone can vary depending on the density of coral populations. Overall, a maximum of 10 licenses are given each year, each costing 3000 Euros. The harvesting period in each year lasts from April 1 to December 31. Harvesting is allowed only manually by scuba diving using a pick. Whenever professional coral harvesters find coralligenous formations, they must immediately inform the local port authorities before any harvesting can be undertaken. Collection, transportation, processing, selling of red coral (*Corallium rubrum*) is forbidden, without special permission. Permissions are valid for one year but their validity duration cannot be more than 9 months (Dounas *et al.*, 2010).

Until now, only three out of the five geographical zones of the Greek Seas have been harvested (N. Aegean, S. Aegean-Island of Crete, and Ionian Seas) (Dounas *et al.,* 2010).


**Figure 14 - Greek fishing zones (from Dounas *et al.,* 2010)**

## ITALY

Since 1965, National Law 14th July 1965, n. 963 "Maritime Fishing Regulation," implemented by President of the Republic's Decree (DPR) 2nd October 1968, n. 1639, established specific regulations for the exploitation of discovered coral banks in Italy. In particular, the above-mentioned Law established that fisherman who finds a new coral bank has to declare the discovery to marine authority in order to be allowed to its exploitation for the next two years (Art. 16). Furthermore, President of the Republic's Decree (DPR) 2nd October 1968, n. 1639, issued for implementation of this Law, specified that discovery declaration of a new bank has to include personal data of the fisherman, day of discovery, position and extension of the bank (Art. 123) and that fishing season lasts all the year (Art. 124).

Apart from the national legislation, the harvesting of red coral in Italy is regulated with specific laws/regulations at the local level in Sardinia and Tuscany.

In Sardinia red coral fishery is regulated by 2 Regional Laws: n. 59/1979 afterward integrated and modified by the Regional Law 23/1989, that introduce several restrictions in order to improve sustainable exploitation, conservation of coral resources, and protection of marine ecosystems. Since 1989 only manual harvesting with hatchet is permitted by professional fishermen equipped with scuba-diving devices. All the other fishing methods are banned. Financial aids were provided to sustain transition from destructive dragging methods (Saint Andrew’s cross and Ingegno) to allowed gears (hatchet). In 1988 and 1989 contributions (up to 70% of total costs) were given to fishermen to purchase new fishing equipment (non-selective gears).

The regional permit must be renewed annually and is issued or suspended by means of regional councillor’s decree. The fishermen can apply for the permit only if they can prove to have effectively collected coral in two distinct harvest seasons in the previous 5 years. Furthermore, annually, within January, in compliance with the Regional Council decision and once the opinion of the Regional Technical Advisory Committee is acquired, the councillor’s decree establishes the harvesting effort (harvesting time, maximum daily amounts of coral, allowed areas, the fee amount for license, minimum harvesting size).

Additional harvesting permits can be issued in order to allow scientific research. For ecological and biological protection, requirements the councillor’s decree can forbid coral harvesting in specific areas for a minimum period of 3 years.

If a fisherman collects red corals without the due permit, along with the confiscation of the vessel, of the scuba equipment and of the corals, he shall pay a fine (from 2500 to 25000 Euros) and cannot obtain a permit for at least 3 years. If an authorized diver collects coral in a prohibited area, along with the confiscation of the vessel, of the scuba equipment and of the corals, he shall pay a fine and cannot re-obtain the permit for at least 3 years. The permit will be suspended for at least one year if the fisherman, fishes by diving other species.

The 2012 Regional Sardinian Decrees (N 761GAB/DecA/42; 1374/DecA/94; 1203/DecA/82 and 83) establish that: the harvesting season lasts from 15$^{th}$ May to 15$^{th}$ November (exceptional prorogation), the minimum harvesting size is 10 mm basal diameter with a tolerance of 20% (the measurement should be done with a caliper at midpoint from the base and the first ramification); a maximum of 25 permits fixed (license fee is fixed at 1000 euro); a maximum of 2.5 kg of harvested red coral per day per fisherman; in each vessel there can be a maximum of two fishermen (both with the regional permit); new-harvested red coral has to be maintained in sea water for a minimum of 30 minutes in the net (size ≥ 5 mm) in order to allow the dispersion of gametic products; the apices, accidentally broken, should be left in the harvest site immediately after the collection. Every year coral fishermen have to provide daily harvesting data (coral amounts, position, and depths of fishing areas) within 30 days from the end of harvesting season. Since 2008, harvesting is allowed only under 80m of depth. The coordinates of the areas closed to fishing are also provided in the decree; they are seven protected areas (5 MPAs and 2 National Parks), an area especially designed for the recovery of the resource in the North-Western coast near Capo Caccia – Alghero, 2 areas in the North-East and East Sardinian coast closed due to the strong impact of towed gears used in the past. The landing of catches is authorized only in 8 designated ports; a special procedure for the traceability of red coral is implemented with the obligation of sealing all the colonies caught during each dive in separate plastic bags, with a unique univocal labelled code. The prohibition to use the ROV for prospection and harvesting, and a special derogation of its use for prospection to divers that are involved in a scientific programme funded by the RAS (Autonomous Region of Sardinia) where the use of ROV is allowed only and monitored by the presence on-board of scientific observers.

In Tuscany a Regional law n. 66/2005 regulates the harvesting. A recent decree of the 23rd July 2012, n. 42/R, has closed red coral fishing until the 31st December 2013. From 1st January 2014 fishing will be allowed under strict regulations described in the Art.2: harvesting allowed only under 60 m depth, minimum basal diameter of 8 mm with a tolerance of 5% of overall weight of harvested coral undersized, fishing is allowed only by hand with the use of a peak, no ROV is allowed on-board.

## MALTA

At present, *Corallium rubrum* is strictly protected in Malta, where no exploitation is contemplated. Such a situation has arisen from the verbatim transposition of Habitats Directive species lists into local environmental legislation (Deidun, 2010).

## MONACO

Since at least 1989 two marine reserves (protected zones) were created, one for fishing and the other for coral protection, off the coastline of Monaco (GFCM, 1989). Nowadays, *Corallium rubrum* habitat is protected and no exploitation is allowed (CITES, 2010).

## MONTENEGRO

*Corallium rubrum* is protected under the Decree on putting the protection on certain plant and animal species (Official Gazette RM no. 76/06) issued by the

Institute for Nature Protection 12.12 2006. No data on specific regulation of the red coral fishery exists. The FAO global production database records data for the period from 2006 to 2010.

## MOROCCO

In 2005, the Department of Fisheries promulgated a decree 2-04-26 (January 17, 2005) setting conditions and procedures for harvesting coral. This text fixed the general terms of coral fishing, taking into account the need for rational exploitation of this resource by fixing fishing effort through limitation of the number of ships, harvested quotas by ship, and periods of fishing per zone. Moreover, it stipulates that access to fishing is limited only to ship-owners able to justify the possibility of total treatment in Morocco of the harvested coral, either directly, in a transformation unit, or by a contract of delivery to a third owner or owner of such a unit.

Since the 1980s red coral is harvested by scuba diving; the divers must use a net basket and a sharp marteline which makes it possible to cut the base of the coral colony (Dridi *et al.,* 2010).

In Morocco red coral banks occur mainly in two areas, both along the Mediterranean coasts (Topo and Tofino) and the Atlantic coasts, in particular in the oceanic area ranging from Tangier to Larache but also in other southern areas.

As concerns the Mediterranean banks:

- with the aim of protecting the coral at the level of Topo into the National park of Al Hoceima (Marine Protected Area) the department of marine fisheries closed fishing for 10 years (order n° 1954-05 October 10th, 2005).
- a fishery decree 2.655-06 (November 13, 2006) regulated red coral by quota, but had not set up any size limit, in the marine area named "Tofino", in front of Al Hoceima: fishing boats were limited to a number of 10; every boat had a total annual quota of 500 kg and could have a maximum of 3 divers on-board. The boat had to be smaller than 50 tons gross and fishing was permitted only during daytime (Dridi, 2009). The fleet operating in the coral fields was specialized, and consisted of small units provided with a decompression box and equipped with a capacity of 50 TJB (Dridi, 2009). Later on, according to the decree n° 2409-10 (18 August 2010) the harvesting of red coral has been temporary closed in the Tofino area for 10 years.

As concerns the Atlantic banks:

In 2010, a new order was promulgated to regulate the fishing of coral between Larache and Cap Spartel along the Atlantic coasts (order of Minister for

Agriculture and Marine Fisheries n° 1566-10 May 14th, 2010 regulating the fishing of red coral in between the Cap Spartel and Larache). In 2011 in the same zone a decree of Minister for Agriculture and Marine Fisheries (n° 1980-11 May 6th, 2011 regulating the fishing of red coral in between the Cap Spartel and Larache) has defined the depth limit for harvesting in the depth range between 40 and 80 m.

