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Proceedings of the First International Workshop on *Corallium* Science, Management, and Trade

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The International Workshop on *Corallium* Science, Management, and Trade is the first of two workshops convened to better understand the biological status of precious corals in the family Coralliidae, the adequacy of existing management measures, and the benefits and limitations of a potential CITES Appendix-II listing at enhancing conservation of this taxa. The meeting was convened in response to an Appendix-II listing proposal submitted by the U.S. at the 14th meeting of the CITES Conference of Parties (COP 14), specifically to address questions pertaining to the ability to effectively implement a possible CITES listing. The workshop would not have been possible without the financial support provided by the NOAA Coral Reef Conservation Program (CRCP) and NOAA Fisheries, and supplementary funding from The Ocean Foundation.

The meeting was organized and convened under unusual circumstances, with all meeting facilities, travel arrangements and lodging arranged under an extreme time crunch. Our steering committee, including Glynnis Roberts, Frank Parrish, Laura Noguchi, Jeremy Linneman, and Ernie Cooper were instrumental in helping me shape the working group tasks and agenda, and ensure we had the optimal mix of participants. This meeting would not been possible without the dedicated logistical support provided by Jeremy Linneman and Glynnis Roberts. I am extremely grateful to both Jeremy and Glynnis, who managed to shift locations from the Mediterranean, identify a new venue, and secure participation by Pacific experts in just under a month. Jeremy and Glynnis devoted several weeks prior to the workshop to communicate with the *Corallium* experts from the region, complete their travel arrangements, and assist them in developing presentations, white papers, and other background information. Jeremy and Glynnis also compiled all of the reports and background information into a detailed workshop document that guided discussions and deliberations. During the workshop, they provided invaluable assistance in organizing each session, providing audio-visual assistance, addressing technical issues, and making sure each participants' needs were promptly and thoroughly addressed.

I would like to acknowledge each of the keynote speakers, including Georgio Tsounis, Giovanni Santangelo, Sergio Rossi, Vin Fleming, Laura Noguchi, Ernie Cooper, Frank Parrish, Tony Montgomery, Susan Torntore, Joyce Wu and Soyo Takahashi, Abdelaziz Zoubi, Chi-Shin Chen, Niphon Phongsuwan, Julia Robertson, and Nozomu Iwasaki. Their detailed presentations during the first and second days of the meeting highlighted key issues surrounding these taxa and provided a framework for the working group deliberations. These talks included comprehensive background information on various aspects of *Corallium* biology, population status, fisheries, and trade. I am most grateful for the dedicated efforts of the three working group chairs, Frank Parrish, Vin Fleming and Sergio Rossi, who facilitated discussions on their respective topics and compiled the information into detailed working group reports. I would also like to give special thanks to all of the participants, each of whom contributed their expertise to the development of these reports. Everyone was extremely congenial and respective of various viewpoints, and without these dedicated efforts, the outcomes of this workshop would have been much less comprehensive.

The workshop successfully addressed many of the most pressing workshop questions and issues surrounding the effective conservation of *Corallium,* and it provides a framework for the second workshop, to be held in the Mediterranean in the fall of 2009. We look forward to continued collaborations with all of the participants, and would like to thank everyone for their involvement. Together, we can ensure the conservation, sustainable harvest, and trade of these jewels of the sea.

PREFACE

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Introduction

Corallium has been intensively harvested for centuries, and both landings and population data provide strong evidence that most commercially viable *Corallium* beds are now depleted. Long term trends in landings from both the Pacific and Mediterranean and available data on population demographics of Mediterranean *C. rubrum* populations provide considerable evidence that known commercial beds of *Corallium* have declined to less than 20-30% of their historic baseline, meeting the criteria required for a CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) Appendix-II listing (Bruckner 2009). Nevertheless, questions remain regarding the effective implementation of a potential listing. There are difficulties in identifying *Corallium* specimens to species, especially processed material (polished and dyed jewelry including powdered and reconstituted *Corallium*). Identification to family (Coralliidae) or genus (*Corallium*, *Paracorallium*) may be possible and may be allowed under CITES, mirroring the approach taken with some of the other listed corals. If a CITES listing were adopted, countries would need to develop procedures for handling stockpiled coral harvested prior to a listing, which would be considered pre-Convention and could be traded under a CITES exemption document. There are also large local markets and trade between neighboring European Union countries, which would not be regulated by CITES.

While regulating the international trade in *Corallium* presents challenges, a CITES listing could reduce illegal trade and promulgate stronger management and enforcement efforts by giving both exporting and importing countries joint responsibility for ensuring that trade is sustainable. A CITES listing requires monitoring and annual reporting of international trade, filling critical gaps in knowledge of harvest and trade levels. A listing would also promote research on the status and trends of *Corallium* populations and the impacts of fisheries, as well as the adoption of sustainable management approaches. Exporting countries would be required to meet non-detriment requirements of a CITES Appendix-II listing. While new administrative burdens would be associated with a CITES listing for *Corallium*, these are not insurmountable, having been successfully resolved in other species that presented similar challenges including stony corals, antipatharians, and seahorses.

The following information includes a brief summary of what is known about the harvest, trade, and population status of *Corallium.* This is followed by an overview of recent activities undertaken to conserve these species through CITES, and the rationale for technical workshops on *Corallium.*

Corallium fisheries and trade

Precious corals in the family Coralliidae are important deep-water resources that are harvested in the western Mediterranean Sea and in the western north Pacific Ocean, including traditional harvest areas off Japan, Philippines, and the island of Taiwan. Historic fishing grounds also occur around Emperor Seamounts and Midway Island, and limited *Corallium* resources have been collected in several locations off Hawaii, but current harvest from these areas is negligible or non-existent.

These corals have been highly valued since ancient times for use in the fabrication of jewelry, amulets, and art objects. The history of precious coral exploitation began in the Mediterranean with the red coral, *Corallium rubrum*, which has been found with 25,000 year old Paleolithic human remains. During ancient times, most red coral was collected after heavy storms broke off branches and washed them up on shore. Harvest of living colonies of *Corallium* started about 5000 years ago with Greek fishermen using kouralio or iron hooks to dislodge colonies from deeper water. Beginning around 1000 AD, the ingegno or St. Andrew's Cross—a wooden cross with attached nets—was dragged across the bottom to entangle coral. The "barra italiana," a version of a coral dredge made of heavy iron bars with nets attached along its length, was also widely used following the emergence of large-scale commercial fisheries off Italy in 1830. Commercially valuable colonies of *Corallium* were first discovered in the Pacific off Japan in the early 1800s. Most Pacific landings over the next century were from mid-depth beds (100-400 m depth) off Japan (Okinawa and the Bonin Islands) and China (Taiwan). In 1965, Japanese fishermen discovered a large bed of *C. konojoi* on the Milwaukee Banks in the Emperor Seamount Chain, and in the mid 1980s a deepwater species was discovered at depths of about 1500m.

Each new discovery of a *Corallium* bed led to "coral rushes," where both effort and landings rapidly increased and then declined as resources were overexploited. For example, landings of *Corallium* from the Pacific reported by Japan and China (Taiwan) show five major peaks over the 45 years for which data have been compiled. Taiwan's reported landings were 2-3 times greater than that reported by Japan, with 4 major peaks in landings of *C. secundum* in 1969 (112 t), 1976 (102 t), 1981 (270 t), and 1984 (226 t), with Midway coral (*Corallium* sp. nov.) accounting for over 90% of the world's production from 1983-1986 (564 t). Landings by Taiwan remained at low levels (< 5 t) over the next 20 years with exception of two small peaks in 1996 (12 t) and 2002-2004 (35 t) of *C. elatius* from mid-depth coral beds between Taiwan and the Philippines. Annual yield from Japan was the greatest from 1979-1984 (57-91 t/yr) with 70-90% consisting of Midway coral. Reported landings declined to 2.6 t in 1987 and have remained at < 5 t/yr over the last 20 years, consisting mostly of *C. elatius* (mean = 1.9 t/yr) and *C. japonicum* (1.2 t/yr) with lower amounts of *C. konojoi* and *Corallium* sp. nov. (0.22 t/yr).

The total yield of *Corallium rubrum* from the Mediterranean reported over a 30 year period (1976-2006) was 1250 t with 33.5% from Italy, 17.6% from Spain, 15.3% from Tunisia, and 9.9% from France. Landings from those four major Mediterranean source countries show a decreasing trend over 15 years (> 85% decline from 97 t in 1976 to 12 t in 1992), mostly due to reduced yields from European countries, especially Italy (70 t in 1978 vs. 8 t in 1986). Total annual yield for the four most important Mediterranean countries fluctuated between 12-18 t from 1992-2003 with progressive increases to 26 t by 2006 (FAO 2008). These boom and bust cycles have occurred repeatedly in both the Mediterranean and Pacific, although landings since 1991 have been a fraction of earlier harvest.

While few trade data exist for *Corallium*, the U.S. has kept detailed records of *Corallium* imports for over 10 years. These data suggest that China (including Hong Kong and Taiwan), Japan, and Italy are currently the largest manufacturers of *Corallium* jewelry with most imports destined for the U.S. Other important exporting countries include India, Indonesia, Korea, Thailand, and the Philippines, although the origin of the raw material is primarily from the Mediterranean, Taiwan, or Japan. From 2001-2008, the U.S. imported over 28 million pieces of *Corallium* jewelry and 80 t of skeletons. Imports were lowest during 2001-2002, increased significantly from 2003-2005, and then dropped off in 2006, with notable increases in *C. rubrum* in 2007 and 2008. The taxon listed as being traded at highest volume is *P. japonicum*, representing > 75% of all manufactured items and 45% of the raw skeletons imported over the last seven years. Interestingly, *P. japonicum* is extremely rare due to past overharvesting, and these records may represent jewelry manufactured from stockpiled resources, or a misidentification. A high volume of *C. elatius* skeletons was also imported in 2003 (> 9 t), and a large amount of *C. elatius* jewelry was imported in 2005 (> 1.8 million pieces). There were also two major peaks in imports of unprocessed skeletons of *C. rubrum* in 2003 (12.3 t) and 2008 (22.8 t); < 5% of skeletons consist of this taxa during other years, while trade in processed *C. rubrum* jewelry increased sharply in 2006 and 2008 (Bruckner 2009).

Changes in population structure and habitat impacts

Modernization and industrialization of the fishery since the 1950s has led to both rapid exploitation of newly discovered beds and increased illegal fishing, with widespread changes in the integrity of *Corallium* populations now documented throughout much of the Mediterranean (GFCM 1984, 1988, Santangelo et al. 1993, Galasso 2000, Linares et al. 2003). Large, highly branched *C. rubrum* colonies 20-50 cm in height formerly played a paramount role in structuring the coralligenous zone through their trophic activity and biogenic structure. These functions have been lost as most populations in the Mediterranean are dominated by 2-5 cm tall colonies (Cicogna and Cattaneo-Vietti 1993, Garrabou and Harmelin 2002, Tsounis et al. 2007, Santangelo et al. 2007). Landings data may be indicative of similar population declines for Pacific *Corallium* beds, but few biological data are available from these regions.

Corallium typically occurs at densities of < 1 colony/m^2. The only exceptions to this are certain shallow *C. rubrum* populations that are now dominated by recruits and small adult colonies, largely in response to overexploitation (Rossi et al. 2008). Because of the sessile nature of the species, further reductions in density associated with the selective removal of the largest colonies in a coral bed may alter reproductive potential due to allele effects. *Corallium* populations are already fragmented and highly isolated as a result of limited larval dispersal and a high degree of self-seeding, and they exhibit density dependent recruitment (Weinberg 1979, Grigg 1989, Abbiati et al. 1993, Costantini et al. 2007a, b). Remnant colonies within coral beds below minimum legal size of harvest may contribute to rebuilding of these depleted populations only if these beds are protected from fishing, but this may take decades due to their slow growth and size-dependent reproductive output (Garrabou and Harmelin 2002).

Colonial gorgonians that characteristically form highly complex, branched colonies are dependent on the occurrence of large colonies to ensure successful reproduction and recruitment. A shift from historic measures of 20-50 cm height to less than 5 cm, like that reported for the Mediterranean, is equivalent to a loss of 80-90% of the reproductive modules of individual colonies. *Corallium rubrum* can become sexually mature at a young age (2-3 cm height), although colonies don't achieve 100% fertility until about 6 cm height (Santangelo et al. 2003, Torrents et al. 2005, Tsounis et al. 2006b). The spawning potential in gorgonians increases exponentially with size, with larger arborescent colonies producing up to 98% of the recruits (Babcock 1991, Beiring and Lasker 2000, Santangelo et al. 2003, Torrents et al. 2005). Populations of *C. rubrum* today are dominated by small colonies (mean = 3 cm) with one or two branches. These corals are capable of producing tens to hundreds of larvae annually, as compared to thousands of larvae produced by colonies that are double or triple in size (Santangelo et al. 1993, 2003, 2007, Torrents et al. 2005, Tsounis et al. 2006b, Rossi et al. 2008, Bruckner 2009).

Dredges are known to have caused extensive habitat impacts to the coralligenous zone in the Mediterranean (Chessa and Cudoni 1988), and are likely to have removed most of the largest colonies of *Corallium* from exposed horizontal and gently sloping substrates in deep water, as well as juvenile and undersized colonies of *Corallium.* Coral dredges are also extremely inefficient, as only about 40% of the detached colonies are entangled and retrieved (Grigg 1984). Shifts to a SCUBA fishery in the 1950s allowed less destructive selective harvesting. Nevertheless, areas formerly excluded from dredging in shallow water were suddenly available for exploitation, including corals concentrated on vertical slopes, under overhangs, near cave entrances, and in crevices were coral dredges cannot operate (Rossi et al. 2008). SCUBA fisheries also tend to operate in a "pulse fishing" mode, with local patches being selectively eliminated, leaving only inaccessible and noncommercial sized individuals before another patch is located and eliminated (Caddy 1993).

Management and conservation

A wide variety of approaches have been proposed or implemented to protect *Corallium* from overexploitation. This includes gear restrictions, size limits, quotas, rotational harvest, and spatial closures. During several *Corallium* consultations held by FAO over the last three decades, various experts have emphasized a need to re-examine and adjust the existing measures, based on new information on the biology and population dynamics (Caddy 1993, Tsounis et al. 2007). For example, existing no take areas (protected areas) for *C. rubrum* are relatively small and it is unclear whether they are sited such that they would replenish fished areas, given the high degree of genetic structure, reproduction characterized by brooding, and evidence that populations are self-seeding (Costantini et al. 2007). In addition to the need for larger MPAs, additional areas in shallow water should be closed to fishing, especially where other stressors (e.g. climate change) are having compounding impacts (Bramanti et al. 2007). As one alternative to permanent spatial closures, Caddy (1993) recommended rotational harvest on a 20-30 year cycle. Some rebuilding of populations may occur over this time period, provided that an adequate number of reproductively mature colonies remain to allow replenishment. However, the proposed time frame may be too short to allow full recovery of populations as colonies in areas protected from fishing for 15-30 years are still less than half the reported historic size (Francour et al. 2001, Tsounis et al. 2006a).

There are also concerns that the legal minimum size of *Corallium*, where adopted in the Mediterranean, is too small to ensure the persistence of fished populations. In one of the earliest studies of *C. rubrum*, García-Rodríguez and Massò (1986b) documented the harvest of colonies that were 5-14 years in age, which they concluded was well below maximum sustainable yield (MSY). Using data from demographic studies conducted off Costa Brava, Spain, Tsounis et al. (2007) estimated a MSY of 98 years, whereas the current practice of harvesting colonies once they achieve a 7 mm basal diameter (11 year old colonies) results in only 6% of the potential yield. New methods of aging indicate colony age was underestimated by a factor of 2-4, and growth rates are 2.6-4.5 times lower than previously thought (Marschal et al. 2004, Roark et al. 2006), which further emphasizes the need for a larger minimum size of harvest. For instance, Rossi and Gili (2007) recommended a minimum size of at least 8.6 mm diameter and 10 cm height to allow development of third order branching patterns. This increase could help ensure adequate reproductive output to compensate for fishing pressure.

Consideration of international trade regulations

In 2006, due to environmental concerns associated with *Corallium* fisheries, SeaWeb (a non-governmental organization) petitioned the U.S. to propose *Corallium* for listing in the CITES Appendices. After a detailed review and consultation with *Corallium* range states, the U.S. submitted a proposal at the 14th meeting of the Conference of the Parties (COP 14) in June 2007 to list all species of *Corallium* (pink and red corals) on Appendix-II of CITES (COP 14 Prop.21, Anonymous 2007). This proposal identified seven species of *Corallium* as under considerable threat from harvest and international trade, with other species recommended for listing because of their similarity in appearance to other regulated species (Wijnstekers 1988). Some of the findings highlighted in the proposal included 1) that these species were traded in large numbers and harvest and trade is one of the most significant impacts to the species; 2) populations have declined in abundance and size structure, primarily in fished locations due to heavy fishing pressure; 3) in some locations non-selective gear further impacts populations and habitats; 4) in addition to direct removal of sessile adults, reduction in size structure like that reported for certain *C. rubrum* populations increases the proportion of the juvenile population and causes an exponential decline in reproductive output.

The U.S. proposal for listing *Corallium* in CITES Appendix-II was adopted in committee and later overturned in plenary largely due to perceived challenges in implementing and enforcing this CITES listing, and the conclusion that insufficient data were available on the population status to warrant a listing (Morell 2007). According to an expert FAO review, these species had not declined to 20-30% of the historic baseline, as required for listing a low productivity species in CITES Appendix-II (FAO 2007). While the international community recognized the conservation needs of these species, concerns were expressed about implementation of the listing including difficulties in identification of specimens in trade, needed clarifications regarding personal effects exemptions, and procedures for handling pre-Convention jewelry and other specimens harvested before the listing. The Parties requested two ad hoc events be organized, one in the Mediterranean region and one in the Pacific, to address these outstanding issues prior to re-submission of a proposal at the next CITES COP. These proceedings represent the outcomes of the first workshop.

Addressing questions and concerns surrounding a potential CITES listing

As an initial step to resolve implementation issues and determine if a CITES listing is warranted, NOAA Fisheries secured funding to convene two workshops on *Corallium* Science, Management, and Trade. The first workshop was held in Hong Kong, China during March 2009. This workshop was convened to address a number of science questions regarding the status and trends of known *Corallium* beds, and implementation issues that were identified as factors that would hinder the effectiveness of a potential CITES Appendix-II listing for all species of *Corallium* and *Paracorallium*. The workshop involved a review of *Corallium* biology, *Corallium* fisheries and management, and international trade in coral reef species. This included an evaluation of approaches 1) to address information gaps and research needs; 2) to resolve difficulties in regulating harvest and trade; and 3) to address issues surrounding implementation of a possible CITES listing. The workshop involved one day of keynote presentations on the biology, taxonomy and status of populations, fisheries, existing management approaches, trade and other and threats, uses of *Corallium* and major markets, possible conservation measures including CITES, and detailed country reports. These background presentations were supplemented with relevant documents which have been included in the workshop Proceedings. The plenary talks were followed by two days of concurrent working groups to address science, management, and enforcement knowledge, gaps, and needs, and a final session detailing recommendations and next steps. The working groups included: 1) The Science Working Group, which discussed the state of knowledge of the biology and population status and threats; 2) The Management Working Group, which compiled and assess information on existing national management; and 3) The CITES Working Group, which focused on taxonomy and identification and implementation issues of a potential CITES listing. The specific tasks of each working group and working group reports are included in the Proceedings. Participants included *Corallium* scientists, government officials involved in the management and enforcement of *Corallium* fisheries, CITES officials from exporting and importing countries, the CITES Secretariat, NGOs, and industry representatives.

All of the recommendations and documents included in the Proceedings form the framework and starting point for the second International Workshop on *Corallium* Science, Management, and Trade. It is our hope that several of the representatives at this workshop will also participate in the second workshop, along with a larger representation of experts from all stakeholder groups from the Mediterranean region.

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EXECUTIVE SUMMARY

In March of 2009, approximately 40 experts from government agencies, non-government conservation organizations, the CITES Secretariat, academic institutions and industry convened in Hong Kong to discuss the state of knowledge regarding the biology, population status, trade, and management of precious corals in the family Coralliidae, and to examine issues surrounding the implementation of a potential CITES Appendix-II listing. Background presentations summarized information on the biology and taxonomy, population status, threats, harvest, trade, and management of Coralliidae, with detailed national and regional reports presented from Pacific and Mediterranean range states. Background information was presented on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and how it functions to regulate international trade, including examples from similar taxa listed (black corals) and some of the complications that needed to be resolved to effectively implement a listing. These talks were followed by concurrent working groups to address science, management, and CITES implementation issues.

The family Coralliidae includes 27 described species and several undescribed species of precious corals known as pink and red corals in the genera *Corallium* and *Paracorallium*, of which seven are currently in international trade. These corals have been harvested for thousands of years for use in jewelry, amulets, and to a lesser degree in homeopathic medicines, reaching a peak in the late 1980s with annual landings of about 400 metric tons, and then declining to 30-50 tons per year since 1991. Coralliidae fisheries have primarily involved the use of non-selective dredges and trawls, with limited use of submersibles and a recent shift to SCUBA harvest in the Mediterranean. Long-term trends in landings from both the Pacific and Mediterranean, as well as available data on population demographics of Mediterranean *C. rubrum* populations, provide evidence that known commercial beds of *Corallium* and *Paracorallium* have declined to less than 20-30% of their historic baseline, meeting the criteria required for a CITES Appendix-II listing. Commercial harvest has been characterized by boom and bust cycles, with intensive harvesting following the discovery of a new bed until the resource declines and harvest is no longer commercially viable; landings subsequently decline for a period of years or until a new bed is discovered and the process repeats itself. In addition, Mediterranean populations have undergone significant changes in population demographics in fished areas, shifting from relatively low density populations consisting of large (10-50 cm tall), reproductively mature colonies to small (mean size 3-5 cm), predominantly juvenile colonies often occurring in small patches at very high local densities. With the exception of selected areas off Hawaii, population data for the Pacific are largely unavailable, although new research efforts have been recently initiated off Japan and other locations.

While the group reached a general consensus that Coralliidae populations were overexploited, questions remained regarding the conservation benefits of CITES for these species, and the efficacy of implementing a potential CITES listing. CITES regulates international trade through permits on which specimens are typically identified to species level, which may not be possible for all specimens of Coralliidae due to difficulties of identification – especially of processed material (polished and dyed jewelry including powdered and reconstituted *Corallium* and *Paracorallium*). Nevertheless, identification to the family level (Coralliidae) would be possible for worked specimens and to the genus level for raw coral. The group considered that listing the entire family

and allowing identification of worked specimens at the family level would be easier to implement than the current Appendix-III listing by China of four Coralliidae species.

Stockpiled coral harvested prior to a listing would be considered 'pre-Convention' specimens for CITES purposes, but these would be difficult to differentiate from recently harvested *Corallium* and *Paracorallium.* Options to address this include countries conducting inventories to track and monitor pre-Convention stockpiled coral that is traded, or inviting voluntary declarations of stockpile quantities. The CITES Working Group also noted that fossils should not be excluded from CITES, as these would be difficult to differentiate and trade volumes are low. The CITES Working Group also recommended consistent reporting of specimens in trade, and a CITES personal effects exemption per person of up to a maximum of seven specimens of finished items or one kilogram (2.2lbs), including any ancillary mounting, whichever is the lesser. The working group also highlighted the need for an identification manual and training for enforcement officers. Finally, they suggested that CITES non-detriment findings should be made at the species level taking an ecosystem approach, with considerations for bycatch and impacts from non-selective fisheries.

The Management Working Group summarized the current state of management in range countries, and identified minimum and maximum measures needed to ensure sustainable harvest. The aspects of management included jurisdictions, permits, quotas, gear, size limits, reporting, observers, monitoring, and enforcement. The working group suggested that the measures may differ between shallow SCUBA fisheries in the Mediterranean and deeper non-selective Pacific fisheries. Nevertheless, there were certain minimum measures such as licensing, reporting, quotas, fishery dependent and fishery independent monitoring programs, and enforcement that needed to be in place in each country to properly manage Coralliidae resources. There was general consensus that an effective CITES listing requires collaboration between CITES authorities and relevant fishery management bodies. Whilst CITES provides a mechanism to control international trade, it is fishery management that ultimately determines the sustainability of exploitation of this resource.

The Science Working Group compiled available data on the biology and population status of Coralliidae within Pacific range countries, including Japan, China (Taiwan), and the U.S. (Hawaii). The group concluded that very limited information is available for Pacific populations, especially in international waters around Emperor Seamounts, where most of the Coralliidae species were landed from the 1960s-1980s. Population trends are available for selected locations off Hawaii, with limited information on the impacts of a short-lived fishery. New research off Okinawa, Japan is providing distributional data, new biological information, and some information on population dynamics. The working group also evaluated the value of different types of information for management, including abundance data, population dynamics, biological data, and genetic information. The working group recognized the importance of abundance data, noting that while these data can be used to estimate harvest levels, they cannot be extrapolated to other areas. Knowledge on habitat conditions and requirements for Coralliidae species can assist managers in identifying other potential *Corallium* and *Paracorallium* beds, as well as potential environmental drivers that may enhance or reduce survival and recruitment potential. The group also felt that population data should include measures of size and branching patterns, as these taxa exhibit a size-dependent increase in reproduction, and persistence of large colonies may be required to ensure the long-term persistence of populations. There was also a need for more biological and genetic data to better understand reproductive potential, dispersal ability, connectivity of populations, and likelihood of successful recruitment. Furthermore, knowledge of growth rates and better estimates of age are needed to determine sustainable harvest quotas. The group emphasized the need for baseline evaluations before fishing is undertaken, as well as routine monitoring of collection areas to evaluate fisheries impacts and adapt management as necessary.

The workshop participants recognized the need for improved conservation and management of Coralliidae populations, and most felt that CITES is one tool that could enhance conservation. A listing could reduce both illegal trade and fishing, as well as promulgate stronger management and enforcement by giving both exporting and importing countries joint responsibility for conservation of this resource. A CITES listing requires monitoring and annual reporting of landings and trade, which would fill critical gaps in knowledge of harvest and trade levels. A listing would also promote research on the status and trends of Coralliidae populations and the impacts of fisheries, as well as the adoption of more sustainable management approaches, all of which would help an exporting country make the non-detriment finding that is required for issuance of an export permit for species listed in CITES Appendix-II. However, questions still remain regarding the benefits of a CITES listing. For instance, there are large local markets and trade between neighboring European Union countries, which would not be regulated by CITES. While several new administrative burdens would be associated with a CITES Appendix-II listing for Coralliidae, the outcome of this meeting demonstrates that these are not insurmountable, having been successfully resolved for other species that presented similar challenges, including stony corals and antipatharians.

TERMS OF REFERENCE FOR THE WORKING GROUPS

Working Group 1: The Science Working Group

This group will discuss the state of knowledge of the biology, population status and threats, whether the available science is adequate to estimate decline, and if these species have declined to the extent required to justify a CITES Appendix-II listing. The emphasis will be on Pacific species of *Corallium* and *Paracorallium* that are the target of precious coral fisheries with comparative information for Mediterranean species.

1. How much do we know about Coralliidae in the Pacific? For each country, and in international waters, compile information on:
   - A) Historical extent and range of these species, the ecological history of these corals, and if an estimate of total population size and distribution area is possible to ascertain.
   - B) Current status, including spatial area of occupancy (vertical and horizontal), abundance, and size structure.
   - C) Identify and characterize the threats that have impacted populations, where these occur, and whether they are ongoing, recent, or historic.
   - D) Characterize changes among populations. Include a discussion of the extent of expansion into new habitats,depths, and/or shifts in distribution (i.e. loss of populations at certain depths), and factors that may have mediated these changes.
   - E) Estimate the percent of beds where these corals have declined substantially from some historic level, the percent of beds where populations are stable or recovering, and identify specific locations where these changes have been observed.
   - F) Identify locations that have been impacted by trawl fisheries and the type of information available on impacts from these fisheries.

2. Evaluate the adequacy of existing knowledge and research approaches:
   - A) Identify and evaluate monitoring approaches that have been applied or need to be applied to assess status and trends in these species, including ways to quantify abundance, cover, various life history stages, depth stratified long term distribution and density studies, factors affecting growth and reproductive capacity, and other demographic parameters.
   - B) Identify gaps in assessment and monitoring information (specific countries or locations where the coral is thought to occur, or once did occur but no recent information is available) and what is needed to obtain this information.
   - C) Identify information gaps regarding the biology, life history traits, taxonomy, genetics and what is needed to address these gaps.
   - D) Identify science needs for populations in international waters.

3. Assess decline criteria for these species:
   - A) Discuss relationships between density, abundance, size structure, and the use of size as a surrogate of decline for modular organisms.
   - B) Discuss possible implications of life history on the genetic structure of populations.
   - C) Discuss known information on growth, and how new measures of growth impacts prior determinations of MSY or other management measures.
   - D) Evaluate the adequacy of measures of decline included in the draft 2007 listing proposal, concerns identified through the FAO review, and options for estimating decline in data poor populations drawing from other fisheries.

Working Group 2: The Management Working Group

This group will compile and assess information on existing national management strategies, how they vary between jurisdictions, and their adequacy.

1. Summarize the national management plans for Coralliidae:
   A) Compile information on existing national legislation, regulations, statutes, management approaches, and conservation initiatives that apply to Coralliidae, and develop a table to compare and contrast management approaches between countries and provinces.
   B) Evaluate the effectiveness of national management at protecting these corals, enhancing recovery potential, and where they are being applied.
   C) Summarize how management measures differ across jurisdictions and in international waters.

2. Compile available information on Coralliidae fisheries:
   A) Identify numbers of fishermen and/or fishing vessels within each country or province, types of gear used, effort (seasons etc.), and locations that are currently targeted and how this has changed over time.
   B) Evaluate relationships between landings, how these have changed over time, and how this is related to resource changes and/or decline in demand. Compile available information on value of different species of Coralliidae and fluctuations in value.

3. Develop recommendations on changes needed to management approaches to enhance conservation:
   A) Recommend additional measures that could be implemented on a local, national, and regional scale that are necessary to address threats affecting these species and can help rebuild populations, and where these need to be applied.
   B) Identify strong local management and enforcement efforts among range states to prevent unsustainable harvest of Coralliidae, and gaps where more steps are needed.
   C) Develop an adaptive management approach for Coralliidae that could be applied across jurisdictions to standardize management approaches.
   D) Examine the potential implications of not taking additional steps to conserve these species and the areas where they occur.

4. Compile information on Industry concerns associated with a potential listing and approaches to resolve these difficulties:
   A) Internet sales.
   B) Repairs of jewelry when products are returned (via mail and/or across international borders).
   C) Re-export of *Corallium* and *Paracorallium* (including material imported as skeletons and subsequently exported as a manufactured product.

Working Group 3: The CITES Working Group

This group will address implementation issues of a potential CITES listing.

1. Identification:
    - A) What tools does a law enforcement officer need to identify *Corallium* and *Paracorallium*?
    - B) How feasible is it to identify *Corallium* and *Paracorallium* to the level of genus (and differentiate it from other precious corals), and what implications does this have for the CITES listing and conservation of the species?
    - C) Can we justify a listing based on the findings that adequate science is available only for a single species, and other species are included based on the look alike criteria?
    - D) How do you deal with jewelry or other products that include multiple species of *Corallium*?

2. Origin of species in trade:
    - A) Recommend strategies to address interpretation inconsistencies surrounding Introduction from the Sea and potential implications for Coralliidae.
    - B) Discuss problems and solutions regarding illegal harvest of *Corallium* and *Paracorallium* species, and steps to effectively confirm that specimens in trade were legally obtained.
    - C) Provide options for a suitable approach to address pre-Convention specimens.

3. Administrative burden:
    - A) Discuss measures that would address the potential administrative burden, including increased paperwork load from issuing trade documents for all *Corallium* and *Paracorallium* species and new reporting requirements that might result if Coralliidae is listed.
    - B) Identify national issues that would need to be addressed including new enforcement officers and training programs if the species were regulated through CITES.

4. Commercial trade versus personal items:
    - A) Develop an approach to address Coralliidae jewelry that is purchased by tourists and/or in a person's possession, and identify an acceptable method for the allowable personal exemption, including a discussion of the number of allowable pieces and what considerations need to be taken into account for the differences in weight and/or size between pieces.

5. Linking science and management needs for CITES and Enforcement Authorities:
    - A) Evaluate the type of information that would be needed by Scientific Authorities to establish an export quota and make a non-detriment finding.
    - B) Evaluate difficulties in enforcement if the species were listed and approaches to resolve these issues.

WORKING GROUP REPORTS

Science Working Group Report

The working group was charged with assessing the state of biological knowledge and population information for *Corallium* and *Paracorallium* in Pacific waters, with emphasis on national and international waters that have been or may be targeted by commercial or industrial fisheries. The group also evaluated the adequacy of these data and the types of information that could help in determining sustainable management approaches for *Corallium* and *Paracorallium* fisheries. An evaluation of science needs and gaps in information is also presented for this region.

A. State of existing knowledge of Coralliidae populations and biology in Pacific waters

Japan

1. Distributional data

Dredge and ROV surveys conducted off the southeast part of the Japanese archipelago have identified seven taxa of *Corallium*. Two of these, *C. elatius* (100-276m) and *C. konojoi* (76-276m), are found in multiple locations between Mie in the north to Okinawa in the south. *Paracorallium japonicum* (76-280 m depth range) overlapped with *C. elatius* and *C. konojoi*, but also extended further north to Sagami Bay. Two other non-commercial species have been found off Boso Peninsula, north of Sagami Bay (*C. boshuense* 540 m depth, and *C. sulcatum* 180-540 m depth); *C. pusillum* was identified off Izu Island; *C. inutile* off Kochi; and a single sample of *Corallium* sp was collected at 1200m depth off Ogasawara Island. Coralliidae appears to be absent north of Sagami Bay, possibly because of lower temperatures and other environmental factors. The northern boundary of *Corallium* and *Paracorallium* distribution may be determined by the Kuroshio current, as it deflects to the east in the northern part of Sagami Bay.

Four 100 meter Remotely Operated Vehicle (ROV) transects were recently conducted off Kagoshima area to characterize population dynamics and habitat features. The population surveyed with the ROV was almost mono-specific. The colonies were surrounded by mud, but were attached to rocky substrate in a flat area. Current was not recorded but was not too strong. Nonaka and collaborators also recently completed surveys of *C. japonicum*, *C. konojoi* and *C. elatius* off Okinawa to observe distribution and some population structure parameters (Deep Sea Coral Symposium, Nov. 2008). No other population information is available, with exception of observations made in 1904.

2. Biological data

Samples of *P. japonicum* collected in 1904 identified the presence of eggs, which were larger in March than in September. Stable isotope studies carried out by NI suggest *Corallium* has an intermediate carnivorous-herbivorous diet. NI also examined cross sections of calcein-stained growth rings and radioactive labeling (Pb) samples collected at approx. 100 meters off Okinawa and Kochi areas to estimate age. Colonies had the following growth rates:

P. japonicum 0.30 ± 0.14 SD mm/year (N=5)
C. elatius 0.19 ± 0.15 SD mm/year (N=5)
C. konojoi 0.58 mm/year (N=1)

The Japanese Coral Association is collecting information on precious corals, limited environmental data (temperature, depth, current speed) and landings data for *Corallium* during fishing operations. This group is selectively harvesting coral using ROVs in Okinawa areas and using tangle net dredges off Kochi. Their website (www.sangokumiai.jp) includes general information about various species of *Corallium* and *Paracorallium* used in jewelry manufacture, approaches to harvest corals, and footage on Corallidae habitat. There currently are six videos illustrating the selective harvest of colonies off Okinawa using an ROV. From these videos, the following conclusions were made:1) The habitat was soft bottom-gravel community; 2) The density of corals seems to be low or even sporadic; 3) Other organisms such as soft gorgonians and alcyonarians occur in these habitats. Bottom trawls are not thought to be used in this area.

Fig. 1. Locations known to contain *Corallium* populations. Figure provided by Dr. Nozomu Iwasaki.

Taiwan

There have been no biological studies or population surveys undertaken for Coralliidae in waters surrounding the island of Taiwan. A research program was initiated in 2008, which primarily involves and observer program and an examination of landings to obtain information on population dynamics. Four species of *Corallium* and *Paracorallium* have been identified from fishery catches:

- *Corallium elatius* (momo)
- *P. japonicum* (aka)
- *C. secundum* (miss) *taxonomy has not been confirmed (HI only)
- *C. konojoi* (shiro)

Fishery effort is concentrated in a band that extends from the edge of the shelf between 100 to 1000m depth from the south-western part of the south China Sea (N19° E112°) to waters north-east of the island of Taiwan (N28° E126°) with most effort concentrated from 200 to 500m depth.

No data on abundance, density or size structure are available. Beginning in January 2009, data have been collected on the condition of landed colonies. The first two months of data indicate that only 2% of the colonies were alive when landed, while 15% of them had recently died and 83% consisted of long-dead, eroded fragments.

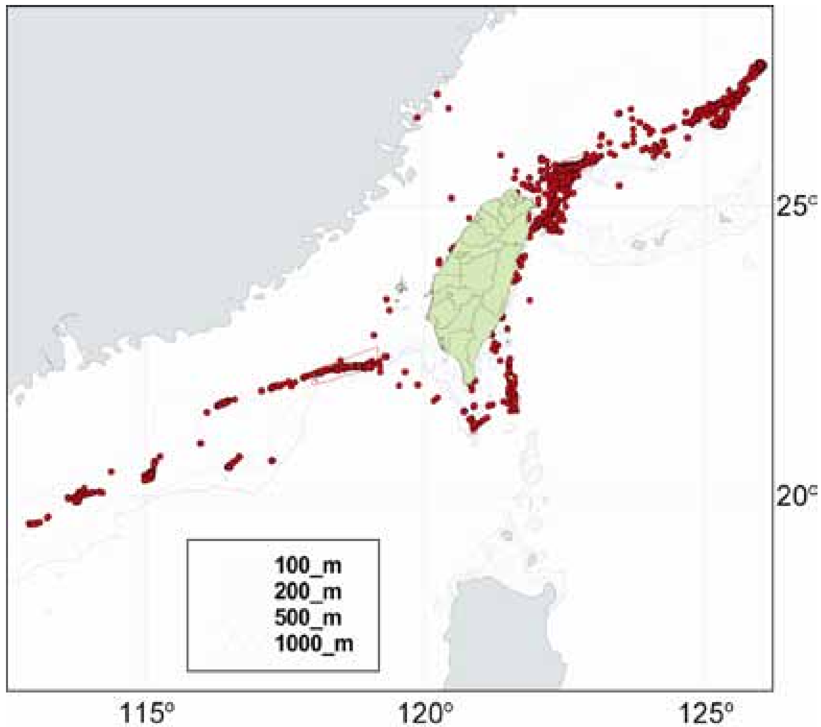

Fig. 2. Distribution of fishing effort for *Corallium* around the island of Taiwan. Figure provided by Dr. Chih-Shin Chen.

International waters around Emperor Seamounts

Corallium populations were first discovered around Koko Seamount (C. *secundum)* in 1965. Additional populations were identified on Koko, Kamu, and Hancock Seamount in 1972 (the report of 1972 Kaiyo Maru survey). An extensive population of an undescribed species (*Corallium* sp. nov.) was discovered in 1978 at the depth of 900-1500m. No scientific surveys were done focused on *Corallium* prior to inception of the fishery or during the period of active exploitation (1965 and 1990) in these areas. ROV surveys (2006) and additional drop camera surveys (2008) were made off Koko Seamount by the Fisheries Agency of Japan in areas formerly targeted by coral drag fisheries, with the primary goal of identifying vulnerable marine ecosystems, of which sessile benthic *Corallium* habitats are included. Out of 44 drop camera surveys conducted during these surveys, *Corallium* was only identified in one area; this area is now proposed as a closed area for trawl fisheries.

Hawaii

1. Distribution and abundance

Deep coral research in Hawaii was initiated in 1970, approximately four years after the discovery of *Corallium secundum* at Makapu'u Bed off Oahu. Makapu'u bed contains the largest known population of *Corallium* in the U.S Pacific, with colonies occurring over an area of about 3.6 km^2. The density and size structure of this population was first characterized in 1971, following three years (1966-1969) of non-selective fishing (1800 kg of *C. secundum* were removed using a coral tangle dredge). The area was resurveyed in 1983 and 1985, following six years of manned submersible harvest (total harvest = 6200 kg). This coral was found to have density of 0.02 colonies m^{-2} in 1971and 0.022 ± 0.01 colonies m^{-2} in 1985. Additional surveys in 2001 found that the bed was larger than previously estimated (4.3 km^2) and corals occurred at a higher density (0.3 colonies/m^2).

Submersible surveys between 350-500 m were conducted at 6 coral beds in the lower Hawaiian Archipelago between 1998 and 2001 to characterize the distribution, abundance, and size structure of precious corals. Two beds, Makapu'u and WestPac, were dominated by *C. secundum*. *C. regale* was the dominant species of *Corallium* at Brooks, Keahole, and Cross sites. *Corallium* was rare at the remaining French Frigate Shoals site.

To date, precious corals have been identified in 17 locations off Hawaii. In some cases, the size of these beds, colony abundances, and size structure are known, but collection of additional data would help improve our understanding of these taxa and the potential for sustainable harvest.