## SLOVENIA

*Corallium rubrum* probably does not exist in Slovenian waters, and therefore it is not protected under Slovenian laws.

## SPAIN

Nowadays the harvesting in external waters is regulated by the Real Decreto 1415/2005 (regulating fisheries and commercialization of the species) and by the Orden APA/1592/2006 (regulating the proceedings for authorizations of this activity).

Coral can be collected in only five areas by a total of a maximum number of 47 authorized divers (Catalonya 12 permits, Illes Balears/Mallorca 10 permits, Illes Balears/Menorca 10 permits, Almería 5 permits, South Atlantic Region ranging from the border with Portugal to Punta Tarifa 10 permits). In 2010, according to the Ministerio de Medio Ambiente y Medio Rural y Marino, only 44 permits were granted (the maximum number was reached in all the over mentioned areas except for Menorca where only 7 permits were granted).

A maximum of 400 kg of coral per fishermen per fishing year is still fixed, allowing a variance of 10% between raw and net weight of coral, including the computation of the harvesting quota approved by the autonomous communities in interior waters. It is forbidden to remove any red coral branch of diameter < 7 mm at the point of fracture. The cutting should be done through the base of central axis. Measurements shall be taken in each and every one of the branches collected and the diameter of the base of each colony collected always above the basal plate fixing the coral to the substrate.

Only manual harvesting by scuba divers using a pick is permitted and only one dive / a day from sunrise to sunset.

The permit to fishermen is issued for one year and for each of the zones and a person may only hold one permit per zone. Authorizations are granted on the basis of seniority at the sole discretion demonstrated in the exercise of authorized activity. If the number of applications exceeds the number of fixed permits for that year, the permit will be drawn among the candidates who have received the same score.

No permits is granted to applicants who have been sanctioned in the exercise of that activity by a final decision of any civil service in the 24 months preceding the date of the application.

The authorization is personal and not transferable. Each diver must fill the logbook of red coral harvesting issued by the Ministry of Agriculture, Fisheries and Food, to be submitted to the Fishermen's Association of the harbour of landing with the coral removed to certify the weight of coral collected and the size of the branches in the relevant pages of the book. Data should be referred to the Functional Areas of the Ministry of Agriculture, Fisheries and Food.

At the time of each sale, the seller and the buyer must complete the relevant data sheet of the logbook of red coral harvesting. The seller must send a copy of that, within 48 hours of sale, to the General Secretariat for Maritime Fisheries and the competent organ of the Autonomous Region in the territory of which the sale occurred. The Ministry of Agriculture, Fisheries, and Food may request to the divers the transfer of red coral samples harvested with the aim of analysing their biology or resource status.

As concerns the harvesting of red coral in the interior waters, local communities are allowed to enact their own regulations.

Specific regulations are in place in the Baleares Islands (Decreto 40/2003, de 25 de abril, por el que se regula la extracción de Coral Rojo en las aguas interiores de las Illes Balears). The harvesting of red coral is permitted in only two interior water areas (North of Mallorca- between cap de Formentor and cap des Freu- maximum number of 4 permits; North of Menorca – between punta Nati and punta de S’Esperó, except for the marine reserve between la punta des Morter, la isla des Porros y el cap Gros- maximum 2 authorizations). Since 2008, the harvesting is forbidden from the 1st of November to the 30th of April of each year, and the number of permits for North Mallorca is increased to 6. According to the Resolución del Consejero de Agricultura, Medio Ambiente y Territorio de 22 de noviembre de 2011 Num. 24241, imposing supplementary means for regulating the harvesting of red coral in the aguas interiores de las Illes Balears no harvesting is allowed in the area called ‘Norte de Menorca’ while in the area Norte de Mallorca the harvesting is always allowed from the 1st of November 2011 to the 30th of April 2012 to 6 authorized divers.

Similarly, in the Comunidad autonoma de Cataloña the harvesting in the interior waters is regulated by law (Decreto 389/2004, por el que se regula la pesca de coral rojo (*Corallium rubrum*) en las aguas interiores del litoral catalán).

Two interior water areas were originally opened to fishing (from the French border to the municipality of Roses-10 permits; from the municipality of L'Escala to Cabo de Begur – two permits 2) but the following year the second area was closed and the 2 licensed transferred to the first area. In 2010 (Orden AAR/167/2010) only the first area is declared open to harvesting with a maximum of 10 licenses, the second is still closed.

It could happen that a single fisherman is granted for both a permit for harvesting in exterior waters and another for interior waters, usually in the same zone of Spain (e.g., Costa Brava in Cataloña) (Tsounis *et al.,* 2010).

According to the 'AAM/49/2012, de 27 de febrero, por la que se establece la campaña de pesca de coral rojo (*Corallium rubrum*) para el año 2012 en las aguas interiores del litoral de Cataluña' the harvesting season is fixed from 1st May to 31st October 2012. The minimum size of harvesting red coral colonies is fixed at 7 mm of basal diameter with a maximum of tolerance of 5% in weight for undersized colonies.

The local government has established reserves for the protection of *C. rubrum* disposing that the removal of red coral at any depth and time of year is forbidden in the three partial nature reserves located in the marine natural park of Cap de Creus (Orden MAH/293/2005; Law 4 / 1998 12 March; DOGC. 2611, of 1.4.1998) and in the natural parks of El Montgrí, las Illes Medes and El Baix Ter (Law 15/2010).

In Cataloña the Spanish Divers that discover a new bank are obliged to inform the Directorate General for Fisheries and Maritime Affairs as much detail as possible (location, abundance, quality). Furthermore, they must inform the Directorate General for Fisheries and Maritime Affairs if they observe any irregularities related to extractive industries, conservation status of the resource and the quality decreases (article 11). Where the number of applications exceeds the authorization must be granted in accordance with the following priority criteria (no penalty for final administrative decision during the two years preceding the application date; the senior year of activity and continuous practice, according to data in files or administrative records). The dives must be performed at least in pairs, and each of the fishermen must hold its own authorization.

## TUNISIA

Tunisian fisheries law requires to professional divers be licensed to exploit coral and sponges; they are not allowed to unroot (eradicate) the colonies. Furthermore, fishermen have to disembark harvested coral in the port indicated by the administration and total amount has to be weighted under the supervision of an agent. Harvesting is prohibited in the areas of Bizerte, from Cap Blanc to Cap Zebit. Moreover, fishing off "Cani" islands has been banned above 50 m of depth.

## TURKEY

Harvest of corals is prohibited since 1990 according to the Turkish legislation/regulation governing fisheries (CITES, 2010). It is prohibited to catch aquatic products by diving, except for sponges (Fisheries Regulation n 22223 10/03/1995, Article 17).

## OTHER COUNTRIES OUTSIDE GFCM

### GERMANY

*Corallium rubrum* was strictly protected in that country for a decade (from January 1987 to June 1997) through the listing of the species in Annex I of the Germany Federal Ordinance on Species Conservation and resulted in a total prohibition of any commercial trade into Germany both from EU and non-EU Member States. The listing revealed significant (irresolvable) identification problems on the species level for enforcement officials in particular for pre-manufactured products, jewellery or products made of coral dust. Wrong identification lead to wrong declarations of seizures of red coral shipments from countries where the species doesn’t occur in the wild (Dietrich, 2010).

### GIBRALTAR (UK)

Red coral is protected in Gibraltar under the Nature Protection Act 1991 Annex V (Animal and plant species of community interest whose taking in the wild and exploitation may be subject to management measures). All trade of the species is restricted under the Endangered Species Act 1991 (amendment 113/2003, Schedule 1). The species is now considered very rare in Gibraltar waters, having disappeared from the shallower waters near the territory. Trade is likewise rare (CITES, 2010).

# INTERNATIONAL LEGAL INSTRUMENTS FOR RED CORAL

## BARCELONA CONVENTION (SAP BIO AND SAP BIO CORALLIGENOUS AP)

CONVENTION FOR THE PROTECTION OF THE MARINE ENVIRONMENT AND THE COASTAL REGION OF THE MEDITERRANEAN known as the Barcelona Convention (revised on 10 June 1995, modifying the Convention for the Protection Of The Mediterranean Sea Against Pollution signed 16 February 1976). The Barcelona Convention has given rise to 10 Protocols addressing specific aspects of Mediterranean environmental conservation, among them the SPA Protocol #6 SPA and BD Protocol#7(Specially Protected Areas and Biological Diversity in the Mediterranean) that includes 3 Annexes. *Corallium rubrum* is listed in Annex III of the SPA/BD protocol (List of 'Species whose exploitation is regulated', last amended in February 2012).