2. Population dynamics

The Makapu'u coral bed has been the focus of fishing and monitoring since the early 1970s. There was no significant change in recruitment throughout this period, although there was a slight shift in the age-frequency distribution. In 1983, age groups between 15 and 35 years old declined in abundance by 2-9% when compared to 1971 surveys, and all colonies older than 35 years old were absent. Over the next 2 years, increases in abundance were observed for the 20-25 year age classes (12%) and 30-40 year classes (1%), but older colonies were still absent. By 2001, all age classes from 20–45 years were at a higher abundance than that observed in 1983, while older colonies were still under-represented.

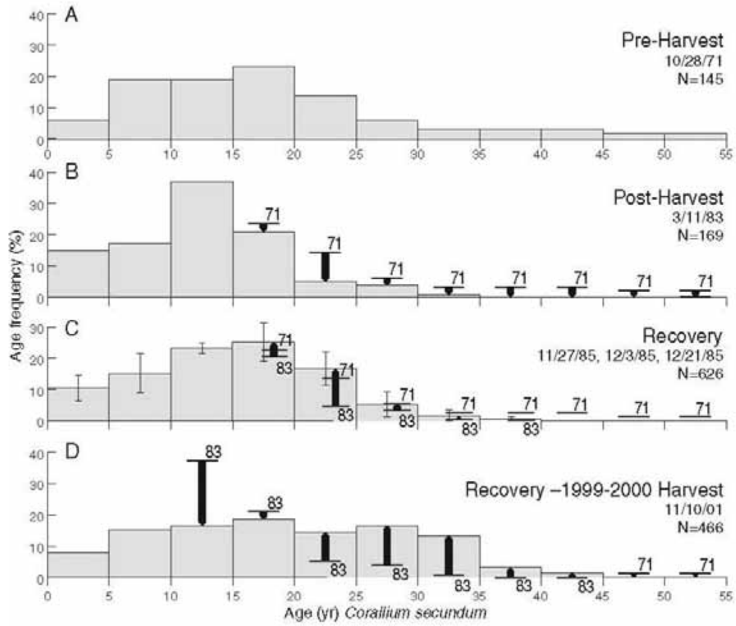

Fig. 3. Age structure (frequency distribution) of pink coral in the Makapu'u Bed, Oahu, in 1971, 1983, 1985, and 2001. Figure taken from Grigg 2002.

3. Biological data

Linear growth rates and ages of *C. secundum* colonies were first estimated from skeletal growth rings (0.9 cm height/yr; Grigg 1976), with 28 cm tall colonies estimated at 29 years. Recent aging studies using radiocarbon determined growth rates of 170 microns diameter/yr, which suggests a 28 cm tall colony is around 70 years old (Roark et al. 2006).

Colonies of *C. secundum* were found to have separate sexes and exhibit broadcast spawning. Colonies achieve sexual maturity at 10-12 years, as determined from growth ring studies (Grigg 1976).

4. Habitat

Habitat for *Corallium* in Hawaii includes hard substrates free of sediment that have strong currents with *C. regale* extending slightly deeper than *C. secundum* (Grigg). *C. regale* appears to exhibit a general preference for outcrops and ledges, while *C. secundum* occurs primarily on flat, hardpan carbonate substrates (Parrish 2007).

B. Value of various types of biological information for management purposes

- Presence/occurrence data
    1. Information on the species present in national or international waters can provide useful distributional and diversity data for a particular region, but information solely consisting of locations of occurrence is not sufficient to determine sites where *Corallium* can be sustainably harvested, and it cannot be used to develop quotas and harvesting placed on population based demographic models.

- Abundance data
    1. Abundance information on colonies within a *Corallium* bed provides valuable information on the status of a taxa in that location, but the data must be combined with knowledge of the entire size of the bed suitable for colonization by the species under consideration, and abundance data must be normalized over the entire bed. Use of density data from small patches, without considering the total number of patches and size of those patches within the bed, can overestimate the total abundance and/or yield because *Corallium* often forms dense aggregations within a limited area, with population abundance declining at the margin of the patch, even though suitable hardground habitat is much more extensive. One approach to resolve this is to have variance to mean ratios calculated on similar samples (e.g. one portion from each transect).
    2. Because fisheries have targeted many known *Corallium* beds in Pacific waters, it may not be possible to determine the true baseline of a "virgin" population, making it difficult to determine what the population looked like historically and whether areas that have been surveyed represent a natural state. Nevertheless, population size age structure can supply precious knowledge on the population history and on population trends. This is apparent even in some well studied populations, such as Makapu'u Bed, where the first surveys were conducted after several years of removal through a non-selective fishery.
    3. Detailed information on the abundance and density of *Corallium* within a known area occupied by *Corallium* can provide useful information on possible levels of harvest for non-selective fisheries, but these data cannot be extrapolated for other beds, solely based on knowledge of the size of those beds. This is because existing data have shown that, even at the same depth, *Corallium* abundance is highly variable both within a bed and between beds. Furthermore, data on density/abundance of one species cannot be directly used to estimate density of another species as these may occur in different habitats and/or have different environmental requirements, even if they occur within the same depth range. This has been shown for two species of *Corallium* found in Hawaii, each of which occupies the same depth and are predominantly found in hardbottom habitats, yet one shows preference for outcrops and vertical areas while the other prefers flat hard pan areas.

- Habitat information
    1. Surveys conducted to identify presence, abundance, and population dynamics of *Corallium* should include compilation of as much habitat and environmental data as possible, as this may provide information that can be used to identify other potential areas where the species may occur and it could form the basis for the estimation of the total available habitat in a region.
    2. Other information that may affect the condition and/or quality of that habitat, such as the presence of high numbers of known predators, unusual environmental conditions that

appear contrary to those preferred by *Corallium* (e.g. large temperature fluctuations, shifting sediments, etc.), or the presence of large numbers of broken, bioeroded, and/or dead colonies should be recorded if possible, as this could be useful in determining things that may limit survival or recovery of populations after human or natural disturbances, and it can serve to identify impacts from previous non-selective target (e.g. coral dredge) or non-target (e.g. trawl) fisheries.

3. Information that enhances the survival and growth of *Corallium* and/or mitigates unsuitable factors (e.g. strong, nutrient rich currents) should also be documented, as this may help estimate potential impacts of different levels of harvest pressure.
4. Whenever possible, the importance of *Corallium* should be assessed because of its potential role as an ecosystem engineer, and considerations of the role of the taxa in the ecosystem should be given when establishing harvest guidelines.

- Population dynamics
  1. The size structure and complexity of colonies (degree of branching) within a population and how that has changed over time is the most important information needed to sustainably manage a population subjected to fishery pressure. This is because colonial animals exhibit size-dependent survival and reproductive parameters including fertility, reproductive output, and possibly resilience of larvae and/gametes (e.g. larger colonies may produce offspring with greater lipid reserves). Using macrophotographs and a scale bar, some of these data can be obtained rapidly by photographing large numbers of colonies.
  2. The most suitable measure of population structure for fishery management purposes is height and branching pattern, as this can be readily ascertained *in situ* using ROVs and submersibles. Diameter data may allow more precise age estimates, but diameter is more difficult to measure in deep water populations inaccessible to SCUBA, and may not be directly relatable to colony height or branching pattern for larger colonies.

- Biological data
  1. Attempts should be made to collect information on reproduction for different species, including sex ratio, size at maturity, and relationships between size and numbers of gametes/per colony, as this can help determine the minimum size at which colonies should be harvested and the potential for recovery following harvest pressure and/or other disturbances.
  2. In areas with ongoing *Corallium* fisheries, representative colonies or parts of colonies should be sampled and preserved for examination of size structure targeted by the fishery, as well as reproductive characteristics, growth rates, and other life history traits (e.g. tips of colonies of known size fixed in formalin or bouins).
  3. For areas with non-selective fisheries, especially when there are no *in situ* data on population structure, measurements of representative colonies can provide some information on the structure of the population in the harvested area. Managers should be cautious when applying these data to management, as the fishery may be targeting a certain portion of the population, and portions of that population (e.g. percent of small colonies) may be missed or underestimated – especially in situations where non-selective gear is used due to losses of colonies during collection.
  4. Condition of colonies collected by fishermen is also indicative of the "health" and stability of a population, as landings consisting of a large proportion of dead, broken,

and encrusted or bioeroded colonies may have experienced previous human or natural disturbances that have negatively damaged those populations. In cases where few live colonies are landed, consideration should be given to limit harvest and/or close an area to allow recovery.

5. Whenever possible, experimental data to evaluate recruitment (e.g. settlement tiles, photos, or ROV transects), growth (labeling of colonies *in situ* and/or direct measurements over time), and other biological parameters should be collected to allow assessment of the potential for recovery and/or expansion of populations, or the time required to restore populations to a natural (pre-harvest) state, and for use in models to estimate MSY and other fishery parameters.

- Genetic information
    1. Knowledge of the genetic structure and connectivity of populations is extremely important and should form a focus of future research efforts, as available data suggest there may be limited connectivity between populations and several areas appear to be self-seeding. This has implications for the management of *Corallium*, as a low degree of genetic exchange between *Corallium* beds suggests these should be managed as separate stocks, such as the approach taken in the U.S. Precious Coral FMP.

- Monitoring
    1. In areas where fishing is allowed, the beds should be examined over time to evaluate changes in population parameters, such as density and size structure, to evaluate threats, impacts, and to ensure populations remain stable and/or increase at allowable levels of removal. If significant changes are observed, considerations should be given to reduce fishing and/or closure of fishing to allow stocks to rebuild.

- Natural threats
    1. Causes for natural mortality (parasites, predators, epidemies, substrate instability/ landslides, global ocean warming, acidification, sedimentation) should be identified and studied.

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Table 1. Fishery dependent data

	Current	Minimum	Medium	Maximum
Data mining		Compile grey literature from fisheries agencies, etc. on historic data (landings, fishing effort, etc.), museum collections, interviews with fishermen	Evaluate stockpiles to get historical information on population dynamics	Determine if populations are changing due to climate change, etc. (Isotopic analysis of samples in old collections to evaluate changes in biology)
Landings reported by fishermen	FAO aggregated annual landings by country and species	Landings by vessel for each trip in port	Landings by region/ location for each country	Landings by specific Corallium bed
Fishing vessels	May or may not be licensed	Accurate Number of vessels operating in each area	Amount of effort per fishing trip related to landings	Amount of effort per unit catch per bed
Observer program	Variable, observer program started for Taiwan in 2009	Random assessment of fishing activities within each country	Dedicated observers for fishing vessels in each location targeted per country at certain times of year	Observer placed on each fishing vessel
Observer data on landings		General information on locations of fishing, gear deployments, duration, and type of benthic organisms landed (e.g. number of trawl surveys with and w/o coral)	Detailed information on location and depth where fishing occurs, amount of landings per deployment, taxa landed by weight	
Observer data on colony basis		Information on condition of colonies landed by species (live, recently dead, eroded), fragment or whole colony		More detailed colony condition (epibionts, degree of bioerosion, relationships between size, and colony condition
Observer data on population dynamics		Random samples of population structure by species within one or more locations (size of colonies, e.g. height)	More detailed assessment of population dynamics by species in multiple locations (height, diameter, weight of colonies)	Full characterization of representative samples in each location and during each trip of population dynamics, branching patterns, etc.
Observer program contributed to advanced biological/ ecological understanding of corals and coral beds		Bycatch	Environmental parameters, deploying camera/rov during collections to characterize habitat	Sampling of colonies sent to experts to characterize reproductive status (e.g. seasonal cycle, sexual structure, relationship with size, etc.), growth rates

Table 2. Scientific survey approaches

Approach	Minimum		Maximum
Simple data collection from boats without special equipment (e.g. Sample collection using tangle nets)	Species occurrence (maps of presence/ absence)		Analyze sample condition, population parameters, biological aspects, etc.
Drop camera	Single images of habitat and presence/absence of *Corallium* (still camera)		Video transects with GPS coordinates, temperature, and general habitat features
ROVs with video	Images of habitat, benthic community structure, presence of coral, depth of occurrence of coral	Environmental parameters (temp, current, etc.), depth-related distribution, patch size, abundance/density along depth gradients, colony condition	Size (height) structure of corals, branching pattern, morphology (laser, ruler to quantify)
ROVs with manipulator arm	More detailed information on growth rates, reproductive parameters, weight, etc. from sampled colonies		Genetic, biochemical, and isotopic analysis of samples
Submersible	Detailed benthic surveys of habitat, *Corallium* population structure, etc.		Experiments to enhance understanding of biological processes such as recruitment, transplantation work, etc.

Management Working Group Report

The membership of this working group was assigned four tasks: 1) Summarize the management plans used in fisheries that harvest *Corallium* spp.; 2) Compile information on *Corallium* spp. fisheries; 3) Develop recommendations needed to enhance management and the conservation of the *Corallium* spp. resource; and 4) Compile information on the industry concerns associated with potential CITES listing and approaches to resolve these difficulties. Based on the groups' experience and the materials they had at hand, it was decided that the group would focus on items 1, 3, and, to a lesser degree, 4. The business of addressing item 2 was deferred till the next international workshop.

To address the first task, management measures were surveyed across the membership of the working group. The intent was to generate a list of measures that could be used in a survey to query the management of *Corallium* spp. fisheries worldwide. Aspects of management included jurisdictions, permits, quotas, gear, size limits, reporting, observers, fishery dependent and fishery independent monitoring program, and enforcement. The locations of fisheries present in the working group included Spain, Hawaii, Taiwan, Morocco, and Italy. In addition, the group considered high-seas fisheries and the recent Appendix-III listing of four *Corallium* and *Paracorallium* spp. in China. The intent of the Table 1 is to serve as starting point for further data collection on management, and to provide a context for the next international workshop planned for Italy in 2009. The working group discussed a wide range of management strategies for fisheries, ranging from those directed at deep water *Corallium* spp. to those focused on shallow resources. Gears used in the harvest of deep coral included tangle nets, submersibles, and divers. Monitoring of coral resources ranged from a minimum level of data derived from periodic landings to fishery independent surveys from long term monitoring.

Table 1. List of management measures in *Corallium* spp. fisheries from membership of the management working group.

Management measures	Hawaii	Spain	Taiwan	Italy	IT Sardinia	Morocco	China	High Sea
***Corallium* harvest banned**	No	No	No	No	No	No	Yes	No
Within country jurisdictions state/ prefectural								
Exclusive rights (cultural, claim rights)		?						
Established fishing areas	Yes	Yes inner/ outer waters	Yes	?	Yes	Yes	NA	No
Coral bed closure for recovery (rotation)	Yes	No	No	?	Yes	Yes	NA	No
Establish refugia for *Corallium* spp.	Yes	Yes	Yes	Yes	Yes (MPAs)	Yes	?	No
Permits/licenses issued	Yes	Yes	Yes	Yes		Yes	NA	No
License validity expires	1-2 years	1 year/ renewable	1 year	1 year	1 year	1 year	NA	NA
License restrictions	Person & bed specific	Diver	Vessel	?	Yes	Boat	NA	No
Vessel restriction	None	None	None	?	Yes	<50 ton gross wt	NA	No
Time of day restrictions (surveillance)	None	Fishing permitted from sunrise to sunset	None		No	Daytime	NA	No
Allowed fishing days/ year	Season	1 May-30 October	220	?	Season	None	NA	No
Quotas in place	Yes	Yes	Yes	Yes	Yes	Yes	NA	No

Dead *Corallium* spp. part of quota	NA	NA	Yes	No	No	NA	NA	No
Harvest season	1 July - 30 June	1 May - 30 October	Yes	No		No	NA	No
Purpose for established season	Monitor fishery	Weather suitable	Weather suitable		To limit the fishing time	NA	NA	No
Gear	Select sub/ ROV	Scuba only	Tangle nets	Select/ scuba	Scuba only	Scuba only	NA	Tangle nets
Minimum size	Yes	Yes	No	No	Yes	No	NA	No
Reporting	Yes	Yes	Yes	Yes	Yes	Yes	NA	?
Report landings	Yes	Yes	Yes	Yes	Yes	Yes	NA	?
Report gross weight	Yes	Yes	Yes	No	Yes	No	NA	?
Report composition live, dead, fossil	NA	NA	Yes	No	No	NA	NA	?
Report depth/location	Yes	Yes	Yes	No	Yes	Yes	NA	?
Report operation time/ dives	Yes	Yes	Yes	No	Yes	Yes	NA	?
Interval of reporting required	Daily	Daily	Daily	No	Yes	Daily	NA	?
Report number of colonies	Yes	No	No	No	No	No	NA	No
Report sales	Yes	Yes	Yes	No	No	Yes	NA	?
Observers used in fishery	No	No	Yes	No	No	No/Surveys	NA	No

Level of observer coverage	NA	NA	Every boat once a year	NA	NA	NA	NA	NA
Spatial monitoring	No	No	Yes	No	No	No	NA	?
Fishery independent monitoring program	Pulse-Research	Pulse-Research	None	Very Pulse Funding	Pulse-Research	Pulse-Research	NA	No
Reports of bycatch in coral fishery	NA	NA	Observer Reports	No	No bycatch	None	NA	No
Corallium spp. bycatch in other fisheries	None	None	None	No bycatch	None	None	?	No
Enforcement	CG and Fisheries	Coast Guard	CG & Fisheries	CG	Coast Guard	Marine Authority	?	No
Penalties	Fine	Fine	Confiscation of gear/lose license	Mild	Mild to Strong is fine	Marine Authority	?	No

To address task 3 "Develop recommendations to enhance management," the working group tried to capture the variability in *Corallium* spp. fisheries worldwide. It was recognized that the management measures to be employed can be fishery specific. Measures that can be readily implemented in the shallow coral fishery of the Mediterranean may not be possible in the deep coral fisheries of the Pacific. So the group opted to identify a range of suitable management measures that should be considered for any *Corallium* spp. fishery. The minimum and maximum level of management for each management measure was proposed in Table 2 to describe the range in *Corallium* spp. fisheries. Selection of management measures for any fishery is the responsibility of their management authority, and the purpose of this table is to provide a range of options that can improve conservation and monitoring of the industry and its resource. The working group further proposes that *Corallium* spp. fisheries should strive to implement management practices that enhance the status (the resource yield and the wider ecology) on a sustainable basis.

Table 2. Range of management measures (minimum and maximum) used in *Corallium* spp. fisheries.

Management measures	Minimum measures	Maximum measures
***Corallium* spp. harvest banned**	NA	
Within country jurisdictions state/prefectural	Jurisdictions should be defined, including any exceptions	
Exclusive rights (cultural, finder claim rights)	If allowed – define the process for defining these rights	
Established fishing areas	Knowing where the fishing is happening/homogenizing internal-external waters	Define boundaries and density of coral in fishing areas
Coral bed closure for recovery (rotation)	Based on the growth rate of the species being harvested	
Establish refugia for *Corallium* spp.	Areas known to have corals set aside a reproductive reserve	To preserve reproductive, dispersal, gene flow the wider ecology
Permits/licenses issued	Number of permits based on best available science	Permits based on a resource assessment to ensure sustainability.
License validity expires	Validity should serve as a means of re-evaluating the fishery	Expiration dependent on quota monitoring
License restrictions		To control the rate of fishing, and number of resources exploited
Vessel restriction		A means to control the location and the fleet size
Time of day restrictions (surveillance)		A means to improve surveillance
Allowed fishing days/year		A means to control effort
Quotas in place	Quota based on best available data, (e.g. prior fishery landings)	Bed specific quotas based on survey data
Dead *Corallium* spp. part of quota	Should know the percentage of dead	Include dead in the quota as appropriate
Harvest season	Not required, but a limit on number of days/year suggested	Not necessary if permit and quota controls in place

Purpose for established season	NA	NA
Gear	Impacts of gear should consider growth rate & quota control	Selective harvest only
Min size	When present observers collect size information	Yyes
Reporting	Yes	Yyes
Report landings	Yes	Yes
Report gross weight	Yes	Yes
Report composition live, dead, fossil	Yes	Yes
Report depth/location	Yes	Yes
Report operation time/dives	Yes	Yes, need to generate CPUE
Interval of reporting required	Daily	Daily
Report number of colonies	No	Yes
Report size of landed colonies	No	Yes
Report sales	Yes	Yes
Observers used in fishery	Not needed if other controls are in place.	Yes
Level of observer coverage	NA	At levels determined necessary
Spatial Monitoring	Limiting vessel size/range	VMS
Fishery independent monitoring program	Cost-shared data collection through industry	Establish long term monitoring of demographics and ecology
Reports of bycatch in coral fishery	Determining there is no bycatch	Selective harvest only
Corallium spp. bycatch in other fisheries	Identify and quantify	If present eliminate
Enforcement	Yes, document all fishing (legal & illegal)	Compliance of legal fleet and preventions of illegal fishing
Penalties	Low fiscal impact (fines)	Loss of permit, confiscation of vessel, jail term.

For item 4 “Compile industry concerns associated with potential listing (…),” the working group identified a few concerns that were voiced to membership by industry prior to attending the workshop. The most common concerns were the species identification problem and determining the source of the coral. Because this workshop had a working group dedicated to this topic, it was left to that group, and discussion in this group was limited to issues of stockpiling, impacts to trade of legal coral operations, and problems of personal effects jewelry moving across borders. To address the stockpile issue, it was proposed that this coral would have to be registered/certified as pre-Convention material for use in trade. The nature of this “certification process” was not discussed, although it was noted that black coral is already listed by CITES and continues to be traded legally, andt could serve as an example of what would be involved with a *Corallium* spp. listing. Listing under CITES would result in some level of inconvenience to the shipping and movement of industry material. It is not clear how jewelry sold and then returned across international borders for repairs will be accommodated under a CITES listing. The European Union was identified as a place with multiple coral fisheries and no internal border control, presenting a special circumstance for monitoring the traffic of the coral resource. Examining the 20 year history of the trade of black coral and other products regulated by CITES would provide insight as to the level of impact we could expect on the industry if *Corallium* spp. were listed.

Proposed next steps for 2009 workshop in the Mediterranean region:

1) Have the history of *Corallium* spp. landings for each fishery submitted in advance of the workshop to address item 2.

2) Use the tables in this report to survey management measures in established coral fisheries world wide prior to the next workshop.

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CITES Working Group Report

General points

Although a number of CITES implementation issues were referred to the group to consider, it was felt that many of these were generic to trade in CITES specimens and few were unique to trade in Coralliidae. As such, many of these issues were ones with which Management Authorities (MAs) and enforcement officials (EOs) had to deal with routinely, even if they were not all straightforward. Those issues for which Coralliidae posed special problems, notably in the identification of worked specimens in trade, were also ones which related to trade in black corals, which had been listed on CITES for >20 years. Indeed, some of the approaches suggested here for red corals, might also be usefully extended to improve implementation of trade in black corals.

1. Identification:

A) How feasible is it to identify Coralliidae only to the level of genus (and differentiate it from other precious corals), and what implications does this have for the CITES listing and conservation of the species?

a. The WG concluded that, where **worked specimens** were concerned, it may only be possible to identify such specimens to the level of the Family Coralliidae. As there were two genera within the Family, and future taxonomic revision may create more, it was not possible to readily identify worked specimens to genus level. This proposal should be incorporated in any listing proposal to form the justification required by Res Conf. 12.3 Part XIV.e.i for the use of higher taxon names on permits.
b. Where **raw or dead corals** (*sensu* Res Conf. 11.10) were concerned, the group felt that the standard presumption should be that these be identified to species level. However, it was also recognized that on occasions this may be difficult and thus identification to Family level may on occasions be justified. However, should the Family be listed on Appendix-II at COP 15, the extent to which identification to species level might be possible might be best referred to a decision directed to the Standing/Animals Committee to examine further prior to COP 16 (this approach would also be valuable for black corals and to revise guidance on stony corals in Notification 2003?/020). Knowing the country of origin of dead corals narrows down the likely range of species in trade.
c. Given the difficulties of identifying worked specimens to genus and species level, an Appendix-II listing of Coralliidae will be easier for MAs and EOs to implement than the current App-III listing of four *Corallium* and *Paracorallium* spp.
d. Coralliidae powder is also in trade and may be used for traditional medicines and other purposes. As this product is labeled it is, by definition, readily recognizable (Res Conf 9.6) and so should be subject to CITES controls. In the absence of any label, identification of Coralliidae powder is likely to be impractical.

B) Can we justify a listing based on the findings that adequate science is available only for a single species, and other species are included based on the look alike criteria?

a. Yes – this is a routine approach in CITES. However, the previous listing proposal did not use the look-alike criterion when proposing the genus *Corallium*.

b. How do you deal with jewelry or other products that include multiple species of Coralliidae and/or with other CITES specimens? This is a routine issue for CITES Parties to address – for example, specimens in trade may comprise carvings with inlay of ivory and hawksbill turtle shell and can be traded on single permits – therefore we do not foresee any insurmountable difficulties arising from any listing of Coralliidae in this respect.

2. Origin of species in trade:

A) **Recommend strategies to address interpretation inconsistencies surrounding Coralliidae and Introduction from the Sea and potential implications.**

a. Introduction from the Sea (IFTS) is an issue which goes beyond Coralliidae alone and is being addressed through a working group of the Standing Committee. Whether permits should be issued by the state of landing or by the flag state of a fishing vessel remains to be resolved. Nevertheless, IFTS remains a problematic issue, notably regarding which body should be responsible for making non-detriment findings and how multiple fleets exploiting one resource might be addressed.
b. However, it was unclear to the group how much coral was being harvested on the high seas and how big a problem this might be in practice. The relevant RFMO for the Mediterranean has closed fisheries on the high seas and so this is not an issue there; this would only be an issue for Pacific countries. The CITES Working Group looked to the Management Working Group to discuss the role of RFMOs in the Pacific. We recommend that information is sought as to the extent to which Coralliidae are taken from the high seas.
c. The CITES WG recommends that Coralliidae is brought to the attention of the IFTS WG as an example of a taxon that is currently being exploited on the high seas and for which some resolution or guidance is likely to be required (if listed on Appendix-II). Such guidance needs also to advise on the process for making non-detriment findings.

B) **Discuss problems and solutions regarding illegal harvest of Coralliidae species, and steps to effectively confirm that specimens in trade were legally obtained and provide options for a suitable approach to address pre-Convention specimens.**

a. Traders, when applying for permits, will have to demonstrate to the MA that their specimens were legally obtained.
b. Dealing with pre-Convention specimens, including stockpiles of raw and/or worked red corals, is an issue that is not restricted to Coralliidae and is one for individual MAs to consider and address within their own jurisdiction based on their analysis of volumes in trade and any risks.
c. Options include countries conducting inventories to track/monitor pre-Convention stockpiled coral that is traded or inviting voluntary declarations of stockpile quantities. Nevertheless, there will be difficulties in tracking the movements of specimens into and from such stockpiles and this approach may not be practical in all situations.

d. Preventing illegally taken specimens from being 'laundered' through stockpiles may be difficult and illegal take is best prevented by appropriate management of fisheries and landings rather than subsequently.

e. The WG also agreed that a listing should <u>not</u> provide an exemption for fossilized corals (cf Scleractinia). Defining and distinguishing fossilized coral is likely to be difficult and the proportion of genuinely fossilized Coralliidae in trade is likely to be low. Where specimens of long-dead corals are in trade (e.g. *C. rubrum* known as 'sciacca') these should still require permits but non-detriment findings are likely to be simple.

3. Administrative burden:

A) Discuss measures that would address the potential administrative burden including increased paperwork load from issuing trade documents for all Coralliidae species and new reporting requirements that might result if Coralliidae is listed. Develop an approach to address Coralliidae jewelry that is purchased by tourists and/or a person possession, and identify an acceptable method for the allowable personal exemption, including a discussion of the number of allowable pieces, and what considerations need to be taken into account for the differences in weight and/or size between pieces.

a. The use of the personal effects exemption provides a means to avoid permit issue for many tourist souvenirs (though not all Parties use this approach).

b. The CITES WG recommends that any future listing proposal use the same personal effects limit (for inclusion in Res Conf 13.7) as raised at COP 14 (report of Committee I Report 14 Rev. 1) which was: *up to a maximum of seven specimens of finished items or 1 kilogram (2.2lbs) including any ancillary mounting per person, whichever is the lesser. Where a specimen is comprised of multiple pieces of [Coralliidae], it should be treated as one specimen.*

c. There is also the option for MAs to provide semi-completed certificates to traders dealing in large numbers of specimens, thus further easing administrative burdens.

d. The WG also agreed that consistent reporting is necessary. CITES guidance currently recommends reporting dead corals by weight, the second preference being number of specimens. One suggestion discussed was to use weight for raw coral and number of specimens for worked coral (because items of jewelry may comprise materials other than coral). The working group would support the issue of better guidance for reporting items in trade being raised at the next COP, as this affects many species not just Coralliidae.

B) Identify national issues that would need to be addressed including new enforcement officers and training programs if the species were regulated through CITES including what tools does a law enforcement officer (EO) need to identify Coralliidae? Evaluate difficulties in enforcement if the species were listed, and approaches to resolve these issues.

a. Key enforcement issues were the need to detect wildlife products in trade, inspect and identify the content of these shipments and, where appropriate, validate permits. Subsequently, respond to any violations through national law. All of these required access to appropriate ID guides and expertise including, where necessary, expert witnesses to support investigations and prosecutions. None of these issues are unique to Coralliidae.

b. The group discussed what an enforcement officer would be tasked with doing; ultimately he/she is tasked with detecting violations of national law including those which support CITES. Identification is necessary to undertake the previous tasks and this becomes increasingly difficult if identification to species is required. Useful tools to assist EO's in this respect are:
    i. ID guide based on morphological characteristics;
    ii. Contact list of experts to call and confirm;
    iii. Specimen reference collections.
c. Other enforcement issues included checking large volume shipments where a sampling approach would have to be used. It was noted that most inspections are of imports, less so on exports.
d. Training for EOs in identification is valuable, including an overview of various uses of the product, how products are manufactured (a possible key to identification), different characteristics of species etc.
e. The ID guide is being developed with the goal of producing a tool that can be used effectively with little training. Virtual online training is another option.
f. ID material is needed in multiple languages, especially in the languages of those countries most involved in the trade (the guide will be produced in official CITES languages but would need funding for translation into other languages such as Chinese, Japanese, and Italian).
g. Training kits with photographs and sample specimens would be another useful aid to enforcement officials.
h. It is desirable to have an ID guide ready to accompany any listing proposal to address any identification questions regardless of the fact that Res. Conf. 11.19 only requests Parties to provide such guidance within a year of a listing proposal being accepted.

5. Linking Science and Management needs for CITES and Enforcement Authorities

A) Evaluate the type of information that would be needed by scientific authorities to establish an export quota and make a non-detriment finding

a. Identifying and evaluating the information needs for NDFs is a role for Scientific Authorities (the 2008 Mexican non-detriment finding workshop provided useful guidance on approaches to NDFs).
b. However, the WG noted that there are taxonomic issues relating to NDFs. If trade and/or harvest of Coralliidae are recorded only at the genus or family level, NDFs should still be attempted to the species level. It should be recognized that this also depends upon available biological and taxonomic information.
c. The group also recommended that NDFs for Coralliidae should take an ecosystem approach. It is important to ensure that non-selective fisheries do not damage the role in the ecosystem provided by these species.
d. NDFs should also take into consideration any bycatch of Coralliidae from fisheries targeting other species, which should be monitored by harvesting countries. It is

not clear where and how much bycatch (if any) is occurring and whether or not this enters trade.

BENEFITS OF A CITES APPENDIX-II LISTING FOR CORALLIIDAE

1. It would require exporting countries to make a determination, based on available scientific data, that trade is not detrimental to the survival of the species.

2. It would provide trade data not currently available; fill some (but not all) gaps in knowledge in regards to the international volume of trade in Coralliidae, its destinations and market flows and stockpiled volumes in each country. It would highlight areas where scientific and trade research should be conducted to better inform management and enforcement.

3. Identification of worked specimens in trade at Family level would in practice be simpler than implementing the current Appendix-III listing of four species.

4. It would provide the option for Significant Trade Review if required and allow adjustments as necessary based on findings.

5. It would raise awareness with the general public, industry, and other stakeholders that sustainability is a concern with this resource. The aim of a listing would be to prevent unsustainable use of the resource which would ultimately benefit the long term viability of the industry that depends on it. Nevertheless, those whose livelihood may depend on the red coral trade may feel threatened by any listing (but their livelihoods might be equally at risk by doing nothing to ensure the sustainability of the resource).

6. The group noted that for any listing to be effective it is imperative for CITES authorities to collaborate with relevant fishery management bodies. Whilst CITES provides a mechanism to control international trade, it is fishery management that ultimately determines the sustainability of exploitation of this resource.

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WHITE PAPERS AND REGIONAL REPORTS

Precious Corals in a Global Marketplace

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1. Introduction

Corallium rubrum, from the Mediterranean, has been made into beads and used by diverse cultures around the world for millennia and this is the species that is the benchmark or the gem standard that has defined the term "precious coral" for millennia. Today, however, the definition of precious corals has expanded to not only incorporate other of the "newer" *Corallium* species such as *C. elatius*, *C. secundum*, *C.japonicum*, and *C. konojoi*, but several other types of unrelated corals such as "bamboo" and "sponge" corals, black corals, gold corals, and blue corals. I propose that many of these precious gem corals not only reflect but enhance *Corallium rubrum's* history, cultural identity and meanings in a rapidly changing global fashion marketplace. I discuss precious coral in this paper as beads and as jewels, as items of dress and as a commodity that began in a long-term, extensive cross-cultural trade originating in the Mediterranean region, particularly in Italy.

Historically, *Corallium rubrum* or precious red coral as an organic material has carried different meanings based on its physical properties, such as its ancient use in the entire Mediterranean area as an amulet against the evil eye.[1] Red coral and stones, such as ruby, cornelian, and bloodstone, have been widely and historically associated with blood and amuletic power in Europe, Central and Western Asia, and Africa. Coral sprigs worn as amulets around his neck were used to protect the newborn Christ Child in many 15th and 16th century European paintings of the Madonna and Child. *Corallium rubrum's* Greek and Roman mythological association with Medusa's blood and fertility[2] translated into its early Christian religious symbolism as the blood of Hebrew sacrifice or of Christ, as the fire of redemption, and as the "tree of life." In the Middle Ages, coral beads were greatly in demand for rosaries not only because of coral's magical and protective properties, but its red color, which connected it to the rose and rose garden as the spiritual identity of the Virgin Mary in medieval Christian iconography.

From the time of classical Rome, Italy has been the center of Mediterranean trade, as well as the center of coral harvesting, manufacturing, and the trade of coral. Coral beads had high decorative and cultural value in dressing and adorning the body throughout Europe from the 10th through 17th centuries, with all of these important meanings. It was used for jewelry because it was so plentiful, and is seen in numerous paintings worn as necklaces, brooches, bracelets, hair ornaments, and mixed with other gems and jewels such as pearls. Outside of Europe, at this same time, coral was greatly favored and widely worn in India, Persia, and China. Marco Polo mentions his surprise at the great amount of coral used in Tibet. In North Africa, especially in Morocco, and in Arabia, coral was worn in large amounts by women in their jewelry.

From the classic Roman age, *C. rubrum* had a high economic value as an important commodity in the wide-ranging and centuries-long Mediterranean luxury trade, travelling the silk and spice routes between Europe, India, China, and the Middle East. Coral beads were a major Roman export to India through the sixth century, where it was traded for pearls, other gems, spices, and pepper. In the medieval luxury spice trade coral was categorized as a spice and held a prominent place in the commercial life of the Middle Ages. After the early 16th century, coral placed first in exports to the East, and was an essential commodity in all trade with India, where it was traded for diamonds. Coral beads were a primary export commodity from Italy that were transformed into a powerful currency for trade with West Africa in the period of European expansion and were used in the European-West African slave trade.

The value and trade of coral beads and jewelry in our contemporary global marketplace have been influenced by these historical meanings and traditions, and I have proposed that today's very different commercial markets for various types of corals reflect *C. rubrum's* historic trade, use, and meanings. Today, the Pacific *Corallium* species and other types of red and pink corals travel in the wake of *C. rubrum's* significance and also hold an important place in these markets. Coral beads have high value because they are worn in specific and special ways. Contemporary market categories are based on the production of different beads that result from different physical properties of coral, and each has diverse needs based on different interpretations of coral's historical meanings within the contemporary perspective of coral as a highly valued organic material.

2. The Italian Coral Industry—*Corallium* Bead Production in Torre del Greco

Since the 17th century, most of the Mediterranean coral has been fashioned into beads in an Italian industry centered in Torre del Greco, which is in southern Italy in the province of Campania, on the southwestern coast of the Gulf of Naples. Torre del Greco has long been known as a coral town, as "the world's capital of coral," and their economy depends almost exclusively on the transformation and trade of coral. Coral bead making and exporting in Torre del Greco is a multi-million dollar industry. Today, Torre del Greco competes with Taiwan and Japan as one of the most important locations in the world for the production of coral beads. In 2000, according to industry reports, Italy accounted for 90% of red coral commerce and the production of coral objects worldwide. Torre del Greco is Italy's leading exporter of coral beads and coral products like jewelry, and Italy's coral industry consists of, for the most part, a high-quality, high value-added commodity chain, a luxury production and trade. In 2000, 80% of coral objects and beads made in Torre del Greco were exported throughout the world from over 320 active businesses and workshops. This is changing, and Asscocoral, the association of the Italian coral industry, reported in 2007 that the coral sector included 250 active businesses and 2,500 workers (Notiziario 2007). The reality of *Corallium's* Appendix II listing will have a major impact in numerous socio-cultural and socio-economic contexts, not just in Italy but in Asia.

Based on my fieldwork observations in 2000, the two most prevalent *C.* species worked in Torre del Greco are *C. rubrum* and *C. elatius*, although I also noted the presence of *C. japonicum*, *C. konojoi* and *C. secundum.* According to more current sources, 70% of the raw *Corallium* processed in the Italian industry is from Pacific sources, specifically exported from Japanese and Taiwanese markets (FAO 2007; Santangelo, personal communication, March 2009). Mediterranean and Pacific varieties of *Corallium* have very different physical characteristics that play a role in limiting or pre-determining the final products of coral beads. I have summarized some of these characteristics in Table 5. The oldest and most well-known species is *Corallium rubrum*, and this prized red coral is called *Sardegna* in Torre del Greco, Italy, and Taiwan. As a gem, *C. rubrum* is uniformly red, and various shades of red are found. Natural color can span a wide range of hues from the most coveted deep oxblood red to an orange-red that is still highly prized.

Newer *Corallium* species from the Pacific Ocean come in a wide spectrum of colors ranging from pure white through shades of pink, salmon, and orange to a very dark ox-blood red. In comparison to *Corallium rubrum*, Pacific corals are larger in size and dimension, more compact in structure, and thus easier to handle. They can be more highly polished and more perfectly shaped, but they do not have uniform coloration throughout either surface or interior. Pacific corals are important in the Italian coral sector because Mediterranean coral is so scarce. By the end of the 19th century, enormous quantities of raw Pacific coral from Japan began to be exported into Italy. This crisis led to changes in the structure of the coral industry. Torrese coral businessmen went to India to sell manufactured coral goods from Torre del Greco, and to Japan to buy raw coral for working in Torre del Greco. This direct, international, commercial trade in coral kept business alive, and is a way of doing business that still characterizes the Torrese coral industry today. Scuba diving has increased tremendously the expenses and price of the raw coral pulled from the Mediterranean and international regulations related to harvesting and trade of endangered species also restrict the supplies of raw coral from the Mediterranean. So the bulk of the raw coral in Torre del Greco is now imported from Pacific waters via Japan and Taiwan, and many beads and other pieces of worked coral for jewelry are imported from Taiwan. Taiwan also now supplies large quantities of coral beads, much quicker and cheaper, for international markets formerly supplied by Torre del Greco manufacturers. However, Torre del Greco is known for the high quality of their products, and as a luxury production center.

A coral bead must go through up to 12 stages of production before it is finished (see Tables 1 and 2). Bead production is highly labor-intensive, still very much a process of working by hand with mechanization replacing hand tools in some steps. Essentially, however, methods of production of coral bead making today are the same as those used in the past. The nature of a piece of raw coral strongly determines the choice of finished products and, consequently, the finished product determines how the coral is processed and the beads produced. After harvesting, the raw coral is first washed to soften and remove a good portion of the brownish crust or skin called *coensarc.* The coral is then separated according to its size, color, and form or shape. Larger "bushes" or branches of raw coral are separated from the trunk at their intersections and the branches cut crosswise into smaller, uniform pieces (Fig. 1). In this step, damaged areas can also be removed or cut and separated. Selection at this point can be quite laborious and the waste can be enormous, depending on the type of coral. Pacific coral especially can arrive out of the water covered in knots, rot, and blemishes. This step is considered the most important in the entire process of coral production. Once further sorted, pieces are cut into smaller, more uniform and manageable shapes and sizes or "bead blanks" on an electric diamond saw blade under water and these blanks are then sorted into more refined groups by color and diameter based on final end use (Fig. 2). The coral pieces specifically intended to be made into beads (as opposed to flat cabochons or carved/incised pieces) are separated and sorted by diameter by passing them through a series of large bronze-bottomed sieves or riddles with graded holes to divide them into their various sizes.

Beads are first roughly shaped using an electric carborundum grinding wheel with the coral piece held tight and shaped by hand in a large wooden pliers (Fig. 3). This step simply takes off or rounds off and smoothes out the rough edges and removes remainders of crust or *coensarc* to expose the hard exoskeleton. In some cases, like *frange* or the rougher, cylindrically shaped beads

Fig. 1. Cutting coral into bead blanks. The raw coral branches are cut crosswise with an electric diamond-edged circular saw; water is used to cool the saw blade and keep coral dust down.Torre del Greco, May 2000, S.J. Torntore.