With a view to furthering the implementation of the SPA Protocol the Contracting Parties of the Barcelona Convention established the RAC SPA (Regional Activity Centre for Specially Protected Areas) in Tunis in 1985. RAC/SPA developed a Strategic Action Programme for the Conservation of Biological Biodiversity in the Mediterranean Region (SAP BIO) which was adopted by the Contracting Parties in 2003. The basic objective of this Strategic Action Plan is to foster the improving of knowledge of marine and coastal biodiversity, improve the management of existing, and favour the creation of new Marine and Coastal Protected Areas, enhance the protection of endangered species and habitats, contribute to the reinforcement of relevant national legislation and national and international capacity building. Regarding marine ecosystems, the SAP BIO, in particular, recognizes special attention to the coralligenous community and emphasizes the negative indirect effects of the use of active gear, particularly trawls, often used illegally at shallow depths, causing the destruction of vast stretches of coralligenous bottoms. Furthermore, it stresses how the uncontrolled recreational activities, such as over-frequentation by divers, could cause erosion of this sensitive ecosystem. More specifically, among the proposed priority actions in Category III (ASSESSING AND MITIGATING THE IMPACT OF THREATS ON BIODIVERSITY) the Priority Action N° 21 (Assessment, control and elaboration of strategies to prevent impact of fisheries on biodiversity) Objective f (Mediterranean strategy to eliminate particularly harmful fishing practices) call for the Geographical identification of priority areas with a significant occurrence of coral fishing using the Saint Andrew Cross.

Later on, in 2008, a specific SAP BIO Coralligenous AP (Action Plan) was adopted by the Contracting Parties, in order to propose a work programme aiming to conserve the Coralligenous ecosystem. Although it does not have a binding legal character, this Action plan was adopted as a regional strategy setting priorities and activities to be undertaken. Among the major threats affecting the Coralligenous community special care is given to the commercial exploitation of red coral (*Corallium rubrum*), whose stocks have strongly declined in most areas, for which an adequate management of this extremely valuable and long-lived species is considered necessary.

## BERN CONVENTION

CONVENTION ON THE CONSERVATION OF EUROPEAN WILDLIFE AND NATURAL HABITATS (19.IX.1979) known as the Bern Convention, which has the aim to conserve wild flora and fauna and their natural habitats, especially those species and habitats whose conservation requires the co-operation of several States. Particular emphasis is given to endangered and vulnerable species, including endangered and vulnerable migratory species. In particular, *C. rubrum* is listed in Annex III of the Bern Convention (list of the 'PROTECTED FAUNA SPECIES', in force since 1 March 2002 and regularly revised by the Standing Committee). According to Articles 7 and 8, appropriate and necessary legislative and administrative measures should be taken by the Contracting Party in order to ensure the protection and the regulated exploitation of the wild fauna species specified in Appendix III. Measures to be taken shall include: closed seasons and/or other procedures regulating the exploitation; the temporary or local prohibition of exploitation, as appropriate, in order to restore satisfactory population levels; the regulation as appropriate of sale, keeping for sale, transport for sale or offering for sale of live and dead wild animals. In respect of the capture or killing of wild fauna species specified in Appendix III Contracting Parties shall prohibit the use of all indiscriminate means of capture and killing and the use of all means capable of causing local disappearance of, or serious disturbance to populations of a species. Among the Contracting Parties, those where red coral is probably present are: Albania, Croatia, Cyprus, France, Greece, Italy, Malta, Monaco, Montenegro, Portugal, Spain, The former Yugoslav Republic of Macedonia, Turkey, Morocco, Tunisia, the European Union.

## EU LEGISLATION

The European Union: several laws explicitly call on the conservation of red coral and the protection of the Coralligenous community

### HABITATS DIRECTIVE

The COUNCIL DIRECTIVE 92/43/EEC of 21 May 1992 (and following amendments Directive 97/62/EC, Regulation (EC) No 1882/2003, Directive 2006/105/EC), known as the Habitats Directive, which is intended to help maintain biodiversity in the Member States by defining a common framework for the conservation of wild plants and animals and habitats of Community interest. *Corallium rubrum* is listed in Annex V of the European Union Habitats Directive (List of the "Animal and plant species of Community interest whose taking in the wild and exploitation may be subject to management measures”). On the contrary, despite their recognized importance, the Coralligenous assemblages are not explicitly listed in the Habitats Directive (in a broader sense they can fall under the “Reefs Biogenic concretions” habitat type habitat 1170 and “Caves” habitat 8330, already listed in Annex I) but their specific inclusion as a priority natural habitat type is highly encouraged by the RAC/SPA, because this would enable at least EU countries to set up an ecological network of conservation areas in the framework of Natura 2000.

## COUNCIL REGULATION (EC) NO 1967/2006

The over-mentioned EU regulation deals with management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea. Amending Regulation (EEC) No 2847/93 and repealing Regulation (EC) No 1626/94 in Article 2.12 gives a definition of "coralligenous habitat", in Article 4.2 states that “Fishing trawl nets, dredges, shore seines or similar nets above coralligenous habitats and maërl beds shall be prohibited” and Article 4.4 that this prohibition “shall apply to all Natura 2000 sites, all special protected areas and all specially protected areas of Mediterranean interest (SPAMI) which have been designated for the purpose of the conservation of these habitats under either Directive 92/43/EEC or Decision 1999/800/EEC”. Article 8.1e,g states that ‘towed devices for harvesting red coral or other type of corals or coral-like organisms’ as well as ‘St Andrew's cross and similar grabs for harvesting, in particular, red coral or other type of corals or coral-like organisms’ shall not be used for fishing or kept on board. Actually, the ban to use the St. Andrew’s cross was already include in the 1994 EC Council Regulation No 1626/94.

Apart from being part of the international convention, several countries have enacted specific laws related to *C. rubrum*. Actually, only the banks of *C. rubrum* within the limit of the 12 nautical miles from the coast (territorial waters) can be regulated by national laws. A summary of the principal laws and regulations has been presented in the country profiles section.

# INTERNATIONAL LEGAL FRAMEWORK FOR MANAGEMENT OF RED CORAL

With the growing scarcity of fish resources, ensuring sustainable and equitable management of biodiversity from local to global levels is the objective of many Conventions and Laws.

In fact, the availability of 'good' legal instruments for fisheries management is crucial.

The following paragraphs recall the main international legal instruments dealing with sustainability, precautionary approach, and responsible fishery practices.

For a more exhaustive information and discussion the reading of the IUCN report titled 'Towards Sustainable Fisheries Law A Comparative Analysis' is highly recommended (Winter, 2009).

## SUSTAINABLE (RESPONSIBLE) FISHERY

United Nations Convention on the Law of the Sea (UNCLOS) (adopted in 1982)

Article 56(1)(a) UNCLOS, coastal states have 'sovereign rights for the purpose of exploring and exploiting, conserving and managing' the living resources

Article 61(1) UNCLOS, the coastal state 'shall determine the total allowable catch of the living resources in its exclusive economic zone'.

Article 61(2) UNCLOS, '[t]he coastal state… shall ensure through proper conservation and management measures that the maintenance of the living resources in the exclusive economic zone is not endangered by over-exploitation'.

Article 61(2) UNCLOS paragraph 3: Proper conservation and management measures shall be 'designed to maintain or restore populations of harvested species at levels which can produce the maximum sustainable yield'.

Article 61(2) UNCLOS coastal state should to take 'into account the best scientific evidence available to it' in determining conservation and management measures, albeit not to base its action solely on such evidence.

Article 62(4) UNCLOS contains a non-exhaustive catalogue of conservation measures and 'other terms and conditions' that the coastal state may establish. It includes the licensing of fishermen and vessels; fees; catch quotas; area, time and gear restrictions; minimum fish sizes; monitoring requirements; and enforcement procedures.

Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks ('UN Fish Stocks Agreement') (adopted in 1995).

Its objective is 'to ensure the long-term conservation and sustainable use of straddling fish stocks and highly migratory fish stocks through effective implementation of the relevant provisions of UNCLOS'.

Article 5 provides that, in order to conserve and manage straddling and highly migratory fish stocks, coastal states and states fishing on the high seas shall 'adopt measures to ensure [their] long-term sustainability… and promote the objective of their optimum utilization'.

Annex II on Guidelines for the Application of Precautionary Reference Points in Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks elucidates the role of MSY under the Agreement. The Annex distinguishes (i) conservation, or limit, reference points, which identify safe biological limits for harvesting, and (ii) management, or target, reference points, which define management objectives within safe biological limits. MSY is to be regarded as a 'minimum standard for limit reference points', rather than a management objective. Under the Agreement, management objectives will have to be set below MSY and thus at a lower level than was previously required under UNCLOS.

Article 5 further include the development and use of selective and environmentally safe fishing gear and the limitation of fishing effort to levels commensurate with the sustainable use of fishery resources, as well as monitoring, control and surveillance measures.

Article 5(b) requires that conservation and management measures are based on the best scientific evidence available to the coastal state. Under the Agreement, coastal states must further assess the impacts of fishing, other human activities and environmental factors on target stocks, dependent and associated species, and other species belonging to the same ecosystem, promote and conduct scientific research, and collect and share data and information.

FAO Code of Conduct for Responsible Fisheries ('FAO Code of Conduct' or 'the Code') (adopted by consensus at the Twenty-eighth Session of the FAO Conference on 31 October 1995).

It sets out 19 'general principles' from which the remaining provisions of the Code are derived.

Article 6.1 asserts that '[t]he right to fish carries with it the obligation to do so in a responsible manner so as to ensure effective conservation and management of the living aquatic resources', and calls upon states and individual users to conserve aquatic ecosystems.

According to Article 6.2, '[f]isheries management should promote the maintenance of the quality, diversity and availability of fishery resources in sufficient quantities for present and future generations in the context of food security, poverty alleviation and sustainable development'.

According to its Art. 6.2, fisheries management measures 'should not only ensure the conservation of target species but also of species belonging to the same ecosystem or associated with or dependent upon the target species'. Critical fisheries habitats should be protected and rehabilitated (Art. 6.8); conservation and management decisions should be based on the best scientific evidence available (Art. 6.4).

Art. 7 FAO Code of Conduct specifically address fisheries management. The overriding objective is the long-term conservation and sustainable use of fisheries resources (Art. 7.1.1, 7.2.1). In particular, states 'should ensure that levels of fishing effort are commensurate with the sustainable use of fishery resources' (Art. 7.1.8, Art. 7.6.3).

The Code envisages conservation and management measures 'designed to maintain or restore stocks at levels capable of producing maximum sustainable yield, as qualified by relevant environmental and economic factors' (Art. 7.5).

According to Art. 12.1, 'States should ensure that appropriate research is conducted into all aspects of fisheries', so as to provide a sound scientific basis for decision making. In particular, '[i]n the absence of adequate scientific information, appropriate research should be initiated as soon as possible' (Art. 12.3). The actions required to promote such research, as well as the collection and efficient use of data, are concretized through Art. 12.2-20 Paragraphs 5 and 6 of Art. 12 call on states to establish the necessary research capacity, with special provisions on support to developing countries in paragraphs 18 and 20.

The Plan of Implementation of the World Summit on Sustainable Development (JPoI), adopted by the World Summit on Sustainable Development held in Johannesburg in 2002.

It addresses the 'sustainable development of the oceans'.

Actions are asked for 'at all levels' to achieve sustainable fisheries include the maintenance at or restoration of stocks to levels that can produce MSY, 'with the aim of achieving these goals for depleted stocks on an urgent basis and where possible not later than 2015' (Para. 31(a)).

'the scientific understanding and assessment of marine and coastal ecosystems as a fundamental basis for sound decision making', inter alia through cooperation and promotion of 'the use of environmental impact assessments and environmental evaluation and reporting techniques (Para. 36).

## THE PRECAUTIONARY PRINCIPLE

Principle 15 of the Rio Declaration as the most frequently cited formulation provides that '[i]n order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation'. In the fisheries management context, however, the precautionary principle or approach has found specific recognition.

UN Fish Stocks Agreement

Article 3(1) Paragraph 1 provides that '[s]tates shall apply the precautionary approach widely to conservation, management and exploitation of straddling and highly migratory fish stocks in order to protect the living marine resources and preserve the marine environment'. Paragraph 2 specifies the content of the precautionary approach by stating that '[s]tates shall be more cautious when information is uncertain, unreliable or inadequate. The absence of adequate scientific information shall not be used as a reason for postponing or failing to take conservation and management measures'.

Annex II to the UN fish stock Agreement provides guidelines for the application of 'precautionary reference points'. Precautionary reference points are so-called 'target reference points' defining management objectives, and 'limit reference points' identifying safe biological limits for harvesting. The action to be taken if such reference points are exceeded must be determined in advance. This means that conservation measures will automatically become applicable. Moreover, when precautionary reference points are approached, ongoing fishing activities would have to be characterized as overfishing. It may thus be argued that Article 61(2) UNCLOS itself, laying down the duty of coastal states to ensure that the marine living resources are not endangered by overexploitation, requires a halt to fishing in such instances.

Additionally, states are obligated under the Agreement to 'adopt plans which are necessary' to conserve non-target species and protect habitats of special concern. Article 6(6) requires the adoption of cautious conservation and management measures, including catch and effort limits, for new or exploratory fisheries as soon as possible, which are to remain in force until sufficient data allow assessment of the long-term impact on the stocks.

Besides, the Agreement provides for emergency measures to be taken where natural phenomena adversely affect straddling or highly migratory fish stocks, so as to ensure that fishing does not exacerbate such impacts. Notably, the same applies where fishing activities themselves seriously threaten the sustainability of such stocks.

**The FAO Code of Conduct** also accords a central role to the precautionary approach:

'States should apply the precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment. The absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures.'

In broadly the same the Code calls upon states to take into account a number of uncertainties in implementing the precautionary approach; to determine target and limit reference points and the action to be taken when they are approached or exceeded; and to adopt cautious conservation and management measures for new or exploratory fisheries, as well as emergency measures to avert certain detrimental effects of fishing.

Moreover, the **UN General Assembly** Resolution A/RES/61/105 on sustainable fisheries calls upon states 'to apply widely, in accordance with international law and the Code, the precautionary approach… to the conservation, management and exploitation of fish stocks… and also calls upon States parties to the [UN Fish Stocks]. Agreement to fully implement the provisions of article 6 of the Agreement as a matter of priority'.

The precautionary approach to fisheries conservation and management thus qualifies as a general principle of international law within the meaning of Article 38(1) (c) ICJ Statute.

## ECOSYSTEM APPROACH TO FISHERY (EAF)

According to Lackey (1999), ecosystem management is "the application of ecological, economic, and social information, options, and constraints to achieve desired social benefits within a defined geographic area and over a specified period".

It involves "management decisions which involve a broad awareness of the consequences of fishing or other human actions to an ecosystem….used to infer the necessity of understanding multispecies interactions and questions of altered structure of the biological community" (ecosystem stability)" (FAO-ACMRR, 1979).

It aims at: (1) maintaining viable populations of all native species in situ; (2) representing within protected areas all native ecosystem types across their natural range; (3) maintaining evolutionary and ecological processes; (4) managing over periods of time of sufficient duration to maintain evolutionary potential of species and ecosystems; and (5) accommodating human use and occupancy within these constraints (Grumbine, 1994, cited by Larkin, 1996).

The term "Ecosystem Approach to Fisheries" (EAF) was adopted by the FAO Technical Consultation on Ecosystem-based Fisheries Management held in Reykjavik from 16 to 19 September 2002 (FAO, 2003)

EAF is defined by Ward *et al.,* (2002) as "an extension of conventional fisheries management recognizing more explicitly the interdependence between human well-being and ecosystem health and the need to maintain ecosystems productivity for present and future generations, e.g. conserving critical habitats, reducing pollution and degradation, minimizing waste, protecting endangered species".

In general, the approach is taken as requiring: (1) definition and scientific description of the ecosystem in terms of scale, extent, structure, functioning; (2) assessment of its state in terms of health or integrity as defined by what is acceptable to society; (3) assessment of threats; and (4) maintenance, protection, mitigation, rehabilitation, etc., using (5) adaptive management strategies.

The concepts and principles of an EAF are not new, as they are contained in a number of international instruments, agreements and conference. According to Garcia *et al.,* 2003 these include: • the 1972 World Conference on Human Environment; • the 1982 United Nations Law of the Sea Convention; • the 1992 United Nations Conference on Environment and Development and its Agenda 21; • the 1992 Convention on Biological Diversity; • the 1995 United Nations Fish Stocks Agreement; and • the 1995 FAO Code of Conduct for Responsible Fisheries.

A summary of the content of these instruments as well as further information on this issue can be found in:

Garcia S.M., Zerbi A., Aliaume C., Do Chi T., Lasserre, G. 2003 The ecosystem approach to fisheries. Issues, terminology, principles, institutional foundations, implementation and outlook. FAO Fisheries Technical Paper. No. 443. Rome, FAO. 71 p. Annex I

# REFERENCES


Abbiati M., Buffoni G., Caforio G., Di Cola G. and Santangelo G., 1992 Harvesting, predation and competition effects on a red coral population. Netherlands Journal of Sea Research 30: 219-228.