Fig. 2. *Corallium elatius* branches cut into smaller, uniform shapes called bead blanks. Torre del Greco, May 2000, S.J. Torntore.

called *fabbrica,* this might be the only stage of shaping, although they may be further refined and polished. It is important to note here that today it is possible to purchase coral pieces from Japan and China (specifically Taiwan) already prepared to this stage. It is also possible to import finished beads from these locations. Many workshops and independent producers import both beads and the roughly-shaped Pacific coral blanks and then finish them as needed in Torre del Greco. This alternative solves many problems for smaller Italian workshops and artisans, including the high price and unpredictable supply of raw coral, the subsequent difficulty of keeping raw coral in stock, and the low price of the coral blanks. These rough blanks can be produced in Asian locations very inexpensively and in large quantities, making the final Italian product less expensive for the producer and more cost effective in the marketplace.

Fig. 3. Rough shaping of the coral bead blanks using an electric carborundum grinding wheel with the coral piece held in a large wooden pliers. Torre del Greco, May 2000, S.J. Torntore.

Larger beads and all of those with other forms (cylindrical, oval, barrel, flat, etc.) are shaped individually by hand. Rough coral bead blanks are held in wooden pliers, or put onto an iron needle in a wooden stick (if the hole has been drilled), and each surface is ground down on a large, vertically mounted electric carborundum grindstone, which also uses water to facilitate the process. Smaller beads are placed onto a wooden stick with resin gum so that they can be more easily shaped in all three-dimensions, and the shape of larger beads will also be refined this same way. Smaller spherical beads, called *pallini,* make up the bulk of production and export in Torre del Greco. They are produced by a machine in which two large grindstones of carborundum are used—one is mounted horizontally underneath a rotating round bronze disk that has a pattern of numerous small holes cut into it and is like a flat round sieve or riddle (Fig. 4). Batches of the small rough pieces of coral are pushed by hand into the holes of the disk, the second horizontal grindstone is lowered above the disk, and it is turned on. The holes keep the coral pieces in place while the grindstones shape them to match the size of the round hole, and the vibrations of the machine assure that the coral pieces jump around enough to get ground on all sides and make a perfectly rounded bead.

Fig. 4. Making small, spherical pallini beads by machine. Torre del Greco, May 2000, S.J. Torntore.

After all of the shaping steps, holes are drilled by hand using a very fine diamond drill bit with water (Fig. 5). This step requires a great deal of expertise, precision, and skill, and is done by specialists. Each bead is drilled one at a time, halfway through each side to make a straighter hole and prevent breakage. When they arrive at this stage, the coral beads have a milky or cloudy film covering the surface, so the beads are submersed and soaked in a solution of water and hydrogen peroxide to cleanse or "purify" their color. They are then polished in a large barrel tumbler where the abrasive action of pumice mixed with detergent and water gives the beads a clear shiny surface.

Objects like coral cabochons or incised pieces then go directly to a goldsmith or jewelry workshop to be mounted in gold, platinum, or silver, and readied for sale, or go to the venue that placed the order for them. Coral beads instead go through one additional major step before mounting processes or sales. The stringing process is the final step of production and one of the most time-consuming. It is completely accomplished by hand by women working at a factory workshop or

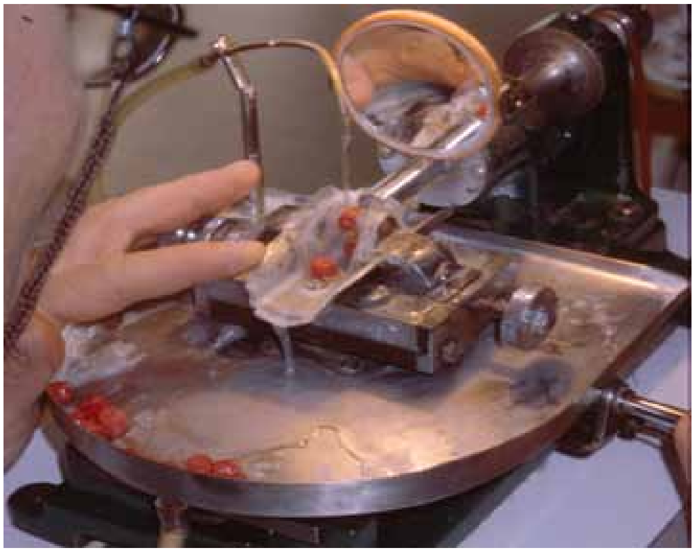


Fig. 5. Drilling the holes in coral beads. Here the shaped bead is mounted into a vice which slides back and forth onto the stationary diamond drill bit to make the half hole. A mirror is attached above the drill bit so that the artisan can control placement of the holes. As in many other production steps, water is used to control heat and dust. Torre del Greco, May 2000, S.J. Torntore.

at home. Finished strands are braided or knotted together. The bundles of beads are packaged for general wholesale distribution as beads, or made into various styles of necklaces or other items for three different markets. As an example of how time-consuming the process is, it takes between 10.5 and 14.5 days to produce one kilo of the small beads called *pallini* (see Table 3 for a chart of accumulated time related to the various stages of bead production).

Coral beads are named according to their shape and size (see Table 4). In some cases, they are also referred to by a specific finish or characteristic, such as the term *fabbrica* for the roughly finished imperfect beads of different shapes. The chart in Table 4 identifies the major characteristics of the most common terms and coral beads that I observed in workshops, retail shops, or as worn. Every piece and scrap of coral is utilized in some form, and the smallest little scrap is drilled with a hole and made into the beads called *spezzati,* for instance, to satisfy a specific market demand or custom. *Pallini* are the bulk of the production in Torre del Greco, and one of the products that is primarily mechanized; *frange* and *spezzati* are second in production amounts.

3. Italian *Corallium* Coral Jewelry Markets

Different beads are made for different markets. Very particular destinations and target markets were identified by coral producers in Torre del Greco for specific types of coral beads and bead products. I have categorized these specific markets under the larger headings of Fashion, Ethnic, and Tourist markets. These categories are based on differing characteristics of beads and jewelry, as well as the terms that were used by manufacturers, jewelers, exporters, and retailers, and they are also based on the differing values of coral and coral beads.

The fashion market category is based on current, constantly changing fashions and styles. In this market category, coral beads are strung in carefully graduated sets, based on the historic parure or matching set, or combined with carved or incised coral pieces or gold and platinum beads. This market prefers highly refined beads that require a great deal of hand work to shape, polish, and match. Imperfections in coral are not tolerated, unless the “ethnic look” is fashionable, as it is right now, and then slight variations may add character to a piece. Mediterranean coral is the preferred color and type within this market, although pink and red Pacific corals are also sold.

The spherical *pallini* twisted into multiple strand necklaces called torchons or torsades are the most popular type of bead for the fashion market. This style consists of several strands of small *pallini* twisted together into a choker or collarbone length necklace, with a decorative clasp. The more expensive corals are made into high quality beads that are then mounted and combined with other high quality expensive materials like 18-24 kt gold, platinum, diamonds, pearls, and other precious stones. In Italian and European fashion markets, these seemingly unchanging styles are considered classic styles and purchased in the same way that pearl necklaces are made and purchased—small details like size of beads, length or number of strands, or material and style of clasp may change each season or every couple of years. Although perhaps somewhat of a cliché in the Italian fashion market today, they are easily read as something that is expensive and classy, worn by a certain level of society like gold and genuine diamonds and expensive pearls are worn and understood in the United States. In Torre del Greco, coral beads in this market category hold the highest value overall for bead producers.

The ethnic market relates to all of the uses outside out the fashion market, and excluding the tourist market. It also includes all of those markets where coral beads are used for non-fashion functions. Beads directed to ethnic markets are very different than the fashion market beads in shape, size, and texture—they are larger in many cases, and less refined in shape and texture. The *fabbrica* or rough-textured type of bead in different sizes and shapes, such as the *barilotti* and *cannettine* beads, are the most common. A strand of *fabbrica barilotti* that were very roughly shaped, with numerous holes and inclusions, were described as popular for a Mexican market in 2000 (Torntore 2002). The branch coral beads called *frange* are also sometimes sold as part of this market.

The West African, and particularly Nigerian market, for example, prefers larger *cannette* and *barilotti* shapes, in some of the lighter shades of pink or orange Pacific corals, in a wide range of sizes. Darker Sardegna red coral is also prevalent in the Nigerian market. Beads directed to specific ethnic markets in Nigeria, for instance, include Pacific and Mediterranean corals worn by the Kalabari Ijo ethnic group of the Niger Delta area. In the ethnic market, as in many cultures, coral beads are worn as personal adornment, but they are not simply a matter of individual taste. According to Dr. Joanne Eicher (1998), coral beads have become an important vehicle through which the Kalabari Ijo ethnic group store, exchange, display, and transmit wealth, status, and prestige. They are a symbol of Kalabari identity and cultural survival. Some of the Pacific *Corallium* coral beads used by Nigerians also represent a large secondary resale market that I discovered here in the U.S. In the last 10 years of tough economic times in Nigeria, many of these family beads have come back into the global market, and have been stolen or sold from Nigerian family collections to Hausa traders and then re-sold to American bead dealers who may reshape them for other markets such as Buddhist Tibetan monk refugees or folk jewelry collectors in the U.S. The ethnic market category encompasses diverse cultural settings around much of the world. In this category, beads made for Italian and European ethnic markets include specific regional uses for traditional or folk purposes based on historical uses, such as the wedding necklaces worn by Polish women with their folk costume. It includes locations such as India, the Middle East, and Asia. The Southwest American Indian jewelry sector is also a large portion of this ethnic market, where coral has been combined for many decades with turquoise and silver.

The tourist market caters to producing and selling less expensive souvenir types of items. One of the coral items most described as part of the American tourist market was inexpensive costume jewelry necklaces of branch coral beads called *frange,* and simple, inexpensive necklaces made from waste coral pieces called *spezzatti*. Although these types of beads are all produced from coral pieces that would otherwise be thrown out as unworkable, they represent a significant amount of time to cut, polish, drill, and string. Italian or European tourists may buy something that looks fashionable, like a torchon necklace, instead of a more inexpensive souvenir-type of item. However, their purpose was to purchase it as a sentimental or souvenir of their vacation or trip rather than as an investment or classic fashion accessory. The pale pink *pelle d'angelo* or angel-skin colors of Pacific coral made into costume jewelry or simple, inexpensive 3-4 strand necklaces are also commonly popular with American tourists. Sponge coral started out in this market, but now has come into its own in all of the various niches from high end to tourist.

It should be noted that there is an extensive cross-over between all of these markets, especially when, as is the case right now, the "ethnic look" is fashionable. This current "ethnic look" includes many of the features from both ethnic and tourist market categories of coral beads—rough *fabbrica* beads in larger *cannette* and *barilotti* shapes, and the use of bright red Pacific corals instead of the more subtle Mediterranean colors. Bamboo corals have also come into all of the fashion market niches, as shown by many high end bamboo pieces in fashion magazines or on the runway. The current look also includes high fashion necklaces with multiple rows of *frange* mixed with amber, turquoise, silver, and metallic coins that imitate specific ethnic looks such as Moroccan or Berber jewelry. All of these coral beads have been seen for the past 10-12 years on the fashion runway, in fashion-related magazines, and in jewelry ads.

Florence, Italy is one of the largest markets for coral for both a local Italian fashion and tourist market and the international tourist market. Unmounted and mounted beads are sold in many high-end shops along the Ponte Vecchoio, such as U. Gherardi, and others. Coral jewelry is also sold in many of the smaller, lower-end tourist shops. I found that, in many of these shops, all red coral is touted or promoted by vendors as "Italian" (i.e., Mediterranean or *C. rubrum*) even though in most cases it comes from Japan or Pacific waters. This is because Mediterranean *Corallium rubrum* is the most familiar and famous coral in terms of color and recognition—it is the coral that is used as the "gold standard" for all other corals in terms of color, name, and quality, both historically and today, in the fashion, ethnic and in tourist markets. The color of Mediterranean coral has been beloved and most prevalent for several centuries. In addition, place is related to the associations of coral beads, in several respects—coral comes from the sea and is a natural product related to familiar marine environments like that of Mediterranean sea or related to memories of a seaside vacation; coral comes from Italy and all things Italian are popular today, especially in the United States, and so therefore are imbued with a certain quality.

In this sense, Pacific *Corallium* corals as Italian coral beads can be seen to be simultaneously global and local, playing on the connotation of "Italian" with high style and exquisite craftsmanship in the production of luxury items, and the connotation of coral as Italian because the beads are produced in and exported from Italy. In this way, the notion "Made in Italy" or "Italian" also increases the market value of low quality or "waste coral" beads, such as *frange*, as popular tourist items purchased by Americans, for instance. Beads such as these, as I found out, are advertised as made of Italian or Mediterranean coral whether they are or not. Italian tourists purchase the coral beads not because they are Italian per se, but because they have specific meanings related to an Italian concept of seasonal jewelry in addition to the sentimental value they have when purchased on vacation at the seashore.

Coral and coral beads have high investment value in different circles, an important aspect of their value. This is found in Italy and Europe where there is an understanding and appreciation of coral as a luxury commodity. In certain circles, coral beads and jewelry are purchased solely for their market value, purchased for the number of grams of coral and weight of the gold, not for their fashionableness or style, or for the creative expression or handwork that they represent. The value of the coral and gold will only increase over time, so in this sense they are an investment, not strictly a piece of jewelry to be cherished and shown off every time it is worn. The raw coral is so expensive and scarce, and it is so expensive to continue production by hand in the face of mounting Asian competition. On one hand, it means commercializing the product even more, raising the retail sales price to reflect the real costs of production and design, and, as in the fashion industry, positioning a quality product by creating a name for it. When worn as status symbols, coral jewelry has the power to communicate a person's economic status and display prestige in many diverse cultural and social contexts.

If we look at all of the factors I have mentioned, coral beads come with a high value in terms of their preciousness as an organic material. As they move through time and space and through various cultural settings, coral beads are examples of complex networks and relationships, and illustrate varied players or actors. Coral, as a natural material, holds value through intrinsic physical or aesthetic qualities such as color, hardness, size, shape, and the amount of skill required to work it, as well as its relative or comparative rarity and scarcity as a natural material. This rarity is a source of value in and of itself, and this value is compounded by the degree of difficulty to obtain the material or objects made from it, and the distance they must travel as well as the sense of how exotic they are.

Wearing coral beads and jewelry of a certain value and design can indicate power and status in terms of wealth, but also in coral's form and workmanship, and the perception of taste. Material wealth is often measured in terms of prestige goods like coral beads destined for conspicuous display or display of ethnic identity and tradition. Certainly the availability of coral and coral beads is intertwined with price and value, with scarcity, rarity, and supply. We can see how the cost of coral beads relates to labor, production processes, and a specific Italian model of business and production. The value of this global product is determined not only by supply and demand, but by perceptions of rarity, and is shaped by manufacturers, merchants, and consumers. Economic value is added at each step in the process of production, and the greatest increase comes when the beads are mounted and prepared as a piece of jewelry or sold as a string of beads in a retail outlet or export sale for three primary markets. The value of coral is not necessarily dependent on supply and demand, and the meanings related to coral are not necessarily contingent on the superficial sources of its price. Much of the value of coral comes from its history and the meanings associated with it as an organic material from the Mediterranean.

4. A Snapshot of the Coral Industry in Taiwan[4]

Four *Corallium* corals from Pacific sources around Taiwan and Japan are the primary species used in the Taiwan industry: *japonicum, elatius, secundum, and konojoi*. Red *C. japonicum* (the newer classification of *Paracorallium japonicum* was not used in Taiwan) is called "Aka" or "Oxblood" and colors ranged from the deep dark red color to somewhat lighter reds. Pink *C. elatius* corals are called "Momo" and found in an extensive range of colors from orange-yellow to brick red, and peachy red to salmon pink. Momo was described as the type of coral used in greatest quantity for production. Another type of pink coral is used with a more subtle pink hue or a mixed dark-and-light coloration, called "Sensei" or "Deep Sea." Found near Midway Island, in deeper waters than *C. elatius*, it was unclear whether this coral is *C. secundum* or *C*. sp. nov (Midway deepsea coral)—I heard both classifications. A white coral with small red spots, *C. konojoi*, is called "Shiro" or "Konjoi." I did not observe this coral in any great supply in shops or production, and was told that harvests had been reduced more recently. The lightest pale pink color, described as *C. secundum*, is called "Angel Skin," "Miss," or "Misu," and this was said to have become very rare and more valuable than the lighter *C. elatius* or *C.konojoi* colors.

A type of *C. elatius* that is frequently harvested and used in production was called "eroded coral" or "Mushi." This coral is a type of older, dead coral in which the exoskeleton has become very porous and is full of sponge-like holes. The amount of erosion or damage to the coral depends on how long it has been lying dead on the sea floor. Much of the eroded coral was worked as jewelry or carvings even with the sponge-like texture, and was somewhat expensive; some beads and carved pieces were highly porous and some had minimal holes. There was also another type of non-living coral used particularly in carvings, called "volcano coral," in which the coral exoskeleton was completely encased in lava from underwater volcanic eruptions. Both of these types of coral require additional processing to remove the layers of lava or the more-damaged outer layers of erosion to get to the colored material inside.

The harvest of eroded and lava-covered "volcano" corals in Taiwanese waters today was reported as 80-90% of the Taiwanese total catch compared to the take of live corals. It was noted that available quantities of raw materials are limited, but industry respondents were confident that the fisheries were well-managed through the vessel tracking system used by the Taiwanese government. In fact, producers in Taipei and fishermen interviewed in the fishing port of Su-Ao discussed the Taiwanese practice of selective harvesting. The fishermen explained that they use their GPS and triangulate with different readings on GPS and sonar to identify appropriate mounds of eroded or volcano coral or live coral and then selectively dredge for their target without taking anything else. Producers primarily purchase raw corals from commercial middlemen or from fishermen they know and have worked with in the past. Based on landed reports at each port, the middlemen buy the raw corals at port and then sell it to the producers.

According to the Taiwanese producers, the three most important coral production sectors in the world are Taiwan, Italy, and Japan. Taiwan had no coral industry to speak of until it was introduced by Japan as part of their Asian-Pacific colonial expansion during WWII. Although the Taiwanese coral industry is approximately only 60-70 years old in comparison to the centuries-long history of the Italian coral sector, coral production is considered an important "traditional work" in Taiwan. As it was explained, Japan was looking for cheap labor and so taught the Taiwanese to fish and work coral for a Japanese market. Once introduced, Taiwan's coral industry developed quickly. In 1993(?), the Industrial Development Bureau noted that the peak of Taiwan's coral production was from 1966-1979, and that during this time period, Taiwan's total production accounted for 80% of world production. Historically, the centers of production and sale were the Pescadores Archipelago, the port of Su-Ao in NE Taiwan, and Kaohsiung in western Taiwan. Statistically, it was reported in 1993(?) that during the peak period there were over 10,000 participating in the industry, including over 1,000 factories of various sizes and over 500 stores selling coral products. Taiwanese producers noted that the sector today includes 2,000-3,000 companies/workshops/ factories and over 30,000 people who work with coral and depend on the coral sector in some way for their livelihood. This means the Taiwanese coral sector currently might be two-to-three times larger than at what is considered its peak.

The bulk of the production process is accomplished through a cottage industry or informal economy consisting of a very long production chain with numerous people working on products from raw material to commercial point. The larger Taiwanese companies work the entire chain of production from raw through finished product. Smaller, individual workshops may purchase raw coral and process it to some stage before they sell it to a jewelry producer or larger coral company, or they may contract with a larger coral producer for materials to process by the piece to some stage (bead blanks, finished beads, cabochons, or carved items). Most of the coral production and commercialization takes place within a model of small to medium (SMEs) family businesses, as in the Italian coral sector. Families working coral today go back three to four generations, and the three or four largest companies are all family-owned and -run.

There are two major divisions of production for finished coral products in the Taiwanese industry: 1) the production of smooth/polished coral beads, cabochons, and small carved/incised items for use in jewelry and religious items such as prayer beads or rosaries, and 2) the production of decorative coral carvings and sculpture as objects of art for Asian consumers, collectors, and museums. A sub-division of this latter category is that of mounted branches of polished "trees" of raw coral as an object of natural beauty. A third major division is the production of semi-finished coral products, such as rough-cut bead blanks, for sale to domestic and international coral producers. Workshops or factories in Italy, for example, purchase these unfinished blanks for processing in order to shorten the Italian value-added chain, cut Italian production and labor costs, and maximize profits.

The breakdown of coral production in Taiwan was estimated at approximately 60% people and 40% mechanization in a highly labor-intensive chain. Even the use of mechanization requires a great deal of hands-on experience and knowledge in order to work the coral. Some of the machinery used for coral production has been developed and/or adapted from that of the Japanese pearl industry—such as the machine that drills holes in the beads from both ends at once. The machinery used to cut the coral branches, make the bead blanks, and refine the bead shapes appears very similar to those used by the Italian coral sector; coral is processed under running water by hand using diamond and carborundum grinders and cutting wheels. In general, methods of processing include the major steps of production found in the Italian industry:

1) Washing to remove the raw coral's crust or outer skin and expose the colored exo-skeleton;
2) Cutting the main branches by hand to rough out bead shapes or branch shapes based on pre-determined uses for each piece of raw coral;
3) Shaping to further refine shapes for both smooth/jewelry or carving types of production (this is one step where Taiwanese production diverts from Italian—the majority of bead production is by machine rather than hand, and smaller bead shapes, such as tiny rice kernels, are sourced out to small workshops in Vietnam or China for final production of beads and stringing). From this point on, coral to be carved goes to a "dry" workbench for incision by hand with both electric and non-electric tools such as drills and chisels;
4) Sanding or tumbling on both types of production to refine the surface of the final product;
5) Polishing is the final step to create the lustrous surface, done by hand using a polishing compound and small polishing wheel or processing the pieces in hydrochloric acid.

While I observed a great range in quality and price of Taiwanese products (smooth and incised jewelry pieces, beads, cabochons, and small carvings) in both Hong Kong and Taipei, I saw a large proportion of high quality, high priced, exquisitely carved and finished pieces used for jewelry and as decorative objects of art in the larger retail shops and museums in Taipei. The vast quantity of carved and incised coral pieces (whether used in jewelry or as decorative art) produced in Taiwan is the major difference between the Italian and Asian production and markets. Carved roses (for a Euro-American market) and peonies (for an Asian market) are by far the most commonly carved pieces observed for sale. Buddhist religious figures and images from religious myths are a common theme in pieces carved for Asian markets, and numerous traditional "auspicious" designs relating to good fortune—birds, fishes, insects, gourds, and coins—and the Chinese zodiac were observed. Many rings, brooches, and necklaces were made of smooth, highly polished coral cabochons or beads combined with small diamonds and/or pearls in both yellow and white gold settings. Coral beads were also combined with black onyx and what was labeled as black coral, and numerous pieces in shops used contrasting colors of coral together in the same piece.

Taiwanese coral industry output consists primarily of exports of raw coral and decorative products. The majority of Taiwan's coral products are exported, but Taiwanese and Chinese domestic consumer markets are increasing. In general, the two main target markets for Taiwanese *Corallium* coral products are a higher-end, luxury market and an international tourist market for lower quality products. The largest markets for Taiwan coral are China, Japan, Korea, Italy, the United States, and Europe. Major domestic sales points for coral products are tourist areas, jewelry stores, museums, and local art/craft shops. Approximately 90% of Taiwanese coral is exported—10% of this is raw and 90% is processed or finished in some form. In contrast to both the Italian and Japanese coral industries, producers stated that the Taiwanese sector is much larger and while still labor-intensive, labor in Taiwan is much cheaper and therefore many products do not have to be expensive, high quality products.

Taiwan is also the largest exporter of raw *Corallium* materials and semi-processed, semi-finished products such as bead blanks to Italy and Japan. For approximately 20 years, Taiwan had been exporting a minimal amount of *Corallium* materials and products to China, especially for religious and cultural uses in Tibet. However, within the last five years, approximately 50% of the total exported *Corallium* materials and products are going to China, where a domestic jewelry market is currently booming in larger cities. China has also begun exporting large quantities of raw *Corallium* corals and processing them into beads at even lower labor costs for the global market, in direct competition with Taiwan. One of the results of this has been a higher valuation of coral in Taiwan (most likely resulting from reduced quantities of supply through harvest limitations and increased demand). In addition, the CITES Appendix-III listing has fostered the idea that China has now become a range state for *Corallium* corals, even though there is, technically, from the Taiwanese perspective, no harvesting of *Corallium* corals in Chinese waters and minimal production in China compared to Taiwan. China also harvests and produces a major percentage of the non-*Corallium* coral products on the market, such as bamboo and sponge coral beads.

While producers said that they do not see many changes in trade today, the Taiwanese coral sector is working very hard to maintain the tradition of coral work and further commercialize their products outside of their current market sectors. Producers are strategically working to raise market competiveness by emphasizing quality design and production, and encouraging creation and marketing of products that can be exported into a more global marketplace by following contemporary trends in design and style rather than relying on traditional Asian styles. The top three coral companies are also working to promote coral as a component of jewelry, to increase the value of coral as a gem combined with other gems and precious materials such as gold, platinum, and pearls. These companies and several smaller workshops regularly exhibit their work at the major jewelry and gem shows in Hong Kong, New York, Tucson, and Vicenza.

Family companies are working to promote coral pieces related to Asian culture, religion, and art, to add meaning and value to products for Asian export and Asian tourist markets in Taiwan. They are also creating new meanings and Taiwanese domestic markets, where there has not been a tradition of wearing or use of coral, just fishing and production for export; in the last four-to-five years domestic demands are increasing. Many Chinese come to Taiwan to purchase coral jewelry and many Asian Buddhists come to purchase coral chips for offering as prayers at the temple. Another push for local markets has been Taiwanese government programs to promote domestic products, crafts, and arts—coral jewelry is now featured next to the more traditional jade jewelry in the airports and Taiwanese tourist shops. Two of the largest companies are also working hard to educate the public about coral—what it is, where it comes from, differences between types of corals—through demonstrations, museum exhibits, knowledgeable sales staff, and small in-store displays.

5. Other Types of Red-to-Pink Coral in Fashion Production

The decrease in the harvesting of gem-quality *Corallium* corals in recent years has led to a proliferation of other species that can be made to resemble the *Corallium* corals, and to the enhancing or bleaching and dyeing of lower quality *Corallium* corals to create the desired product that resembles the gold standard. According to Prost (2001), it has been reported by dealers in the U.S. that a large portion of the new coral entering the market is color-enhanced. Estimates were as high as 90-95% on the market. Based on my own observations, I would agree with these estimates, and further note that the color-enhanced corals referred to above are both dyed bamboo and color-enhanced, resin- or polymer-impregnated sponge corals. I have not yet observed any color-enhanced *Corallium* corals in this market, but they have been reported (Smith et al. 2007).

Bamboo corals (*Keratoisis* and *Lepidisis* genera) are so named because of their growth structure—the branches resemble bamboo canes. This coral is a combination of calcium carbonate or calcareous material in the internodes with longitudinal parallel striations, and a proteinaceous or horny brown gorgonin material in the dark nodes with a concentric-radial structure. Bamboo corals occur in shades of white to pale yellow or grayish brown, and are very successfully dyed in various colors using aniline dyes to imitate the colors of *Corallium* species. If the gorgonin is removed, or the diameter and size of the branch is large enough, it is possible to make a bead or cabochon that hides the brown gorgonin. But its presence doesn't seem to detract from its use or deter its beauty to the consumer.

The "sponge coral," *Melithaea ocracea,* is incredibly popular right now for jewelry. This soft coral has a very abrasive and somewhat brittle skeleton, and the spongy appearance gives this coral its name. It is usually an orangey-red color, with interspersed reticulation, stripes, or internodes of a soft brown/beige or yellowish color—giving it a variegated appearance. It is sometimes dyed a darker red, or sometimes seen in a yellowish and red coloration that resembles an apple (it may be that this second type of sponge coral is another *M.* spp.). To be used for jewelry, it is impregnated with a resin or polymer to give it a smooth appearance and consolidate the structure so it can be polished and shaped.

6. *Corallium* Identification—Raw vs. Gem Corals

Historically, the term "precious coral" referred to *C. rubrum* as the primary famous and high value jewelry coral in production and trade. The term expanded to incorporate the Pacific *Corallium* corals as they were added to the market, such as *C. elatius*, *C. secundum*, *C. japonicum*, *C. konojoi,* and *C.* sp. nov. Today, the use of this term has been further expanded to incorporate any of the unrelated coral genera in trade for jewelry and fashion markets, such as the Isididae family of "bamboo" corals and the *Melithaea* genera of "sponge" corals. Indeed, the concept of precious corals as gems today also encompasses the *Antipatharian* black thorny corals, the Gorgonian black corals, the golden corals made from these black corals, the true gold corals such as the Hawaiian *Gerardia* species, and the blue *Heliopora* species. The term precious coral is commonly used in gemological industry references to categorize gem corals, for example, in the same way that "precious" and "semi-precious" are used to categorize diamonds, emeralds, and other stones or minerals used commercially for jewelry and embellishment of dress.[3]

In practice, there are different methods for identifying species of *Corallium* corals which depend on whether the coral specimens are still in a raw state or have been worked or processed into beads, cabochons, or carvings. Raw and whole dried specimens of *Corallium* are relatively easily identified to the genus and species levels by specialists using an electron microscope. Implementation of this method is based upon SEM examination and identification of the coenenchymal sclerites found in the crust of the raw coral or SEM examination of skeletal axis formation and axial pits or polyp base openings (see particularly the work of Bayer and Cairns). It should be noted that the three key features of these types of diagnostic examination are specialized knowledge, expensive instrumentation, and the presence of the coenenchymal tissue. Raw *Corallium* species are also identified based on colony size, morphological properties in the skeleton such as holdfast size and structure, branching characteristics (i.e., tree- or fan-like branching, branch number, length and weight, types of twig and terminal ends) and dimensionality or planar structure related to curvature and branching (i.e., branching in one plane or three-dimensionally), amount and types of bifurcation, cross-section characteristics (i.e., shape, diameter size, color change, canal formation and location, presence of radial, concentric or spicular structures), or skeletal color and locations of color variations.

Many of these morphological features can be observed and examined visually by eye, with coral in situ, and without additional instrumentation in the lab when full raw branches or branching structures are available. However, once the coenenchymal tissue or crust has been removed and the branches have begun to be cut and polished in the production process, identification by morphological features changes. This process might be referred to as the gemological identification of the coral, which includes examination of such features as optical properties (luster, translucency or opacity, density, and color), hardness (based on Mohs' scale), specific gravity, refractive index, skeletal mineral phases (calcite or aragonite) and organic/inorganic content (gorgonin, keratin, etc.), luminescence, solubility, characteristic inclusions, or surface and cross-section features (i.e., parallel longitudinal striations on the surface, pitting, central canal, color changes, etc.; see Table 5 for a listing of some of these properties for *Corallium* corals).

Most of the gemological references describe two specific "fingerprint" characteristics for *Corallium* corals that can be readily identified in hand:

1. A solid texture with few, extremely small cavities or pitting visible on the external polished surface;
2. Parallel longitudinal striations on the surface of the branches of the coral, and scalloped structures in cross-section.

These two "fingerprint" characteristics are readily apparent under microscopic examination. They are natural features of the coral as organic substances and are a result of the growth patterns of *Corallium* corals. Although bamboo corals also exhibit the longitudinal striations and a solid texture similar to *Corallium* corals, the presence of the black gorgonin substance of the nodes precludes its identification as a possible *Corallium* coral. Sponge coral's porous structure and the distinctive two-color reticulated pattern also precludes being mistaken for a *Corallium*.

Key tests for the identification of *Corallium* corals, according to the Gemological Institute of America's *Gem Identification Lab Manual* (2005), include refractive index (1.486-1.658), birefringence (0.172—accompanied by a birefringence blink), and magnification to confirm the presence of the key structures noted above. Further, Smith et al. (2007) found that Raman analysis can conclusively determine the natural origin of the red-to-pink colors of *Corallium* corals because carotene, their natural coloring agent, has a signature Raman spectrum. Other experimental research is being conducted on precious or gem corals to further identify corals to genera and species once they have been worked, through microscopic gemological properties—skeletal composition (i.e., chemical, crystallographic, and mineralization processes), molecular structure, as well as coloration (Kaczorowska et al. 2003; Rolandi et al. 2005; Bocchio et al. 2006; Smith et al. 2007). Using both destructive and non-destructive methods of experimentation, they are investigating corals through various methods of elemental analysis, spectroscopy (FTIR, Raman, infrared, nuclear magnetic resonance, X-ray photoelectron), and other sophisticated scientific analytical methods. These studies have made serious progress in characterizing and classifying precious corals and in finding non-destructive or non-invasive methods to distinguish not only species but natural from artificial gems without destroying the sample.

For example, Kaczorowska et al (2003) conclude not only that analysis of the micro-reflected spectra obtained through FTIR and Raman spectometry "may be an important step in creating databases containing detailed information about particular coral species," but that they are a "method of choice for investigating valuable objects containing corals as a rapid and non-destructive technique useful in practical applications (jewelry, archeology, and collection)." Rolandi et al. (2005) state that because specific gravity is so dependent on a coral's porosity it is not a good identification tool. Instead, they recommend use of refractive indices (as determined by the distant vision method) and both FTIR and Raman spectrometry as useful indicators of species: "With the use of both methods the characterization of genera and species of Cnidaria that have gem potential has been shown to be possible." Bocchio et al. (2006) have shown that Cnidaria species have either calcitic or aragonitic skeletons, thereby extending the data of Rolandi et al and providing clear distinctions between Octocorallia (mostly calcitic) and Hexacorallia (mostly aragonitic) corals. As mentioned above, Smith et al. (2007) investigated methods to determine the origin of coral colors in pink-to-red corals to identify whether a piece is colored naturally or was color-treated or dyed. In exploring both destructive and non-destructive procedures, their conclusions agree with previous studies that specific non-invasive or non-destructive methods can be used to categorize not only color origin but closely identify precious corals: "A careful R.I. reading, S.G. determination, and infrared (IR) spectroscopy—combined with observation of specific growth-structures—may provide clues to the particular species of the coral." I would conclude this quick and superficial look at these studies by suggesting that a next step might be creation of a matrix or table that pulls together the data from these studies on genera and species of all of the precious corals.

In addition to all of these very expensive and sophisticated methods of analysis, there are simple and inexpensive techniques which can be utilized in the field or lab to determine general identification characteristics in order to distinguish *Corallium* or calcareous corals from imitations made of glass or plastic, for example, or to determine the presence of a dye or use of a resin coating with various precious corals. I have experimented with many of these methods and recommend their effectiveness and usefulness in many settings when field substantiation or corroboration of suspicions are required. For example, as a calcite, the coral will react on contact with a drop of hydrochloric acid and display a strong effervescence; muriatic acid is readily available for this use (O'Donoghue 2006; Torntore personal experimentation). Calcareous shell used to imitate coral will also effervesce with hydrochloric acid, but the structure of a shell in cross-section or on the surface is different than coral. Vinegar, as an acid, will also cause calcitic corals to effervesce; the use of acids is destructive to coral and will damage the coral's surface.

Swabbing the surface of a coral bead or cabochon with acetone (or nail polish remover) or, sometimes, vinegar, can detect the use of an aniline dye to color coral, or a swab or short soak with water will detect use of a water-soluble dye used to enhance color. Chipping or splitting a bead to examine its interior will also frequently show the lack of dye penetration, but traces of dye or more deeply colored areas may also be visible under magnification, using a hand lens, in small cavities, defects, or pre-existing surface cracks to allow detecting artificial coloration without damaging the piece. Another area that can be readily examined without damage to detect color or dye penetration variations is the cross-section of beads around their stringing hole. In the laboratory, IR and Raman spectroscopy methods can be used to identify dye molecules used for color enhancement (Smith et al. 2007).

Plastics can be detected by gently prodding the surface of the bead or cabochon with the heated tip of a small sewing needle or dissecting pin to melt it. Plastics also give off an acrid odor when heated, and conchiolin corals give off a characteristic protein or burning hair odor when heated. Some resin coatings can also be detected with this method. Acrylic resin coatings or acrylic polymer consolidation materials (such as those used for sponge coral) can also be swabbed with a small amount of rubbing alcohol which will mar or melt the surface of the resin. Acetone or a product like Jasco® epoxy remover can also be used as a swab or soak to detect the use of resin coatings or impregnated consolidation polymers.

Table 1. General Categories of Coral Production.

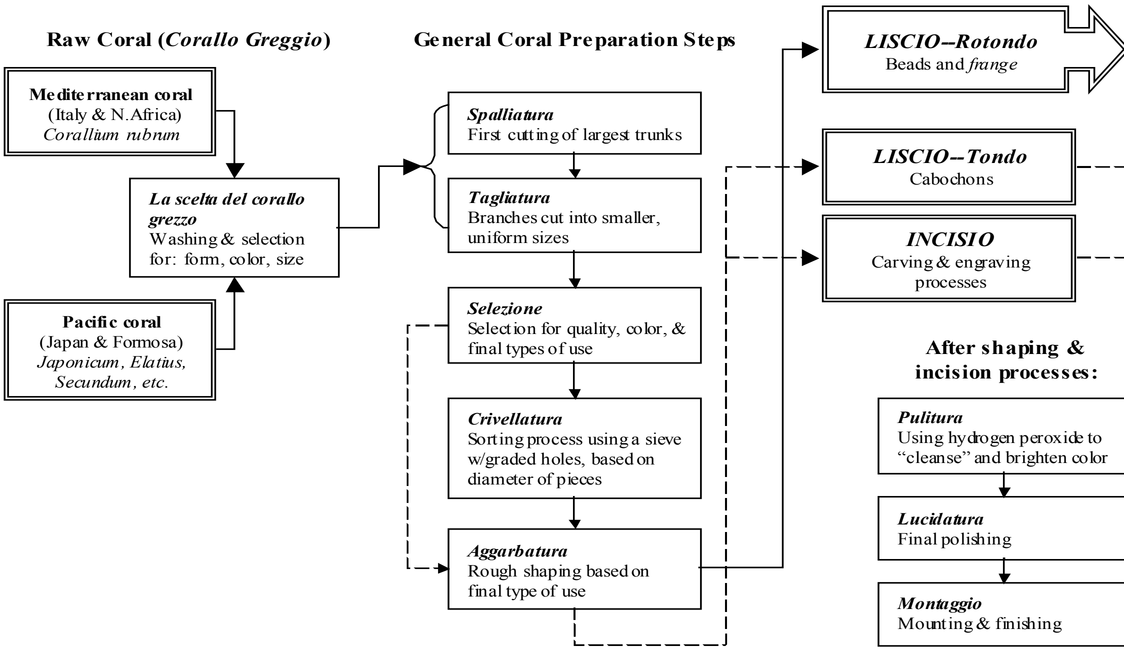
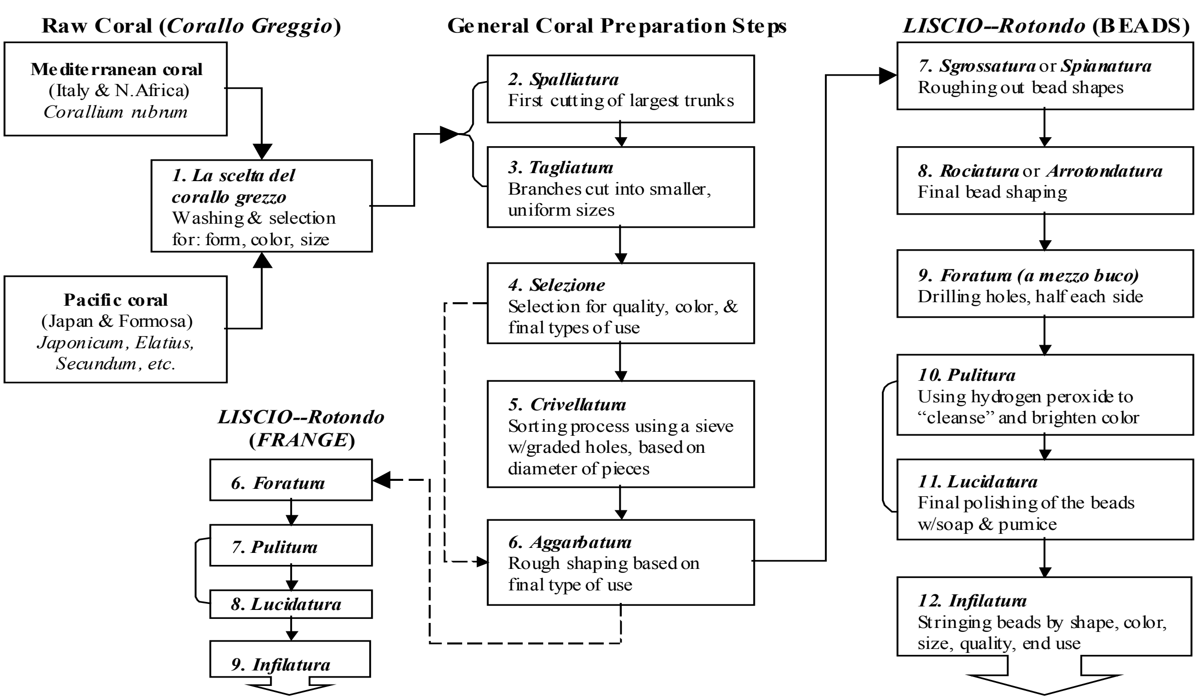


Table 2. Coral Bead Production Process.