Abbiati M., Novelli S., Harmelin J.G., Santangelo G., 1997 Struttura genetica di popolamenti simpatrici e allopatici di corallo rosso. In: Cicogna F, Bavestrello G, Cattaneo-Vietti R (eds) Biologia e tutela del corallo rosso e di altri ottocoralli del Mediterraneo. Ministero delle politiche agricole, Rome, p 5–21

Abbiati M., Santangelo G. & Novelli S., 1993 Genetic variation within and between two Tyrrhenian populations of the Mediterranean alcyonarian *Corallium rubrum*. Marine Ecology Progress Series, 95, 245–250.

Akrour A., 1989 Annex Q: Communication algérienne sur la législation de la peche au corail. Report of the second GCFM technical consultation on red coral in the Mediterranean. FAO, Rome.

Angiolillo M., Canese S., Salvati E., Giusti M., Cardinali A., Bo M., Greco S., 2009. Presence of *Corallium rubrum* assemblages below 50m along the Calabrian coasts. In: UNEP-MAP-RAC/SPA, 2009. Proceedings of the 1th symposium on conservation of the coralligenous bio-concretions (Tabarka 16–19 January 2009). Pergent-Martini C., Brichet (eds) RAC/SPA publ. Tunis.

Ardila NE, Giribet G, Sánchez JA., 2012 A time-calibrated molecular phylogeny of the precious corals: Reconciling discrepancies in the taxonomic classification and insights into their evolutionary history. BMC Evolutionary Biology 246.

Aurelle D., Ledoux J. B., Rocher C., Borsa P., Chenuil A. *et al.,* 2011 Phylogeography of the red coral (*Corallium rubrum*): inferences on the evolutionary history of a temperate gorgonian. Genetica 139: 855-869.

Ballesteros E., 2006 Mediterranean coralligenous assemblages: A synthesis of present knowledge. Oceanography and Marine Biology - an Annual Review 44: 123-195.

Bavestrello G., Cerrano C. and Cattaneo-Vietti R., 2010 Biological interactions affecting the growth rates of red coral (*Corallium rubrum*) colonies, pp. 151-158 in Proceedings of the International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean, edited by E. Bussoletti, D. Cottingham, A. Bruckner, G. Roberts and R. Sandulli. NOAA Technical Memorandum CRCP-13, Silver Spring, MD, Napoli.

Berti M., 2003 La pesca e il commercio del corallo nel Mediterraneo e le prime "compagnie dei coralli" di Pisa tra XVI e XVII secolo in La pesca in Italia tra età moderna e contemporanea. Produzione, mercato, consumo, edited by G. Doneddu and A. Fiori. Edes, Sassari.

Beverton R. J. H. and Holt S. J.,1957. "On the Dynamics of Exploited Fish Populations," Chapman and Hall, London, 1957, p. 179

Bo M., Bertolino M., Borghini M., Castellano M., Covazzi Harriague A., Di Camillo C. G., Gasparini G., Misic C., Povero P., Pusceddu A., Schroeder K. & Bavestrello G., 2011 Characteristics of the Mesophotic Megabenthic Assemblages of the Vercelli Seamount (North Tyrrhenian Sea). PLoS ONE 6, e16357.

Bramanti L., Iannelli M., Santangelo G., 2009 Mathematical modelling for conservation and management of gorgonian corals: youngs and olds, could they coexist? Ecol Model 220:2851–2856

Bramanti L., Magagnini G., De Maio L. and Santangelo G., 2005 Recruitment, early survival and growth of the Mediterranean red coral *Corallium rubrum* (L 1758), a 4-year study. Journal of experimental Marine Biology and Ecology 314: 69-78.

Bramanti L., Movilla J., Guron M., Calvo E., Gori A., Dominguez-Carrió C. & Rossi S., 2013. Detrimental effects of Ocean Acidification on the economically important Mediterranean red coral (*Corallium rubrum*). Global Change Biology 19(6):1897-1908

Bramanti L., Rossi S., Tsounis G., Gili J.M., Santangelo G., 2007 Settlement and early survival of red coral aon artificial substrate in different geographic areas: some clues for demography and restoration. Hydrobiologia 580:219–224

Bruckner A.W., 2009 Rate and extent of decline in *Corallium* (pink and red coral) populations: existing data meet the requirements for a CITES Appendix II listing. Marine Ecology Progress Series 397: 319–332.

Caddy J. F., 1975 Spatial model for an exploited shellfish population, and its application to the Georges Bank scallop fishery. J. Fish. Res. Board Can. 32(8): 1305-1328.

Caddy J. F., 1988 Recent developments in research and management for wild stocks of bivalves and gastropods. In J. F. Caddy (Editor), Marine invertebrate fisheries: Their assessment and management, p. 665-700. John Wiley-Intersci. Publ., John Wiley & Sons, N.Y.

Caddy, J. F. 1993 Background Concepts for a Rotating Harvesting Strategy with Particular Reference to the Mediterranean Red Coral, *Corallium rubrum*. Marine Fisheries Review 55:10-18

Calcinai B., Cerrano C., Iwasaki N. and Bavestrello G., 2010 Biodiversity and ecology of sponge boring into precious corals: a worldwide overview, pp. 165-171 in Proceedings of the International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean, edited by E. Bussoletti, D. Cottingham, A. Bruckner, G. Roberts and R. Sandulli. NOAA Technical Memorandum CRCP-13, Silver Spring, MD, Napoli.

Calderon I., Garrabou, J., Aurelle, D. 2006 Evaluation of the utility of COI and ITS markers as tools for population genetic studies of temperate gorgonians. Journal of Experimental Marine Biology and Ecology 336(2):184–197

Caley M. J., CarrM. H., Hixon M. A., Hughes T. P., Jones G. P. *et al.,* 1996 Recruitment and the local dynamics of open marine populations. Annual Review of Ecology and Systematics 27: 477-500.

Cannas R., Caocci F., Follesa M. C., Grazioli E., Pedoni C., Pesci P., Sacco F., Cau A. 2010 Multidisciplinary data on the status of red coral (*Corallium rubrum*) resource in Sardinian seas (central western Mediterranean), pp. 40-57 in Proceedings of the International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean, edited by E. Bussoletti, D. Cottingham, A. Bruckner, G. Roberts and R. Sandulli. NOAA Technical Memorandum CRCP-13, Silver Spring, MD, Napoli.

Cannas R., Caocci F., Follesa M. C., Pedoni C., Pendugiu A. A., Pesci P., Sacco F., Cau A., 2011 The red coral resource in Sardinian seas: a multidisciplinary survey on *Corallium rubrum* populations. Studi Trent. Sci. Nat. 89: 9-18.

Casu M., Casu D., Lai T., Cossu P., Curini-Galletti M., 2008 A molecular tool for genetic surveys in the red coral (*Corallium rubrum*): an inter-simple sequence repeats (ISSRs) perspective. Biochem Syst Ecol 36:77–83

Caswell H., 2001. Matrix Population Models: Construction, Analysis and Interpretation. 2nd Ed.Sinauer Associates, Sunderland, Massachusetts.

Cattaneo-Vietti R. and Bavestrello G., 1994 Four years rearing experiments on the Mediterranean red coral. . Biologia Marina Mediterranea 1: 413-420.

Cerrano C., Bavestrello G., Bianchi C. N., Cattaneo-vietti R., Bava S., Morganti C., Morri C., Picco P., Sara G., Schiaparelli S., Siccardi A., Sponga F. 2000 A catastrophic mass-mortality episode of gorgonians and other organisms in the Ligurian Sea (Northwestern Mediterranean), summer 1999. Ecology Letters 3: 284-293.

Cerrano C., Cardini U., Bianchelli S., Corinaldesi C., Pusceddu A., Danovaro R., 2013 Red coral extinction risk enhanced by ocean acidification. Sci Rep 3.

Cerrano C., Bavestrello G., Cicogna F. and Cattaneo-Vietti R., 1999 Nuove esperienze sul trapianto e sugli effetti del prelievio di corallo rosso nel mar ligure., pp. 57-73 in Biologia e tutela del corallo rosso e di altri ottocoralli del Mediterraneo., edited by F. Cicogna, G. Bavestrello and R. Cattaneo-Vietti. Ministero per le Politiche Agricole, Roma.

Chessa L. A. and Cudoni S., 1989 Red coral, *Corallium rubrum* (L.), fishing in the "Bocche di Bonifacio" (Northern Sardinia, Italy). FAO, Rome (Italy). General Fisheries Council for the Mediterranean, FAO, Rome (Italy). Conseil General des Peches pour la Mediterranee.

Chintiroglou H., Dounas C. and Koukouras A., 1989 The Presence of *Corallium rubrum* (Linnaeus, 1758) in the Eastern Mediterranean Sea. Mitteilungen aus dem Museum für Naturkunde in Berlin. Zoologisches Museum und Institut für Spezielle Zoologie langBerlinrang 65: 145-149.