The two flow charts in Tables 1 and 2 on bead production are based on Stampacchia and De Chiara (2000), in Torntore (2002).

Table 3. Time required to complete each production phase in making coral beads.

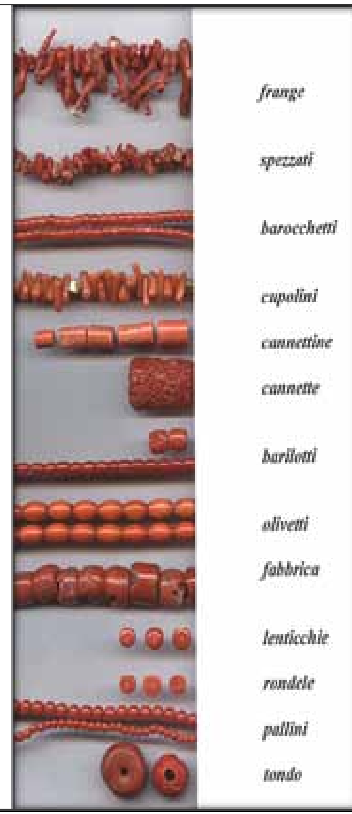
Production phase	Technology	Time to work 1 kg of raw coral**	Accumulated time in hours to make pallini (8 mm) from 1 kg raw coral	
		Min-max	Industriale	Artigianale
CUTTNG SPALLIATURA TAGLIATURA	Circular saw with diamond blade	1.5-2 hours	2	2
SORTING (by diameter) CRIVELLATURA	Crivellatrice	1.5 hours	3.5	3.5
ROUGH SHAPING AGGARBATURA	Carborundum grindstone	4 hours	7.5	7.5
ROUGHBEAD SHAPE SGROSSATURA SPINATURA	SGROSSATRICE	.5 hour	8	23.5
	Manually	1-3 days		
FINALBEAD SHAPE ROCIATURA (Arotondatura)	ROCIATRICE	1.5 hour	9.5	39.5
	Carborundum grindstone	1-3 days		
DRILLING HOLES Foratura	Macchine foratrici	1-2 days	21.5	51.5
POLISHING Lucidatura	BURATTO	1-2 days	(+16=37.5)*	67.5
	Manually	depends		
MOUNTING With gold Montaggio con l'oro	Manually	5 days	61.5 (+40=77.5)*	107.5
FINAL POLISHING PULITURA SGRASSATURA	Spazzole elettriche ed abrasivi (electric brush and abrasives)	1 day	69.5 (+8=85.5)*	115.5
TOTAL		85.5 - 115.5 hours	69.5 (+ 64)* (85.5)* hours	115.5 hours

*Numbers in parentheses equal the number of *industriale*/hours with *lucidatura* step added in.
**Calculations based on processing 1 kilogram of raw coral to make a product of middle to low quality, in the form of *pallini* of 8 mm diameter. Different levels of technology are given—by hand or by machine. The term *industriale* refers to process using machines in production phases; *artigianale* refers to tasks accomplished manually, by hand.

From Stampacchia and De Chiara (2000, pp. 242-243), in Torntore (2002).

Table 4. This chart and list identifies the major characteristics of the most common *Corallium* coral beads as produced in Torre del Greco.

frange	twig or branch tips, hole at one end (5-50 mm long)
spezzati	small chips or fragments of coral with holes
barocchetti	small, short, irregular barrel-shaped pieces of coral, holes lengthwise
cupolini	small thick rounded twigs, holes in middle of lengthwise direction
cannettine	straight cylindrical shape, holes lengthwise, smaller diameter & length
cannette	larger rounded cylindrical shape
barilotti	straight, barrel-shaped, holes lengthwise, variable diameter & length
olivetti	olive-shaped, various sizes, holes lengthwise, always described as “old-fashioned”
Fabbrica	“factory coral,” any shape, rough-polished with imperfections & holes
lenticchie	small, flat, rounded disk-shape like lentils, holes in center
rondele	small, short, flat shape, center hole
pallini	smallest round beads (2-10 mm)
tondo	larger spherical/round beads



From Torntore (2002)

[4] This section is based on preliminary research conducted in Taiwan over five days in March 2009, after attending the First International Workshop on *Corallium* Science, Management, and Trade, in Hong Kong. It was conducted under sponsorship of WWF-Canada and was related to preparation of the “Precious Coral Identification Guide.” I gathered data through several channels: conducting formal and informal interviews, shopping and observation at the Taipei Jade Market, attending a special meeting of the Taiwan Jewelry Industry Association, traveling to the coral fishery port of Su-Ao in northeastern Taiwan, visiting three coral museums (two in Taipei and one in Su-Ao), and visiting several large coral jewelry shops and workshops in Taipei.

Table 5. Characteristics of *Corallium* coral species used in fashion markets

Species	Trade name	Location and habitat	Color	Morphological characteristics--Raw	Morphological characteristics--Worked
Corallium rubrum	Sardegna (Italy)	Mediterranean Sea: western coasts of Italy; Sicily; Sardinia; North Africa (Morocco, Algeria and Tunisia); southern coast of France (historically); eastern coast of Spain (historically); found at depth of 30 to 200 m (better qualities at depths lower than 50 m).	Generally uniformly red, with various shades of red, from very dark red to pale pink and white (pink and white are rare); mostly uniform, consistent color throughout	Three-dimensional or tree-like branching structure with average branch of 20-25 cm long x 10-15 cm wide x 1-15 mm diameter; weight of each branch between 100-150 gr.	Clusters of pinholes in cross-section are remnants of central canal. Longitudinal striations on surface give ribbed or striated pattern. Extends parallel to branch structure. Pits, pock marks, stones, etc. designate lower quality. Sinuous canals in direction of axis
Corallium rubrum	Sciacca (Italy)	Mediterranean Sea off the southwestern coast of Sicily (near town of Sciacca); considered a “dead” coral; found in three layers of banks at depths of 150-200 m; fished from 1875-1887	Salmon or orange pink, from intense to pale shades, occasionally yellowish marks	Tree-like branching with longer branches than Sardegna; similar sizes and weights to Sardegna	
Corallium japonicum	“Moro” (Italy) “Aka” (Taiwan) “Aka sango” (Japan), oxblood red blood	Pacific waters around islands of Japan, Viet Nam, Okinawa, and Taiwan; found at depths of 80-300 m	From white to intense red. Dark to very dark orangey red, with interior longitudinal core of white. White and lighter colors may have red spots where branches intersect.	Fan-shaped branching structure with average branch of 25 cm long x 12 mm diameter; average weight of each branch 200 gr.	Vitreous structure or surface. Difficult to work; numerous imperfections and waste material
Corallium elatius	Cerasuolo or Satsuma (Italy); “Momo” (Japan, Taiwan)	Pacific waters around islands of Japan, Taiwan, Philippines, Okinawa; found at depths of 150-300 m	Bright red, salmon, orange colors, with interior longitudinal core of white; “anima” in color; inconsistent color; waves and subtle changes in lengthwise and around branch structure; white spots at branch intersections. Pale pink to deep red.	Fan-shaped branching structure with average branch of 35 cm long x 25 mm diameter; average weight of each branch 500 gr. Extremely large diameter branches.	Dense, compact structure. Striations parallel to branch structure (hard to see). Best to incise, shape, polish; hard to see striations if highly polished; sinuous light and dark pink layers, often located around a central white area.

Table 5. Characteristics of *Corallium* coral species used in fashion markets (Continued)

Corallium elatius [NOTE: There is confusion in the literature as to whether "angel skin" is *C. elatius* or *C. secundum*]	"Boké" (Japan); "Angel skin" (English); Pelle d'angelo (Italy)	Hawaii, Taiwan	Pink and pale colors, with interior longitudinal core of white; "anima" in color; inconsistent color; waves and subtle changes in lengthwise and around branch structure; white spots at branch; Pale pink colors of various intensities; white to pale, soft rosy pink; intense, deep pink	Fan-shaped branching structure with average branch of 12 cm long x 12 mm diameter; average weight of each branch 200 gr.	Very dense structure. Striations parallel to branch in cross-section. In *C.* species, striations can appear as faint concentric or radial lines; sinuous light and dark pink layers, often located around a central white area.
Corallium konojoi	Bianco (Italy); "Shiro" (Japan)	Pacific waters around islands of Japan, Chinese island of Hainan, Okinawa; found at depths of 80-200 m	White; white with red or pink spots	Fan-shaped branching structure with average branch of 12 cm long x 12 mm diameter; average weight of each branch 200 gr.	
Corallium secundum [NOTE: There is confusion in the literature as to whether "angel skin" is *C. elatius* or *C. secundum*]	Pelle d'angelo (Italy); "Boké" (Japan); "Angel skin" (English) ; "Miss" (Taiwan)	Hawaii, SE Japan, Taiwan	Pale pink colors of various intensities; White to pale, soft rosy pink; small orange spots	Fan-shaped branching structure with average branch of 12 cm long x 12 mm diameter; average weight of each branch 200 gr.	Very dense structure. Striations parallel to branch in cross-section. In *C.* species, striations can appear as faint concentric or radial lines; sinuous structure with small orange spots
Corallium secundum (?)	Rosato or Midway	Pacific waters around Midway Island; found at depths of 400-600 m; discovered in 1965	White; spotted or veined pink; light pink	Fan-shaped branching structure with average branch of 25 cm long x 15 mm diameter; average weight of each branch 200 gr.	
Not classified (?)	Garnet	Pacific waters around Hawaiian and Midway islands; found at depths of 700-900 m; discovered in 1970	Deep or intense pink and violet pink colors with garnet red veining	Fan-shaped branching structure with average branch of 25 cm long x 15 mm diameter; average weight of each branch 200 gr.	
Corallium sp. nov (?) Not classified (?)	"Deep sea" "Sensei" (Taiwan) "New Coral"	Pacific waters around Hawaiian and Midway islands; found at depths 800-1500 m; discovered in 1979	Bright pink with strong red markings (never solid color)	Fan-shaped or series of primary and secondary parallel branches with average branch of 30 cm long x 10 mm diameter; average weight of each branch 150 gr.	Very dense structure. Striations parallel to branch in cross-section. In *C.* species, striations can appear as faint concentric or radial lines

Compiled from: Ascione (1998); Balletta and Ascione (1992); Cicogna and Cattaneo-Vietti (1993); Iacobelli Coralli (http://www.iacobellicoralli.com/iacora12b.htm); Liverino (1998); Pedersen (2004); (Rolandi et al (2005); Torntore (2002); Torntore (personal comm., 3/09, Taiwan)

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ENDNOTES

1 See Torntore (1999) for a history of *C. rubrum's* use as amulet and full references.

2 See Torntore (1999, 2002, 2004) for full references.

3 Bienfang and Trapido-Rosenthal (2007) are the only source in either marine science or gemological references I found that separates commercial jewelry corals into "precious" and "semi-precious" categories. According to their taxonomy, precious corals include commercial *Corallium* species, several gold corals in the family Primnoidae and the *Gerardia* sp., bamboo corals in family Isisiidae (*Acanella* spp.) and Lepidisisidae (*Lepidisis olapa*), and the black Antipatarian corals. The corals listed in their semi-precious category are also used primarily for jewelry but not as highly valued because of their abundance and high porosity compared to the "precious" corals. These include stylasterine corals and *Allopora*, blue *Heliopora* corals, the organ pipe corals (*Tubipora*), and several *Melitodiidae* corals.

The Fishery and Trade of *Corallium* of East Asia

Joyce Wu, Soyo Takahashi

TRAFFIC East Asia

1. Introduction

Corallium species are the most valuable precious corals, distributed at deep water rocky bottom habitats, typically aggregating on banks and seamounts, under ledges, and in and around caves in the Mediterranean Sea, Atlantic Ocean, Indian Ocean, Western Pacific Ocean and Eastern Pacific Ocean (CITES COP 14, Proposal 21). *Corallium* has been traded for more than 5000 years (CITES COP 14, Proposal 21). From the time of Ancient Rome, *Corallium* was mainly exported from Italy to India (Torntore 2002). In the late 1800s, Italy started to import Western Pacific *Corallium* from Japan, and then re-exported to Asia and Africa (Torntore 2002). After the 1870s, the center for *Corallium* harvesting and processing had expanded to Asia, such as Japan and Taiwan (Lai 2006).

According to the FAO's fishstat data, Taiwan and Japan are the only two areas with *Corallium* production since 1964 and 1983, respectively. Four Pacific *Corallium* species have been listed as CITES Appendix-III species by China, since July 2008. To date, no attempt has been made to draw the dynamics of *Corallium* trade in the world or in East Asia. The CITES species trade data for 2008 is not yet available at WCMC (World Conservation Monitoring Center), the CITES trade data maintenance center. And no harmonized system code has been designed for *Corallium* species. Thus, the dynamics of *Corallium* trade is be difficult to draw.

This article reviews the harvesting and trade status of *Corallium* in the key *Corallium* trade centres of East Asia, based on the public accessible data such as Customs records and FAO data. The importance of having more complete trade dynamics for better *Corallium* resource management is also assessed.

2. *Corallium* trade with East Asia

Currently, there is no specific Harmonized System Code (HS Code) for any commodity of *Corallium* species or precious coral. The most relevant commodity code under the Harmonized System is 0508.00 for unworked, powder or waste of coral, shell of mollusks, crustaceans or echinoderms and cuttlebone, and 9601.90 for worked and articles of other animal materials (the latter code is rather general when compared with the 9601.10, which is assigned specifically to worked and articles of ivory) (Table 1).

Table 1. Harmonized System Code for coral related commodities

Harmonized System Code for coral related commodities	
0508.00	Coral and similar materials, unworked or simply prepared but not otherwise worked; shells of molluscs, crustaceans or echinoderms and cuttlebone, unworked or simply prepared but not cut to shape; powder and waste thereof
9601.90	Worked Other Animal Carving Material, and Articles of These Materials
HK HS code for coral related commodities	
0508.00.90	Coral and Similar materials, unworked or simply prepared but not otherwise worked, shells of molluscs, crustaceans or echinoderms and cuttle-bone, unworked or simply prepared but not cut to shape, other than powder and waste
9601.90.00	Worked Bone, Tortoise-Shell., Horn, Antlers, Coral, Mother-of-Pearl and Other animal carving material, and articles of These Materials, NESOI
CN HS code for coral related commodities	
0508.00.10	Powder & Waste of Coral, Shells of Molluscs, Crustaceans, etc.
0508.00.90	Coral; Shells of Molluscs, Crustacenans, etc.
9601.90.00	Animal Carving Material (excl. Ivory)
JP HS code for coral related commodities	
import	
0508.00.100	Coral and similar materials, unworked or simply prepared but not otherwise worked, powder and waste thereof
9601.90.100	**Worked Bekko and coral, and articles of Bekko or coral**
export	
0508.00.200	Coral and similar materials, unworked or simply prepared but not otherwise worked, powder and waste thereof
9601.90. 000	Worked bone, tortoise-shell, horn, antlers, coral, mother-of-pearl and other animal carving material, and articles of these materials (including articles obtained by moulding)
TW HS code for coral related commodities	
0508.00.11.004	Coral and similar material
0508.00.12.003	Powder and waste of coral and similar material (incl. for Chinese drugs)
9601.90.41.007	Worked coral materials
9601.90.42.006	Articles of coral

Generally, customs judiciaries in East Asia, such as Hong Kong, mainland China, Japan and Taiwan have followed the HS coding system with at least two customs commodity codes including coral materials and products. Hong Kong has two 8-digit commodity codes that are most similar to the global HS codes, but specify the code of 9601.90.00 to animal materials of bone, tortoise-shell, horn, antler, coral, mother-of-pearl and others (Table 1). Customs judiciary in mainland China has three 8-digit commodity codes, include two codes starting with 0508; both cover coral and other categories of animal materials, but separate the powder and waste from other types of raw material. The other code is 9601.90.00, and covers the same category of materials, animal carving materials, exclude ivory, as the code for Hong Kong and global.

Customs judiciaries of Japan have four 9-digit commodity codes (Table 1); the codes of 0508.00.100 and 0508.00.200 represent import and export, respectively, for the commodities of unworked, powder and waste of coral and similar materials. The code of 9601.90.000 is used for export of worked products of bone, tortise-shell, horn, antler, coral, mother-of-pearl and others. However, for import, the code of 9601.90.100 is more specific where it is limited to coral and bekko products only.

Customs judiciary in Taiwan uses four commodity codes for coral and related materials. Two codes start with 0508, and are for raw and powder coral, and two codes start with 9601, and are for worked and finished coral products.

However, no single customs commodity code mentioned above is specific to *Corallium* species. Thus, direct comparison for *Corallium* trade among Hong Kong, mainland China, Japan and Taiwan is not possible.

At the current stage, the only customs data that might be able to provide some insight of *Corallium* trade is the Japan customs commodity code 9601.90.100 which is "worked and products of Bekko or Coral" (Table 1). Bekko refers to all marine turtle shell products in Japan. Since all marine turtles (*Caretta caretta, Chelonia mydas, Dermochelys coriacea, Eretmochelys imbricate, Lepidochelys* spp. and *Natator* spp.) are CITES Appendix-I species, and all trade would be recorded with UNEP, the data under this code would only include a very limited amount of Bekko products. The UNEP data shows that Japan imported a small amount of carvings, bones, carapaces, leather products, derivatives and live specimens of *Caretta caretta, Chelonia mydas* and *Eretmochelys imbricate* from France, Portugal, Canada, Italy, Austria, mainland China and others, between 2002 and 2007; but no imports from Taiwan. Thus, Japan's import record under the customs code of 9601.90.100, with Taiwan, would not include Bekko (marine turtle) products. Since Japan customs include worked and products of Bekko and Coral under one commodity code, it's reasonable to assume that the coral commodities could be included in this code, as products with similar usages as Bekko. Those coral commodities under the customs code of 9601.90.100 would be precious coral, used as jewelry and ornaments.

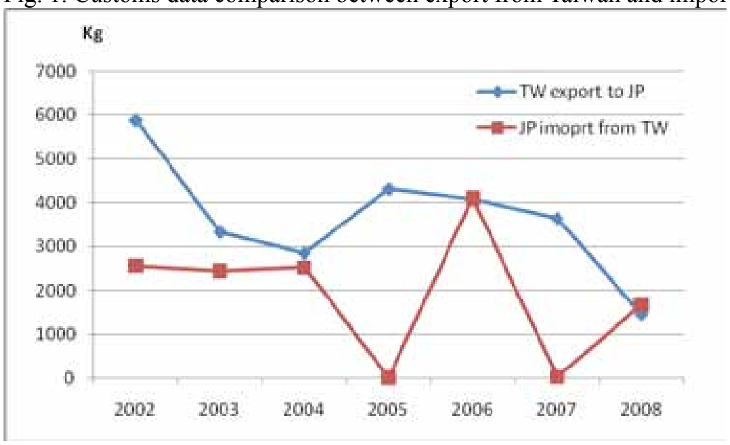
Table 2. Japan customs import data of 9601.90.100, worked and products of Bekko or Coral (Kg).

	2002	2003	2004	2005	2006	2007	2008	%
Australia				0				0%
Cameroon				8				0%
China mainland	**17**	**304**	**101**	**4,606**	**138**	**5,802**	**275**	**44%**
France					1			0%
Germany	0				0	0		0%
Hong Kong	34	17	47	0	98		25	1%
India				0		0		0%
Italy	12	17	2	2	2	2	2	0%
Korea Republic	0		21	56		688		3%
Thailand			0					0%
Taiwan	**2,559**	**2,450**	**2,523**	**9**	**4,105**	**20**	**1,665**	**52%**
USA				26		1	10	0%
Viet Nam		0	0					0%
Total	**2,622**	**2,788**	**2,694**	**4,707**	**4,344**	**6,513**	**1,977**	100%

Source: Japan Customs statistics

According to Japan Customs' data, Japan imported precious coral from 1977 to 6513 kg from between 2002 and 2008, mainly sourced from Taiwan and mainland China (Table 2). If one compares Japan's import data of worked coral products with Taiwan's export data of worked and article coral (Fig. 1), the data of 2004 and 2006 matches well, but the data of 2002, 2005 and 2007 shows a big gap. Although this difference may not link to illegal trade, it shows insufficiencies with data management and indicates a challenge for good trade monitoring and regulation.

Fig. 1. Customs data comparison between export from Taiwan and import to Japan.



Source: Japan and Taiwan customs data.
Note: Volume of TW export to JP was added up from two customs commodity codes 9601.90*.41.007 worked coral materials and 9601.90.42.006 articles of coral.*

Table 3. Taiwan coral export – worked coral and articles of coral (Kg).

	2002	2003	2004	2005	2006	2007	2008	%
Cuba	276	196	85	266	0	0	0	1%
Germany	109	227	192	155	74	116	85	1%
Spain	494	377	370	246	179	212	15	2%
Hong Kong	2,286	503	913	557	3,097	1,173	622	**8%**
Italy	3,640	8,326	3,995	2,348	3,599	3,428	1,199	**24%**
Japan	**5,886**	**3,329**	**2,848**	**4,313**	**4,084**	**3,642**	**1,443**	**23%**
USA	2,599	5,361	4,147	3,560	3,261	2,194	1,804	**21%**
Viet Nam	4,410	3,896	2,272	3,209	317	2,221	3,575	**18%**
others	807	430	459	472	1397	240	167	4%
TOTAL	**20,507**	**22,645**	**15,281**	**15,126**	**16,008**	**13,226**	**8,910**	

Source: Taiwan customs (data include customs commodity code of 9601.90.41.007 for worked coral and 9601.90.42.006 for articles of coral.

According to Taiwan customs export data (Table 3), Italy, Japan, the USA, Viet Nam and Hong Kong are the main destinations for worked and article coral. For imports (Table 4), Taiwan imported worked and article coral from Viet Nam, Hong Kong, Japan, Myanmar and mainland China.

Table 4. Taiwan coral import – worked coral and articles of coral (Kg).

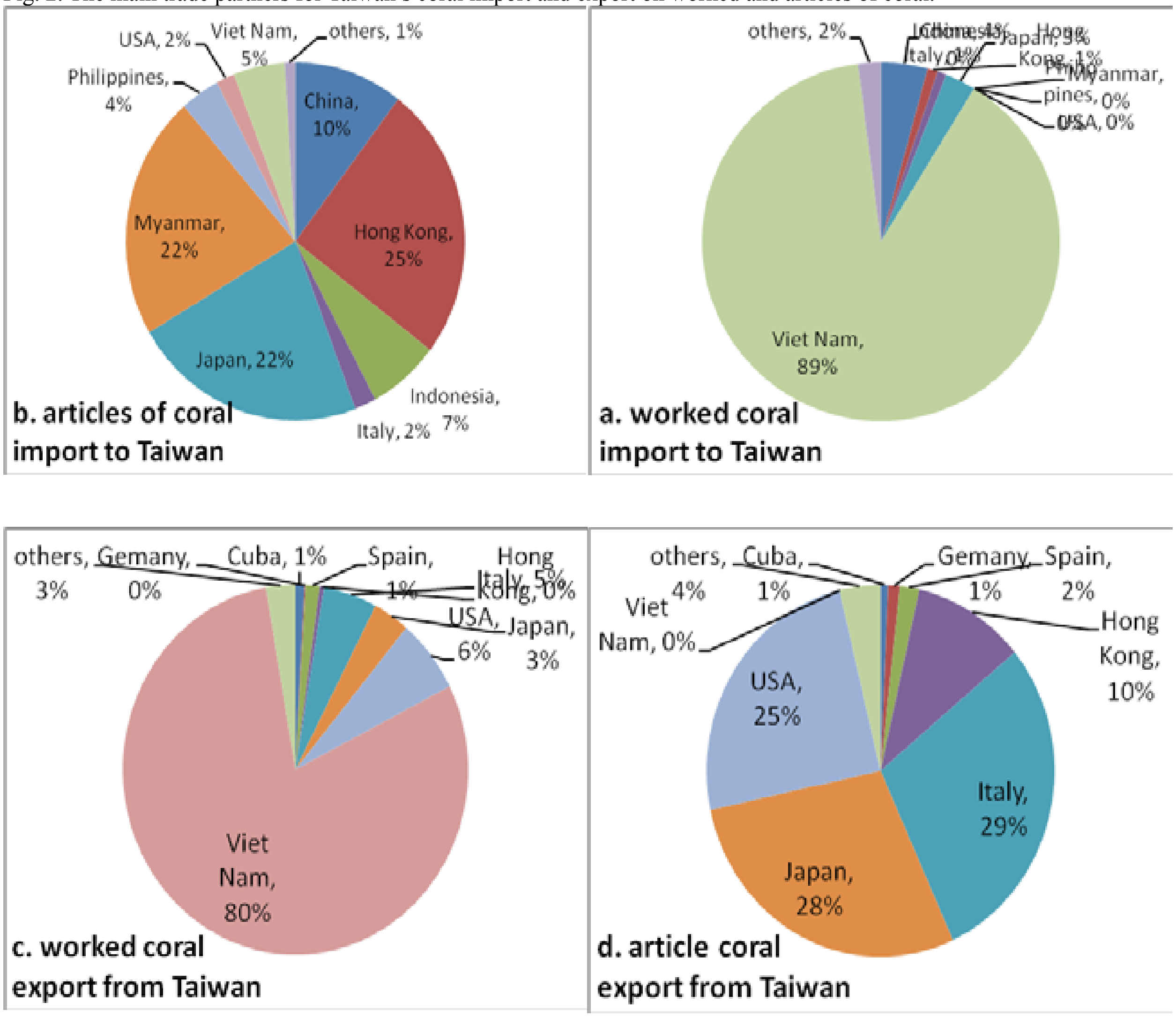
	2002	2003	2004	2005	2006	2007	2008	%
Mainland China	**158**	**996**	**1,067**	**1,296**	**268**	**931**	**342**	**12%**
Hong Kong	**3,320**	**2,191**	**950**	**968**	**2,600**	**846**	**1**	**22%**
Indonesia	0	0	0	0	0	0	**2,932**	4%
Italy	149	161	207	220	69	165	32	2%
Japan	**78**	**8,682**	**158**	**288**	**319**	**90**	**363**	**15%**
Myanmar	0	0	0	0	**9,490**	0	0	**14%**
Philippines	0	0	37	0	0	0	**1,580**	2%
USA	23	21	0	14	128	293	281	1%
Viet Nam	**1,244**	**2,366**	**2,102**	**2,394**	**3,575**	**1,528**	**1,300**	**25%**
OTHER	0	141	61	122	0	1	50	1%
TOTAL	**4,973**	**14,662**	**4,588**	**5,412**	**16,451**	**3,901**	**6,956**	**100%**

Source: Taiwan customs (data include customs commodity code of 9601.90.41.007 for worked coral and 9601.90.42.006 for articles of coral.

Italy, Japan and the U.S. are the traditional markets for *Corallium* and/or precious coral products, but not Viet Nam. Further breaking down the data for the import and export of worked and articles of coral (Fig. 1 a, b, c and d) shows that Viet Nam is an important partner for Taiwan's worked coral trade, but not for articles of coral. Some information from researchers and traders has suggested that Viet Nam would play a role for the Taiwan coral processing industry. Although this is a reasonable explanation, further study on the trade volume and products needs to be done to confirm this.

According to traders, Hong Kong hosts the largest jewelry exhibitions in Asia annually. Many coral jewelry trades from Taiwan also join the exhibitions and trade coral in Hong Kong annually. This indicates Hong Kong's unique role as an exhibition and trade centre of coral jewelry, given that Hong Kong is not a harvest and processing location for precious coral, including *Corallium.*

Fig. 2. The main trade partners for Taiwan's coral import and export on worked and articles of coral.



Source: Taiwan customs data (2001-2008)

3. *Corallium* harvest regulation in East Asia

Corallium species are listed in Category I under China's rare species protection law since 1988, with strict regulation. Since July 5, 2008, China further issued a proclamation for the enhancement of *Corallium* regulation. This regulation prohibits the harvest, export and re-export of *Corallium.* Trade of *Corallium* is allowed in China under authorized licenses, and the import of *Corallium* to China has to be processed with prior approval.

Corallium harvest regulation in Taiwan was renewed in January 2009. Vessels harvesting *Corallium* are regulated by license. Harvest zone and maximum harvest days per year are also restricted under the regulation. VMS (Vessel Monitoring System) emission, daily logbooks, designated landing ports, centralized auction markets and observer programmes are used to monitor the fishery and to enforce the regulation. Fifty-six vessels are licensed to harvest *Corallium* legally under the new regulation. Harvest and export quantities are limited to 200 and 120 kilograms, respectively, per vessel per year. Confiscation of fishing gear and the suspension of *Corallium* harvest license would be imposed for violation of the *Corallium* regulation in Taiwan.

Corallium harvest is also regulated in Japan, by the prefectural governors (Kochi, Okinawa, Kagoshima, Nagasaki), according to the fishery rule for adjustment under the Fishery Law and Conservation Policy for Marine Resource. In Japan, both fishermen and vessels are regulated by license for legal harvest. Legal harvest zone for *Corallium* fishery are designated. The rule does not limit the *Corallium* harvest season or quota in Japan. A new penalty for violation of Fishery Law has been effective since April 1, 2008. Any violator will be punished with the maximum penalties of 2 million JPY or three years imprisonment, or both.

4. Conclusion

East Asia is significant in *Corallium* trade, with Taiwan and Japan as historical players, and Hong Kong and mainland China rising in importance in the *Corallium* trade. However, the available data is not able to show the quantity and status of trade. East Asia is also an important *Corallium* source area, with different levels of harvest regulation in mainland China, Taiwan and Japan. However, the enforcement result is not available and the impact on harvest and trade were not evaluated in this report.

5. Recommendations

- Encourage all states and markets involved with the harvest, processing and trade of *Coralllium* species to develop **species and products specific harmonized system codes** for monitoring the trade on the raw, rough worked, semi-finished and finished *Corallium* commodities. The better the trade monitoring, the better resource management could be made sustainable. This would be very important for conservation of *Corallium* species, as well as the fishermen, workers and traders who depends on *Corallium* for living.
- For a comprehensive understanding of the *Corallium* trade, in addition to the record and monitoring of imports, exports and re-exports of all *Corallium* commodities, the domestic trade of *Corallium* in East Asia should also be surveyed, recorded and monitored.
- Encourage all states and areas involved with *Corallium* harvest to keep detailed records of *Corallium* fisheries. The data should be species specific, and public access to the fishery and trade data should be maximized, subject to meeting a confidentiality requirement.
- *Corallium* is precious not only to the jewelry industry, but it is also precious to the environment. People are interested in *Corallium* from differing aspects, including biologists, conservationists, history and culture researchers, social workers and government authorities from different countries. These people should all work together to conquer the nature challenge, reveal the precious coral mysteries of the sea and work out a management for its sustainability.

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Biology of Japanese *Corallium* and *Paracorallium*

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1. Distribution

Japanese red coral (*Paracorallium japonicum*), pink coral (*Corallium elatius*) and white coral (*Corallium konojoi*) are distributed and harvested in waters near Japan.

Japanese red coral (*P. japonicum*): distributed on the rocky bottom at a depth of 76 m to 280 m in Sagami Bay, Pacific coast of Japan, in the waters from the Ogasawara Islands to Taiwan and off the coast near the Goto Islands, Nagasaki, with a height of up to 30 cm (Kishinouye 1903, Seki 1991, Kishinouye 1904).

Pink coral (*C. elatius*): distributed on the rocky bottom at a depth of 100 m to 276 m in the waters near Wakayama, Pacific coast of Japan, from the Ogasawara Islands to the northern South China Sea and off the Goto Islands, Nagasaki, with a height of up to 1 meter (Kishinouye 1903, 1904, Nonaka et al. 2006).

White coral (*C. konojoi*): distributed on the rocky bottom at a depth of 76 m to 276 m in the waters of Wakayama, Pacific coast of Japan, in the waters from the Ogasawara Islands to the northern South China Sea and off the Goto Islands, Nagasaki, with a height of up to 30 cm (Kishinouye 1903, Kishinouye 1904, Nonaka et al. 2006, Seki 1991).

2. Taxonomy

In 2003, when the family Coralliidae was subdivided into two genera, *Corallium* and *Paracorallium*, Japanese red coral was classified into *Paracorallium* (Bayer and Cairns 2003). The genus *Paracorallium* is characterized by autozooids seated in axial deep pits with beaded margins; and by longitudinal grooves on the surface of the axis. However, the pits supposedly characteristic of the genus are not observed in Japanese red coral in Kochi. And the beaded margins were not mentioned in the first report on Japanese red coral either while a pit under each polyp was clearly demonstrated in it (Kishinouye 1903). Considering these facts, careful examination is necessary to confirm whether Japanese red coral belongs to the genus *Paracorallium*.

It is suggested that pink and white corals should be each divided into two groups according to branching structures and widths (Nonaka et al. 2006). But more work must be done before determining whether they are different species or intraspecific variations.

Mitochondrial DNA sequences of the corals have been analyzed to solve the problem mentioned above. As a preliminary research, genetic relationships among precious corals were analyzed by small-subunit ribosomal RNA (srRNA) (Uda, Suzuki and Iwasaki, unpublished). Two types of srRNA sequences were obtained from several samples of Japanese red coral, while the only one identical sequence was obtained from several samples of pink and white corals. Comparison of these sequences indicated that the difference is at most 3.0%. Therefore, Japanese red, pink and white corals can be regarded as one group.

3. Reproduction and growth

Biological and ecological information on precious corals harvested in Japan is very little. The genital organs of Japanese red, pink and white corals develop in the siphonozooids (Kishinouye, 1904). Kishinouye (1904) examined eggs and spermatids of Japanese red coral collected in March and in September. The eggs and spermatids in March were larger in number and bigger in size than in September, leading Kishinouye to the conclusion that the reproduction season for the red coral was spring.

To estimate the growth rate, we took a new approach using synchrotron infrared rays, in addition to Toluidine blue staining method and the radiogenic lead-210 (^{210}Pb) age determination method (Iwasaki, Yamada and Hasegawa, unpublished). Stained with Toluidine blue, the axial calcareous skeleton of Japanese red coral demonstrated the organic matrix. Observation of the matrix indicates that the radial growth rate of Japanese red coral, if one ring is formed annually, is 0.15±0.04 mm/year. The lead-210 method shows that of pink coral is 0.15 mm/year.

When thin axial sections of Japanese red and pink corals were radiated with the synchrotron infrared micro-beam from the center in the outward direction or in their growth direction, continuous infrared absorption spectra were obtained. At certain wave numbers, changes in absorbance were recorded. The cycle of fluctuation in Japanese red coral ranges from 170 to 250 µm, while that of pink coral ranges from 130 to 140 µm. Since those figures are roughly in accordance with the distances between the growth rings of Japanese red coral demonstrated with the staining method and the radial growth rates of pink coral with the lead-210 method, they should be the yearly fluctuation. Synchrotron radiation is found to be a useful tool for measuring the growth rate.

4. Fishery

Japanese red, pink and white corals are harvested in Kochi, Kagoshima and adjacent waters of Okinawa. Fishing methods vary in different localities. In Kochi, fishermen drag traditional nets with stone weights on the sea floor, catching the pieces broken off entangled in the nets. In Kagoshima and off Okinawa, manned or unmanned underwater vehicles are used.

Coral fisheries in Japan are authorized by prefectural governors and fishing methods, areas and periods are different in prefectures. In a case of manned or unmanned underwater vehicles, fishermen follow self-imposed minimum size limits that allow them to harvest corals only above a certain size.

5. Sustainable use and research needs

Japanese red, pink and white corals are not included in the list of endangered species of animals in Japan (Red List issued by the Ministry of Environment in 2006). On the other hand, Japanese red coral is considered to be at risk for declining in number, although not an endangered species, in "Basic Data of Rare Wild Aquatic Organisms in Japan" published by the Fisheries Agency.

In order to assess the amount of precious coral resources and fishing pressure on them, and realize sustainable use of them, it is essential to have knowledge on the density, biomass and life history of precious corals. We have just started the research that should have been done much earlier.

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What We Have Learned About Red Coral and What We Need to Learn for its Rational Management

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1. A long history

The precious coral red coral *Corallium rubrum* (L 1758), is a long-lived, slow-growing precious gorgonian endemic to Mediterranean and neighbouring Atlantic rocky bottoms (Weinberg 1978, Zibrowius et al. 1984), where it dwells between 20 and 350 meter depth. The bright red, calcareous axial skeleton of this sea fan represents highly valuable raw material for carving art objects and jewellery. As early as pre-dynastic Egypt, down to nowadays, this species has been widely traded. The harvesting, wholesaling and carving of this precious coral has traditionally been centred in Torre del Greco (Naples, Italy) since the early nineteenth century, but over the last few decades coral craftsmen have taken up their activity in diverse Mediterranean and East Asian countries. Overall, these activities involving several thousand people worldwide (Cicogna and Catteneo-Vietti 1993, Santangelo et al. 2004), depend on the supply of *Corallium rubrum* (and on the supply of other coral species from the Pacific Ocean, too). In general, the lack of suitable harvesting strategies and adequate enforcement has resulted in a "pulse" fishing mode, which has also been fostered by ever-more efficient professional diving techniques (Santangelo et al. 1993, Santangelo and Abbiati 2001, Tsounis et al. 2007).

2. Population biology

Red coral is an aposymbiotic modular Anthozoan (Octocorals, Gorgonians, Coralliidae) whose diet is mainly composed of organic detritus and small zooplankton (Tsounis et al. 2006b). Colonies are gonochoric and during a limited time-period in early summer release planulae, which mainly settle near their parent colonies (Weinberg 1979, Santangelo et al. 2003, Bramanti et al. 2005) and reproduction is mainly sexual (Santangelo et al. 2003, Bramanti et al. 2005, Tsounis et al. 2006a). The species is structured into genetically different, isolated, self-seeding populations (Abbiati et al. 1993, Costantini et al. 2007). As red coral is long-lived (>100 years: Garrabou et al. 2002, Roark et al. 2006) and sexual maturity is reached early (Santangelo et al. 2003, Torrents et al. 2005), several reproductive generations coexist within the same population. Colonies exhibit low growth rates (Garrabou and Harmelin 2002, Marschal et al. 2004, Bramanti et al. 2005), and the size/age structure of current coastal populations shows a dominance of small/young colonies. In such populations, older colonies have become progressively rarer, exhibiting dramatically decreasing survival rates (Santangelo and Abbiati 2001, Tsounis et al. 2007).

Different populations have different life-histories (due, in the case of exploited species, also to different harvesting pressures) leading to different densities, size-age structures, recruitment and growth rates. The specific structure depends also on their specific habitats (Gili and Coma 1998). A cohort of newly settled colonies in a 25-meter deep horizontal cave near Marseille (Fr.), followed for 22 years (Garrabou and Harmelin 2002), revealed highly parsimonious population dynamics: high survival (ca 52% and 41.4% of colonies survived over 10 and 22 years, corresponding to 4.8% and 2.7 % mortality y^{-1}, respectively), yet low colony average basal diameter growth rates (0.24±0.05 mm/year) and low recruitment rates (recruits were only 4.5 % of the whole population, on average). Studies focussed on colony growth rate (basal diameter) during the first 4 years of colony life on other populations (Calafuria and Portofino MPA, Ligurian Sea, Italy), showed higher, similar values (0.62±0.19 Bramanti et al. 2007, and 0.62 mm/y^{-1} Cerrano et al. 1999, respectively). The Calafuria population shows faster population dynamics: only 3.5% of colonies survived up to the 10^{th} diameter class (corresponding to an age of about 14-15 years) and recruits were 31.47% of the overall population (Santangelo et al. 2007). The Calafuria population is crowded, dwells on a plankton-rich, vertical cliff and is periodically harvested, while the Marseille population lives, undisturbed, in a sheltered cave, partially isolated from other populations and with a limited plankton supply. Differences in recruitment and survival rates were also found in other shallow-water populations (Elba Island in Italy and Isle Medes MPA and Cap de Creus in Spain, Tsounis et al. 2006, Bramanti et al. 2007, Vielmini et al. in prep.).