Cicogna F., 2000 Il corallo rosso del Mediterraneo (*Corallium rubrum*): pesca e legislazione per una corretta gestione della risorsa in Corallo di ieri, corallo di oggi : atti del Convegno, Ravello, Villa Ruffolo, 13-15 dicembre 1996. E di Puglia, Bari.

Cinelli F., and Tunesi L., 2009 Il coralligeno pp. 13-28 in Quaderni Habitat n 22 - biocostruzioni marine - elementi di architettura naturale, edited by G. Relini. Min Ambiente tutela territorio e mare

CITES, 2010 CoP15 Proposals for Amendment of Appendices I and II. Proposal 21, 15th Meeting of the Conference of Parties, Doha Qatar.

Coma R., Pola E., Ribes M. and Zabala M., 2004 Long-term assessment of temperate octocoral mortality patterns, protected vs. unprotected areas. Ecological Applications 14: 1466-1478.

Corriero G., Abbiati M. and Santangelo G., 1997 Sponges inhabiting a Mediterranean red coral population. Marine Ecology 18: 147-155.

Costantini F., Carlesi L., Abbiati M., 2013 Quantifying Spatial Genetic Structuring in Mesophotic Populations of the Precious Coral *Corallium rubrum*. *PLoS ONE*, 8(4):e61546.

Costantini F., Fauvelot C. and Abbiati M., 2007a Fine-scale genetic structuring in *Corallium rubrum*: evidence of inbreeding and limited effective larval dispersal. Marine Ecology-Progress Series 340: 109-119.

Costantini F., Fauvelot C. and Abbiati M., 2007b Genetic structuring of the temperate gorgonian coral (*Corallium rubrum*) across the western Mediterranean Sea revealed by microsatellites and nuclear sequences. Molecular Ecology 16: 5168-5182.

Costantini F., Rossi S., Pintus E., Cerrano C., Gili J. M., Abbiati M., 2011 Low connectivity and declining genetic variability along a depth gradient in *Corallium rubrum* populations. Coral Reefs: 1-13.

Costantini F., Taviani M., Remia A., Pintus E., Schembri P. J., Abbiati M., 2010 Deep-water *Corallium rubrum* (L., 1758) from the Mediterranean Sea: preliminary genetic characterisation. Marine Ecology 31: 261-269.

Costantini F., Tinti F., Abbiati M., 2003 Sistematica molecolare e filogenesi di *Corallium rubrum*. Biol Mar Mediterr 10:73–75

Crocetta F. and Spanu M., 2008 Molluscs associated with a Sardinian deep water population of *Corallium rubrum* (Linne, 1758). Mediterranean Marine Science 9: 63-85.

Deidun A., 2010 Lack of comprehensive census data hampers conservation and management of *Corallium rubrum* colonies, pp. 206 in Proceedings of the International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean, edited by E. Bussoletti, D. Cottingham, A. Bruckner, G. Roberts and R. Sandulli. NOAA Technical Memorandum CRCP-13, Silver Spring, MD, Napoli.

Del Gaudio D., Fortunato G., Borriello M., Gili J.M., Buono P., Calcagno G., Salvatore F., Sacchetti L., 2004 Genetic Typing of *Corallium rubrum*. Marine Biotechnology 6(6):511-515

Di Geronimo I., Rosso A. and Sanfilippo R., 1994 I banchi fossiliferi di *Corallium rubrum* al largo di Sciacca (Canale de Sicilia). , pp. 75-107 in Il corallo rosso in Mediterraneo, arte, storia e scienza., edited by F. Cicogna, G. Bavestrello and R. Cattaneo-Vietti. Ministero Risarse Agricole Alimentari Forestali, Roma.

Dietrich J., 2010 Lessons learned from national trade regulations established for the red coral, *Corallium rubrum* in Proceedings of the International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean, edited by E. Bussoletti, D. Cottingham, A. Bruckner, G. Roberts and R. Sandulli. NOAA Technical Memorandum CRCP-13, Silver Spring, MD, Napoli p 195

Dounas C., Koutsoubas D., Salomidi M., Koulouri P., Gerovassileiou V., Sini M., 2010 Distribution and fisheries of the red coral *Corallium rubrum* (linnaeus, 1758) in the Greek seas: an overview, pp. 106-114 in Proceedings of the International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean, edited by E. Bussoletti, D. Cottingham, A. Bruckner, G. Roberts and R. Sandulli. NOAA Technical Memorandum CRCP-13, Silver Spring, MD, Napoli.

Dridi A., 2009 Mediterranean Red Coral, pp. 109-116 in Proceedings of the First International Workshop on *Corallium* Science, Management, and Trade, edited by A. W. Bruckner and G. G. Roberts. NOAA, Silver Spring, MD,.

Dridi A., Zoubi A. and Taleb S., 2010 The red coral exploitation in Morocco, pp. 115-118 in Proceedings of the International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean, edited by E. Bussoletti, D. Cottingham, A. Bruckner, G. Roberts and R. Sandulli. NOAA Technical Memorandum CRCP-13, Silver Spring, MD, Napoli.

FAO, 2013 FAO Fisheries and Aquaculture Department. Aquatic Species Distribution Map Viewer. Sardinia coral *Corallium rubrum* (downloaded in March 2013 at http://www.fao.org/figis/geoserver/factsheets/species.html?species=COL-m&prj=4326)

FAO, 2003 The ecosystem approach to fisheries. FAO Technical Guidelines for Responsible Fisheries. No. 4, Suppl. 2. Rome, FAO.

FAO-ACMRR, 1979 Interim Report of the ACMRR Working Party on the Scientific Basis of Determining Management Measures. Rome, FAO Fisheries Circular, No. 718: 112 pp.

Follesa M.C., Cannas R., Cau Al., Pedoni C., Pesci P., Cau A. 2013 Deep-water red coral from the island of Sardinia (North-western Mediterranean): a local example of sustainable management. Marine and Freshwater Research http://dx.doi.org/10.1071/MF12235

Freiwald A., Beuck L., Rueggeberg A., Taviani M. and Hebbeln D., 2009 The white coral community in the Central Mediterranean Sea Revealed by ROV Surveys. Oceanography 22: 58-74.

Galasso M., 2000 Pesca del *Corallium rubrum* in Sardegna nell'antichità attraverso l'indagine archeologica, cartografica e I rilevamenti in mare. In: l'Africa romana Atti del XIV Convegno di Studi Sassari 7-10 Dicembre 2000.

Gales L. E. and J. F. Caddy, 1975 YRAREA: A program to demonstrate effect of exploitation on a contagiously distributed shellfish population. Can. Fish. Mar. Serv., Tech. Rep. 582,79 p.

Gallmetzer I., Haselmair A. and Velimirov B., 2010 Slow growth and early sexual maturity: Bane and boon for the red coral *Corallium rubrum*. Estuarine, Coastal and Shelf Science 90:1-10

Garcia S.M., Zerbi A., Aliaume C., Do Chi T., Lasserre, G. 2003 The ecosystem approach to fisheries. Issues, terminology, principles, institutional foundations, implementation and outlook. FAO Fisheries Technical Paper. No. 443. Rome, FAO. 71 p. Annex I

Garcia-Rodriguez M. and Massò C., 1986a Algunas bases para la determinaciòn de la edad del coral rojo (*Corallium rubrum* L.) del Mediterràneo. Bol Inst Esp Oceanogr 3: 65-74.

Garcia-Rodriguez M. and Massò C., 1986b Estudio biomètrico de poblaciones del coral rojo (*Corallium rubrum* L.) del litoral de Gerona (NE de Espana). Bol Inst Esp Oceanogr 3: 61-64.

Garcia, S. 1984. Modelisation et exploitation rationelle des stocks decorail precieux: Une premiere approche. FAO Inform. Pesca 306, 142 p.

Garrabou J., Ballesteros E. and Zabala M., 2002 Structure and Dynamics of North-western Mediterranean Rocky Benthic Communities along a Depth Gradient. Estuarine, Coastal and Shelf Science 55: 493-508.

Garrabou J., Coma R., Bensoussan N., Bally M., Chevaldonné P. *et al.,* 2009 Mass mortality in Northwestern Mediterranean rocky benthic communities: effects of the 2003 heat wave. Global Change Biology 15: 1090-1103.

Garrabou, J., and Harmelin J. G., 2002 A 20-year study on life-history traits of a harvested long-lived temperate coral in the NW Mediterranean: insights into conservation and management needs. Journal of Animal Ecology 71: 966-978.