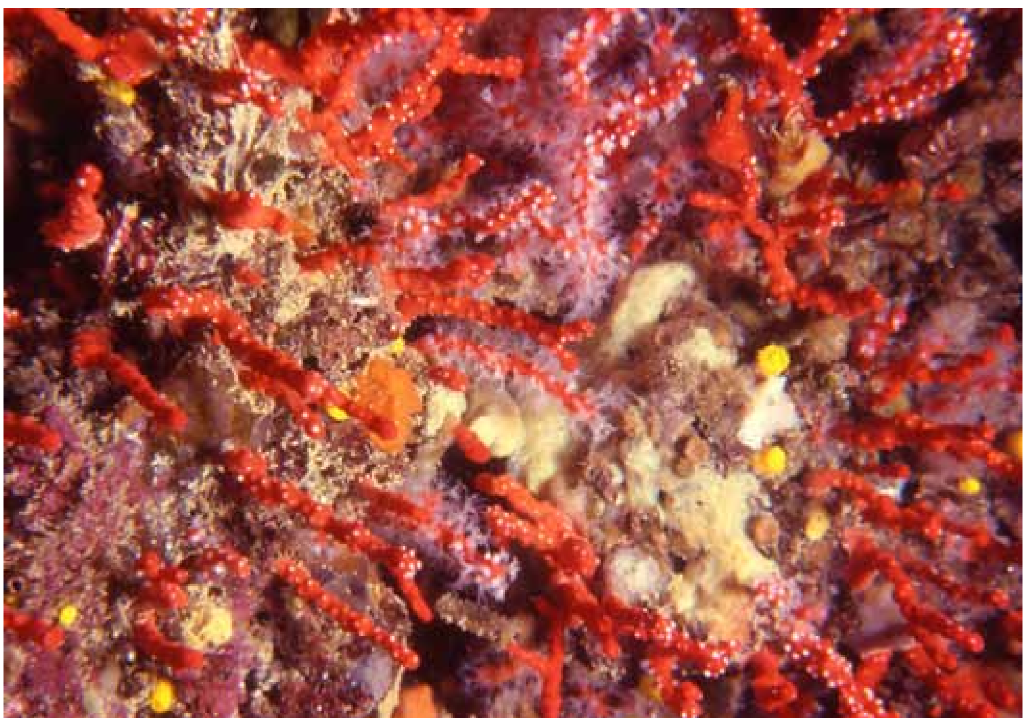

Fig. 1. The shallow (20–45 meter deep) population of Calafuria (NW Mediterranean Liguria Sea Italy). Colonies are crowded (33 col. dm–2) have few branches and the average diameter is 4.6±1.12 mm. More than 50% of these colonies are affected by boring sponges, greatly reducing their economic value.

Recently (late summer 1999 and 2003) a new source of mortality has been added to over fishing: some shallow-water populations in the North-Western Mediterranean suffered, in the upper portion of their bathimetric distribution, anomalous mortality events associated with a sharp temperature increase (Garrabou et al. 2001, Bramanti et al. 2005, Torrents 2007). As a thorough evaluation of the impact, in terms of mortality, of such events on long-lived species requires a long-time series of data collected before and after the event, few studies of the long-term effects of mass mortality exist (Linares et al. 2005, Cupido et al. 2008). However, a demographic approach, based on sound population data, may provide a good prediction of the mass mortality impact on population dynamics. Population dynamic models, based on sound demographic data, may provide reliable simulations of population trends overtime, as can be seen in the following paragraph.

3. Population modelling

In a recent paper, Tsounis et al. (2007) applied the Beverton and Holt maximum yield per recruit model (Beverton and Holt 1957) to a Spanish red coral coastal population (Cap de Creus – Costa Brava). This simplex and conservative model indicates only the time at which one cohort reached its maximal biomass (a trade-off between the colony biomass growth and the loss due to natural mortality) and thus can be harvested gaining the maximum yield. However, the reproductive output occurring in a real red coral population, in which several reproductive generations co-exist, cannot be included into the model. Such reproductive output is highly relevant, mostly for populations of modular organisms like red coral which reproductive output increases exponentially with colony size (Santangelo et al. 2003). More complex dynamic models, class (or life-stage) structured, in

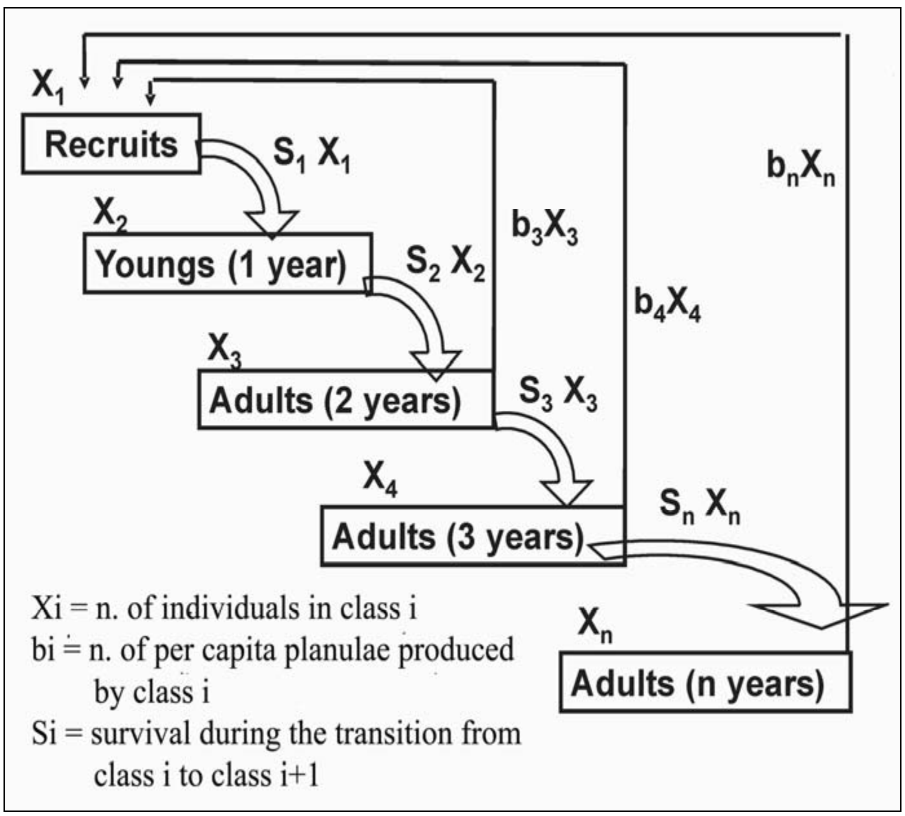

Fig. 2. The size-age structured model representing the complex dynamics of red coral populations.

which both mortality and reproductive output are included (Caswell 2001) can project population trends overtime under different reproduction rates and mortality pressures. Conservation biology applies such demographic models to assess population performance, to highlight the causes of poor performance,

$$X(t+1) = L(n(t))\,X(t)$$
$$X(t) = [X_1(t), X_2(t), \ldots\ldots, X_n(t)]$$

$$L = \begin{vmatrix} b_1S_0(n(t)) & b_2S_0(n(t)) & \ldots\ldots & \ldots\ldots & \ldots\ldots & b_nS_0(n(t)) \\ S_1 & 0 & 0 & 0 & 0 & 0 \\ \ldots\ldots & S_1 & 0 & 0 & 0 & 0 \\ \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots \\ 0 & 0 & 0 & \ldots\ldots & S_{n-1}(n(t)) & 0 \end{vmatrix} \quad \begin{vmatrix} X_1 \\ X_2 \\ X_3 \\ \ldots\ldots \\ X_n \end{vmatrix}$$

b_i = reproductive rate: n. of per capita planulae produced by class i
S_i = survival of class i
X_i = n. of individuals in class i

Fig. 3. The transition matrix (Caswell 2001). L is the population growth rate.

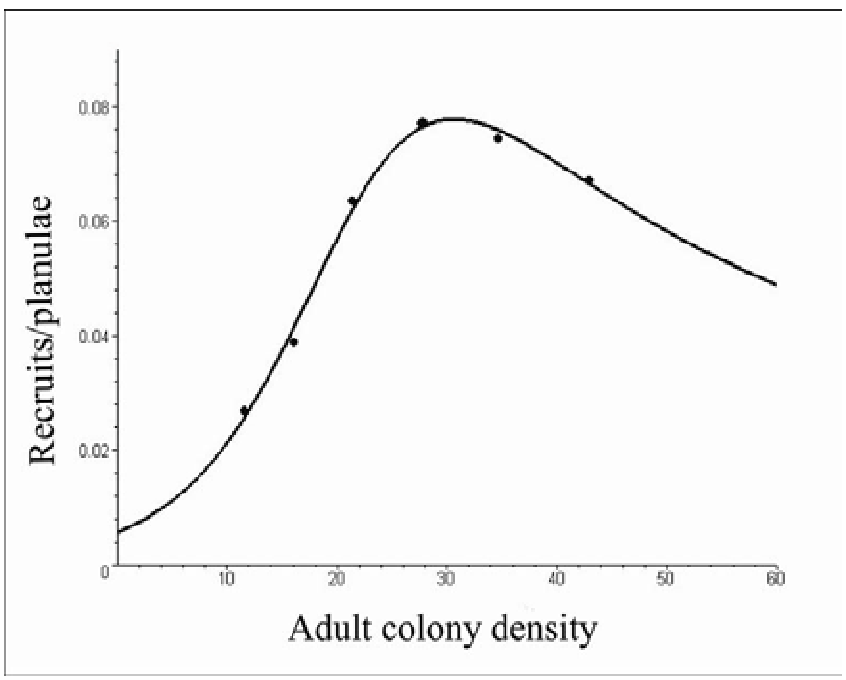

Fig. 4. This control function, based on experimental, field data recorded in the shallow Calafuria coral population, shows an increase of the ratio number of recruits/ number of larvae produced for low colony density, and a decrease for higher densities. This finding is a clue for density-dependence in crowded red coral shallow- water populations like the Calafuria one.

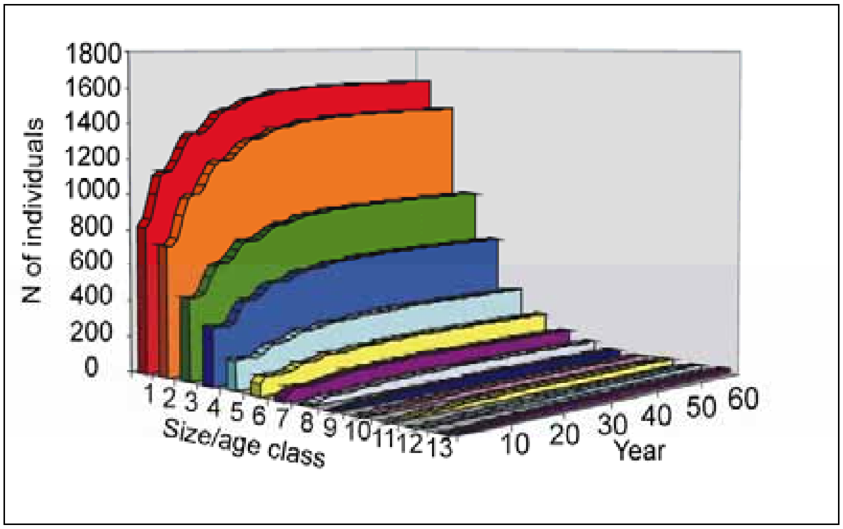

Fig. 5. Simulation of the effects of increased survival of larger-older colonies (classes 5-13). Recruitment saturation is reached after about 30 years of enforcement. Different classes are represented by different colours.

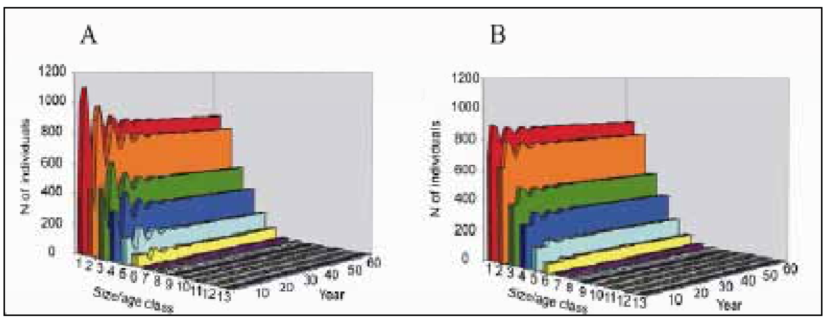

Fig. 6. Simulation of the effects of a single mass mortality event as occurred in late-summer 1999. A: mortality values are those reported for the Calafuria population (Bramanti et al. 2005); B: mortality values are those reported for the Marseille population (Garrabou et al. 2001). Both populations completely recover after about 15 years.

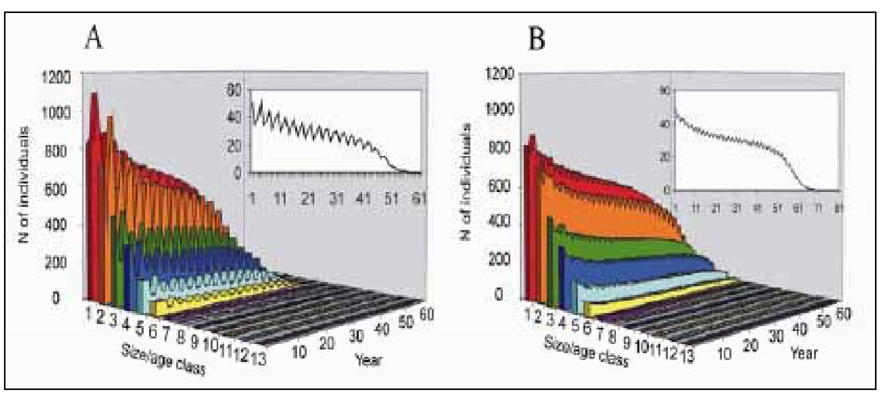

Fig. 7. Repeated mortality events with a 3 year periodicity could lead both populations to extinction.

to indicate suitable management strategies and to forecast population viability (Ebert 1999, Fujwara and Caswell 2001, Beissinger and Mccullough 2002).

The features of red coral populations – their semi-closed reproductive structure and discrete reproductive period, together with an exhaustive life-history data set of one coastal population (Calafuria, Ligurian Sea, Italy) – have enabled us to simulate the population trends over time by means of a discrete, age-structured, non-linear demographic model, which combines survival and fecundity parameters (Santangelo et al. 2007). In the following we show some simulations of the trends of a shallow-water population under different mortality pressures due to harvesting and mass mortality. It is worth to remember that: 1) simulations are only efforts to project population trends overtime and not forecast: "*a forecast is an attempt to predict what will happen; a projection is an attempt to describe what could happen"* (Bessinger and McCullough 2002); 2) these simulations refer to a shallow-water, dense local population (Calafuria-Italy) composed by small colonies in which recruitment density/dependence really occurs (Santangelo et al. 2007). All the figures here presented are redrawn after Santangelo, Bramanti, Iannelli: Population dynamics and conservation biology of overexploited Mediterranean red coral J. Th. Biol. 444; 2007.

The model (Fig. 2) represents the life-cycle of the population structured in different size-age classes; the Leslie-Lewis transition matrix (Fig. 3) allows, on the basis of abundance, survival and reproduction rates of each class to project the population structure over time (Figs. 5, 6, 7). Figure 4 represents the density-dependence of recruitment, really found in the crowded population studied (Caley et al. 1996). Simulation in Figure 5 represents the effect of an increase of population survival due to protection, which leads to recruitment- saturation (no further new individual can add to the population). Simulations in Figures 6 represents the response of the population to single anomalous mortality events, like those recorded at Calafuria and Marseille in 1999 (Fig. 6a and 6b., respectively): these simulations are based on the mortality data reported in Bramanti et al. 2005 and in Garrabou et al. 2001, respectively. Figure 7 indicates that an increased frequency of anomalous mortality events could lead local populations to extinction. Further details are reported in Santangelo et al. 2007.

Both model and simulations here shown are examples of what we can do on the basis of reliable demographic data. Similar models (presumably without any density-dependence) will be set out also on deep-dwelling red coral populations, when their density, size/age structure, reproductive features and mortality rates will be known.

Also if researches are still in progress about demography of shallow-water populations and there is now a good knowledge on some of them, some questions are still opened, in particular: is there any control of population density on colony growth rate? Is the present status of some of these populations, showing extremely high densities (up to 3.000 small colonies/ m^2), small size and early age at first reproduction original or due to the high fishing pressure they suffered in the past? We recently found some reproductive, female colonies with an height of 1 cm (Vielmini et al. in prep.). Some of these populations (as those in Portofino and Medes MPAs) are now protected, some other are subject to some sporadically harvesting (e.g. Calafuria population) and some other is still suffering overharvesting (Cap de Creus), we do not know if past overfishing have induced drastic changes in their structures (further discussion on this topic is reported in Bramanti et al. 2009).

GROWTH RATE (mm/year)

	Direct diameter measure (A)	Growth rings counts	
0.24 ± 0.05 (Garrabou and Harmelin 2002)	SNS in a cave	1.32 (Garcia Rodriguez and Massò, 1986)	Petrographic (B)
0.62 ± 0.19 (Bramanti et al., 2005)	SNS on a vertical cliff	0.91 (Abbiati et al., 1992)	Petrographic (B)
0.62 (Cerrano et al., 1999)	NS in a cave	0.35 (Marschall et al., 2004) (0.15 Torrens et al. 2007)	Organic matrix Staining (C)

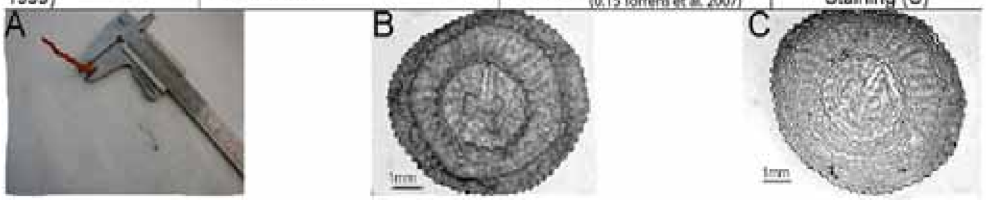

Fig. 8. A Direct measurement of growth on colonies of known age; B dark bands by petrographic method; C Growth rings by organic matrix staining methiod. SNS = semi-natural substrate.

But the real, deep, dramatic lack of knowledge concerns the deep-dwelling populations which are those with the highest economic value. Some data on the size structure of Spanish (Costa Brava) fishing crops have been reported by Garcia-Rodriguez and Massò in 1986 (Garcia-Rodriguez and Massò 1986). More recently, a ROV survey, carried out off Cap de Creus (Spain) revealed a different size-structure in populations dwelling in deeper areas (60-230 m) not affected by mass mortalities and less pressed by harvesting, but even such structures seems to be far from ancient times (Rossi et al. 2008). Some other ROV surveys have been made on deep-dwelling populations by professional fishermen and by researchers; those made by Massimo Scarpati in Sardinia showed coral populations, living between 90 and 120 meter depth, composed by large (>30 cm in height) colonies. Unfortunately such populations were not examined, until now, by statistical and demographic tools. An other ROV survey, carried out off Calabria coasts (South of Italy) between 50-200 meter depth, revealed the dominance of small colonies (50% of colonies were smaller than 10 cm in height) and low density (1-90 col. m^{-1}) (Angiolillo et al. 2009). Generally a tight, inverse relationship between size and density of colonies, with smaller size and higher densities was found at shallower depths (Bavestrello et al. 2009). Some further recent data, gathered by examining fishing crops harvested between 93 and 107 m depth in Western Sardinia in 2007 and 2008 revealed a constant size structure with similar modal classes (10 mm of diameter and 40 g of dry weight) together with some exceptional colony of about 500 g (Pedoni et al. 2009).

At present no exhaustive data on age/size structure, colony growth rate, reproduction, recruitment, population growth rate and mortality of deep-dwelling populations is already known.

In the following we will address three basic points for the study of red coral population dynamics: 1) Colony growth rate and age assessment; 2) Reproduction features and reproductive output; and 3) Recruitment rates. Research on deep-dwelling populations should be addressed towards these points.

4. Colony growth rate assessment

C. rubrum is known to be a long-lived species, but how “long” its life span can be is still controversial and the object of research. The assessment of the annual growth rate of red coral colonies is essential to assign them to different age classes and to determine the age structure of the populations. Three different methods have been applied (up to now) to determine the age of coral colonies (the first two supplied by sclerochronology): 1) Petrographic method (Garcia Rodriguez and Massò 1988, Abbiati et al. 1992, Santangelo et al. 1993); 2) Organic matrix staining of thin sections from the base of colonies (Marschal et al. 2004, Torrents et al. 2007), which allows one to read annual growth rings; 3) Direct measurements of new settled colonies of known age, a not destructive approach to the study of colony growth rate, based

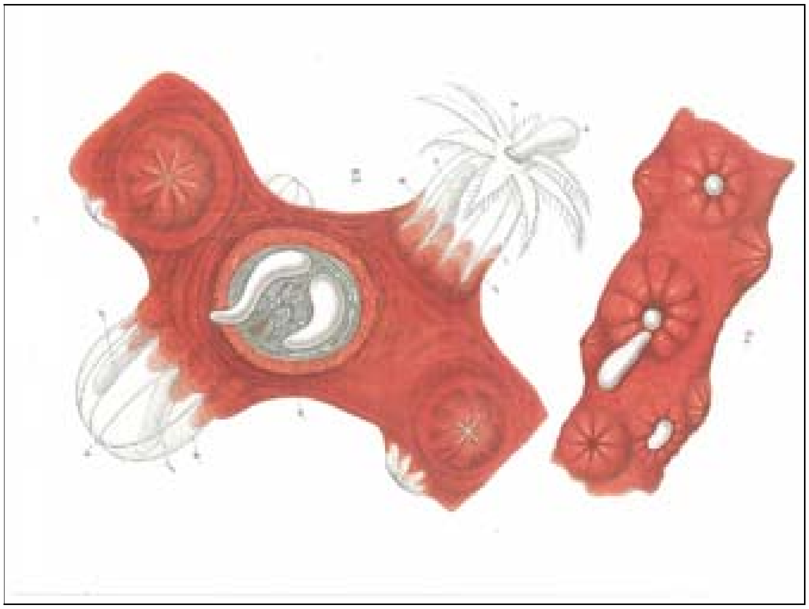

Fig. 9. The release of red coral planulae described by Lacaze-Duthiers (1864).

Size/age class	N of individuals in each size/age class Xi	Fecundity (mean n of larvae produced by each polyp) q	Survival Xi/Xi-1 (S)	Mean number of planulae produced by each colony	Larvae produced by each class (biXi)
1	822	0.00		0.00	
2	731	0.00	**0.889**	0.00	0.00
3	463	0.87	**0.563**	2.89	1338.86
4	323	0.87	**0.393**	10.03	3240.58
5	167	0.87	**0.203**	21.59	3605.88
6	73	0.87	**0.089**	39.02	2848.47
7	21	0.87	**0.026**	56.41	1184.57
8	12	0.87	**0.015**	77.72	932.65
9	4	0.87	**0.005**	103.23	412.91
10	3	0.87	**0.004**	131.87	395.61
11	3	0.87	**0.004**	164.57	493.71
12	1	0.87	**0.001**	201.46	201.46
13	1	0.87	**0.001**	242.65	242.65

Table 1. Static Life-history table of a red coral population (Calafuria-Italy) in which all the main demographic parameters are reported (after Santangelo et al. 2007, modified).

on artificial or semi-natural substrates on which new settled colonies can be followed during their growth for a determined time interval (Cerrano et al. 1999, Garrabou and Harmelin 2002, Bramanti et al. 2005).

In 1986, Garcia-Rodriquez and Massò proposed a petrographic method (Fig. 8.B) based on the count, under polarized light, of dark bands on thin-sections from the base of *C. rubrum* colonies (Garcia-Rodriquez and Massò 1986). Unfortunately, as the dark bands highlighted by this method were not annual, colony age was underestimated. Only in recent years, a new, more reliable method to determine the annual colony growth rate was set out by Marschal et al. (2004). Such "organic matrix staining method" allowed to read growth rings Fig. 8.C) which were checked to be annual by calcein labelling in vivo. The method is based on two different features of the red coral skeleton, i.e., skeleton density and concentration of organic matrix, respectively. Decalcification and staining with Toulidine-blue of the remaining organic matrix allowed the researchers to highlight the annual growth rings. In contrast with other gorgonian species (e.g. Grigg 1974), growth rings were never observed in the central region of the red coral axial skeleton. The first growth ring always appeared at some distance from the centre probably because of the mechanism involved in calcium deposition change during growth in the first 3-4 years of growth (Marschal et al. 2004).

Reliable measures of colony growth rate were also made by directly following new settled colonies on ad hoc settlement plates during some years and then measuring them (Fig. 8.A) (Garrabou and Harmelin 2002, Bramanti et al. 2005, these papers will be examined again in section 6). This last method, slow but not destructive, allowed to determine the colony growth rate along the first years of red coral life-cycle (1-4); as growth cannot be determined by the organic matrix staining-method during that period, the two methods give complementary information on annual growth rate in different phases of red coral life span. The colonies studied by Garrabou and Harmelin settled on limestone plates located in an horizontal, 25 long- cave, showed a lower growth rate than those studied by Bramanti and colleagues (0.24±0.05 and 0,62±0.19 mm/y of basal diameter, respectively). These values overlap the colony growth rate measured by Cattaneo and colleagues on the natural substrate at Portofino (Cerrano et al. 1999). On the basis of the overall findings we can assess that the growth in diameter is higher during the first 3-4 years, than, progressively decreases with age. Other parameters, as colony weight (increasing exponentially with age) are better descriptors of colony growth (Santangelo et al. 1993).

5. Reproduction

The basic features of red coral reproduction have been described (and drawn in a magnificent way!) by Lacaze-Duthiers (1864) (Fig. 8). A further description of reproduction was given by Vighi (1972) and the reproductive structure of a shallow population was described by Santangelo and colleagues (Santangelo et al. 2003). Torrents and colleagues determined the age at maturity of a French red coral population (Torrents et al. 2005). Moreover Torrents identified some effects of environmental stress on colony reproductive output (Torrents 2007). The study of population reproductive structure is basic for demographic studies. In particular sex ratio, size/age at sexual maturity, fertility (the percentage of fertile female colonies) and fecundity (the average number of planulae each female colony produces) must be determined. Fecundity of colonies in each size/age class is calculated as the number of fertile polyps of each colony multiplied by the fecundity of each polyp (Table 1) (Santangelo et al. 2003). In Table 1 is reported the life-history table of the Calafuria population set out by Santangelo and colleagues in which reproduction data are included (Santangelo et al. 2004, 2007).

Assessment of colony and population reproductive output is necessary to set out “static” life history tables (Ebert 1999) in which data on density, fertility and fecundity of each age class are reported (Table 1). The only papers on red coral reproduction (in addition to a section of the beautiful, historical Lacaze-Duthiers’ book of 1864) are the paper of Vighi (1972), Santangelo and colleagues (Santangelo et al. 2003), Torrents (Torrents et al. 2005, Torrents 2007) and Tsounis and colleagues (Tsounis et al. 2006). Obviously small colonies have a lower individual reproductive output than larger ones having more polyps, but they are so numerous in coastal populations that their overall reproductive output is high. If we examine the life-table in Table 1 we can observe that the main part of planulae (74%) is produced by the first 3 reproductive classes, which, also if composed by smaller colonies are the more abundant. The survival of shallow populations, harvested and subject to anthropogenetic disturbance, could be due to their small size/young age at first reproduction and to the larval output of the numerous smaller/younger colonies. On the basis of these findings the reproductive output of shallow-populations, like that of Calafuria, cannot be defined as “low.” Moreover we must to consider that, also if the number of planulae produced is high, the number of recruits is lower depending on population density (Fig. 4) and the ratio between number of eggs produced and the number of recruits found in the population is small: 18.2 planulae produced only 1 recruit, or in other words, only 5.5% of planulae survive becoming recruits.

Table 2. Recruitment density measured in different habitats and in different areas.

RECRUITMENT DENSITY (recruits/dm^2)	
Semi natural substrate in a cave near Marseille	Semi natural substrate on a vertical cliff
1,3 recruits/dm^2 (Garrabou and Harmelin 2002, 1st year)	6.24±4.26 recruits/dm^2 (Bramanti et al. 2005) Calafuria.
0.178 recruits/dm^2 (Garrabou and Harmelin 2002, years 2-22)	0.4-0.6 recruits/dm^2 (Cerrano et al. 1999 Monaco) 1.6±1.96 recruits/dm^2 (Medes) 1.1±1,4 recruits/dm^2 (Elba Island) (Bramanti et. al 2007)

6. Recruitment

Recruitment (the supply of new individuals to a population by means of reproduction) is one of the main processes determining both population structure and dynamics (Caley 1996). For demographic studies it is extremely important to identify recruits. Recruitment rates can greatly vary in space and time, moreover it is necessary to distinguish between natural and methodological variability. There are few studies on the recruitment process in red coral populations, here we examined the few papers in which data on red coral recruitment are reported: Cerrano et al. 1999, Garrabou and Harmelin 2002, Bramanti et al. 2003, Bramanti et al. 2005, Bramanti et al. 2007 (Table 2). Some preliminary data have been reported by Cerrano and colleagues (Cerrano et al. 1999), which found, on artificial substrates set out off Monaco an average density of 0.4-0.6 recruits dm^2. A wider description of red coral recruitment process was reported by

Garrabou and Harmelin (2002). The population studied settled on semi-natural limestone plates located in a horizontal, 25m long cave, a peculiar, partially isolated environment. Red coral planulae reached only seldom the inner part of the cave in which the settlement plates were located, thus recruitment was only occasional. This "pulse" recruitment occurred once around 1979 (when 52 settlers were found); after that time recruitment events were sparse and only few settlers (1-5) added to the original population in each occasion. The findings reported in that paper are sketc.hed in Fig. 10: in A the "net recruitment rate" (the difference between the number of died individuals and the new settlers in the same year) is reported, while in B the trends over 22 years of the "new settled population" are reported. As can be seen the net-recruitment rate is negative in the majority of years; this finding, confirmed by the densities reported in Table 2 (left column) indicates that, during the 22 years of the experiment the new settled population reduced and could even extinguish if a new abundant larval input will not reach again (like in 1979) the inside of the cave.

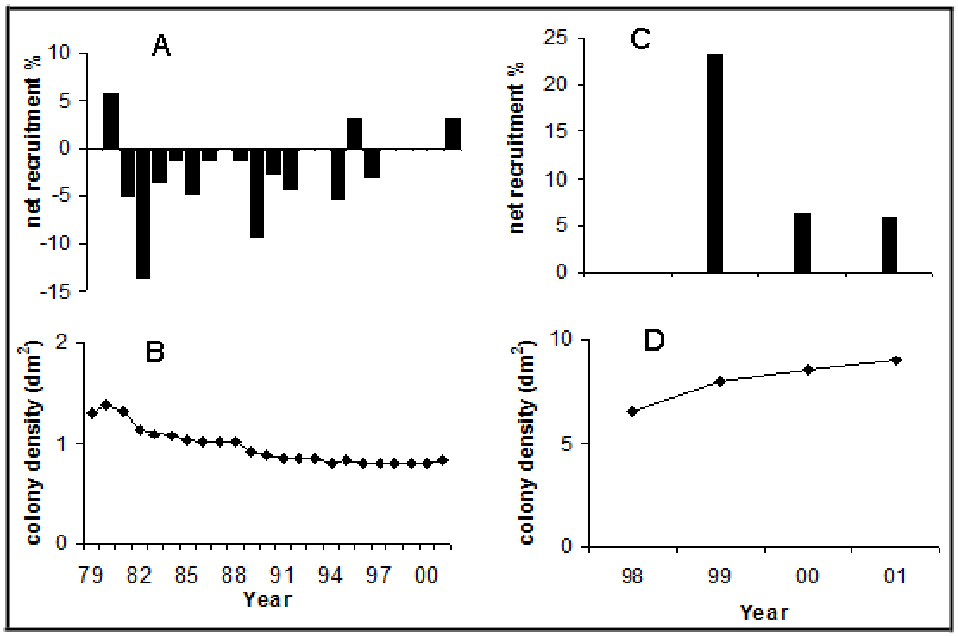

Fig. 10. Different trends of new settled populations: net recruitment (recruitment-mortality) A: in a deep, horizontal cave (Marsiglia), C: on a vertical cliff (Calafuria LI). B and D: the two population trends.

More recently Bramanti and colleagues (Bramanti et al. 2003, Bramanti et al. 2005) studied red coral recruitment of Calafuria population and successively (Bramanti et al. 2007) in the populations of Medes Islands (Spain) and Elba (Italy). They used semi-natural settlement plates made of Carrara-marble of a size (10x10 cm) suitable for macro photographs. On such macro photographs recruits were easily identified. Tiles were fixed on the vaults of the crevices in which red coral colonies dwell just before the reproductive period. The whole procedure was patented by the authors. As can be seen in Fig. 10 C and D the new settled population showed positive net-recruitment values and positive population trends during the 4 years of the experiment. Overall the findings from Bramanti and colleagues indicate a high variability in recruitment rates between different populations and years with highest recruitment values (Table 2) and positive net-recruitment in the shallow Calafuria population (Fig. 10).

7. Recovery from disturbance

The only data we have gathered on recovery are those collected at Medes Islands MPA, which show a significant dominance of larger colonies, as compared with those collected in a neighbouring, unprotected area. Despite the lack in both populations of colonies beyond the 15th size class, their current size distributions differ, the average colony eight being significantly higher at the Medes Islands MPA ($F=1.39$; $n=820$; $P < 0.0005$). This last finding strongly suggests some positive effect of the red coral harvesting ban in force at Medes for the last 15 years.

Exhaustive data on recovery after a fishing stop will be gathered by studying the NW Sardinian deep-water population which has been closed to fishing since several years.

8. Fishing

Fishing data revealed a reduction of about ⅔ of the overall Mediterranean fishing crop during the period 1978-2005. This reduction occurred in the period 1982-1984, than the production remained roughly constant. A peak in coral yield, due to the discovery of Alboran banks was recorded in 1983. In general, the lack of suitable harvesting strategies and adequate enforcement has resulted in a boom and bust fishing mode as occurred in Morocco (peak in 1988 and collapse in 1990) or in a constant decline (Tunisia 1981-1990) (Santangelo et al. 1993). Official red coral fishing data have been drawn from the FAO Yearbook fishery statistics (FAO 2007). As such data are usually provided by red coral wholesalers, and illegal fishing and black-market trade are common, they certainly underestimate the overall Mediterranean yield, but, unfortunately, they are the only data available (Santangelo and Abbiati 2001).

Change in size-structure of fishing yields with a shift towards smaller size was also underscored by comparing the frequency distribution of colony size (basal diameter) in two Spanish fishing crops collected in the same area (Cap de Creus) in 1984 (Garcia-Rodriquez and Massò 1986) and 2002. Although both curves are significantly skewed ($P < 0.01\%$), the value of the skewness coefficient, G1 (Snedecor and Cochran 1989), for the most recent crop (2002) is about ½ that of the older one (1.45 and 2.25, respectively). Such difference is due to the lack of larger colonies in recent fishing crops, as the size classes 16-26 have been depleted by selective fishing (from Santangelo et al. submitted).

Concerning fishing of the Mediterranean red coral two main points must be underlined:

1) Trawling (i.e. fishing with highly destructive devices called St. Andrew's Cross and Ingegno) have been banned from the Mediterranean since 1994 (this was due to Italian researchers involved at that time in a common Italian preliminary research project on red coral; for details see Cicogna and Cattaneo 1993).

2) In Sardinia (the region of Italy in which the main part of the Italian coral is harvested) both Ingegno and St. Andrew's Cross have been banned since 1989 and fishing was allowed by SCUBA diving and by pick only. Sardinia Region issued ad hoc laws on red coral fishing, which are more restrictive than the national one; in 2006, 38 coral fishing licences were released; in 2007, coral fishing was stopped, and in 2008 it was again allowed with the following limits:

- Number of licenses limited to 20.
- Daily weight allowed for each licence: 2.5 kg.
- Minimal colony size (diameter): 10 mm (a 20 % variability is allowed)
- Minimal fishing depth: 80 m.
- Fishing period: 1 June – 15 October
- In several areas coral fishing is banned.

There is a clear will of Sardinian authorities to induce professional fishermen to harvest only few larger, high valuable colonies (applying a minimal colony size of 10 mm instead of 7 mm as in other Mediterranean countries, small individual quotas, and a minimal fishing depth). Large, healthy colonies have an economic value about 20 folds higher than smaller ones. Many divers use ROV to find such larger colonies before diving.

9. Recommendations for management approaches

Some shallow-water populations like the Calafuria one are composed only by small, overcrowded colonies and seem to possess a good, albeit slow, recovery capability – a feature typical of long-lived species with populations provided of early sexual maturity, several reproductive generations and high reproductive output. For such populations, a single anomalous mortality event may have limited effects on survival. Some other shallow populations (like that at Cap the Creus) showed a population size-structure depleted of larger colonies (those > 0.7 mm in basal diameter, the legal size), lower densities and lower recruitment rates – clear symptoms of recent overexploitation (Tsounis et al. 2006, Vielmini et al. in prep.) Moreover, as over-fishing is now coupled with anomalous mortality events, such co-occurrence could dramatically diminish the resilience of populations living in shallow water. There is no real risk of global extinction for this species, due to its early sexual maturity, wide bathymetric and geographic distribution range, comprehensive of several MPAs. Nevertheless, an increased frequency of anomalous mortality events, superimposed to overharvested shallow populations, could lead some of them to local extinction. Thus such shallow-water populations should be protected.

The future of red coral harvesting is thus linked to deep-dwelling populations; their exploitation needs careful management based on sound population and fishing data, reliable analysis of demographic trends which will allow to establish minimal colony size and culling exploitation plans. Some years ago rotating harvesting strategies, which could be effective if applied at a national or local scale, have been suggested for red coral by Caddy (Cicogna and Cattaneo-Vietti 1993). Otherwise the Mediterranean most precious living resource could be commercially extinguished, and an age-old artistic tradition could be irretrievably lost in the near future. Only well-deliberated policies of sustainable fishing (and real enforcement), in which harvesting will be matched to population growth rates (Dobson 1998, Grigg 2001), can provide the conservation of exploitable populations of the Mediterranean red coral.

10. Research needs

No exhaustive research project on the Mediterranean red coral has ever been funded by EU, FAO or other international authorities. Italian authorities funded two small, preliminary research projects in 1991-93 and 1996-97. After these researches have been promoted, two books and several scientific papers, dealing mainly with shallow populations, have been published. Due to the lack of funding in the following years only few scientific papers, dealing again with shallow-water populations, have been further published.

There is a great need of research on deep-dwelling, exploited (or exploitable) populations, carried out at a Mediterranean scale. Suitable data on spatial structure, colony growth rate, size/age and sexual structure, reproductive output and recruitment, natural mortality and recovery in the different populations are needed. Moreover fishing historical data too must be carefully examined. All this could allow (with the help of suitable demographic models, Fujiwara and Caswell 2001) both rational harvesting and conservation of this precious Mediterranean resource.

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The Status of *Corallium* spp. in Hawaii and the U.S. Pacific: Population Status, Trends and Threats, Fisheries, Trade, Management, Enforcement and Conservation

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1. Information on the regions *Corallium* spp. populations

A. Area of distribution and habitat types

The two commercially sought *Corallium* spp. known from the exclusive economic zone (EEZ) of the U.S. Pacific Islands are *Corallium secundum* (pink coral) and *Corallium regale* (red coral). Many other *Corallium* spp., and one species of *Paracorallium,* have been reported from the Hawaiian Archipelago including *C. abyssale* (Bayer 1956), *C. ducale* (Bayer 1955), *C. Kishinouyei* (Bayer 1996), *C. niveum* (Bayer 1956), *C imperiale* (Bayer 1955), *C. laauense* (Bayer 1956), and *Paracorallium tortuosum* (Bayer 1956), none of which have been commercially harvested in the past. Identifications of *Corallium* spp. can be difficult and the genus is currently being reviewed by researchers worldwide. Field identification is complicated by the corals' growth into similar shaped fans of comparable sizes with a variety of color shades. Field surveys using submersibles in 2003 in the remote Northwestern Hawaiian Islands raised questions about in-situ identifications between *C. laauense* and *C. regale* and the name *C. laauense* was used in place of *C. regale* to report findings in publications by Parrish and Baco 2007, and Parrish 2007. *C. laauense* historically identified from the channel waters off Laau Pt on the Island of Molokai is paler in color than the more widely found red coral *C. regale*. Subsequent discussions determined that the name *C. regale* must be used to refer to what appears to be red coral for consistency until modified by a published taxonomic analysis. The Hawaiian Archipelago has been the subject of multiple expeditions using submersibles. Except for a few dives in the Line Islands conducted in 2005 the rest of the U.S. Pacific Islands are un-surveyed. The waters around Guam, CNMI, American Samoa, Howland and Baker Island have not been visited by research submersibles.

Corallium spp. can be found as an isolated individual colony but usually occurs in patchy distributions known as "coral beds." Colonization and growth of the coral colonies require exposed substrate subject to strong bottom current (Grigg 1993). The coral can be found growing both on carbonate and basalt/manganese substrates with *C. secundum* typically seen in uniform low relief bottom, and *C. regale* seen in habitats of variable relief (Parrish 2007). *Corallium* beds are usually dominated by one of the two taxa. Patches of *Corallium* spp. have been visually identified at 17 sites throughout the full length of the Hawaiian Archipelago (Grigg 1975, 1976, 1993, Parrish and Baco 2007). An unknown species of *Corallium* was harvested in abundance from a region NW of Midway atoll referred to as the Midway grounds (Grigg 1993). In-situ coral research surveys have yet to be conducted in that area.

B. Abundance, size structure and condition

The Makapu'u coral bed off Oahu, Hawaii is the most diverse and well studied of the coral beds in the Hawaiian Archipelago. Located in the Kaiwi Channel (350-450 m) between the islands of Oahu and Molokai the bed comprises an area of about 3.6 km^2 of *C. secundum* at a mean density of 0.22 colonies per square meter (Grigg 1988). Being the most accessible coral bed in the archipelago much of what is known about Hawaiian *Corallium* spp. is based on the Makapu'u population. *C. secundum* and *C. regale* are gonochoristic (Grigg 1993, Waller and Baco 2007) and are estimated to reach reproductive maturity at 12–13 years (Grigg 1993). These species are relatively long lived, with some of the oldest colonies observed within Makapu'u Bed about 0.7 m in height and approximately 80 years old (Grigg 1988). Recent radiometric work indicates greater longevity with *C. secundum* growing at half the rate previously thought (Roark et al. 2006). Populations of *C. secundum* are thought to be recruitment limited, although in favorable environments such as Makapu'u populations are relatively stable, suggesting that recruitment and mortality are in a steady state (Grigg 1993). Visual surveys of the Makapu'u bed using submersibles indicate *C. secundum* colonies average 15–20 years of age (Grigg 1993). Based on historical growth rates with a natural mortality rate in absence of fishing pressure was estimated at 6% (Grigg 1984, 1993). Population trends analyzing fishing pressure found that the coral abundance remained similar after a period of harvesting pressure that reduced the biomass by extracting older/larger corals (Grigg 2002). Submersible surveys conducted in different coral beds indicate that the composition, density and patch size of *Corallium* spp. can vary greatly (Grigg 1975, 1976, Parrish 2007).

C. Threats

Damage from fishing gear

Damage to *Corallium* spp. populations due to unintended impacts from fisheries are thought to be minimal in the U.S. Pacific Islands. Although mobile bottom-tending gear (e.g. trawls, dredges) were banned from the mid 60s to the mid 70s, Soviet and Japanese trawlers worked the south end of the Emperor Chain (e.g. Coco Seamount, Milwaukee Seamount, Colahan Seamount) and some of the seamounts at the north end of the Hawaiian Archipelago, including those later included as part of the U.S. exclusive economic zone (e.g. Hancock Seamount, Seamount 10, Seamount 11, Ladd Seamount) (Uchida and Tagami 1984). The primary fishing target was *Pseudopentaceros wheeleri* (armorhead) and *Beryx* spp. (alfonsinos) (Uchida and Tagami 1984). In 2003, submersible dives at Seamount 11 found a large area with coral stumps and no new colonization (Baco pers. obs). It could not be determined if this affected area was the result of mobile bottom-tending gear used in the early 1970s but if so, recovery clearly requires decades.

Bottom longlines are not permitted in the Pacific Islands Region. Pelagic longlining set for tuna and swordfish is permitted and is the region's largest fishery. Longlines must be set at least 25 miles, and in most cases 50–75 miles from emergent parts of the Hawaiian Archipelago (WPFMC 1991). This regulation was adopted to prevent conflicts with the coastal trolling fishery but it also reduces the possibility that the gear will affect deep corals on the slopes and seamounts of the Hawaiian Ridge. One exception is Cross Seamount located ~100 miles south of Oahu. A popular fishing site for monofilament handline fishing and some longline activity, it has accumulated numerous large fragments of monofilament line draped over the summit (Parrish and Baco 2007).

Bottom-set traps have been used to catch lobster and shrimp in the Hawaiian Archipelago. The Northwestern Hawaiian Islands trap fishery for *Panulirus marginatus* (Hawaiian spiny lobster) and *Scyllarides squammosus* (slipper lobster) is now closed, but had always operated in waters shallower than deep coral habitat (Polovina 1994, DiNardo and Moffitt 2007). Trap fishing for the deepwater shrimp *Heterocarpus laevigatus* and *Heterocarpus ensifer* is a small-scale pulse fishery limited to the main Hawaiian Islands that has landed 680 metric tons since the fishery's inception in 1984 (PIFSC unpub. data). The shrimp trapping overlaps the depth range of deep corals (Ralston and Tagami 1992, Moffitt and Parrish 1992), but actual impacts to deep corals have not been documented.

Coral Harvesting

As elsewhere in the world the skeleton of Pacific *Corallium* spp. is sought as raw material for the jewelry industry. This material is obtained from harvesting in U.S. waters and imports from foreign coral fisheries. *Corallium* spp. are the primary target species of the Hawaiian precious coral fishery. Harvested *Corallium* spp. coexist with other commercially harvested corals in the same depth zone including gold coral (*Gerardia* spp.), bamboo coral (Isididae) and other species (Grigg 1984). Coral harvesting has been subject to management under both federal and state regulations since the 1980s. Precious corals were fished initially using nonselective tangle net dredges, but regulations now require the use of selective methodologies such as a submersible or remote operated vehicle. The U.S. fishery and coral fishing by foreign fleet in adjacent international waters will be addressed in detail in the fishery section below.

Mineral Prospecting

Oil or gas exploration does not occur in the Pacific Islands Region. Historically, some research has focused on the prospect of mining manganese nodules that are formed at abyssal depths. Recently, interest in cobalt-rich manganese mining has resurged and large areas of the Pacific seabed, some of which include U.S. Pacific Islands and seamounts, are part of the potential mining areas (International Seabed Authority www.isa.org.jm/en/seabedarea/default. Further studies of these cobalt-rich regions to determine deep-coral abundance and potential mining impacts should be considered a high priority.

D. Conservation areas (e.g. MPAs)

U.S. State and Federal waters in the Pacific Islands are closed to trawling and dredging—the fishing techniques most destructive to deep corals. The only area that is specifically closed to protect deep corals was WESTPAC Bank (located N.W. of Nihoa) in the Northwestern Hawaiian Islands. It was set aside by the Western Pacific Fishery Managements Council's Precious Coral FMP as a refuge from coral harvesting. Visual surveys of the bed using a submersible confirmed *Corallium secundum* was reasonably abundant at the WESTPAC bed (Parrish 2007). Despite some interest, domestic precious coral fishing has never occurred in the Northwestern Hawaiian Islands. In 2001 the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve was established by Executive Order (No. 13178 and No. 13196) and prohibited most commercial fishing, including all harvesting of deep corals in the Reserve. In 2006, the NWHI was proclaimed a national monument by Presidential Order under the Antiquities Act of 1906 and renamed Papahānaumokuākea Marine National Monument. In early 2009, three additional National Marine Monuments were established by Presidential order. The three included a monument for the U.S. Line and Phoenix Islands, Rose Atoll, and the three islands of the Northern Marianas along with the Marianas Trench. Prior to the designation as monuments many of these areas were subject to restrictions on fishing due to their status as National Wildlife Refuges administered by the U.S. Fish and Wildlife Service or fishing regulations implemented by the Western Pacific Fishery Management Council and the National Marine Fisheries Service. Outside of the U.S. Exclusive Economic Zone some resources are managed through known fisheries such as the longline and purse-seine fisheries while other resources are unregulated and unmonitored.

E. Monitoring and research programs

The presence of a managed precious coral fishery prompted the need for a research and monitoring program for Hawaii's deep corals. As a result deep coral research moved from its historical focus on taxonomy (Grigg and Bayer 1976), to one of population assessments and estimates of age and growth (Grigg 1965, 1975, 1988, 1993, 2002). In recent years, management research has expanded to include work assessing the connectivity of coral taxa across the Hawaiian Archipelago (Baco and Shank 2005, Baco et al. 2006) and ecological associations between corals and other fauna (Parrish et al. 2002, Parrish 2006). In the process of conducting this research study sites are established, thermographs are deployed, and colonies are marked for future re-measurement, all of which contributes to a data stream that monitors the deep coral ecosystem.

Mapping Research

Advances in multi-beam sonar mapping have provided detailed bathymetry and backscatter imagery products for the Hawaiian Archipelago and are increasingly including other portions of the U.S. Pacific (Miller et al. 2003, Parke and Wang 2005). These products provide a bathymetric context for coral surveys and assist in the inference of the presence of deep corals.

F. Information Gaps and research needs

Population information on *Corallium* spp. is limited and the ability to identify biomass decline requires monitoring over time. In no circumstances has an assessment of absolute abundance been conducted for any of the coral beds. The cumulative visual observations from submersible surveys conducted at the Makapu'u coral bed is the best assessment conducted to date (Grigg 1993). The sessile and conspicuous nature of the corals make them easy to survey assuming one has ample access to appropriate technology (sub, ROV, AUV) that can work in the depth and high current environment of the coral beds. Only a few areas that have been subject to coral harvesting have any pre-exploitation data making the development of populations trends from an un-impacted state difficult. There are un-harvested beds that may serve as points of comparison but the varying environmental influences (e.g. temperature, flow, oxygen) between areas on coral growth and survivorship are poorly understood. Historical and anecdotal information can give an idea about the maximum colony size, but not detailed data about the population structure. At the minimum for harvested species there should be studies to develop and refine demographic data including growth, longevity, recruitment and dispersion limits.

2. Nature of *Corallium* fisheries

Like many places the *Corallium* harvest in the Pacific Islands region tends to be a "pulse-fishery" with episodes of intense fishing separated by long periods of dormancy. The activity of domestic harvesting of *Corallium* is a function of the industry's appraisal of the market and the economic viability to harvest corals under the established fishery management regulations. The pulses in the foreign *Corallium* fishery that historically operated in the adjacent international waters reflect of the history of resource discovery and then depletion (Grigg 1993).

A. Type of fisheries

All harvesting of *Corallium* spp. in the Pacific Islands is commercial in nature either the result of dedicated coral harvesting operations or a bycatch product of trawl fisheries (except in the U.S. EEZ). The deep depth and remote location of *Corallium* spp. resources requires a significant capital investment for ship time and collecting gear effectively excluding harvesting for artisanal or subsistence use.

B. Estimated number of coral harvesters

The size of the foreign fleet operating in the region has varied widely over history depending on the discovery of coral resources. In 1978, the "coral rush" to harvest the *Corallium* spp. discovered at Midway Grounds (Emperor Seamounts) involved more than 100 boats from Japan and Taiwan working the area until 1984 when the resource was depleted (Grigg 1993). Currently no foreign coral harvesting is known to be occurring in the region. All domestic harvesters of *Corallium* spp. in Hawaii function under a federal permit and the regulations require landing and sales reports be filed (see appended forms). Since the 1980 implementation of the FMP, there has never been more than one harvester operating simultaneously.

C. Types of gear used

Initially all harvesting, foreign and domestic, used dredges or what were called tangle nets. These were often sections of pipe or other source of weight with nets attached. The gear would be dragged along the bottom as the vessel drifted or motored to dislodge, entangle and recover the coral colonies. To reduce ecological damage and improve the sustainability of the Hawaii fishery, the University of Hawaii developed a selective harvesting system employing a manned submersible. Commercial harvesters (Maui Divers of Hawaii) used this system to make annual landings of *Corallium* spp. and other corals until the operation was discontinued in 1978 because of high insurance related operating costs. The Hawaiian *Corallium* fishery remained dormant until it was revived by American Deepwater Engineering (ADE). ADE used two one-person submersibles to exploit the only established commercial bed (Makapu'u bed) and an exploratory area (Keahole bed) in 1999–2000. Fishing activities ended due to marginal investment returns and loss of potential fishing ground due to the 2000 declaration of the Northwestern Hawaiian Islands as a Coral Reef Ecosystem Reserve per Executive Order 13196 (Grigg 2002). In 2002, the Hawaii precious coral fishery management plan was amended to prohibit the use of nonselective gear (e.g. tangle nets, dredges) throughout the U.S. Pacific Islands management area.

D. Landings

In the mid 1960s most of the *Corallium* landings came from the Milwaukee Banks and surrounding seamounts in the Emperor Seamount chain 800 km northwest of Midway Island in the Hawaiian Archipelago (Grigg 1993). Harvests of *Corallium secundum* peaked at 150 t in 1969, but remained low for the next few years until an un-described deep water species (Midway coral, *Corallium sp.*) was discovered at 900–1500 m depth. Landings climbed to 300 t in 1981 (Grigg 1993) flooding the market with Midway coral, and prices fell making coral fishing less economically viable. Landings dropped to ~84 t, causing an increase in demand and the fishing persisted annually until yield dropped to 20–30 t and ended with 3 t in 1988 (FAO 1983). Part of the 1988 harvest (500 kg *C. secundum*) was obtained from Hancock Seamount most of which were considered poor quality (Grigg 1993). In 1991, less than 3 t of precious coral production was recorded Pacific wide (FAO 1983, Grigg 1993), suggesting overexploitation of all known beds.

The Hawaiian fishery for *Corallium* has been primarily limited to a single bed of pink coral (*Corallium secundum*) at 400 m off Makapu'u, Oahu. A total of 8227 kg of pink coral was removed between 1973 and 1978 (Grigg 1993). Because the Hawaiian fishery is a single company, confidentiality rules prevent reporting of landings data. However, Grigg working closely with the industry has provided some historical record of what was harvested (Table 1). During the most recent episode (1999-2000) the permitted quota was not filled at either of the two beds where corals were collected. Grigg (2002), reported removal of 60% of the allowed coral quota (1216 kg) at the Makapu'u Bed and 20% (211 kg) at the Keahole Bed. The Hawaiian precious coral fishery remains dormant today although a permit was issued in 2009 for Makapu'u coral bed. The permit holder is looking to use remote operated vehicles (ROV) as a harvesting tool.

Table 1. Harvesting history for kilograms of *Corallium* spp. in the Hawaiian precious coral fishery.

Period of Harvest	Company	Gear	*C. secundum*	*C. regale*
1966-69	United fishing	Dredge	1800	0
1973-1978	Maui Divers of Hawaii	Submersible	6427	0
1988	Vessel Aukai	Dredge	500	0
1999-2001	American Divers	Submersible	1216	61

E. Locations open and closed to fishing

With the recent establishment of four National Marine Monuments in the U.S. Pacific Islands more areas are closed than are open to coral harvesting. Closure of the Northwestern Hawaiian Islands protects the *Corallium* spp. beds that have been recently visually surveyed identified as far north as Seamount 11 (NW of Midway) (Parrish and Baco 2007). The presence of *Corallium* spp. in the Monuments of the Line and Phoenix Islands, Rose Atoll, and the Northern Marianas are unknown. Areas left open to commercial coral harvesting include the Main Hawaiian Islands, American

Samoa, Guam, Rota, Tinian, and Saipan. Other than the Hawaiian Archipelago, the presence of *Corallium* spp. is undocumented in the rest of the U.S. Pacific Islands currently open to harvest.

F. Management regimes

Coral harvesting on high seas seamounts adjacent to the U.S. Pacific islands EEZ is subject to international fleets and is unregulated and unmonitored. International panels have been formed to begin assessing impacts to identify vulnerable marine ecosystems (VME) in international waters. Of particular interest are seamounts and their deep coral habitats. Currently there is little information other than the history of coral landings with which to evaluate the condition of deep corals in international waters.

Fishery management in the U.S. Pacific Islands is the responsibility of the Western Pacific Fishery Management Council (WPFMC 2007). The council prepares and administers fishery management plans (FMPs) for conserving and managing fishery resources within the 3 to 200 mile U.S. exclusive economic zone (EEZ). The WPFMC and other U.S. regional management councils were empowered by the 1976 Fishery Conservation and Management Act (FCMA) (later called the Magnuson-Stevens Act (MSA)). Deep corals also occur within state and territorial waters, and can be governed by their laws and regulations. In Hawaii, both WPFMC and the State of Hawaii work to develop rules and regulations that are congruent and manage the fishery as a biological unit. The Precious Coral FMP classifies known coral beds within the Western Pacific region and designates the amount of corals that can be harvested from each bed. All the known coral beds are located in the Hawaiian Archipelago but the FMP includes provisions for exploratory fishing in other areas of the U.S. Pacific. The beds are classified as: 1) Established Beds, 2) Conditional Beds, 3) Refugia Beds, and 4) Exploratory Permit Areas. Established beds have a history of harvest for which fishery control points can be established such as maximum sustainable yield (MSY) or optimal yield (OY). Makapu'u and the Auau Channel (which is shallow black coral only) are the only designated Established precious coral Beds in the FMP. Conditional beds have MSYs estimated based on their perceived size relative to established beds. There are four conditional beds: Keahole Point, Kaena Point, Brooks Banks and 180 Fathom Bank. Weight quotas and colony size limits were implemented for Established and Conditional Beds. The WESTPAC Bed is designated as a refugia bed, where no harvest is permitted. With the designation of the Northwestern Hawaiian Islands as a National Marine Monument, the beds located within (Brooks Banks, 180 Fathom Bank and WESTPAC) are closed to harvesting. Exploratory permit areas were established for the unexplored portions of the U.S. EEZ. These include areas of Hawaii, Guam and CNMI, American Samoa, and all remaining U.S. Island Possessions. The allowable take for Exploratory Beds was arbitrarily set at 1000 kg as a cost-share incentive for exploration. Much of this exploratory area has since been set aside as National Marine Monuments prohibiting coral harvesting.

G. Monitoring and enforcement of fisheries

All harvesting and sales of precious coral are reported in a standardized reporting logs (appended forms) and coral harvesting vessels and catch are subject to inspection by enforcement agents of the National Marine Fisheries Service and/or State of Hawaii.

H. Problems with existing fisheries, including illegal harvest

Currently, there are no reports or rumors of illegal coral harvesting. However, in the past Japanese and Taiwanese coral draggers were very active in the Emperor Seamounts beginning in 1965 and continuing into the 70s and even the 80s, with sporadic reports of their entry into U.S. waters within the 200 mile EEZ (Grigg 1993). One documented event occurred in 1978 at Hancock Seamount just inside the 200 mile U.S. EEZ. A Coast Guard flight carrying NMFS enforcement agents photographed two Japanese coral draggers, the Hoku Maru and the Manpuku No.18. Much of the U.S. Pacific Island region is remote and unpopulated and such activity could go undetected. Given the slow growth of deep corals and low recruitment rates, even brief periods of illegal dredging could have lasting effects.

3. Extent of international trade

A. Type of products in trade, volumes of export and import, and origin

The U.S. is a large importer of precious corals, including un-worked coral as raw material for crafting jewelry. Corals are supplied to jewelry manufacturers as whole colonies, branches, or polished beads. The Hawaiian precious coral industry imports a portion of its raw material including *Corallium* spp. from international sources generating an estimated $30 million/year in revenue at the retail level (Grigg pers comm. 2009). In 2002 there was a spike in the export of *Corallium* spp. from Italy into the U.S. about five times higher than previous and following years. It is not known if this is marketing of a stockpile or discovery and harvesting of a new coral bed. Italy and China exported about 90% of all their precious corals to the U.S., where Italy's contribution decreased from 50% in 2002 to less than 4% in 2006. Purchase of coral from Thailand has risen from 0.2% in 2001 to 5% in 2006. China and Taiwan sent 84% of 1,807,357 precious coral products into the U.S. in 2006.

B. Number and type of industry representatives (buyers, jewelers, exporters, etc.)

In spite of various logistical and economic limitations over the past 50 years, the precious coral industry in the State of Hawaii has grown to $70 million annually and employs over 1000 people (Grigg pers comm. 2009). Hawaii has one large retailer, Maui Divers, as well as some small businesses selling *Corallium* products. It is undocumented how much of these products are imported rather than domestically harvested.

C. Information on value, retail, and wholesale prices

Finally, the value of the resource itself, can vary between $100 and $1000/kg (Grigg 2002), and has always been marginally sufficient to produce sustainable profits for the industry.

4. CITES considerations

A. Feasibility of implementing a CITES listing

Although an anecdotal proposal, both the FAO *ad hoc* Expert Advisory Panel as well as the CITES expert panel agreed on the significance of conserving the genus *Corallium* (CITES 2007). These models could be used to reduce yields and preserve habitat complexity and biodiversity. The conservative management plans conflict with short-term socioeconomic interests and decision makers therefore hesitate to implement them (Bearzi 2007). Ideally, conservation of *Corallium* spp. resources should be undertaken at the local level but most places don't have the resources needed to monitor and enforce regulation properly and the international fishery on the high seas remains largely unregulated. Despite the lack of needed resources locally-based management is likely the most effective solution to conserving *Corallium* spp, and the wider deep coral community. However, CITES can offer advantages for the management of a species. CITES was developed for the regulation of trade and is largely a reaction to the lack of resource management on a broad scale. Coral fisheries have very unique dynamics unlike most fisheries. The harvested product has a long shelf life, can be processed in multiple countries and is manufactured into several types of products that are difficult to identify. Monitoring the trade of these types of products can provide useful data on the patterns and source of raw material. These patterns may provide useful insight on potential impacts of such harvest and highlight areas or regions of most concern.

B. Gaps and uncertainty concerning CITES

An international venue such a CITES is really the only means to bring attention to the issues of *Corallium* spp. worldwide. However there are real challenges to successful implementation of CITES, including:

- Species identification problems particularly for coral material that has been polished where many of the characters used for identification are removed.
- Inability to track the use of ground coral fragments in resin composites for jewelry pieces.
- How to deal with coral stockpiled in warehouses from historical fishing.
- An inability to determine the origin of coral.
- The impact of CITES regulation on shipping raw and worked products (including finished jewelry) of U.S. businesses that currently operate under regulation.
- Concern that CITES will be adopted in place of implementing other local conservation efforts such as fishery management or enforcement.

C. CITES problems and solutions for black coral.

Black coral has been listed under CITES appendix two for more than two decades (1981) and a review of trade and enforcement records could indicate the degree of difficulty with listing of *Corallium* spp. Particularly, it would be beneficial to look at the volume of trade, seizures of material that is clearly illegal, and problems with moving finished jewelry in business and as personal effects. As trade in black coral has continued since the CITES listing a review of the impacts and effectiveness would bring insight to the challenges of listing the genera *Corallium*.

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APPENDIX

1 – Western Pacific Precious Coral Harvest Log Report

2 – Instructions Precious coral Harvest Log Report

3 – Western Pacific Coral Sales Log Report

4 – Instructions Western Pacific Precious coral sales report

5 – *Corallium* Fishery Regulations for the Western Pacific Region

OMB NUMBER: 0648-0214
Expiration Date: 2/10/10
Logsheet Serial No. 000001

NOAA National Marine Fisheries Service

Western Pacific Precious Coral Daily Harvest Log

Collector/Company Name:____
Vessel Name:____________ PERMIT NO.:________ Radio call sign:_______
Date of Harvest:________ Harvest method:__________ Area Fished:_________
Start time (24 hr clock):_______ Start Lat.:__________ Start Lon.:__________
End time (24 hr clock):_______ End Lat.:__________ End Lon.:__________
Harvest depth range (fathoms-max/min):________/_________
Number of Dives:______ No. of hours fished (bottom time):____________
Port of Landing: ____________________________________
Video Record Provided: ( )Yes/( )No (applies to submersible/ROV harvest only)

Catch Information

Common Name	Species (names subject to change)	Number of Coral Trees Harvested	Weight Harvested (pounds)
Pink Coral	*Corallium secundum*		
	Corallium regale		
	Corallium laauense		
Gold Coral	*Gerardia* sp.		
	Callogorgia gilberti		
	Narella sp.		
	Calyptrophora sp.		
Bamboo Coral	*Lepidisis olapa*		
	Acanella sp.		
Black Coral	*Antipathes* sp.		
	A. dichtoma		
	A. grandis		
Comments: (current, bottom type, bottom topography, bottom slope, proximity to land, etc.)			

Marine Mammal/Other Species Interactions

(Enter numbers; please identify in appropriate box)	Marine Mammal	Other
Observed in area		
Observed in vicinity of gear		
Interfering with fishing operations		
Other interactions (specify type)		

Logged by Vessel Captain/Operator
Print name:____________________________ Date: _____________
Signature:____
Please submit to: Pacific Islands Fisheries Science Center, ATTN: FMAP, 2570 Dole St., Honolulu, HI 96822.

INSTRUCTIONS FOR COMPLETING THE WESTERN PACIFIC PRECIOUS CORAL HARVEST LOG REPORT

Effort information

COLLECTOR/COMPANY NAME: Individual name (black coral diver), company name of submersible/ROV.
VESSEL NAME: Name of support vessel.
PERMIT NO.: Western Pacific Crustacean Fishery Permit number.
RADIO CALL SIGN: Radio call sign.
DATE OF HARVEST: Date of precious coral harvest.
HARVEST METHOD: Precious coral harvest method, i.e. submersible, hand harvest.
AREA FISHED: General area fished, i.e. island or bank name and location.
START TIME: Start time (24 hour clock) of harvesting operations.
START LATITUDE, START LONGITUDE: Start location of harvest operations.
END TIME: End time (24 hour clock) of harvesting operations.
END LATITUDE, END LONGITUDE: End location of harvest operations.
HARVEST DEPTH RANGE: Maximum and minimum depth of harvest operations (fathoms).
NUMBER OF DIVES: Number of dives conducted in the day.
NO. OF HOURS FISHED (bottom time): Total bottom time of harvesting (all dives combined).
PORT OF LANDING: Port of vessel return (e.g., Honolulu, Hilo, Kodiak, Los Angeles, etc.).
VIDEO RECORD PROVIDED: Check the appropriate box if submersible or ROV dive video is submitted with the report.

Catch Information

NUMBER OF CORAL TREES HARVESTED: Total number of coral trees harvested, tallied by individual species groups.
WEIGHT HARVESTED (lbs): Total wet weight of coral trees harvested, tallied by individual species groups.

Marine Mammal/Other Species Interactions Observations

Enter number of individual species observed in the appropriate activity designation box. Please identify if possible.

CONTACT AND VERIFICATION INFORMATION

CAPTAIN/OPERATOR: Print full name, sign on signature line, date of report completion.

VESSEL REPORTING OBLIGATION REQUIREMENTS

The operator of any fishing vessel subject to the requirements of the Code of Federal Regulations, Title 50, Section 665.81 must maintain onboard the vessel an accurate and complete record of catch, effort, and other data on report forms provided by the Regional Administrator. All information specified on the forms must be recorded on the forms within 24 hours after the completion of each fishing day. Each form must be signed and dated by the fishing vessel operator. The original logbook form must be submitted to the National Marine Fisheries Service within 72 hours of each landing of management unit species. **Submit log report to: Pacific Islands Fisheries Science Center, ATTN: FMAP, 2570 Dole St., Honolulu, HI 96822.**

OMB NUMBER: 0648-0214
Expiration Date: 2/10/10

NOAA National Marine Fisheries Service

Western Pacific Precious Coral Sales Log

Seller Information

Collector/Company name:____________________

Vessel name:__________ Permit Number:__________

Date of Landing:__________ Port of Landing:__________

Buyer Information (Fill out a separate form for each buyer)

Name of Buyer:____________________

Business Address:____________________

____

Telephone: (____)__________

FAX: (____)__________

E-mail:__________

Sales Information

Common Name	Species Name (subject to change)	Number of Coral Trees Sold	Weight Sold (pounds)	REVENUE ($$$)	DATE OF SALE
Pink Coral	*Corallium secundum*				
	Corallium regale				
	Corallium laauense				
Gold Coral	*Gerardia* sp.				
	Callogorgia gilberti				
	Narella sp.				
	Calyptrophora sp.				
Bamboo Coral	*Lepidisis olapa*				
	Acanella sp.				
Black Coral	*Antipathes* sp.				
	A. dichtoma				
	A. grandis				
Other(specify)					

Captain/Operator/Agent

Print name:____________________

Signature:__________ **Date:** __________

Submit form to: Pacific Islands Fisheries Science Center, ATTN: FMAP, 2570 Dole St., Honolulu, HI 96822

INSTRUCTIONS FOR COMPLETING THE WESTERN PACIFIC PRECIOUS CORAL SALES REPORT

Seller Information

Collector/Company name: Individual name (black coral diver), company name of submersible/ROV.
VESSEL NAME: Name of support vessel.
PERMIT NUMBER: Western Pacific Precious Coral Permit number.
DATE OF LANDING: Date of vessel return to port.
PORT OF LANDING: Port of vessel return (e.g., Honolulu, Hilo, Kodiak, Los Angeles, etc.).

Buyer Information

NAME OF BUYER: Name of the first level buyer, i.e. initial buyer of the product from the permit holder. ***Fill out separate Sales Form for each buyer.***
BUSINESS ADDRESS: Address of first level buyer.
TELEPHONE: Business or other contact telephone number of ***first level buyer***

> ***First level buyer***: (1) the first person who purchases, with the intention to resell management unit species or portions thereof that were harvested by a vessel that holds a valid permit or is otherwise regulated under Subpart D of 50 CFR Part 665; or (2) a person who provides recordkeeping, purchase, or sales assistance in the first transaction involving management unit species (such as the services provided by a wholesale auction facility).

FAX: FAX number of the first level buyer.
E-MAIL: e-mail address of first level buyer.

SALES INFORMATION

Values should be input into the correct column matching the species and product form.
SPECIES NAME: If species is not listed then fill in the species in the "Other (specify)" box.
NUMBER OF CORAL TREES SOLD: Number of live coral colonies removed from the bottom.
WEIGHT SOLD (lb): List total weight sold in pounds.
REVENUE: Total value ($) of the product.
DATE OF SALE: Date of product sale.
CAPTAIN/OPERATOR/AGENT: Print full name, sign on signature line, date of report completion.

VESSEL SALES REPORTING OBLIGATION REQUIREMENTS

The operator of any fishing vessel subject to the requirements of the Code of Federal Regulations, Title 50, Section 665.41 must submit to the National Marine Fisheries Service, within 72 hours of offloading of crustacean management unit species, an accurate and complete sales report on a form provided by the Regional Administrator. The form must be signed and dated by the fishing vessel operator. **Submit form to: Pacific Islands Fisheries Science Center, ATTN: FMAP, 2570 Dole St., Honolulu, HI 96822.**

Upon request any first level buyer must allow an authorized officer of the National Marine Fisheries Service or designee of the Regional Administrator to access, inspect, and copy all records relating to the harvest, sale, or transfer of any product taken by a vessel that has permits issued under 50 CFR 665.41.

Corallium Fishery Regulations for the Western Pacific Region

The Fishery Management Plan (FMP) for the precious corals fisheries of the western Pacific region was implemented in September 1983 (48 FR 39229). It established the plan's management unit species and management area, as well as classifying several known beds.

Amendment 1 to the FMP became effective July 21, 1988 (50 FR 27519) and applied the management measures of the FMP to the Pacific Remote Island Areas (Palmyra and Johnston Atolls, and Wake, Kingman, Jarvis, Baker, and Howland Islands) by incorporating them into a single Exploratory Permit Area, expanded the management unit species to include all species of the genus *Corallium*, and outlined provisions for the issuance of experimental fishing permits designed to stimulate the domestic fishery.

Amendment 2 to the FMP became effective January 22, 1991 (56 FR 3072, January 28, 1991) and defined overfishing for Established beds as follows: An Established bed shall be deemed overfished with respect to recruitment when the total spawning biomass (all species combined) has been reduced to 20% of its unfished condition. This definition applies to all species of precious corals and is based on cohort analysis of the pink coral, *Corallium secundum*.

The following *Corallium* regulations are listed in the Code of Federal Regulations (see 50 CFR 665 for complete precious corals regulations):

Subpart B Western Pacific Fisheries General

Precious coral means any coral of the genus Corallium in addition to the following species of corals:

Common name	Scientific name
Pink coral (also known as red coral)......	*Corallium secundum*.
Pink coral (also known as red coral)......	*Corallium regale*.
Pink coral (also known as red coral)......	*Corallium laauense*.

Precious coral permit area means the area encompassing the precious coral beds in the management area. Each bed is designated by a permit area code and assigned to one of the following four categories:

(1) Established beds. (i) Makapu'u (Oahu), Permit Area E-B-1, includes the area within a radius of 2.0 nm of a point at 21[deg] 18.0[min] N. lat., 157[deg] 32.5[min] W. long.

(ii) Au'au Channel (Maui), Permit Area E-B-2, includes the area west and south of a point at 21[deg] 10[min] N. lat., 156[deg] 40[min] W. long., and east of a point at 21[deg] N. lat., 157[deg] W. long., and west and north of a point at 20[deg] 45[min] N. lat., 156[deg] 40[min] W. long.

(2) Conditional beds. (i) Keahole Point (Hawaii), Permit Area C-B-1, includes the area within a radius of 0.5 nm of a point at 19[deg]46.0[min] N. lat., 156[deg]06.0[min] W. long.

(ii) Kaena Point (Oahu), Permit Area C-B-2, includes the area within a radius of 0.5 nm of a point at 21[deg]35.4[min] N. lat., 158[deg]22.9[min] W. long.

(iii) Brooks Bank, Permit Area C-B-3, includes the area within a radius of 2.0 nm of a point at 24[deg] 06.0[min] N. lat., 166[deg]48.0[min] W. long.
(iv) 180 Fathom Bank, Permit Area C-B-4, N.W. of Kure Atoll, includes the area within a radius of 2.0 nm of a point at 28[deg]50.2[min] N. lat., 178[deg]53.4[min] W. long.
(3) Refugia. Westpac Bed, Permit Area R-1, includes the area within a radius of 2.0 nm of a point at 23[deg] 18[min] N. lat., 162[deg]35[min] W. long.
(4) Exploratory areas. (1) Permit Area X-P-H includes all coral beds, other than established beds, conditional beds, or refugia, in the EEZ seaward of the State of Hawaii.
(ii) Permit Area X-P-AS includes all coral beds, other than established beds, conditional beds, or refugia, in the EEZ seaward of American Samoa.
(iii) Permit Area X-P-G includes all coral beds, other than established beds, conditional beds, or refugia, in the EEZ seaward of Guam.
(iv) Permit Area X-P-PI includes all coral beds, other than established beds, conditional beds, or refugia, in the EEZ seaward of the U.S. Pacific Island possessions.
(v) Permit Area X-P-CNMI includes all coral beds, other than established beds, conditional beds, or refugia, in the EEZ seaward of points 3 nautical miles from the shoreline of the CNMI.

Subpart F Precious Corals Fisheries

Sec. 665.81 Permits.
(a) Any vessel of the United States fishing for, taking, or retaining precious coral in any precious coral permit area must have a permit issued under Sec. 665.13.
(b) Each permit will be valid for fishing only in the permit area specified on the permit. Precious Coral Permit Areas are defined in Sec. 665.12.
(c) No more than one permit will be valid for any one vessel at any one time.
(d) No more than one permit will be valid for any one person at any one time.
(e) The holder of a valid permit to fish one permit area may obtain a permit to fish another permit area only upon surrendering to the Regional Administrator any current permit for the precious corals fishery issued under Sec. 665.13.
(f) General requirements governing application information, issuance, fees, expiration, replacement, transfer, alteration, display, sanctions, and appeals for permits for the precious corals fishery are contained in Sec. 665.13.

Sec. 665.82 Prohibitions.
In addition to the general prohibitions specified in Sec. 600.725 of this chapter and in Sec. 665.15, it is unlawful for any person to:
(a) Use any vessel to fish for, take, retain, possess or land precious coral in any precious coral permit area, unless a permit has been issued for that vessel and area as specified in Sec. 665.13 and that permit is on board the vessel.
(b) Fish for, take, or retain any species of precious coral in any precious coral permit area:
(1) By means of gear or methods prohibited by Sec. 665.88.
(2) In refugia specified in Sec. 665.12.
(3) In a bed for which the quota specified in Sec. 665.84 has been attained.
(4) In violation of any permit issued under Sec. 665.13 or Sec. 665.17.
(5) In a bed that has been closed pursuant to Sec. Sec. 665.85 or
665.90.
(c) Take and retain, possess, or land any live pink coral or live black coral from any precious coral

permit area that is less than the minimum height specified in Sec. 665.86 unless:
(1) A valid EFP was issued under Sec. 665.17 for the vessel and the vessel was operating under the terms of the permit; or
(2) The coral originated outside coral beds listed in this paragraph, and this can be demonstrated through receipts of purchase, invoices, or other documentation.

Sec. 665.83 Seasons.
The fishing year for precious corals begins on July 1 and ends on June 30 the following year, except at the Makapu'u and Au'au Channel Beds, which have a two-year fishing period that begins July 1 and ends June 30, two years later.

Sec. 665.84 Quotas.
(a) General. The quotas limiting the amount of precious coral that may be taken in any precious coral permit area during the fishing year are listed in Table 1 of this part. Only live coral is counted toward the quota. The accounting period for all quotas begins July 1, 1983.
(b) Conditional bed closure. A conditional bed will be closed to all nonselective coral harvesting after the quota for one species of coral has been taken.
(c) Reserves and reserve release. The quotas for exploratory areas will be held in reserve for harvest by vessels of the United States in the following manner:
(1) At the start of the fishing year, the reserve for each of the three exploratory areas will equal the quota minus the estimated domestic annual harvest for that year.
(2) As soon as practicable after December 31 each year, the Regional Administrator will determine the amount harvested by vessels of the United States between July 1 and December 31 of that year.

Sec. 665.85 Closures.
(a) If the Regional Administrator determines that the harvest quota for any coral bed will be reached prior to the end of the fishing year, or the end of the 2-year fishing period at Makapu'u Bed or Au'au Channel Bed, NMFS shall publish a notice to that effect in the Federal Register and shall use other means to notify permit holders. Any such notice must indicate the reason for the closure, the bed being closed, and the effective date of the closure.
(b) A closure is also effective for a permit holder upon the permit holder's actual harvest of the applicable quota.

Sec. 665.86 Size restrictions.
The height of a live coral specimen shall be determined by a straight line measurement taken from its base to its most distal extremity. The stem diameter of a living coral specimen shall be determined by measuring the greatest diameter of the stem at a point no less than 1 inch (2.54 cm) from the top surface of the living holdfast.
(a) Live pink coral harvested from any precious coral permit area must have attained a minimum height of 10 inches (25.4 cm).

Sec. 665.87 Area restrictions.
Fishing for coral on the WestPac Bed is not allowed. The specific area closed to fishing is all waters within a 2-nm radius of the midpoint of 23[deg]18.0[min] N. lat., 162[deg]35.0[min] W. long.

Sec. 665.88 Gear restrictions.
Only selective gear may be used to harvest coral from any precious coral permit area.

TABLE 1 TO PART 665—PRECIOUS CORAL QUOTAS

Type of coral bed	Name of coral bed	Harvest quota in kilograms	Number of years
Established Beds	Au'au Channel	Black: 5,000	2
	Makapu'u	Pink: 2,000	2
		Gold: 0 (zero)	--
		Bamboo: 500	2
Conditional Beds	180 Fathom Bank	Pink: 222	1
		Gold: 67	1
		Bamboo: 56	1
	Brooks Bank	Pink: 17	1
		Gold: 133	1
		Bamboo: 111	1
	Kaena Point	Pink: 67	1
		Gold: 20	1
		Bamboo: 17	1
	Keahole Point	Pink: 67	1
		Gold: 20	1
		Bamboo: 17	1
Refugia	Westpac	All: 0 (zero)	--
Exploratory Areas	Hawaii, American Samoa, Guam, CNMI, U.S. Pacific Remote Island Areas	1,000 per area (all species combined except black corals)	1

Notes:
1. No fishing for coral is authorized in refugia.
2. A moratorium on gold coral harvesting is in effect through June 30, 2013.

Mediterranean Red Coral

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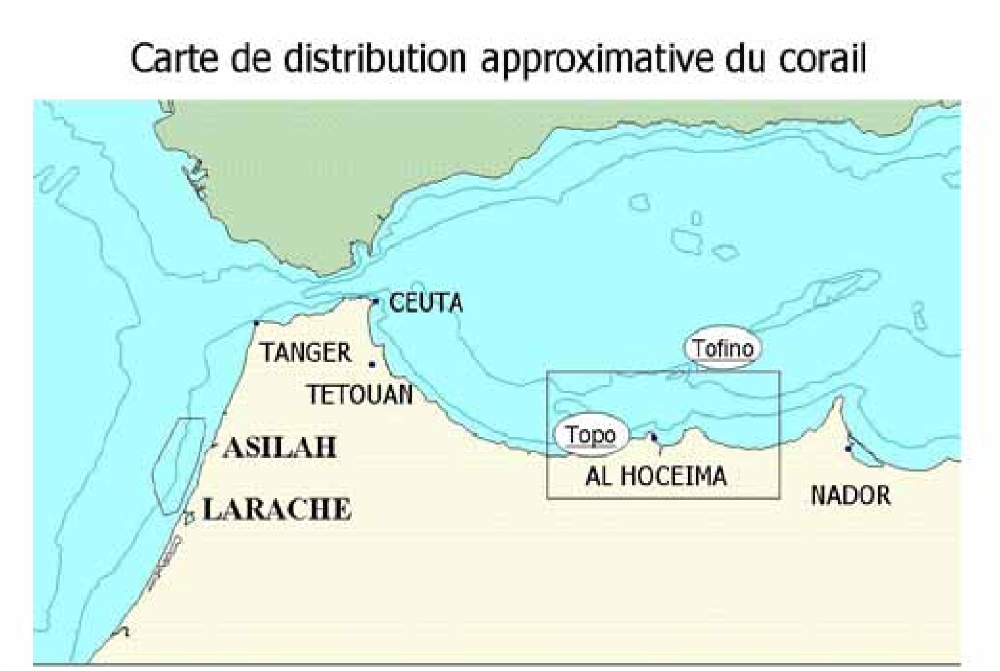
1. Introduction

Red coral, *Corallium rubrum*, is an endemic marine animal of the Mediterranean. This animal makes cylindrical arborescent colonies of red color, is equipped with tentacles directed in all directions, and populates rocks, sandy and volcanic sites, and overhangs the roofs of caves.

Red coral contributes to the biodiversity of marine flora. Moroccan Mediterranean coasts have the privilege to still shelter fields of this species which has been very appreciated for a long time. However, this typically Mediterranean species is also observed along the Moroccan Atlantic side – in particular in the area ranging between Tangier and Larache. There also exist other areas in the south of Morocco, which can shelter red coral and will be the subject of later prospections.

The exploitation of red coral in Morocco shows rather original economic characteristics by comparison to other maritime resources. It is a rare resource, in great demand within the jewelry industry, and not easily renewable.



Distribution map of red coral.