Garrabou, J., E. Sala, A. Arcas and M. Zabala, 1998 The impact of diving on rocky sublittoral communities: a case study of a bryozoan population. Conserv Biol 12: 302-312.

Garrabou, J., T. Perez, S. Sartoretto and J. G. Harmelin, 2001 Mass mortality event in red coral *Corallium rubrum* populations in the Provence region (France, NW Mediterranean). . Mar. Ecol. Prog. Ser. 217: 263-272.

GFCM, 1984 Technical consultation on red coral resources in the Western Mediterranean. FAO, Roma.

GFCM, 1989 Report of the second GCFM technical consultation on red coral in the Mediterranean. FAO, Rome.

GFCM, 2010 Transversal Workshop on Red Coral Italy, Alghero, 16-17 September 2010

GFCM, 2011 Second Transversal Workshop on Red Coral Ajaccio, Corsica (France), 5-7 October 2011

Grigg R.W., 1976 Fisheries management of precious and stony corals in Hawaii. UNIHI-SEAGRANT, TR-77-03.

Grigg R.W., 1984 Resource Management of Precious Corals. A review and application to shallow water reef building corals. Marine Ecology 51: 57-74

Grigg R.W., 1988. Precious coral fisheries of the Pacific and Mediterranean. In J. F. Caddy (Editor), Marine invertebrate fisheries: Their assessment and management, p. 637-645. John Wiley-Intersci. Pub!., John Wiley & Sons, N.Y.

Grigg R.W., 2002 Precious corals in Hawaii: discovery of a new bed and revised management measures for existing beds. Mar Fish Rev 64(2):13-20

Grigg R.W., 2004 Harvesting impacts and invasion by an alien species decrease estimates of black coral yield off Maui, Hawai'i. Pacific Science 58:1-6.

Grumbine R.E., 1994 What is ecosystem management? Conserv. Biol. 8, 27–38

Gulland J.A., 1970 The fish resources of the ocean. FAO (Food Agric. Organ. U.N.) Fish. Tech. Pap. 97, 425

Harmelin J.G., 1984 Biologie du corail rouge. Paramètres de populations, croissance et mortalité naturelle. Etat des connaissances en France. FAO Fish Rep 306:99–103

Harmelin J.G., 2010 Lacaze-Duthiers' legacy: advances in scientific knowledge of *Corallium rubrum* from French works after 1864, pp. 10-18 in Proceedings of the International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean, edited by E. Bussoletti, D. Cottingham, A. Bruckner, G. Roberts and R. Sandulli. NOAA Technical Memorandum CRCP-13, Silver Spring, MD, Napoli.

Harmelin J., 2007. in litt. to IUCN/TRAFFIC Analyses Team, Cambridge, UK.

Hereu B., Linares C., Diaz D. and Zabala M., 2002 Avaluació de l´episodi d´espoli de corall vermell (*Corallium rubrum*) de la zona de la Pedrosa (Costa de Montgrí) i de les mostres incautades els dies 21 I 22 de Desembre de 2002. , pp. Departament de Medi ambient, Generalitat de Catalunya., Barcelona.

IUCN/TRAFFIC, 2009 Analyses of the Proposals to Amend the CITES Appendices at the 15th Meeting of the Conference of the Parties

Lacaze-Duthiers H., 1864 Histoire naturelle du corail. Bailière, JB.

Lackey RT, 1999 Radically Contested Assertions in Ecosystem Management. Journal of Sustainable Forestry Volume 9, Issue 1-2, 1999

Larkin P.A., 1996 Concepts and issues in marine ecosystem management. Reviews in Fish Biology and Fisheries, 6(2), 139-164.

Ledoux J.-B., Garrabou J., Bianchimani O., Drap P., Féral J.P. *et al.,* 2010a Fine-scale genetic structure and inferences on population biology in the threatened Mediterranean red coral, *Corallium rubrum*. Molecular Ecology 19: 4204-4216.

Ledoux J.-B., Mokhtar-Jamaï K., Roby C., Féral J.-P., Garrabou J. *et al.,* 2010b Genetic survey of shallow populations of the Mediterranean red coral *Corallium rubrum* (Linnaeus, 1758)]: new insights into evolutionary processes shaping nuclear diversity and implications for conservation. Molecular Ecology 19: 675-690.

Ledoux J.-B., Aurelle D., Feral J. P., Garrabou J. and C. Marschal, 2010c Experimental approach to the potential response of a long-lived invertebrate species facing the warming in the NW Mediterranean. Rapp Comm int Mer Médit 39: 568.

Linares C, Hereu B, Zabala M., 2000 Avaluació de la població de corall *Corallium rubrum* de les illes Medes: exercici 1999. Seguiment temporal de la reserva marina de les illes Medes. Informe anual 1999. Departament de Medi Ambient, Generalitat de Catalunya, Barcelona

Linares C., Bianchimani O., Torrents O., Marschal C., Drap P. *et al.,* 2010a Marine Protected Areas and the conservation of long-lived marine invertebrates: the Mediterranean red coral. Marine Ecology-Progress Series 402: 69-79.

Linares C., Diaz D., Hereu B. and Zabala M., 2003 Avaluació de ala poblacio de corall *Corallium rubrum* de les illes Medes. Exercici 2003. Seguiment temporal de l'area marina protegida de les illes Medes. Infomre annual. Any 2003. , pp. 56-66. Departament de Medi Ambient, Generalitat de Catalunya, Barcelona

Linares C., Zabala M., Garrabou J.G., Coma R., Diaz R. *et al.,* 2010b Assessing the impact of diving in coralligenous communities : the usefulness of demographic studiest of red gorgonian populations. Sci. Rep. Port-Cros natl. Park 24: 161-184.

Liverino B., 1983. Il Corallo. Ed. Analisi, Bologna: 229 pp.

Liverino B., 1998. Il corallo. Arte Tipografica.

Marchetti R., 1965 Ricerche sul corallo rosso della costa ligure e toscana. I. Distribuzione geografica. Rend. Ist. Lomb. e Lett. 99: 255.

Marini M. and Ferru M.L., 1989 Il corallo : storia della pesca e della lavorazione in Sardegna e nel Mediterraneo. tema, Cagliari.

Marschal C., Garrabou J., Harmelin J.G., Pichon M., 2004 A new method for measuring growth and age in the precious red coral *Corallium rubrum* (L) Coral Reefs, 23 (2004), pp. 43–432

Nonaka M, Muzik K, Iwasaki N., 2012 Descriptions of two new species and designation of three neotypes of Japanese Coralliidae from recently discovered specimens that were collected by Kishinouye, and the introduction of a statistical approach to sclerite abundance and size. Zootaxa 3428:1-67.

Paracuellos M., Nevado J. and Mota J., 2006 Capitulo VI - Riquezas de la mar: La actividad pesquera en caladeros adyacentes. Entre Africa y Europa- Historia Natural de la Isla de Alboran, pp. RENPA, consejeria de Medio Ambiente (Junta de Andalucia), Sevilla.

Perez T., Garrabou J., Sartoretto S., Harmelin J.-G., Francour P. *et al.,* 2000 Mortalité massive d'invertébrés marins: un événement sans précédent en Méditerranée nord-occidentaleMass mortality of marine invertebrates: an unprecedented event in the Northwestern Mediterranean. Comptes Rendus de l'Académie des Sciences - Series III - Sciences de la Vie 323: 853-865.

Priori C., Mastascusa V., Erra F., Angiolillo M., Canese S., Santangelo G., 2013 Demography of deep-dwelling red coral populations: Age and reproductive structure of a highly valued marine species. Estuarine, Coastal and Shelf Science 118: 43–49

RAC/SPA, 2008 Action plan for the conservation of the coralligenous and other calcareous bio-concretions in the mediterranean sea.

Relini G. and Giaccone G., 2009 Priority habitats according to the SPA/BIO protocol (Barcelona Convention) present in Italy. Identification sheets. Biol. Mar. Medit. 16 (supp 1): 1-373.

Roark E. B., Guilderson T.P., Dunbar R.B. and Ingram L., 2006 Radiocarbon-based ages and growth rates of Hawaiian deep-sea corals. Marine Ecology Progress Series 327: 1-14.

Romano J.-C., Bensoussan N., Younes W. A. N. and Arlhac D., 2000 Thermal anomaly in the waters of the Gulf of Marseilles during summer 1999. A partial explanation of the mortality of certain fixed invertebrates? Comptes Rendus de l'Académie des Sciences - Series III - Sciences de la Vie 323: 415-427.

Rossi S., Tsounis G., Orejas C., Padrón T., Gili J.-M. *et al.,* 2008 Survey of deep-dwelling red coral (*Corallium rubrum*) populations at Cap de Creus (NW Mediterranean). Marine Biology 154: 533-545.