Since its discovery in the Moroccan Mediterranean, red coral has been subjected to an intense and irresponsible exploitation – of which the harmful effects became very apparent and showed that the output seems not to be adequate with the renewal of this resource, which is characterized by very slow growth. However, a new strategy of exploitation and a better valuation of the resource were established to ensure the protection and durability of this resource.

2. History of coral exploitation

In Morocco, the exploitation of coral started in the 1970s by foreigners in the zone of Al Hoceima. During these years, the exploitation of coral was done by 2-10 boats (corailleurs), some of which were chartered.

During the 1980s, the zone of Al Hoceima was the most prosperous zone for red coral exploitation (8.6 tons in 1985) which was completely exported in a raw, unworked state. In 3-4 years, the production decreased.

During the 1990s, coral landings continued to fall, with the number of trips from 1991-1992 numbering between 9-23 trips per month. The catch per trip shows a variability ranging between 2 and 6 kg.

In 1992, out of the 146 trips carried out, 80% were in the area of Tofino with a catch of 3.4 kg/trip, and 20% of the trips were in the area of Topos with a harvest of 2.1 kg/trip. The average harvest was 3 kg/trip.

In demographic structure, the Mediterranean area was not interesting anymore because the collected colonies became very small sizes. Consequently, their commercial value fell, which encouraged the 13 units exploiting the coral to change their zone of activity from M'diq and then towards the Atlantic zone.

In 2004, the national fleet again became active in the Al Hoceima zone after a 12 year hiatus. This recovery started in the zone of Topo, which is a coastal area with 6 nautical miles in the Al Hoceima West. After one year of exploitation at this site, the outputs showed a fall which pushed the operators to be directed again towards the broad one with approximately 25 nautical Al Hoceima miles in the area known as Tofino. The latter was the subject of a study through an evaluation campaign carried out in 2003 by two coral boats.

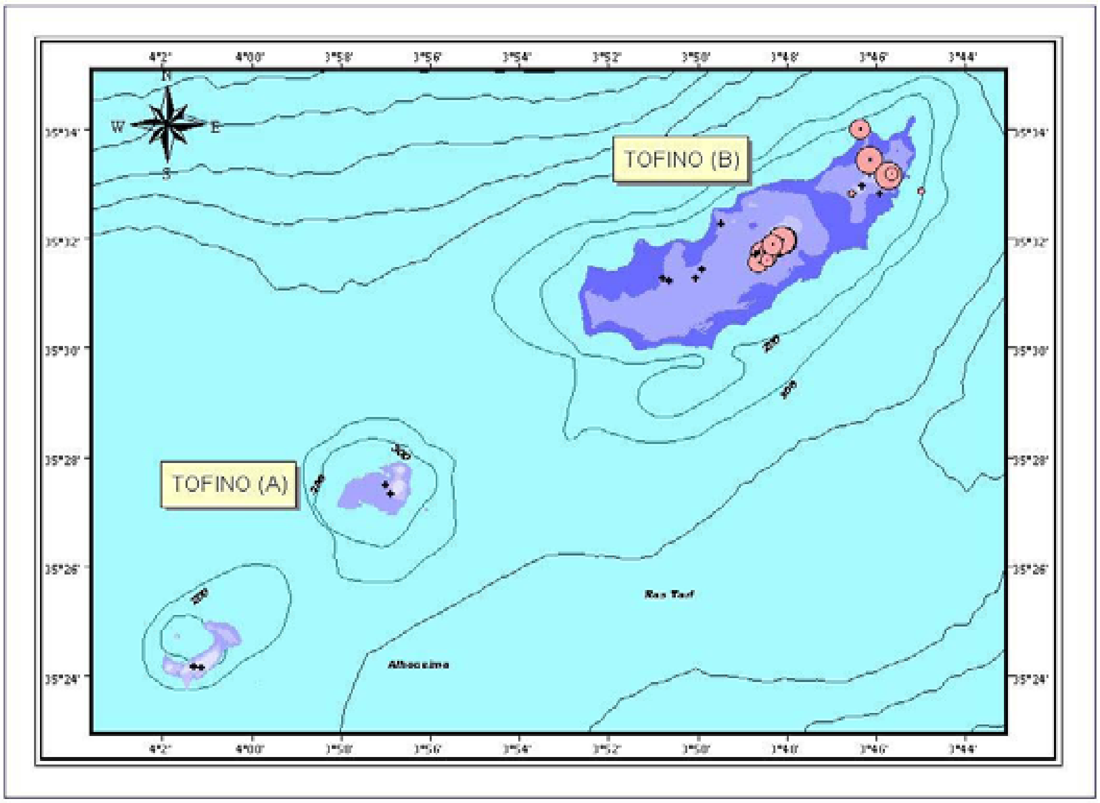
3. Characteristics of the red coral of the Mediterranean

Red coral is a sessile species, completely dependent on the microcirculations of the currents as vectors of food, and it is a passive filterer which traps the small planktonic prey in its tentacles and paralyses them with its nematocysts. The species is able to assimilate the dissolved organic matter of sea water (Allemand 1993a).

The skeleton of red coral is made primarily (85% of the wet weight) of calcium carbonate in the form of calcite. It also includes 5% of other elements such as Mg, Fe, K, SO_4, P_2O_5, SiO_2, Pb, Zn (Maté 1986), and an organic matrix (Allemand et al. 1993b).

The more or less dense red color of the coral is due to carotenoid pigments and not to ferric oxides as it is sometimes believed (Merlin and Dele 1983).

The reproduction of red coral was well studied by Vighi (1972). The sexes are separate; the maturity of female gametes lasts 2 years, while those of the male gonads last 1 year. Reproduction takes place from May to September. Sexual maturity is early and it is acquired at the end the age of 2 years, even though the branches are still very small and only 2 to 3 cm (Vighi 1972).

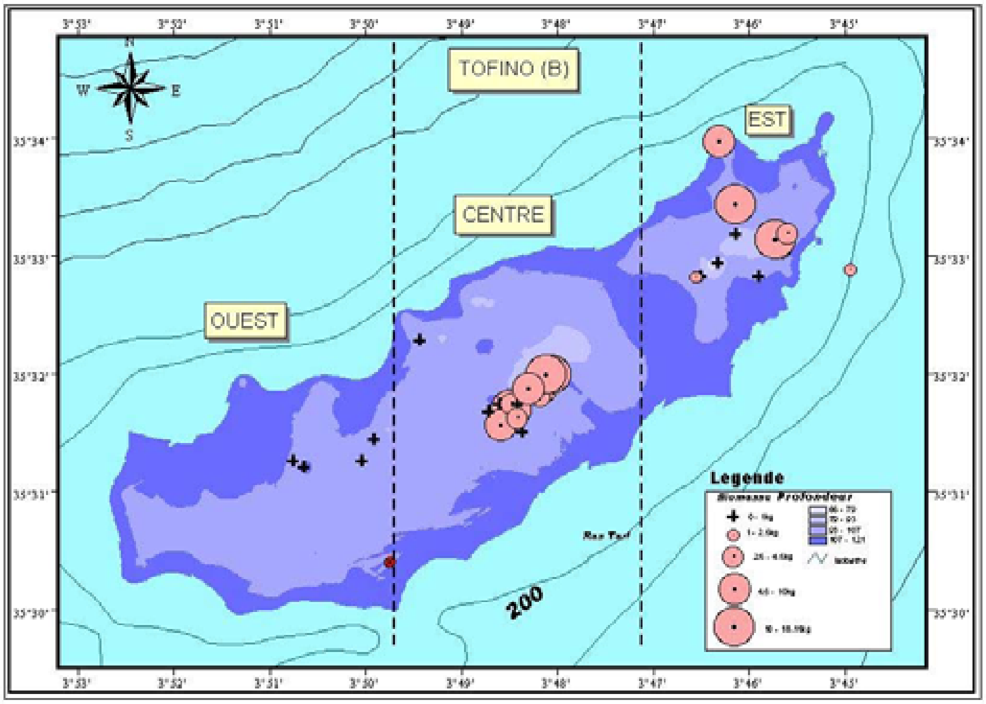


Map 1. Prospection zone

The repopulation of the coral is ensured by the larva, called “planula,” released at the period of 20-30 days. The larva, which has a 1-2 mm length ciliated blister, will swim at the sea waters, and because its lifespan is considered short, it tends to be fixed very quickly after being emitted. In the laboratory, it remains alive 10 days (Grillo and Chessa 1992).

Somewhat recent studies (Abbiati et al. 1993, 1995) showed that genetic flow between the geographically isolated populations is reduced and populations tend to be genetically different.

In Morocco, the red coral of Al Hoceima is characterized by a discontinuous distribution with wide gaps, and surfaces whose abundance is more or points large, with very accessible depths at 40 m to TOPO and beyond 90 m in TOFINO (Dridi and Slimani 2003).



Map 2. Zones of Tofino

4. Prospection surveys of the coral fields

In order to allow the renewal activity of exploiting the coral, the INRH carried out, in partnership with the profession represented by the Association of Inshore Fishing and of Coral in Morocco, a survey on board two coral ships from August 15 to September 9, 2003.

The results of this evaluation survey are summarized as follows (see Map 1):

- The areas of Xauen and Tofino (A) are zones with sandy predominance not showing any trace of red coral.
- The Tofino zone (B) is characterized by strong currents. It presents a relatively important surface (56 km²) to approximate rocky predominance (8.3 km²) in the Centre sector. It is a concentrated zone of red coral. The best yield results from between 80 m and 90 m depth (see Map 2).
- The red coral has a homogeneous demographic structure with an intermediate size of 11.36 cm and an aggregate distribution.
- For responsible exploitation, it is recommended to spread out exploitation over 4 to 5 years, by fixing an annual quota.

5. The fleet exploiting coral

The fleet operating in the coral fields is specialized, and consists of small units provided with a decompression box on board and equipped with a capacity of 50 TJB.

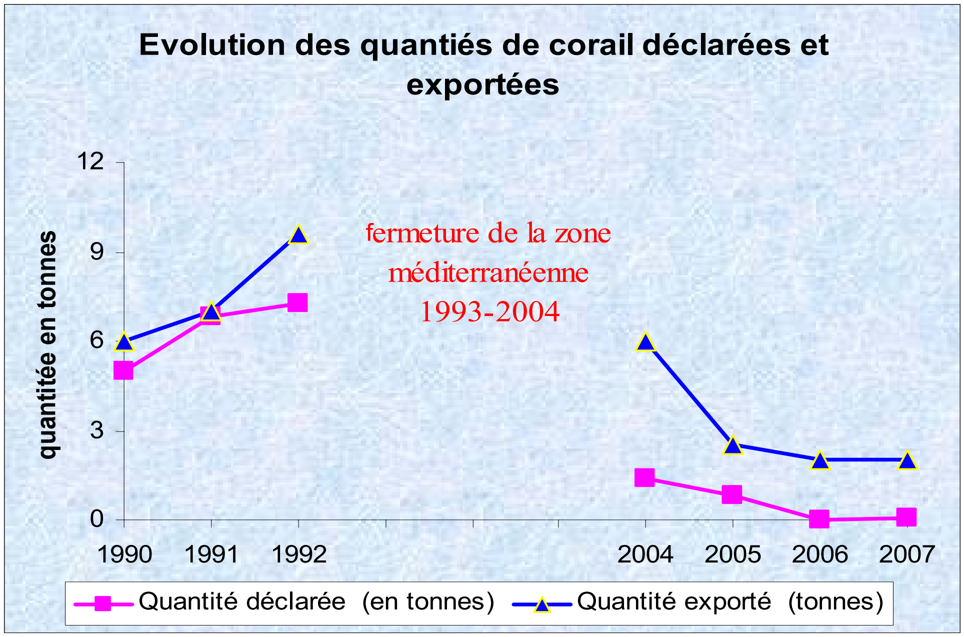


Fig. 1. Evolution of red coral production

At the beginning of exploitation, the number of coral boats was variable, oscillating between 2 and 10 boats all of which were chartered and of foreign nationality. During the 1980s, the number of coral boats rose to 17 units, only to decrease to 13 in 1991 and to become fixed at 10 boats in 1992 (freezing of investment). These boats fished in depths ranging from 30 to 80 meters.

6. Evaluation of red coral potential

The fact that red coral is a limited resource, of great longevity and of very slow growth, requires rational and adequate exploitation in harmony with the producing capacity of this ecosystem.

Red coral has undergone an intensity of harvest and very strong pressure by boats exploiting this resource (Figure 1) since its discovery.

By taking into consideration that the exploitation of red coral knows a great failure of the declarations it was necessary in 2003 to propose a quota which could decrease the pressure of harvesting this species.

7. Regulation

A. International regulation

Red coral is protected by two international regulations, relative convention with the conservation of the wild life and the natural environment of Europe (convention of Bern of 19/09/79) and the Protocol relating to the surfaces especially protected from the Mediterranean and biological diversity from the Mediterranean.

Morocco ratified the Convention of Bern (see BO n°5054 of 7-11-2002) and signed the Protocol of Barcelona 10/06/1995.

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B. National regulation

In 1916, red coral was qualified under Moroccan legislation on maritime wrecks (dahir of March 23, 1916, article 1) and belongs in entirety to article 7 and is subject to a number of conditions. This old legislation dating from the colonial period is exceeded since it is the subject of a regulatory exploitation and not of accidental lucky finds.

Considering the need for a regulation specifically aimed at the organization of exploitation of red coral, in 1992 the Ministry of Fisheries started a text project which took into account the various suggestions and observations of all speakers (INRH, of the professionals, Ministry for Finances).

Among the undertaken measures:

In 2005, with the aim of organizing coral exploitation in accordance with international regulation and its safeguards, the Ministry of Fisheries promulgated decree n° 2-04-26 of 6 hija 1425 (January 17, 2005), which fixed the conditions and procedures of 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.

Fishing is organized at the maritime region located in Al Hoceima through the decree of the Ministry of Agriculture, Rural Development, and Fisheries n° 2.655-06 of 21 choual 1427 (November 13, 2006), which regulates the exploitation of red coral by quota.

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An Overview of the Main Marine Resources (Commercial and Non-Commercial Groups) in the Moroccan Mediterranean

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1. Introduction

The Moroccan Mediterranean coast shelters varied resources, made up by commercial marine species composed by pelagic species, demersals, red coral, and shellfish resources, along with other non commercial zoological groups such as marine mammals, turtles, and more. These resources are distributed along the Mediterranean coast with an abundance that varies throughout the area.

2. Research Programmes of INRH

The research activities of the Moroccan Institute of Fisheries (INRH), at the Mediterranean, are carried out by its regional centres in Tangier and Nador.

Scientific activities relate to the study of the biology of highly valued commercial species and the cartography of their abundance, socio-economic analysis of their fisheries, the assessment of principally exploited stocks, the follow-up of the suitability of the environment and the oceanographic parameters of Mediterranean water and the study of marine biodiversity.

The follow-up of the state of the principally exploited stocks is carried out by sampling landings, by data-gathering the level of exploitation (statistics, activity of fishing), through biological data on the followed species (size frequency, maturity, etc.), and surveys on board Research Vessels. Other data are collected from other Administrations (ONP and DPM), relating to the fleets and their activities (number of days of fishing and/or fishing effort, captures and value). Additional investigations are led with fishing professionals, in particular artisenal fishers, to improve fishing statistics.

The ongoing research programs established by the INRH concern the study of large pelagic fisheries, small pelagic fisheries, the follow-up of trawl fishing, octopus fisheries, shrimp fisheries, shellfish, red coral, marine biodiversity – done by the regular follow-up of mammals and marine turtle strandings on both sides of the Straits of Gibraltar, and the interactions between cetaceans and fisheries. These programs aim to evaluate biodiversity and preserve the populations of these cetaceans. To achieve these goals, the INRH undertook actions for the installation of the network for monitoring cetaceans and strandings.

3. Main Exploited Fisheries Resources

With regard to demersals (see Map 1), the resources are the subject of multi-specific exploitation, mainly by trawlers (114 units) and artisenal fleets (2600 boats). With an average production of approximately 9000 tons, the landings are composed of a multitude of species (seabreams, red mullet, pink shrimp, hake, octopus, horse mackerel, and cuttlefish).

The small pelagics are exploited by approximately 147 units, using specific gear for fishing, but multi-species (sardine, anchovy, horse mackerel, mackerel), targeting particularly sardine (14000 tons), with a total fish production of about 30 600 tons.

The majority of long-liners carry on their activity at the Strait of Gibraltar and also at the ports of Nador and Al Hoceïma; the traps target species of swordfish and blue fin tuna, which are mostly exported to foreign markets – particularly European markets. The average capture of blue fin tuna, espadon and small tuna species for the period 2006-2007 are in intervals of 2400-3000 T, 1500-2000 T and 1722 T, respectively.

Swordfish is targeted by a coastal fleet made up of approximately 350 units, of which approximately 69% are based in the harbour of Tangier. These long-liners have an average size of approximately 13 m, an average horse power of 80 CV and an average TJB of 7. These units, which target primarily swordfish, carried out a production of about 1400 tons. Principal fishing zones of this species are in the Strait of Gibraltar. The principal ports of landings for this species are Tangier, Nador, Al Hoceïma. This species is captured by drifting gill nets, traps, and purse seines.

The tuna-like species are captured mainly by purse seines and in lesser degree by traps. Marketing of these species is done on a local scale. They are intended either for local fresh consumption or for processing industries. Only 8% of these species are captured in the Mediterranean – the main production (92%) is carried out in the Atlantic.

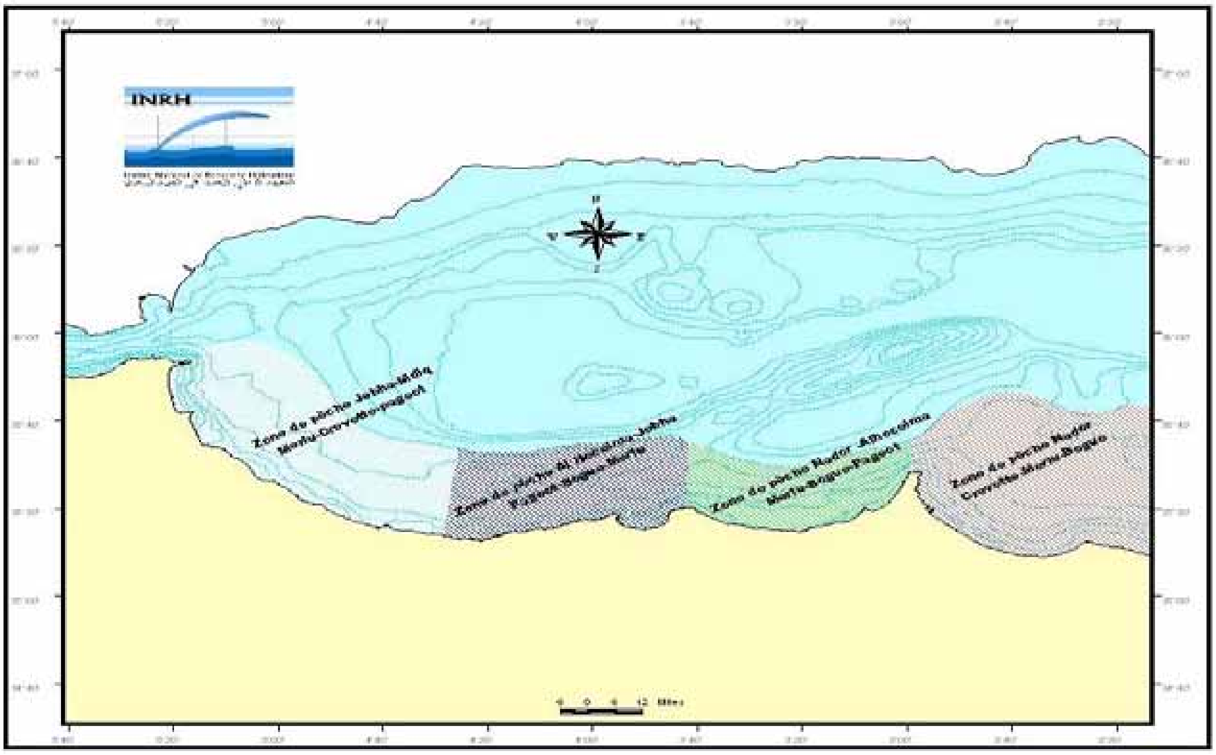
4. Exploitation of Mediterranean Red Coral

At the beginning of the Eighties, the exploitation of red coral in the Moroccan Mediterranean was done by foreigners through authorizations from the Ministry of fisheries. In 1984, two boats chartered by Moroccans began fishing red coral in the Al Hoceïma zone.

Coral exploitation began in the coastal zone of Topo, located at 5 to 6 nautical miles from Al Hoceïma west. After one year of exploitation, harvesting activities shifted to approximately 25 nautical miles north of Al Hoceïma in the area known as Tofino where the activity lasted approximately a year (2002).

Since 2002, exploitation of Mediterranean red coral has been carried out by ten vessels. In order to follow the evolution of this exploitation, the INRH started a series of scientific surveys in 2002, as well as the follow-up of this commercial exploitation.

Thus, two diving surveys were carried out in 2002 and 2003. The first aimed at the exploration of red coral fields in the maritime district of Nador and the second focused on the study of red coral stocks and the estimation of the potentialities of this resource in the region of Al Hoceïma.



Map 1. Localisation of main exploited fish stocks.

The prospections in the East part used the acoustic technique to identify rocks likely to be carrying red coral, as well as observations by diving in search of the corals.

Red coral exploitation started again in May 2004 in the zone of Tofino by 10 boats which were authorized with individual quotas of 500 kg of red coral. The coral harvesters were declared to the port authority of Al Hoceïma.

During 2004, the declared harvested quantity was about 1450 kg, and only 510 kg during the first 7 months of 2005. The captures are destined entirely for export.

Surveys of red coral

In order to determine the new zones likely to shelter coral and to estimate their production potential, from February-March 2007, the INRH proceeded using a prospection network at the level of the geographically delimited rocky zones.

Biological sampling was carried out on coral samples, collected at the time of the dives. These dives are carried out in a systematic way, after identification of the rocks likely to carry coral. The number of dives per zone is decided according to the extent of the rocks carrying the coral.

The results of the dives carried out within zones of Topo (5 dives), of Sidi H’seine (10 dives) and one dive in the zone of Fix-Iris are shown in Map 2.

There was the identification of new fields of red coral, especially in the littoral zone of Sidi H'seine, which constitutes a major stage in the estimation of this resource potential in the Moroccan Mediterranean.

Moreover, the surveyed band in Cala Iris zone showed signs of coral presence which requires further prospection.

Demographic structure of red coral

For demographic structure, sampling was undertaken in the region Topo-Cala Iris; the samples of colonies were measured in individual sizes.

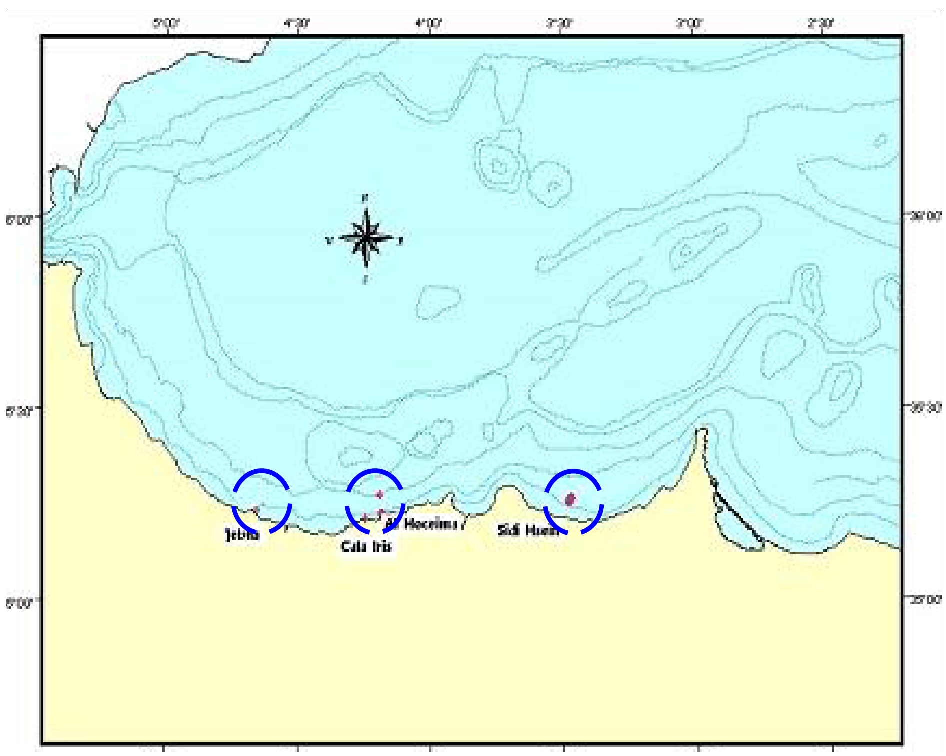
The size structure of colonies in the zones of Sidi H'seine and Topo-Cala Iris were between 3 and 13 cm, with a predominance of small sizes ranging from 6 to 7 cm. The mean sizes in both zones were 7.25 cm and 6.4 cm, respectively. The yields given by station and zone are provided in Table 1.

Other zones surveyed were located at the strait of Gibraltar, which led to the identification of some sites with fields of corals (Map 3). More dives are needed to quantify the regional yields of these species.

Table 1. Yield/hour of red coral in the prospected zone.

N° Stations	Yields (dry weight kg/30 min)			
	Zone of Nador	Zone of Sidi H'seine	Zone of Topo-Cala Iris	Zone of Jebha
1	0	1.8	7.0	0
2	0	2.5	0.0	
3		4.3	5.0	
4		1.7	1.7	
5		0.2	2.7	
6		5.0		
7		0.4		
8		9.1		

In the north Atlantic region, a closure of the coral fields for about 10 years has helped the recovery of the stocks there, and so their exploitation has started again.



Map 2. The identified zone of red coral at the Moroccan Mediterranean.

5. Other Non-Commercial Zoological Groups

Also observed in this zone are zoological groups including marine mammals, dolphins, marine turtles, and others.

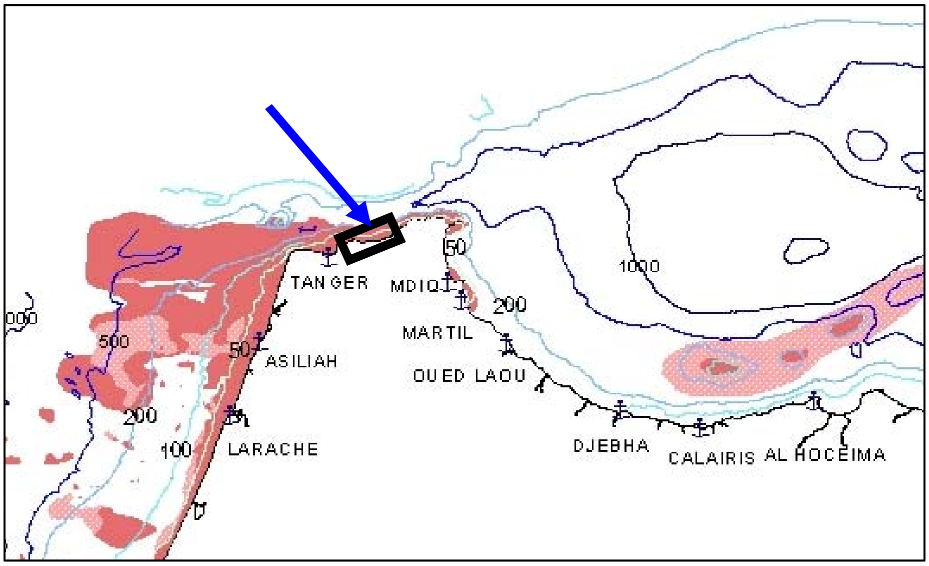
There were many observations of the common dolphin (*Delphinus delphis*), the large dolphin (*Tursiops truncatus*), and to a lesser extent of the blue and white dolphin (*Stenella coeruleoalba*). The simultaneous presence of three species of dolphins constitutes a remarkable fact here in the Moroccan Mediterranean.

The species Caretta caretta is mentioned in Mediterranean Morocco. The luth turtle (*Dermochelys coriacea*) is known to fishermen and present along the littoral Mediterranean, but nesting information is rare.

6. Resource Management

For demersal fisheries, the 40 mm mesh size is used; fishing is prohibited in the coastal zone less than 3 miles at the east of Al Hoceïma city and less than 80 m of depth west of the city. Fish size is controlled at landings; for small pelagics, the number of individuals is measured by kg.

For the large pelagic fisheries, there is the minimum commercial size for swordfish of 125 cm to the fork (or 25 kg of weight) with a rate of tolerance of 15%; the minimum mesh size of 400 mm and a maximum length of 2.5 km; the Prohibition of fishing in the zone ranging between Cape



Map 3. Zone of red coral identified at the Gibraltar site.

Spartel and Saidia for the period from October 15 to November 15. For blue fin tuna, there is the Prohibition of fishing from November 15 to May 15. For coral resources, the main management measures are the establishment of a rotational system of exploitation and the control of harvest.

For the case of octopus, the ministry decree stipulates that the commercial size expressed in weight for the octopus species is 300g by individual for eviscerated octopus and a weight of 400g for non eviscerated ones.

Taking into account the beneficial effect of marine reserves for safeguarding and preserving marine resources, a zone of eco-management was established in the zone of Bokkoya in the Moroccan Mediterranean. This area is located near the town of Al Hoceïma, approximately 150 km in the East of the Strait of Gibraltar, and is of great terrestrial and marine biological value, which contributes greatly to the preservation of vulnerable resources of the region.

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Fishery Management of the Mediterranean Red Coral: A Call for a Paradigm Shift

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1. Introduction

The Mediterranean red coral (*Corallium rubrum* L. 1758, Gorgonacea, Octocorallia) has been used as jewelry since antiquity and is one the most valuable living marine resources (Tescione 1976). It has been harvested for millennia with ever evolving harvesting methods, that, as in most fisheries, have become over-efficient. Today there is overwhelming evidence that almost all known red coral stocks are overexploited (FAO 1983, FAO 1988, Santangelo et al. 1993b, Santangelo and Abbiati 2001, Tsounis et al. 2007). However, management and conservation options are still being debated between the industry, decision makers and even ecologists. Although harvesting pressure, slow growth and isolation of the populations create an unfavorable situation, the threat of species extinction is not clear. On the other hand, local extinction of shallow water populations due to overharvesting and mass mortality events is likely, and economic extinction is certain to occur if management measures are not revised.

The significance of red coral and other cold water coral species is becoming clearer thanks to a growing amount of research showing that not only tropical coral reefs, but also deep corals and precious corals act as ecosystem engineers, providing three-dimensional habitat structure and increasing biodiversity. As a consequence, the interest of long term habitat management contradicts traditional fishery management that allows for a severe modification of the population structure of the target species. Therefore, a paradigm shift is needed to ensure sustainable coral fisheries while maintaining diverse and productive marine habitats. Balanced population structures and connectivity between harvested and protected populations should be maintained, among other measures.

In order to inspire this revision of management and conservation measures, the following text summarizes and highlights relevant features of the ecology of red coral, describes the evolution and present state of the fishery in order to reveal its impact, and discusses future management options.

2. Biology of *Corallium rubrum*

The Mediterranean red coral (*Corallium rubrum* L. 1758, Gorgonacea, Octocorallia) is a sessile colonial cnidarian with an arborescent growth form (Figure 1) that can reach a size of 50 cm (Garrabou and Harmelin 2002), and belongs to the longest living inhabitants of its habitat, living for may be more than 100 years (Riedl 1984, García-Rodríguez and Massó 1986a). *C. rubrum* is a sciaphilic species that can be found in depths of 5 – 300 m, though more commonly at 30 – 200

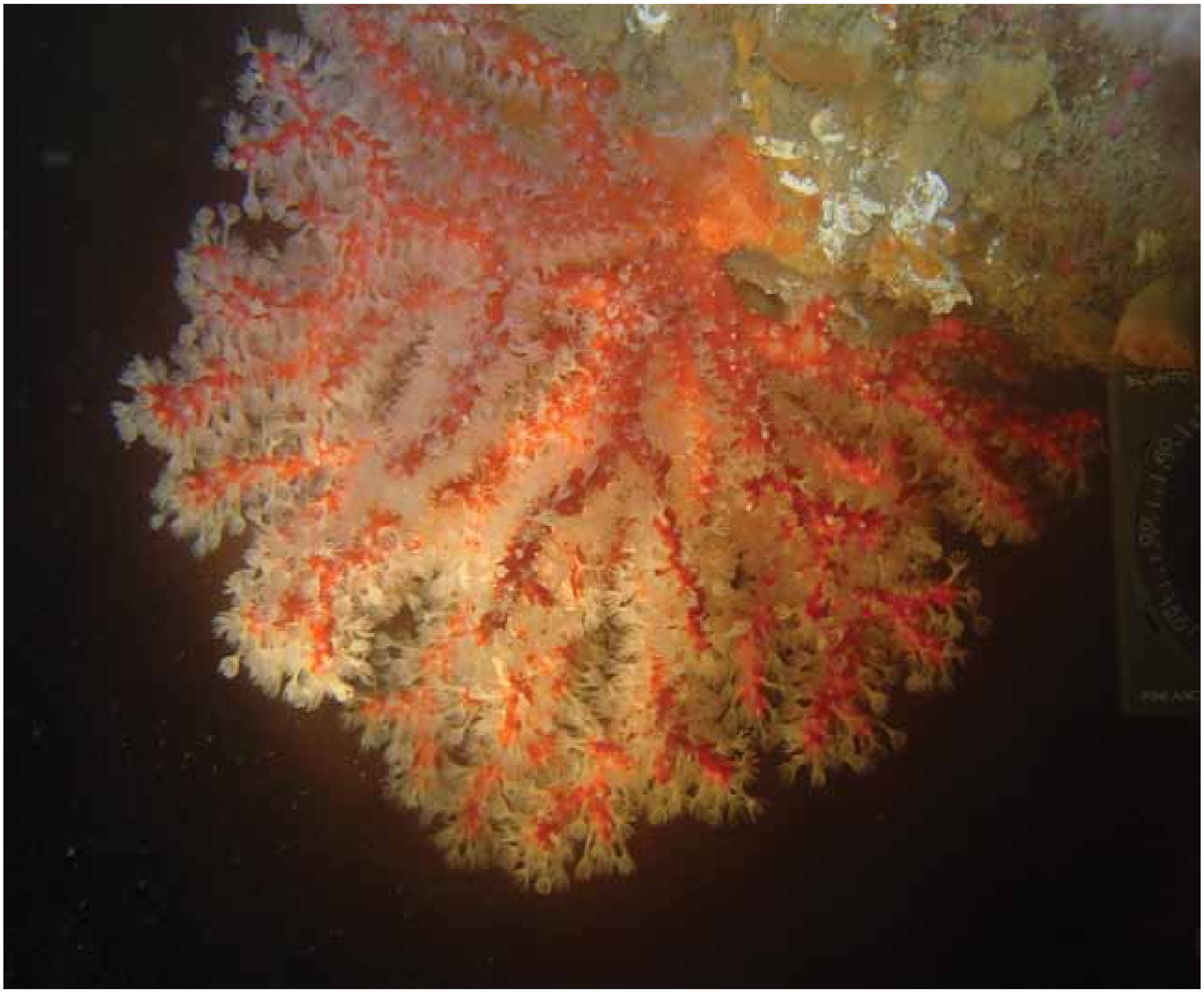

Fig. 1. *Corallium rubrum* colony of ca. 15 cm height, at 55 m depth in a marine protected area. During an extensive two year survey at the Costa Brava (Spain), 7600 colonies were measured, but only few corals of this size were found. Photo: G. Tsounis.

m (Carpine and Grasshoff 1975, Weinberg 1978, Riedl 1984, Rossi et al. 2008), and is distributed throughout the Mediterranean, though mainly in the western part, and at the neighboring Atlantic coasts (Marchetti 1965, Zibrowius et al. 1984, Chintiroglou and Dounas-Koukouras 1989). Its habitat preference is not well understood, but competition with other benthic species (Giannini et al. 2003) and a short dispersal distance (del Gaudio 2004, Constantini et al. 2007) seem to be influential factors. A bionomic study at the Costa Brava in Spain (Ros et al. 1984) shows that 1 km of shoreline corresponds to about 0.01 km^2 of coral habitat.

Detailed information on the distribution of red coral is scarce. The Mediterranean is a temperate oligotrophic sea where some benthic communities show a diversity and complexity that is comparable to coral reefs (Margalef 1985, Ballesteros 2006). However, the typical habitat of red coral is the so called “coralligenous,” probably the most structured and species rich community of the Mediterranean benthos. It is situated in the semi dark sublittoral (Ros et al. 1984, True 1970, Laubier 1966), and extends from the lower level of photophilic algae and sea grasses to more than 100 m depth, where calcareous macroalgae can survive.

It is likely that *C. rubrum* plays a significant role in its habitat, as many coral species are important keystone species in various ecosystems: Corals provide three dimensional complexity to habitats, by structuring and stabilizing the ecosystem (Hiscock and Mitchell 1980, Mitchell et al. 1993) and thus significantly increasing biodiversity (True 1970, Dayton et al. 1974, Jones et al. 1994, Parrish et al. 2002).

The main biological characteristic of all *Corallium* species that makes their sustainable harvesting extraordinarily difficult to achieve, is their extremely slow growth. In the case of *C. rubrum*, long term experimental data show that it grows to colonies of 4 – 8 mm thickness and 1.3 – 7 cm in height in 22 years, with corresponding growth rates of 0.24 ± 0.05 mm $year^{-1}$ in base diameter, and 1.78 ± 0.7 mm $year^{-1}$ in height (Garrabou and Harmelin 2002). The 22 year old corals developed only 1 – 8 branches, further stressing how long it takes for these organisms to provide habitat structure. However, since suspension feeders depend not only on seston concentration but also water movement in order to feed (Gili and Coma 1998), their energy input and consequently growth rates vary according to the habitat and geographic region. Higher diametric growth rates of 0.35 ± 0.15 mm $year^{-1}$ have thus been measured in more exposed environments (with values ranging between 0.15 mm and 0.75 mm $year^{-1}$, Marschal et al. 2004). Furthermore, the new aging methodology used in the latter study resulted in four times lower growth rates than previous data. Measuring actual growth of colonies in their habitat provides without doubt the most robust data, so that we can be confident that the maximum diametric growth rate of red coral, at least during its early life phase, is near 0.62 ± 19 mm $year^{-1}$ (Bramanti et al. 2005). The recovery growth rate of partially harvested colonies, when harvesters break the colony above the base so that it can re-grow has not yet been studied, although it can have important consequences for management.

Due to its slow growth and limited larval dispersion distance (del Gaudio et al. 2004, Calderon et al. 2006, Constantini et al. 2007), red coral cannot be regarded as an efficient colonizer of available substrate (except within the parental patch). Its reproductive capacity is relatively high though, as unlike other precious corals, red coral becomes sexually mature at an early age of 3 – 4 years (Santangelo et al. 2003, Tsounis et al. 2006b). *C. rubrum* populations certainly owe their resilience in large part to this feature, that sets this species apart from other *Corallium* species (Grigg 1989), which in turn must be regarded as more vulnerable.

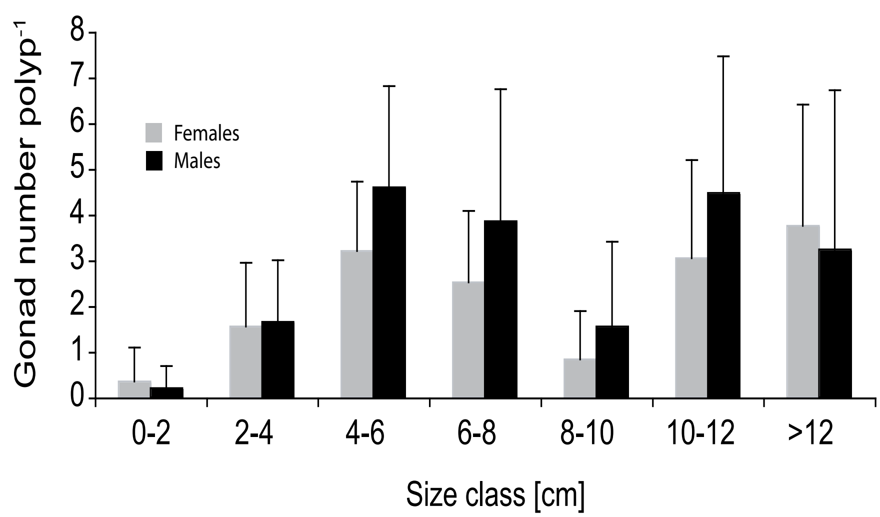

Fig. 2. Gonad number per polyp of various colony height classes (± SD) (grey bars: females; black bars: males) in *Corallium rubrum* colonies (Tsounis et al. 2007b).