Santangelo G, Bramanti L, Rossi S, Tsounis G, Vielmini I, Lott C, Gili J.-M., 2012 Patterns of variation in recruitment and post-recruitment processes of the Mediterranean precious gorgonian coral *Corallium rubrum* Journal of Experimental Marine Biology and Ecology, 411 (2012), pp. 7–13

Santangelo G. and Abbiati M., 1989 A study on a coastal red coral population. FAO, Rome (Italy). General Fisheries Council for the Mediterranean, FAO, Rome (Italy). Conseil General des Peches pour la Mediterranee.

Santangelo G., Abbiati M. and Caforio G., 1988 Structure of a red coral population. Rapp P-V Réun Comm Int Explor Sci Mer Méditerr Monaco 31: 19.

Santangelo G., Abbiati M. and Caforio G., 1993 Age structure and population dynamics in *Corallium rubrum* (L). , pp. 131-157 in Red Coral in the Mediterranean Sea., edited by F. CICOGNA and R. CATTANEO. Min. Ris. Agr. Al. For., Roma.

Santangelo G., Bongiorni L. and Buffoni G., 1997 Recruitment density-dependence in red coral population. Biologia Mar Mediterr 97: 277-281.

Santangelo G., Bramanti L. and Iannelli M., 2007 Population dynamics and conservation biology of the over-exploited Mediterranean red coral. Journal of Theoretical Biology 244: 416-423.

Santangelo G., Bramanti L., Vielmini I. and Iannelli M., 2009 What we have learned about red coral and what we need to learn for its rational management, pp. 71-86 in Proceedings of the First International Workshop on *Corallium* Science, Management, and Trade, edited by A. W. Bruckner and G. G. Roberts. NOAA, Silver Spring, MD.

Santangelo G., Carletti E., Maggi E. and Bramanti L., 2003 Reproduction and population sexual structure of the overexploited Mediterranean red coral *Corallium rubrum*. Marine Ecology-Progress Series 248: 99-108.

Santangelo, G., Bramanti L., Vielmini I. and Iannelli M., 2010 The history of research and harvesting of the mediterranean red coral: potential and limits, pp. 19-32 in Proceedings of the International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean, edited by E. Bussoletti, D. Cottingham, A. Bruckner, G. Roberts and R. Sandulli. NOAA Technical Memorandum CRCP-13, Silver Spring, MD, Napoli.

Sluczanowski, P. R. 1983. A management oriented model of an abalone fishery whose substocks are subject to pulse fishing. Can. J. Fish. Aqua!. Sci. 41:1008-1014.

Stampacchia, P., 2010 Il comparto del corallo di Torre del Greco pp. 121-122 in Proceedings of the International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean, edited by E. Bussoletti, D. Cottingham, A. Bruckner, G. Roberts and R. Sandulli. NOAA Technical Memorandum CRCP-13, Silver Spring, MD, Napoli.

Stiller M. A., Rivoire G., Charbonnier D. and Garcia S., 1984 Biologie et ecologie du corail rouge en Mediterranee francaise. FAO.

Taviani M., Freiwald A., Beuck L., Angeletti L., Remia A. *et al.,* 2010 The deepest known occurrence of the precious red coral *Corallium rubrum* (l. 1758) in the Mediterranean sea, pp. 87-93 in Proceedings of the International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean, edited by E. Bussoletti, D. Cottingham, A. Bruckner, G. Roberts and R. Sandulli. NOAA Technical Memorandum CRCP-13, Silver Spring, MD, Napoli.

Tescione G., 1965 Il corallo nella storia e nell'arte Montanino, Napoli.

Tescione G., 1973. Il corallo nelle arti figurative. Fiorentino.

Thrush S. & Dayton P.K., 2002. Disturbance to marine benthic habitats by trawling and dredging: implications for biodiversity. Annual Review of Ecology and Systematics 33, 449–473

Torrents O., and Garrabou J., 2011 Fecundity of red coral *Corallium rubrum* (L.) populations inhabiting in contrasting environmental conditions in the NW Mediterranean. Marine Biology 158: 1019-1028.

Torrents O., Garrabou J., Marschal C. and Harmelin J.G., 2005 Age and size at first reproduction in the commercially exploited red coral *Corallium rubrum* (L.) in the Marseilles area. Biological Conservation 121: 391-397.

Tsounis G., 2005 Demography, reproductive biology and trophic ecology of red coral (*Corallium rubrum* L.) at the Costa Brava (NW Mediterranean): ecological data as a tool for management. Ph.D. Thesis, University of Bremen, Germany

Tsounis G., Rossi S. and Gili J.-M., 2009 Fishery Management of the Mediterranean Red Coral: A Call for a Paradigm Shift, pp. 153pp. in Proceedings of the First International Workshop on *Corallium* Science, Management, and Trade, edited by A. W. Bruckner and G. G. Roberts. NOAA, Silver Spring, MD,.

Tsounis G., Rossi S. and Gili J.-M., 2010a Identifying population decline in *Corallium rubrum* by using historical information, pp. 33-39 in Proceedings of the International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean, edited by E. Bussoletti, D. Cottingham, A. Bruckner, G. Roberts and R. Sandulli. NOAA Technical Memorandum CRCP-13, Silver Spring, MD, Napoli.

Tsounis G., Rossi S., Bramanti L. & Santangelo G., 2013 Management hurdles for sustainable harvesting of *Corallium rubrum*. Marine Policy 39:361-364.

Tsounis G., Rossi S., Gili J.-M. and Arntz W. E., 2007 Red coral fishery at the Costa Brava (NW Mediterranean): Case study of an overharvested precious coral. Ecosystems 10: 975-986.

Tsounis G., Rossi S., Grigg R., Santangelo G., Bramanti L. *et al.,* 2010b The Exploitation and Conservation of Precious Corals in Oceanography and Marine Biology: An Annual Review 48:161-212.

Tsounis, G., Rossi S., Aranguren M., Gili J.-M. and Arntz W., 2006a Effects of spatial variability and colony size on the reproductive output and gonadal development cycle of the Mediterranean red coral (*Corallium rubrum* L.). Marine Biology 148: 513-527

Tsounis, G., Rossi S., Gili J.-M. and Arntz W., 2006b Population structure of an exploited benthic cnidarian: the case study of red coral (*Corallium rubrum* L.). Marine Biology 149: 1059-1070.

Tu T.-H., Dai C.-F., Jeng M.-S., 2012 Precious corals (Octocorallia: Coralliidae) from the northern West Pacific region with descriptions of two New Species. Zootaxa 3395:1-17.

UNEP/MAP, 2009 State of knowledge of the geographical distribution of the coralligenous and other calcareous bio-concretions in the Mediterranean, Edited by S. Agnesi, A. Annunziatellis, M. L. Cassese, G. La Mesa, G. Mo *et al.*

van Ofwegen L, 2012 http://www.marinespecies.org/aphia.php?p=taxdetails&id=125416

Vielmini I, Bramanti L, Tsounis G, Rossi S, Gili JM, Cattaneo-Vietti R, Santangelo G, 2010 Determination of *Corallium rubrum* population age structure. In: Bussoletti E, Cottingham D, Bruckner A, Roberts G (eds) Proceedings of the International workshop on red coral science, management, and trade: lessons from the Mediterranean. Napoli, September 23–26, 2009, pp 179–182

Vighi M., 1970 Ricerche sul ciclo reproduttivo del corallo rosso (*C. rubrum* (L)) del promontorio di Portofino. Lincei-Mem. Sci. fisiche, Ser. III 1-26.

Ward T., Tarte D., Hegerl E., Short K., 2002 Ecosystem-based management of marine capture fisheries. 2002. World Wide Fund for Nature, Australia. 80 pp.

Weinberg S., 1976 Revision of the common Octocorallia of the Mediterranean circalittoral. I.Gorgonacea. Beaufortia 313: 63-103.

Weinberg S., 1979 The light-dependent behaviour of planula larvae of Eunicella singularis and *Corallium rubrum* and its implication for octocorallian ecology. Bijdr Dierkd 49.

Winter, G. (Ed) 2009 Towards Sustainable Fisheries Law. A Comparative Analysis. IUCN, Gland, Switzerland. xiv + 340 pp.

WP COUNCIL, 2007 Fishery management plan for the precious coral fisheries of the western Pacific region. Western Pacific Regional Management Council, Honululu.

WPRFMC, 2009 Fishery Ecosystem Plan for the Hawaii Archipelago Western Pacific Regional Fishery Management Council, Honululu

Zibrowius H., Monteiro-Marque S. V: and Grasshoff M., 1984 La répartition du *Corallium rubrum* dans l'Atlantique (Cnidaria: Anthozoa: Gorgonaria). Téthys 11: 163-170.