Fertility in red coral does not reach 100% before an age of 6 – 9 years (Santangelo et al. 2003, Tsounis et al. 2006b). The legal minimum of 7 mm in diameter corresponds

Fig. 3. Typical *Corallium rubrum* colony size class found nowadays at the Costa Brava (NE Spain). Photo: S. Rossi.

to ca. 11 year old colonies, depending on the growth rate, which varies according to habitat and geographic region (Bramanti et al. 2005, 2007). Thus the majority of the population has not yet reached full reproductive potential due to fishing pressure (Figure 2). A period of 3 years of reproductive contribution before harvest may not be a sufficiently long period to ensure high recruitment, if compared with black coral in Hawaii, which reaches maturity at 10 – 12.5 years, but is not fished until 20 years old. This is significant in modular, highly branched organisms such as corals, as a small fraction of the older, and therefore larger, colonies contribute the majority of the recruits (Miller 1996, Rossi et al. 2008). In some species, up to 98% of the recruits are produced by the older half of the population (Babcock 1991, Coma et al. 1995, Sakai 1998, Beiring and Lasker 2000, Santangelo et al. 2007).

Another characteristic of red coral that has important implications on its population structure and exploitation, is the short larval dispersion distance: The free swimming phase of red coral larvae lasts only hours or days (Weinberg 1979). Not surprisingly therefore, recent genetic studies demonstrate the occurrence of genetic differences among populations even over short distances of less than 3 km (del Gaudio et al. 2005, Calderon et al. 2006, Constantini et al. 2007). In some overharvested areas the populations are therefore reduced to few isolated patches (Plujà 1999, Rossi et al. 2008).

Unlike growth, reproductive effort and physiological indicators of energy storage (lipid contents) vary only little within a geographic region (Tsounis et al. 2006b, Rossi and Tsounis 2007), but the sex ratio may vary between octocoral populations in the same region (Gori et al. unpublished data), and may have a significant effect on recruitment. Furthermore, population density, sex ratio and gonadal output vary significantly among regions in the Western Mediterranean (Bramanti et al. 2007). It is not yet clear however, whether these differences require substantially different management.

Natural mortality is low in *Corallium rubrum*, as there appear to be no natural predators. The only known threats are the parasitic boring spongae *Spiroxya heteroclite* and *Cliona sarai*, that affect the corals through perforation of their bases until they are perfused with holes and lose structural stability (Abbiati and Santangelo 1989, Bavestrello et al. 1993, Corriero et al. 1997).

Another cause for increased mortality in *C. rubrum* are mass mortality events (Cerrano et al. 2000, Garrabou et al. 2001, Bramanti et al. 2005, 2007). These have been reported as early as 1983 in the French maritime province (FAO 1983), but still very little is known about the cause of these episodes. Although they manifest themselves during abnormally warm summers, it is not clear whether direct temperature tolerance or pathogenic agents or pollutants are causing the mortality events (Garrabou et al. 2001). The fact that Mediterranean suspension feeders suffer a seasonal trophic crisis due to low plankton abundance and water movement in summer (Coma et al. 2000, Rossi and Tsounis 2007), may represent a contributing factor.

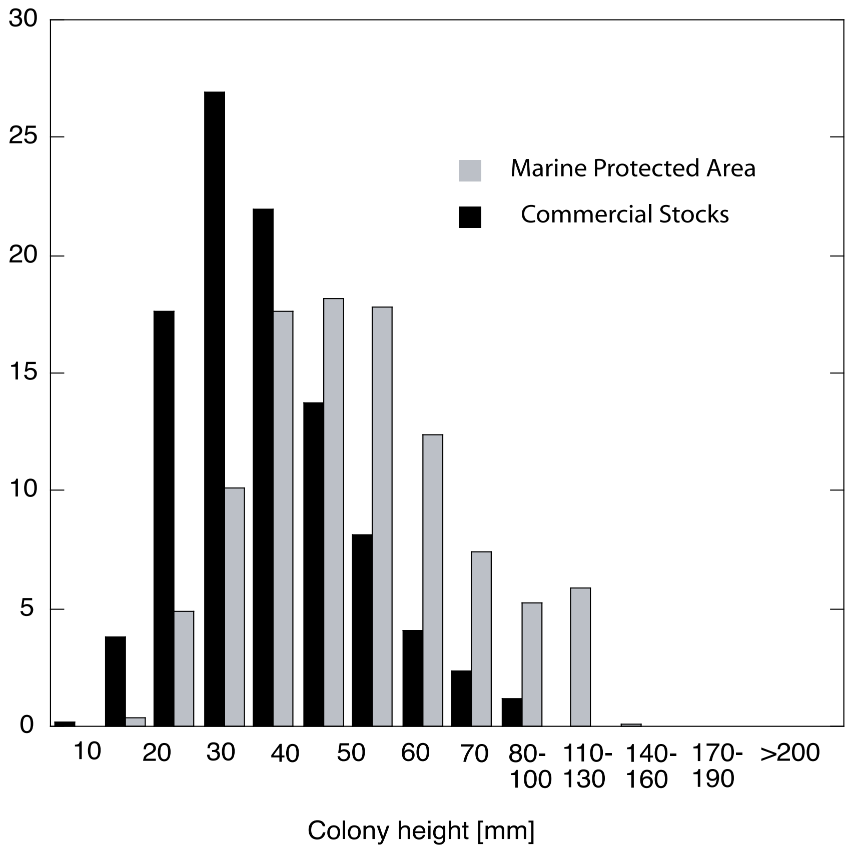

Fig. 4. *Corallium rubrum* colony height distribution of a protected population at the Medas Islands (grey bars), and commercial stocks (black bars), both at the Costa Brava (Spain) (Tsounis et al. 2007).

Mortality as a result of abrasion due to water movement, as observed in shallow water Antipatharian populations (Grigg 1976), is unlikely in *Corallium* species that dwell in deeper habitats and have a rigid skeleton so that branches never touch.

Other biological features, such as feeding, colony orientation, competition for space, activity rhythms, diet composition and feeding rates, as well as seasonality of metabolic products have been studied during the recent years, in an integral approach to understand the species biology and ecology (Rossi 2002, Giannini et al. 2003, Tsounis et al. 2006c, Picciano and Ferrier-Pagés 2007, Rossi and Tsounis 2007, Rossi and Gili 2007, Rossi et al. 2008, Rossi et al. 2009).

3. Population structure

To our knowledge, the only extensive study on the abundance of *C. rubrum* has been conducted at the Costa Brava, and indicates an extreme patchiness, with a total colony abundance on coralligenous hard substrate (20 – 50 m depth) of 3.42 ± 4.39 colonies m^{-2} (Tsounis et al. 2006a). Due to

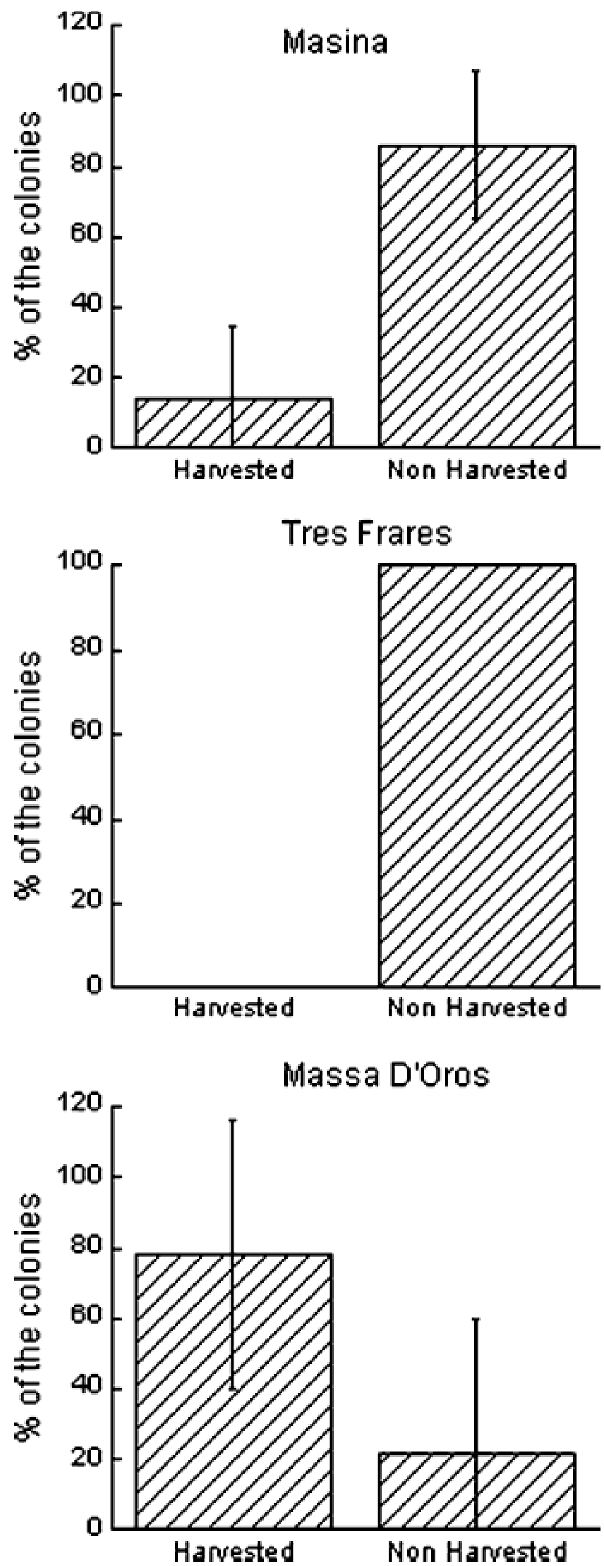

Fig. 5. *Corallium rubrum* demography at 60 – 250 m depth (ROV Survey, see: Rossi et al 2008). A): basal column diameter; B): maximum height. C): number of primary branches per colony in the three surveyed areas. (Mean ± SD).

geographic variation, this study is certainly not representative for the whole Mediterranean. However, the only comparable data available are data on the abundance within patches, which varies considerably among geographic locations as well as between depths and habitats. Values recorded range between 1300 colonies m^{-2} in Calafuria, Italy, 130 colonies m^{-2} at the Costa Brava (Spain), and 400 – 600 colonies m^{-2} in France (Santangelo et al. 1993a, Santangelo et al. 1999, Garrabou et al. 2001, Tsounis et al. 2006a, Rossi et al. 2008). For other regions the presence / absence may be recorded, but in general there is a lack of data on its abundance.

Red coral abundance at the Costa Brava is inversely proportional to depth with deep habitats being characterized by a more scattered distribution, rather than dense patches observed in shallow water (Tsounis et al. 2006a, Rossi et al. 2008). This can have implications on the harvest of deep populations, as a low abundance may make exploitation unfeasible. In general, the extreme patchiness results in a such a high standard deviation, that abundance data are of no particular use for management. Abundance comparisons and identifying population decline are therefore not likely achievable in case of *C. rubrum*, and size/age structures give a better indication of population decline. This is in line with the argument that population size in modular organisms should take number of polyps rather than number of colonies into account.

The presently observed size frequency distribution in shallow water shows that unprotected populations at the Costa Brava consist mainly of small corals under 8 cm height (Figure 3), with an average height of 3.1 ± 0.16 cm (Figure 4), and an average basal diameter and age of 4.8 ± 1.9 mm $year^{-1}$ and 7.5 years respectively (Tsounis et al. 2006a). In comparison, a protection of 15 years resulted in an average height of 4.2 ± 2.5 cm (Tsounis et al. 2006a).

The only two known demographic studies on red coral populations below 50 meters depth show that harvesting pressure is proportional to the degree of accessibility of the sites to divers (Rossi et al. 2008, Angiolillo et al. 2009). These populations have been heavily dredged until 1994, and most of them are still exposed to a considerable harvesting pressure. Populations below 50 m consequently consist of 10 – 16 cm tall colonies, that show a well developed branching pattern, but an average basal diameter of only 9 mm (see Figure 5; Rossi et al. 2008, Angioillo et al. 2009). This is equivalent to just 4 – 8 years of growth above the minimum harvesting limit (see above).

The extremely young population structure is confirmed to be a direct result of over-harvesting (Santangelo et al. 1993b, Santangelo and Abbiati 2001, Tsounis et al. 2007). Consequently, even the oldest marine protected areas cannot serve as a base line for the study of the population structure of red coral. Inter-specific competition may further influence the population structure of red coral (FAO 1983, Giannini et al. 2003), however, to an insignificant degree in comparison to harvesting. Specimens in museums and private collections demonstrate that this species can reach a size of more than 50 cm, arguably 1 m (Bauer 1909, Barletta et al. 1968, Cicogna and Cattaneo-Vietti 1993, Garrabou and Harmelin 2002), but we have no way of determining the percentage of these large colonies in a natural population.

4. Fishery Management and Conservation

Evolution of the fishery

Intentional precious coral exploitation started about 5000 years ago in the Mediterranean, when iron hooks were used to harvest red coral (Grigg 1984). The "fishing" became much more efficient in about 4th century before Christ, when the Greeks or Arabs developed a wooden dredging device that was known as "ingegno," or "Saint Andrew's Cross" (Galasso 1998, 2001). It consisted of a wooden cross with nets attached, that was used to entangle red coral in the Mediterranean Sea. The industrial age saw the use of a metal made dredge called "barra italiana." It is made of a heavy iron bar with nets attached along its length. Even with the most efficient coral dredges or tangle nets, it is estimated that only about 40% of the corals broken off the substrate are entangled and retrieved (WPRFMC 2007).

Fishery statistics before the 1980s were documented by various private or governmental organizations, and are summarized in Tescione (1976). As early as the 1800s the coral fishing fleets made substantial trips to foreign shores in search for new stocks. Industrial scale exploitation for red coral began in the 17th century, when the Kingdom of Naples employed hundreds of boats dredging or netting coral (Tescione 1973). In 1862 there were 347 boats fishing for corals, which in 1864 rose to 1200 vessels, with 24 factories in Torre del Greco (Italy), and 17.000 persons employed in total (Tescione 1976, FAO 1983). Most fisheries depleted their stocks rapidly and moved on to new ones afterwards. This boom and bust exploitation, more similar to coal mining than to a fishery, made for unstable yields, with various peaks and drops (Santangelo et al. 1993b, Santangelo and Abbiati 2001). After its popularization in the 1950s, SCUBA diving quickly found its application in coral harvesting as it allowed to selectively pick large corals in protected crevices that were inaccessible to dredging. In light of the immense ecological damage that dredging inflicts on coral habitats (Thrush and Dayton 2002), coral dredging in EU waters was banned in 1994, however, long after a dramatic drop in yield (see below). SCUBA diving using advanced technology remains the exclusive exploitation method of *C. rubrum* today.

The last major peak recorded lists 100 t per year in 1978, but after a dramatic drop, the reported landings remained below 30 t (Figure 6). In the 1980s France reported a production of about 5 t per year by 40 licensed divers and 1 t by dredging. Responding to the dramatic decrease of yields in the late 1970s and early 80s (Chouba and Tritar 1988, Santangelo and Abbiati 2001), the Food and Agricultural Organization (FAO) hosted technical consultation meetings (FAO 1983, FAO 1988), which, however, resulted in few management changes, other than banning coral dredging.

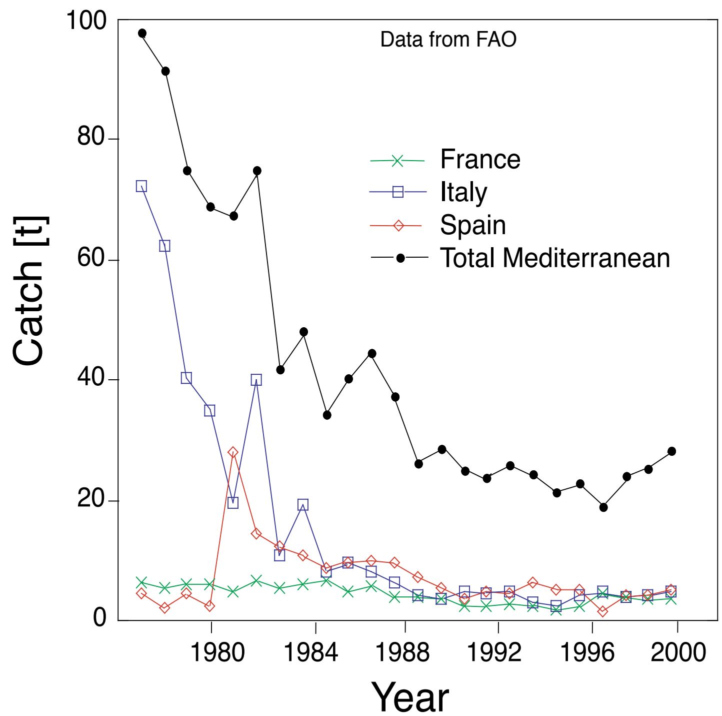

Fig. 6. *Corallium rubrum* harvest in the Mediterranean. Data from FAO.

The overall landings of red coral from the Mediterranean have been relatively stable at 25 – 30 t over the last 15 – 20 years. This is about 25% of what was landed in the late 1970s. However, there are no published data available on the size of landed corals. In absence of these data, a stable or rising yield does not necessarily indicate a sustainable fishery, since the size of landed coral might be decreasing. In fact, coast guard controls indicate that fishermen are forced to harvest ever smaller colonies (Hereu et al. 1999, Hereu et al. 2002, Linares et al. 2003, Fisheries department - Government of Catalunia pers. com.).

Economy and trade

Although *Corallium rubrum* is harvested all over the Mediterranean by independent divers, more than 90% of the harvest is processed in Italy since the 1800s. The specialized red coral jewelry industry situated in Torre del Greco, near Naples (Italy) is estimated to generate more than 230 million $ per year (ASSOCORAL pers. com.). Nowadays only 30% of the processed corals are *C. rubrum*, as 70 – 80% are tropical *Corallium* species imported from Japan and Taipei (Castigliano and Liverino 2004). In fact, Italy has become a major importer of precious corals (CITES 2007).

C. rubrum is sold for relatively high prices: High quality raw colonies are sold for 1500 – 3000 $ per kg, while worked beads sell for 30 $ per gram. Finished necklaces (Figure 7) sell for as much as 20.000 $ (Torntore 2002).

It is however interesting to note that even thin juvenile branches are now bought for 230 – 300 $/kg, while they were practically worthless some decades ago (FAO 1988, Tsounis et al. 2007). Prices for *C. rubrum* have risen from 100 – 900 $/kg to 230 – 1500 $/kg (FAO 1983, Moberg and Folke 1999). Unconfirmed information indicates that single, large *C. rubrum* colonies with a stem diameter of more than 4 cm are reportedly sold for as much as 45.000 Euro per colony.

Modern fishery and its management

Modern management approaches are similar throughout the Mediterranean: Coral harvesting in territorial waters is controlled by a licensing system permitting a controlled number of divers to harvest coral. Harvest quota, as well as minimum size limits, are always used to further control the yield. Management only based on harvest quota is not effective in preventing overharvesting (Federal Register of Commerce 2000), as immature corals can not be protected this way. While the management rules are similar in all fisheries, their degree of enforcement varies among countries.

Fig. 7. *Coralium rubrum* jewelry. Photo: Marta Coll.

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).

Fishing effort varies among countries: 20 Licenses are reported for the Island of Sardinia, (Italy), however with no data on population monitoring having been published. There currently are 16 licenses for all of Spain (Fisheries Department, Government of Catalunia). 9 – 11 of these licenses are restricted to the Costa Brava. 90% of the harvesting effort concentrates on the Cap de Creus area, a sparsely inhabited Peninsula of 190 km^2 size with about 42 km of coastline, that is exposed to frequent northern gales. In contrast to the easily definable coral beds elsewhere (e.g. Hawaii), red coral habitat is very heterogeneously scattered, forming small patches in microhabitats

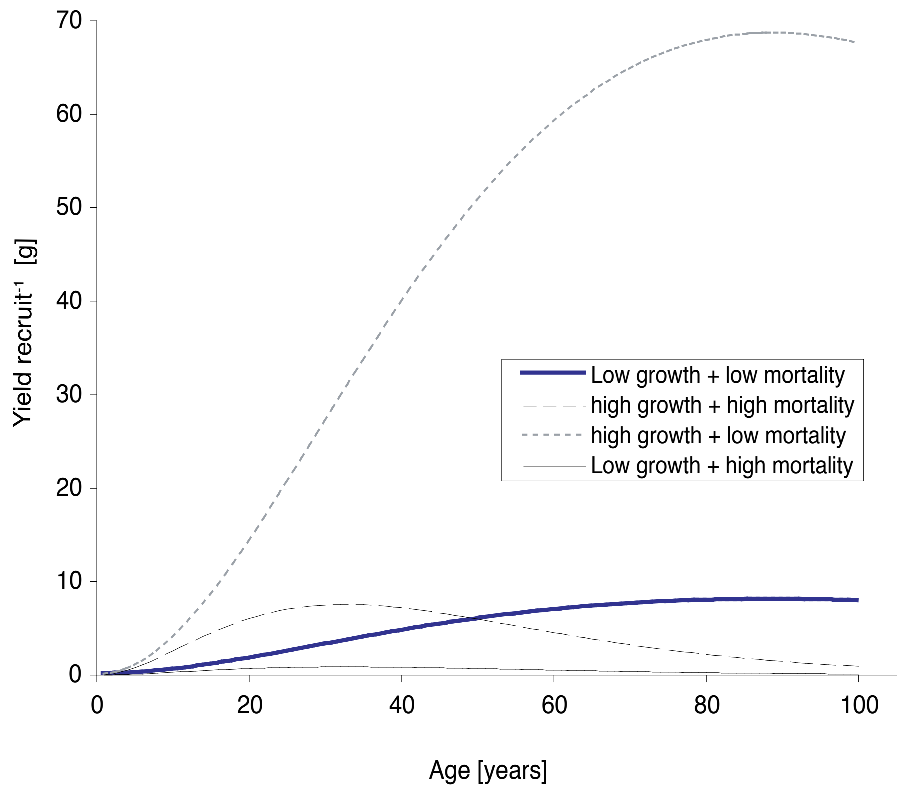

Fig. 8. Yield per recruit curves for *Corallium rubrum* at various growth rates and mortalities (Tsounis et al. 2007).

(Tsounis et al. 2006a), so that above 60 m depth 42 km of coastline may include less than 1 km^2 coralligenous habitat (Ros et al. 1984).

Corallium rubrum harvesting concentrates on the warmer summer months (May – October), removing most of the corals during a time they breed their larvae. This practice should be of little impact (Kwitt et al. 2004), but is an important fact to take into consideration in a socioeconomic analysis, since it means that most of the divers are effectively working part time, and have often invested into other businesses as well (Hotels, Aquaculture, etc.). At the Costa Brava (Spain) all divers are natives, and most of them older than 45 years. They usually form 2-3 person teams that dive together or in turns during the same trip). Fishing trips by European diving teams to North-Africa are common. In Sardinia 80% are non-natives, and divers usually dive alone using mixed gas, from boats that are crewed by one coxswain and one diver (Andaloro and Cicogna 1993).

The minimum harvesting size of 7 mm was introduced when it was already met voluntarily by SCUBA divers, since smaller corals were of little value to the industry (FAO 1983). Two studies determined a value for maximum sustainable yield (Figure 8), of 80 – 98 years (García-Rodríguez and Massó 1986b, Tsounis et al. 2007). García-Rodríguez and Massó (1986b) documented that colonies as young as 5 years were harvested (value adapted to today's more conservative growth rates), and in response recommended a minimum size of 8.6 mm. This has to date not been adopted and 7 mm remains the minimum size of harvest until today (Except Algeria: 8 mm, CITES 2007). When harvesting at an age below MSY in order to obtain optimum yield, fishing effort needs to be sufficiently low. If the fishery is too efficient for the assumed effort, or the effort misjudged (e.g. due to poaching or forged statistics), the stocks can be harvested down to the targeted age at first capture. This is what can be observed in all studied stocks (Santangelo et al. 1993b, Santangelo and Abbiati 2001, Tsounis et al. 2007), and recent coast guard patrols indicate that licensed divers as well as poachers harvest colonies below the legal size limit (Hereu et al. 2002, Linares et al. 2003). Poaching has in some regions proven to be a major threat to the survival of populations and is known to occur even within marine protected areas. There is little published information (but see Cognetti 1989), but poaching has been confirmed at the Costa Brava and Italy, and is probably common throughout the Mediterranean. Unofficial estimates by fishermen themselves quote that there are as many or more poachers active in Spain than licensed divers. In some cases it seems that poachers sell their harvest through licensed divers. Improved enforcement is therefore necessary to manage shallow water populations.

Some regions appear to still be using rotation systems which were conceived in the middle ages (Tescione 1976). These systems allow for the complete depletion of one stock, that is then left to recover, while another stock is harvested. Apart from the impracticability of enforcing a region the necessary 50 or more years that juveniles need to grow to adequate size (the species can probably reach several hundred years, Tsounis et al. unpublished manuscript), this practice disrupts the gene flow through coral populations itself, but it also potentially interrupts migrations of other species that take refuge in coral populations, or benefit otherwise from its presence. Also, in absence of red coral larvae, other species like Leptosamia pruvoti can settle in critical numbers, and permanently impede the re-colonization of red coral (FAO 1983, Giannini et al. 2003).

No discoveries of new coral beds have followed the over-exploitation of known stocks in the 20th century. Recent proposals by the industry to fund exploration of new stocks have been rejected by the government of Italy. The fishery has not extended its reach into deeper depths beyond 150 m, as dredges are prohibited, and submersibles are not economic (Tsounis et al. unpublished manuscript). ROVs are occasionally used for scouting, but remotely controlled extraction does not appear to be feasible. It is furthermore not clear whether deep populations are commercially viable, since red coral appears to grow in low densities at these depths (Rossi et al. 2008). Most of all, recent research shows that deep populations consist of relatively young colonies, as they have not yet recovered from heavy dredging until the year 1994.

Furthermore, exploiting the deeper populations of Mediterranean red coral can be problematic since they may be contributing to the recruitment of shallow water colonies: Red coral larvae tend to be negatively geotaxic at first, trying to settle near their parent colonies, but turn positively geotaxic at a later stage, rising up exploring adequate substrate (Weinberg 1979, FAO 1983). Furthermore, probably the only way deep populations can be harvested while shallow ones are protected is to increase size limits so that small shallow water corals are not harvested.

Regarding new stocks, there is anecdotal information about commercial diving teams running summer expeditions to harvest large red coral colonies growing on international seamounts. It is therefore advisable to identify whether intact populations still exist. The management and conservation of red coral populations in international waters is not regulated at this time. If these populations exist, it is possible they are the last natural populations that could serve as a baseline for ecological research. Some of these habitats could be protected by declaring them UNESCO World Heritage Sites in Danger. However in all cases of declaring precious coral communities in international areas as protected, there is the problem of enforcement. Trade control may thus be considered as a further measure.

Rearing red coral to provide the jewelry industry with unlimited resources has been tested with no notable success (Cicogna and Cattaneo-Vietti 1993). The slow growth rates imply that the risks of the operation are high, and investment return low. However, due to the long recovery time of devastated precious coral populations, it may be feasible to design programs that combine ex-situ or in-situ rearing with transplantation techniques (Rinkevich 1995, Edwards and Clarke 1998, Montgomery 2002, Dayton 2003, Rinkevich 2005). This could enable ecosystem managers to actively restore habitats that have suffered local extinction, and create a network of stepping stones that can ensure a sufficient gene flow and recruitment. First steps into this direction have been made (Bramanti et al. 2005), but it remains a largely unexplored field.

5. Threats

The central problem of the fishery is the depletion of almost all known stocks, without any indications that fishing activity might be reduced in the near future. The colony size of corals monitored in their habitat has been reduced to a level at which the reproductive potential of the population is significantly lower (Santangelo et al. 2003, Tsounis et al. 2007): 100% polyp fertility is reached at a colony height of 4 – 6 cm, while the average size of colonies within commercial stocks is about 3 cm. Furthermore, 96% have not yet grown 3rd order branches, resulting in few polyps per colony and thus a reduced recruitment potential. It has been observed that these 3 cm height colonies liberate an average of 90 planula larvae, while a 10 cm height colony may liberate about 3000 planulae (Rossi et al. 2008). Alarming results from models by Santengelo et al. (2007) demonstrate that these young populations are not able to withstand the combination overharvesting and natural stress factors such as mass mortality events (Santangelo et al 2007, please see the contribution of G. Santangelo and colleagues in this volume).

Under normal circumstances fisheries suffer economical extinction before the ecological extinction of the target species may occur. However, several factors create a unusual and critical situation in the Mediterranean.

One reason is that since the introduction of composite coral manufacture a few decades ago (FAO 1988, Smith et al. 2007), there no longer is a minimum size the industry can use. Even smallest pieces of coral can be ground to powder and formed into beads by mixing it with epoxy or other substances, although it is unlikely that high quality manufacturers offer this type of jewelry. Coral powder is also sold as a miracle cure against a variety of maladies (pers. obs.). Not surprisingly therefore, poachers and licensed divers have in fact been convicted of harvesting small coral in recent cases (Hereu et al. 2002, Linares et al. 2003).

Furthermore, the jewelry industry can continue to harvest *C. rubrum*, sustaining itself by multi species exploitation: Although 90% of all *C. rubrum* is processed in Torre del Greco (Italy), only about 30% of the coral jewelry produced is made of *C. rubrum*, as the demand is met by importing tropical *Corallium* species from Japan and Taipei (Castigliano and Liverino 2004). Similarly, the fishermen can continue fishing a species that is near extinction by using ever evolving technology (mixed gas diving and ROVs), while working part time in summer and maintain themselves by commercial diving or other activities.

Finally, genetic isolation as a consequence of the limited dispersal distance of red coral larvae is a further factor contributing to the risk of local extinction. Red coral populations are so widely dispersed in the Mediterranean that it is difficult to asses the risk of species extinction. The risk of local extinction of shallow water populations is substantial however, and the economic extinction almost certain, as argued above.

6. Conclusions

There is little doubt that the current form of the *Corallium rubrum* fishery is unsustainable and depleted almost all known stocks (FAO 1988, Santangelo et al. 1993, Santangelo and Abbiati 2001, Tsounis 2007). Many shallow water populations are threatened by local extinction, while deep populations have not recovered from centuries of dredging, and would unlikely withstand a heavy harvesting pressure.

Clearly, management should be revised. However, the objective of deep coral and precious coral management should go beyond avoiding local extinction, as precious corals stand out from many other known fisheries due to their significance as structure forming organisms. Traditional fishery management is aimed at an intensive exploitation of one target species, involving a significant modification of its population structure, while maintaining highest possible biomass production. Overfishing is in some cases defined as a biomass reduction of the target species population to 20 – 30% of the base line (CITES 2007, WPRFMC 2007).

In contrast, habitat conservation intends to maintain a population structure of key species and ecosystem engineers that guarantees that these components can perform their function of maintaining a high biodiversity and production. In the case of red coral, protected populations are small, rather rare, and isolated. We therefore propose that precious coral fishery managers maintain a minimum of old colonies within commercial stocks, possibly through creating a network of microreserves, while poaching must be drastically reduced.

7. Management Recommendations

International efforts

1) Given the inadequate local management in the Mediterranean for the last decades, it is likely that the inclusion of *Corallium rubrum* into Appendix-II would limit poaching while providing important data. However, since the 31 known *Corallium* species are difficult to identify, such a listing may probably only be feasible for the whole family Coralliidae. This would make sense, as these species are all slow growing and intensively harvested, and thus likely meet the criteria for inclusion.

However, a special application model for *Corallium* species would have to be designed, to allow for the unique situation of the industry and resource (for example to allow returns of jewelry under warranty for repairs). Decision makers can learn valuable lessons from the example of the thriving black coral fishery in Hawaii that is managed by strong local management (Grigg 2001, Grigg 2004), although its resource (*Antipathes* spp.) is controlled through CITES Appendix-II.

2) Identify potentially existing un-fished or intact populations and protect some of them, e.g. as UNESCO World Heritage Sites. Overharvested sites should be exempt from fishing. All other sites, or new sites, that show a moderate impact may be continued to be harvested under new guidelines and reduced licenses. This will require further research, and care must be taken that once new populations are identified, they are protected before a "coral rush" sets in. Further models for international precious coral habitat protection treaties may be the example of UN Vulnerable Marine Ecosystems (VMEs), that are designed by the Northwest Atlantic Fisheries Organization (NAFO).

Local management

1) Apply strict control of coral fishing: Today the only published landings data list the weight and location of coral harvested. Some other data are furthermore available from authorities, but to our knowledge there is no information on harvested sizes. Authorities need to collect data on the size of the harvested coral. Data on the minimum and, more important, maximum size of harvested coral will give an additional indication of when the stocks are overharvested. Should fishermen consistently fail to harvest large corals, it is a sure indication that a stock is depleted. While this should be recorded locally by fishery authorities, the CITES convention appears to be able to provide size data through its trade control. In any case, continued monitoring of the stocks and protected population is advisable.

2) Increase enforcement against poaching. Trustworthy former coral divers could be employed as consultants for anti-poaching enforcement. Furthermore, in countries where only fines are given, penalties for poaching need to be increased. Unlicensed fishing is not penalized equal to poaching for wildlife on land in some countries. Protection of red coral through CITES would lead to stricter penalty measures at least in Spain, and would therefore strengthen, instead of replace local management.

3) The minimum size limit needs to be revised: An increase of the minimum allowable base limit should be at least 10 mm, and the colony must be branched to a certain degree in order to contain a minimum number of polyps that provide larvae. Since the morphology is subject of geographic variation, the minimum branching allowed for harvesting must be decided locally. This recommendation has been made to the Catalan authorities in 2003, but it is not yet implemented (Rossi and Gili 2004).

4) Research on how cold water corals, deep corals and precious corals act as ecosystem engineers and increase biodiversity and productivity of their habitat (an objective that is in part pursued by the HERMES European project and is soon to be tested locally in the INDEMARES-LIFE project).

5) Research on the causes of mass mortality events. Furthermore, the recovery of population from mortality events, as well the growth of partially harvested colonies should be studied.

6) Increase research on the population structure and distribution of deep populations, and study the larval biology and dispersion limits between shallow and deep populations.

7) Create a network of micro-reserves to ensure gene-flow between deep and shallow populations and between populations along the coast. It is important that commercial stocks also contain micro-reserves, which must be monitored, and/or contain a minimum proportion of large colonies.

8) "Retirement plan:" Reduce number of fishing licenses where necessary, by not renewing licenses of retiring divers. After the surplus participants have exited the fishery and the target number of licenses is reached: When further divers retire, issue "apprenticeship licenses" for two seasons, where the young diver entering the business is allowed to work under supervision of the senior diver who is about to retire. If the final report of the retiring diver to the authorities recommends the apprentice, he is issued a full license, that then replaces the retiring diver. Furthermore, fishermen

can be retrained to act as rangers by monitoring and maintaining a balanced population structure and microreserves, passing from being coral miners to becoming coral gardeners.

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APPENDIX

LIST OF PARTICIPANTS

Name	Organization
Dridi Abdelmajid	Fisheries Biologist, Laboratory of Prospection Demersal Resource (NIRH)
Put O. Ang	Marine Science Laboratory, Department of Biology, The Chinese University of Hong Kong
Jonathan Barzdo	CITES Secretariat
Andy Bruckner	National Oceanic and Atmospheric Administration
Khaki Chan	Marine Conservation Officer, Agriculture, Fisheries and Conservation Department, the Government of HKSAR
Richard Chan	Senior Nature Conservation Officer of the Agriculture, Fisheries and Conservation Department, the Government of HKSAR
Chih-Shin Chen	Assistant Professor, Institute of Marine Affairs and Resource Management, National Taiwan Ocean University
Ernie Cooper	WWF-Canada Director, TRAFFIC & Wildlife Trade
Vin Fleming	UK CITES Scientific Authority, Joint Nature Conservation Committee
Hiroshi Hasegawa	College of Science and Engineering, Kanazawa University
Huang Hui	Professor, The South China Sea Institute of Oceanology, Chinese Academy of Sciences
Kuo-Yao Hung	Senior Technician, Fisheries Agency, Council of Agriculture, Executive Yuan, Taiwan
Nozomu Iwasaki	Usa Marine Biological Institute, Kochi University
Connie Pui Ling Lau	Marine Science Laboratory, Department of Biology, The Chinese University of Hong Kong
Jeremy Linneman	The Ocean Foundation
YM Mak	Fisheries Officer, Agriculture, Fisheries and Conservation Department, the Government of HKSAR

Tony Montgomery	Division of Aquatic Resources, Department of Land and Natural Resources
Laura Noguchi	U.S. Fish and Wildlife Service's Division of Management Authority
Frank Parrish	NOAA Fisheries' Pacific Islands Fisheries Science Center, Honolulu, Hawaii
Niphon Pongsuwan	Senior Marine Biologist and Coral Researcher Phuket Marine Biological Center, Department of Coastal Resources
Glynnis Roberts	National Oceanic and Atmospheric Administration
Julia Roberson	SeaWeb
Sergio Rossi	Institut de Ciència I Tecnologia Ambientals ICTA, Universitat Autònoma de Barcelona UAB
Taleb Said	CITES Delegate, Head of Cooperation Department, National Institute for Fisheries Research (INRH)
Giovanni Santangelo	Vice-director of the Center for the Study of Complex Systems of Pisa University (CISSC).
Soyo Takahashi	Fisheries Programme officer of TRAFFIC EAST ASIA-JAPAN
Susan Torntore	University of Idaho, Moscow, Idaho
Georgios Tsounis	Insitut de Ciències de Mar, Passeig Marítim de la Barceloneta, Barcelona, Spain
Russell J. Westergard	Vice Consul U.S. Consulate General, Hong Kong
Alfred Wong	CITES Officer, the Agriculture, Fisheries and Conservation Department, the Government of HKSAR
Joyce Wu	Programme Officer of TRAFFIC East Asia
Patrick Chung Wing Yeung	Marine Science Laboratory, Department of Biology, The Chinese University of Hong Kong
Yurui Zhou	Division of Fauna Affairs, CITES Management Authority of China
Abdelaziz Zoubi	Head Division of Biostatistics and the Information System, National Institute for Fisheries Research (INRH)

The First International Workshop on *Corallium* Science, Management and Trade: Lessons from the Pacific

Agenda

<u>Monday, March 16, 2009</u>

9:00 – Opening ceremony

a. Welcome and opening remarks
b. Meet and Greet
c. Adoption of the Agenda and working program (Andy Bruckner)
d. Logistics (Glynnis Roberts)
e. Timeline of U.S. conservation approaches for Corallium (Andy Bruckner)

1. Background Presentations
    a. Overview of Corallium biology, ecology and threats (Andy Bruckner)
    b. Distinguishing various types of *Corallium* products (Susan Torntore)
    c. Taxonomy and Identification (Ernie Cooper)
    d. Overview of *Corallium* fisheries: harvest, management and conservation (Andy Bruckner)

10:30 – 10:45 Coffee Break

2. Trends in the International Trade in *Corallium*
    a. Sources, products and volume of U.S. imports (Andy Bruckner)
    b. Corallium fishery and trade of East Asia (Joyce Wu, Soyo Takahashi)

3. Role of CITES as a conservation tool
    a. CITES as a conservation tool (Laura Noguchi)
    b. CITES – a conservation mechanism for deep-sea corals (Julia Roberson)
    c. CITES and Non-Detriment Findings (Vin Fleming)

12:00 – 13:00 Lunch

4. Reports on *Corallium* in the Pacific:
    Summary of existing science, harvest, management, trade and conservation concerns
    a. Management of fishery for precious coral in Taiwan. (Chih-Shin Chen)
    b. Overview of the Hawaiian Precious Coral Fishery (Frank Parrish)
    c. Hawaiian Black Coral Fishery: Other Connections to the Corallium Fisheries (Tony Montgomery)
    d. Laws involved with coral and coral-like fauna protection and seafan diversity in Thailand. (Niphon Phongswan)

18:00 – 19:00 Cocktail Reception

19:00 – 21:00 Welcome Dinner

Tuesday, March 17, 2009

9:00 – 10:30 Reports on *Corallium* in the Pacific:

a. Biology of Japanese *Corallium* and *Paracorallium* (Nozomu Iwasaki and Hiroshi Hasegawa)

5. Regional report on Mediterranean *Corallium:*
    a. What we have learned about red coral and what we need to learn for its rational management. (Giovanni Santangelo)
    b. Fishery Management of the Mediterranean Red Coral: A Call for a Paradigm Shift. (Sergio Rossi, Georgios Tsounis)

10:30 – 10:45 Coffee Break

c. An overview on the main marine resources (commercial and non commercial groups) at the Moroccan Mediterranean. (Abdelaziz Zoubi)

6. Working Group Goals and Objectives (Andy Bruckner)
    a. Assignment to working groups

12:00 – 13:00 Lunch

13:00 – 16:15 Working Group sessions

Working Group 1: The Science Working Group
This group will discuss the state of knowledge of the biology and population status and threats.

Working Group 2: The Management Working Group
This group will compile and assess information on existing national management.

Working Group 3: The CITES Working Group (includes Identification)
This group will address implementation issues of a potential CITES listing, and focus on taxonomy and identification.

16:15 – 16:30 Coffee Break

16:30 – 18:00 Working Group sessions

Wednesday, March 18, 2009

9:00 – 11:00 Initial Working Group reports

10:30 – 10:45 Coffee Break

11:00 – 12:00 Working Group deliberations

12:00 – 13:00 Lunch

13:30 – 16:15 Working Groups finalize reports

16:15 – 16:30 Coffee Break

16:30 – 18:00 Working Groups finalize reports and presentations

Thursday, March 19, 2009

9:00 – 10:30 Group discussion and compilation of recommendations

10:30 – 10:45 Conclusions and Next Steps

a. ID Guide: purpose and feedback (Ernie Cooper)

10:45 – 11:00 Closing ceremony

11:00 – 12:00 Coffee Break

12:00 – 13:00 Lunch